Journal of Multidisciplinary Healthcare

Dovepress
Taylor & Francis Group

Open Access Full Text Article

REVIEW

Summary of Best Evidence for Integrated Airway Management in ICU Tracheostomy Patients

Jixiang Guo[1,2], Yiwen Li[1,2], Dongxue Xie[1,2], Mingyang Zhang[1], Simao Fu[3]

[1]Department of Surgical Anesthesiology-Division 1, Zhongshan People's Hospital, Zhongshan City, Guangdong Province, 528403, People's Republic of China; [2]School of Nursing and Health, Henan University, Kaifeng City, Henan Province, 475004, People's Republic of China; [3]Dean's Office, Zhongshan People's Hospital, Zhongshan City, Guangdong Province, 528403, People's Republic of China

Correspondence: Simao Fu, Dean's Office, Zhongshan People's Hospital, 2 Sun Wen East Road, Zhongshan City, Guangdong Province, People's Republic of China, Email 2059202645@qq.com

Objective: The aim of this study was to comprehensively summarize the best currently available evidence by reviewing and analyzing the relevant literature in the area of care and maintenance of tracheostomy patients in the ICU. The evidence covers a wide range of aspects of postoperative care, complication prevention and management, rehabilitation support, and multidisciplinary collaboration for tracheostomy patients.

Methods: Using the "6S" evidence-based model, we searched multiple databases. The search focused on evidence related to the care of tracheostomy patients, including maintenance, nursing measures, multidisciplinary collaboration, and quality improvement, with the time frame ranging from the inception of the databases to March 14, 2025. Two researchers independently evaluated the quality of the literature, extracted data, and summarized evidence from publications meeting the inclusion criteria.

Results: A total of 12 relevant documents were retrieved, including 6 guidelines, 2 expert consensus papers, 1 best clinical practice guideline, 3 Meta-analyses. Through summarization and induction, 49 best evidence pieces were obtained across three major themes: maintenance and protection, nursing measures, and multidisciplinary collaboration and quality improvement. These were further divided into 15 sub-themes, covering equipment management, environmental optimization, infection prevention, postoperative care, airway humidification, suctioning, tracheostomy tube management, skin care, rehabilitation exercises, complication prevention, and daily assessments.

Conclusion: This research systematically compiles the optimal evidence regarding the care and management of tracheostomy patients, offering a comprehensive foundation for evidence-based clinical practice. It assists healthcare professionals in developing personalized care plans, improving patient safety, reducing complications, and promoting recovery. Future research should focus on optimizing multidisciplinary collaboration, exploring nurse-led interventions, and addressing cultural and resource limitations to further enhance the standardization and personalization of tracheostomy care.

Keywords: tracheostomy, care management, multidisciplinary collaboration, evidence summary, quality improvement, best practices

Introduction

Tracheotomy, a common life-supporting technique in intensive care units (ICUs), is extensively applied to critically ill patients in need of long-term mechanical ventilation or those requiring airway management.[1,2] Tracheotomy rates are as high as 54% in critically ill patients.[3]

Tracheotomy can be classified into Percutaneous dilatational tracheostomy (PDT) and Open surgical tracheostomy (OST). In recent years, PDT has gained increasing clinical application due to its advantages of short procedure time, minimal trauma, and lower cost.[4] Studies have shown that the surgical site infection rate (3.4%) in patients undergoing PDT is significantly lower than that in patients undergoing OST (7%),[5] further driving the development and promotion of this technique. However, regardless of the surgical approach used, postoperative wound care for tracheostomy patients remains a critical common component in ensuring patient safety and promoting recovery. Standardized and scientific nursing measures are of great significance in preventing infections, reducing complications, and improving outcomes.

Received: 18 April 2025
Accepted: 8 July 2025
Published: 4 August 2025

Inadequate incision care may lead to complications such as infection, bleeding, and skin injury.[6,7] A retrospective study showed that the rates of complications during tracheotomy,[8] The incidences of early postoperative complications, late postoperative complications, and all postoperative complications were 1.4%, 5.6%, and 7.1%, respectively. Early complications were defined as those that occurred within one week following tracheotomy, and late complications were those that occurred after one week. Postoperative bleeding was the most prevalent early complication, accounting for 2.6%, while airway stenosis was the most common late complication, making up 1.7%, which not only prolongs hospitalization time but may also endanger the patient's life. Therefore, how nurses protect and care for the incision of tracheostomy patients in the ICU environment is particularly important.

In clinical practice, deficiencies in incision care are mainly manifested in problems such as incomplete cleaning and disinfection, untimely dressing change, improper management of fixation devices, incomplete records of condition observation and lack of health education. The emergence of these problems is usually closely related to insufficient training of healthcare personnel, excessive workload, or shortage of healthcare resources allocation. However, regardless of the specific reasons, these nursing deficiencies may lead to an increased incidence of complications, prolong the recovery cycle of patients, increase their physical pain and psychological burden, and cause additional economic pressure on patients' families and society. Currently, there is a growing global demand for systematic tracheostomy care. Against this backdrop, the Global Tracheostomy Collaborative (GTC), established in 2012,[9] has effectively reduced adverse events, ensured patient safety, and shortened hospital stays through the implementation of quality improvement projects (such as daily assessment checklists and team training).[10] on the above international context, this study aims to provide reliable evidence for clinical practice and systematic, standardized guidance for safer and more efficient care by summarizing the best evidence and systematically reviewing the literature related to incision protection, nursing measures, and comprehensive airway management for tracheostomy patients in the ICU.

Methods

Problem Establishment

We used the PIPOST model developed by the Center for Evidence-Based Nursing at Fudan University in Shanghai.[11] In the PIPOST model "P" is the ICU adult tracheostomy patient;"I" covers incision protection and nursing measures such as cleaning, dressing changes, and routine maintenance; and "P" is the ICU nurse; "O" incidence of incision infection, incidence of bleeding, skin damage, patient comfort, and complication rates; "S" for ICU; and "T" covers evidence types like guidelines, clinical decision-making resources, expert consensus statements, meta-analysis, among others. With this model, we will systematically summarize the best evidence on incision protection and care of tracheostomy patients in intensive care units to guide clinical practice and improve the quality of care.

Literature Retrieval Method

Adhering to the "6S" evidence model, we carried out systematic searches across multiple databases. These databases encompassed UpToDate, Best Practice, the Guideline International Network (GIN), the National Guideline Clearinghouse (NGC), the Registered Nurses' Association of Ontario (RNAO), the Joanna Briggs Institute (JBI), the Evidence-Based Healthcare Center database, the Cochrane Library, PubMed, Embase, and Web of Science, and New South Wales Agency for Clinical Innovation (NSW ACI), Intensive Care Society (ICS), American Association for Respiratory Care (AARC), American College of Chest Physicians (ACCP), and the National Tracheostomy Safety Program (NTSP). Search terms in English encompass: "tracheostomy / airway management / tracheal stoma care / tracheostomy wound care / tracheostomy site care" and "wound care / infection control / skin care / nursing care / postoperative care / dressing change / disinfection / tracheostomy complications" and "meta-analysis / guideline / evidence / practical guidance / expert consensus / systematic review". The search spanned from the establishment of the databases all the way to March 14, 2025. The search terms were adapted according to each database's syntax and indexing rules. An example of the PubMed search strategy is shown in Table 1.

Table 1 PubMed Search Strategy

#1 (((Intubation, Intratracheal[MeSH Terms]) OR (airway management[MeSH Terms])) OR (Respiration, Artificial[MeSH Terms])) OR (tracheotomy[MeSH Terms])
#2 ((((((((((((((((((((((((Intubation, Intratracheal[Title/Abstract]) OR (airway management[Title/Abstract])) OR (Respiration, Artificial[Title/Abstract])) OR (tracheotomy[Title/Abstract])) OR (Intratracheal Intubation[Title/Abstract])) OR (Intratracheal Intubations[Title/Abstract])) OR (Intubations, Intratracheal[Title/Abstract])) OR (Intubation, Endotracheal[Title/Abstract])) OR (Endotracheal Intubation[Title/Abstract])) OR (Endotracheal Intubations[Title/Abstract])) OR (Intubations, Endotracheal[Title/Abstract])) OR (tracheal intubation*[Title/Abstract])) OR (endotracheal tube[Title/Abstract])) OR (ETT[Title/Abstract])) OR (Management, Airway[Title/Abstract])) OR (Airway Control[Title/Abstract])) OR (Control, Airway[Title/Abstract])) OR (Artificial Respiration[Title/Abstract])) OR (Artificial Respirations[Title/Abstract])) OR (Respirations, Artificial[Title/Abstract])) OR (Ventilation, Mechanical[Title/Abstract])) OR (Mechanical Ventilations[Title/Abstract])) OR (Ventilations, Mechanical [Title/Abstract])) OR (Mechanical Ventilation[Title/Abstract])) OR (artificial airway[Title/Abstract])) OR (Tracheotomies[Title/Abstract])
#3 #1 OR #2
#4 (Incision[Title/Abstract]) OR (Wound[Title/Abstract])
#5 ((nurs*[Title/Abstract]) OR (protect*[Title/Abstract])) OR (care[Title/Abstract])
#6 #3 AND #4 AND #5

Notes: #: Indicates the step number of the search strategy, used for logical combinations (eg, #1 OR #2).*: Acts as awildcard, matching any characters after the search term (eg, "nurse*" includes "nursing"etc).

Inclusion and Exclusion Criteria

Inclusion criteria: (1) Studies of Tracheostomy patients ≥18 years of age; (2) Studies related to incision protection and nursing care practices; (3) Literature type of guidelines, expert consensus statements, best practice standards, Meta-analysis and relevant primary research; (4) The languages of the included literature were Chinese and English.

Exclusion Criteria: (1) Duplicate papers, research plans/reports, abstracts, conference papers, papers for which full text is not available. (2) Papers with incomplete content, and evidence that did not pass quality assessment were excluded.

Literature Quality Evaluation Criteria

The methodological quality of guidelines is evaluated by means of the Appraisal of Guidelines for Research and Evaluation II (AGREE II).[12] Expert consensus-based guidelines were appraised with the Australian JBI Center for Evidence-Based Health Care Expert Consensus Evaluation Criteria (2016).[13] For systematic reviews, the AMSTAR 2 tool[14,15] was utilized for evaluation. Regarding evidence summaries and clinical decision-making, when tracing the original literature within the best evidence summaries or clinical decision-making, the appropriate quality assessment tool recommended by the JBI Center for Evidence-Based Health Care was chosen for quality assessment according to the type of original literature.[16]

Process of Literature Quality Evaluation

The quality of the literature was independently appraised by two master's-level nursing researchers who had received training in the evidence-based nursing system. In the event of discrepant evaluations, an organized evidence-based nursing team would reach a decision through deliberation. This team consisted of two supervisors of master's nursing students, a chief nurse practitioner and a deputy chief nurse practitioner; one master's-degree-holding nurse practitioner-in-charge; and two master's nursing researchers. When the conclusions drawn from different evidence sources conflicted, the principles of giving precedence to evidence-based evidence, high-quality evidence, and the most recently published authoritative literature were adhered to.

Thematic Framework and Hierarchical Prioritization

Two researchers independently reviewed all extracted evidence items and conducted preliminary grouping based on their core content and clinical significance. The research team then iteratively constructed and refined the thematic framework through joint discussions, with reference to the key links of tracheostomy care. After multiple rounds of discussion and consensus, 15 sub-themes were finally established for the structured organization of evidence. Second, in terms of evidence prioritization, the following priority criteria were applied: evidence quality (highest priority) > timeliness > applicability and relevance > consistency. These criteria ensured that the most reliable, up-to-date, and relevant recommendations were prioritized in the synthesis of evidence.

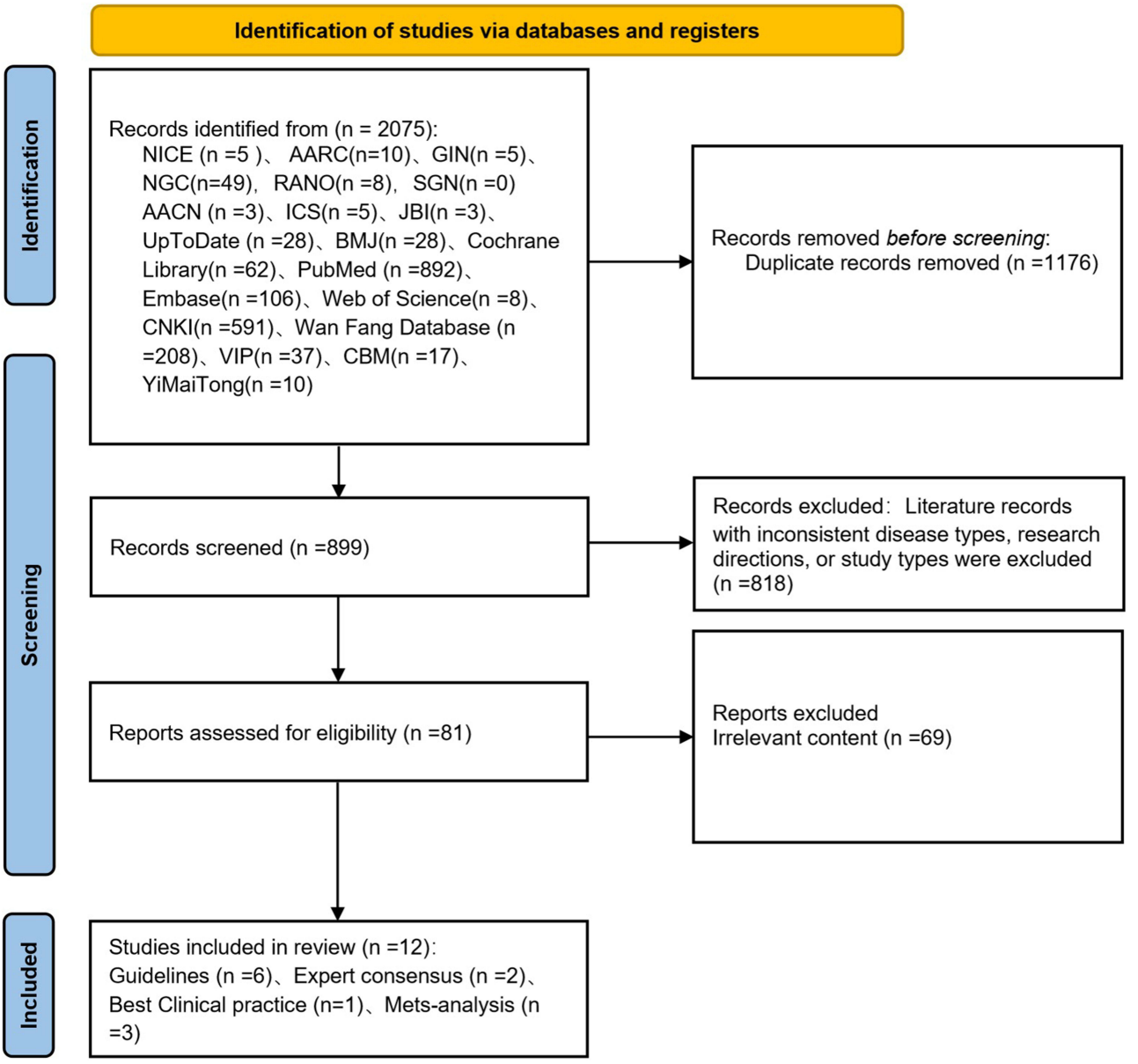

Figure 1 Screening flow chart for literatures.

Abbreviations: AARC, American Association for Respiratory Care; GIN, Guidelines International Network; NGC, National Guideline Clearinghouse; RNAO, Registered Nurses' Association of Ontario; SIGN, Scottish Intercollegiate Guidelines Network; AACN, American Association of Critical-Care Nurses; ICS, Intensive Care Society; CMA, Chinese Medical Association; CNKI, China National Knowledge Infrastructure; VIP, China Science and Technology Journal Database; CBM: China Biology Medicine.

Results

General Information on the Included Literature

A total of 2,075 documents were identified through the search process, of which 12 were selected for inclusion in the study. These included 6 guidelines,[17–22] 2 expert consensus documents,[23,24] 1 clinical decision-making papers,[25] and 3 Meta-analyses.[26–28] The literature screening process is presented in Figure 1.

General Characteristics of the Included Articles

Details such as the author, article title, publication year, source, type, and topic were extracted from the included literature. These are presented in Table 2.

Results of Literature Quality Assessment

Quality Evaluation Results of Guidelines

The quality of relevant articles was comprehensively evaluated, and the AGREE II tool was used to assess included guidelines. Table 3 shows guideline scores across dimensions.

Quality Evaluation Results of Expert Consensuses

The results of the quality assessment of the two expert consensuses[23,24] are presented in Table 4.

Table 2 General Characteristics of Included Literature (n=13)

Included Literature	Literature Source	Publication Year	Literature Topic	Literature Type
Brendan et al[13]	ICS	2020	Guidance For: Tracheostomy Care	Guideline
Ben et al[14]	ICS	2020	Respiratory Support Units: Guidance on development and implementation	Guideline
Constance et al[15]	AARC	2021	AARC Clinical Practice Guideline: Management of Adult Patients with Tracheostomy in the Acute Care Setting	Guideline
Thomas et al[16]	AARC	2022	AARC Clinical Practice Guidelines: Artificial Airway Suctioning	Guideline
Li et al[17]	CNKI	2023	Expert consensus on artificial airway humidification care in adult critical patients	Guideline
NSW ACI[18]	NSW ACI	2021	Care of adult patients in acute care facilities with a tracheostomy	Guideline
CAME et al[19]	CAME	2023	Recommendations for the management and rehabilitation of patients with a tracheostomy	Expert consensus
Trouillet et al[20]	PubMed	2018	Tracheotomy in the intensive care unit: guidelines from a French expert panel	Expert consensus
Robert et al[21]	UpToDate	2022	Tracheostomy: Postoperative care, maintenance, and complications in adults	Best clinical practice guideline
Qiu et al[22]	CNKI	2019	Application of foam dressing in tracheotomy: a meta-analysis	Meta-analysis
Meng et al[23]	PubMed	2019	The application of moist dressings in wound care for tracheostomy patients: A meta-analysis	Meta-analysis
Moser et al[24]	PubMed	2022	Prevention of tracheostomy-related Pressure injury: a systematic review and meta-analysis	Meta-analysis

Abbreviations: ICS, Intensive Care Society; AARC, American Association for Respiratory Care; CMA, Chinese Medical Association; CNKI, China National Knowledge Infrastructure; ACI, Agency for Clinical Innovation; CAME, China Association of Medical Equipment.

https://doi.org/10.2147/JMDH.S532895

Table 3 AGREE II Scores of the Included Guidelines (n=6)

Guidelines	Scope and Purpose	Involved Personnel	Preciseness of Guideline Development	Clarity of Presentation	Applicability	Independence of Writing	Number of Domains/ Criteria ≥60%	Number of Domains/ Criteria ≥30%	Recommendation Level
Brendan et al[13]	91.76	66.67	89.58	94.44	62.50	100	6	6	A
Ben et al[14]	88.89	77.78	71.88	91.67	66.67	100	6	6	A
Constance et al[15]	97.22	88.89	60.42	94.44	91.67	100	6	6	A
Thomas et al[16]	87.03	70.57	59.56	88.89	86.11	83.33	4	6	B
Li et al[17]	88.89	66.67	62.50	83.33	43.75	45.83	4	6	B
NSW ACI[18]	95.83	84.72	60.42	83.33	66.66	97.92	6	6	A

https://doi.org/10.2147/JMDH.S532895

Table 4 Quality Evaluation Results of Expert Consensuses (n=2)

Expert Consensus	①	②	③	④	⑤	⑥
CAME et al[19]	Yes	Yes	Yes	Yes	Yes	Yes
Trouillet et al[20]	Yes	Yes	Yes	Yes	Yes	Yes

Quality Evaluation Results of Clinical Decisions

One clinical decision[25] was included in this study. This decision, sourced from UpToDate, was of high overall quality, thus it was incorporated.

Quality Evaluation Results of Meta-Analysis Studies

Three Meta-analyses studies[26–28] were included in total, and the detailed results of the literature quality evaluation are presented in Table 5.

Best Evidence Synthesis

This study categorized the best evidence regarding the maintenance and care of tracheostomy patients into three major themes: maintenance and protection, nursing interventions, as well as multidisciplinary cooperation and quality enhancement. It was divided into fifteen sub-themes: the following guidelines and consensus were specifically referenced: maintenance and protection refer to Mussa et al;[19] Blakeman et al;[20] NSW ACI[22] wetting and suctioning in nursing measures refer to NSW ACI;[22] CAME;[23] Yue et al[27] skin disinfection refer to ICS et al;[17] Qiu et al;[26] Moser et al[28] for the most detailed steps and contraindications for disinfection. Rehabilitation exercises refer to Blakeman et al;[20] Li et al;[21] NSW ACI[22] covers multidimensional rehabilitation such as breathing, swallowing, and mobility, incorporating multidisciplinary collaboration. Multidisciplinary collaboration for quality improvement refers to the practical experience of NSW ACI;[22] CAME;[23] Robert et al,[25] which improves the overall management level through the formation of professional teams, the development of standardized processes and the continuous optimization of the quality of care.

By summarizing and generalizing the best evidence as shown in Table 6, it is significant to classify the maintenance and care of tracheostomy patients into three areas, which not only covers the needs of the whole cycle from planning to complication prevention but also fully combines the complementary recommendations of the international guidelines and the local consensus, which provides a scientific basis and operational guidance for clinical practice.

Discussion

The Critical Role of Maintenance and Protective Measures in the Management of Tracheostomy Patients

Maintenance and protection measures for tracheostomy patients aim to reduce complications and ensure patient safety through equipment management, environmental optimization, and infection prevention and control. Among these, environmental and equipment management are important measures to prevent hospital-acquired infections (HAIs) in tracheostomy patients. Evidence 4–6 emphasizes that ICUs must be equipped with specialized tracheostomy care

Table 5 Quality Evaluation Results of Meta-Analyses Studies (n=4)

Meta-Analysis Studies	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪
Qiu et al[22]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Meng et al[23]	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Moser et al[24]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes

https://doi.org/10.2147/JMDH.S532895

Table 6 Summary of the best evidence on incision protection and care of tracheostomy patients in the ICU

Category	Evidence Content	Evidence Level
Team building and multidisciplinary collaboration	1. The Tracheostomy Team model is recommended to reduce complications and shorten hospitalization.[15]	5b
	2. Formation of a multidisciplinary team (MDT), including intensivists, respiratory therapists, speech therapists, and nurses, with weekly check-ins to coordinate the plan of care; the team needs to be involved in preoperative decision-making (e.g., assessment of indications), postoperative management, and extubation assessment.[13]	1a
	3. It is recommended to incorporate TCM rehabilitation and combine acupuncture, tuina, and Chinese herbal medicine in an interdisciplinary collaboration.[19]	5b
Environment and equipment	4. Within the ICU, specialized equipment for tracheostomy care, including but not limited to resuscitation kits, suction devices, and ventilators, must be available to ensure that timely and effective care and resuscitation operations can be performed.[13]	1b
	5. Each bed needs to be equipped with 2 oxygen connections, 2 medical air connections, and 1 suction connection. The centralized monitoring system displays blood oxygen, ECG and blood pressure data.[14]	1a
	6. The heated humidifier requires periodic calibration of the temperature sensor to avoid overheating damage.[17]	1b
Infection prevention and control	7. Strict hand hygiene before and after operation, use of aseptic technique during suctioning.N95 mask + face screen required during COVID-19, closed suction system.[13,16] Wear PPE (gloves, isolation gown, goggles).[18] Postoperative contaminated instruments are disposed of as medical waste; environmental surfaces are disinfected (chlorine-containing disinfectant wipes).[21]	5b
Immediate postoperative care	8. Postoperative monitoring of vital signs (blood pressure, respiratory rate, oxygen saturation) and incision conditions (bleeding, infection) is required.[20]	1b
	9. The use of bedside markers (colors to differentiate tracheotomy from laryngectomy), close monitoring of bleeding, subcutaneous emphysema, and trocar position for 24 hours postoperatively are recommended.[13] The first balloon pressure adjustment is done within 1 hour postoperatively (25-30 cmH_2O).[15]	5b
	10. Avoid changing fixation devices for 24 hours postoperatively and use sutures or fixation tapes to ensure that the trocars do not displace[18]; elevate the head of the bed (30°-45°) to promote secretion drainage.	5b
Airway humidification	11. It is recommended that the temperature at the Y-tube be 34-41°C and the absolute humidity be ≥33 mg/L (optimal 44 mg/L); sterilized water for injection is preferred for the humidification solution[17]	5b
	12. Controlled humidifiers are recommended to avoid inadequate or excessive humidification.[13] A heated humidifier is recommended for humidification of mechanically ventilated patients or patients with viscous secretions, while passive humidification is used for spontaneously breathing patients, achieved by means of a heat and moisture exchanger (HME), to ensure that the temperature of the inhaled gas is maintained at 37°C and that the relative humidity reaches 100%.[18]	1a
	13. High-flow humidified oxygen therapy (HFNC) provides positive end-expiratory pressure and improves oxygenation and secretion drainage.[19]	1a
Sputum care	14. Suctioning is indicated by visible secretions, rough breath sounds, decreased oxygen saturation, or increased respiratory rate.[18]	1b
	15. When suctioning is required, care should be taken to ensure asepsis and to avoid overstimulation of the patient by rough handling, and the routine use of humidifying fluids for titration prior to suctioning is usually not required.[13,16,18]	1a
	16. The diameter of the suction tube should be limited to no more than 50% of the diameter of the tracheal tube or tracheostomy cannula; shallow suction is preferred, and deep suction should be performed only when ineffective, and the suction pressure is usually -80~-150 mmHg (1 mmHg=0.133 kPa), or up to -300 mmHg if needed, but it needs to be carefully operated [16]; the time of each suction should be controlled to be less than 15 seconds. or less, with preference given to the use of a closed suction system for manipulation, especially important for those with poor hypoxia tolerance (e.g., ARDS).[15,18,19] The depth of sputum should be 1 cm above the rump, the amount and nature of secretion should be recorded after sputum aspiration, and the frequency of sputum aspiration should be every 2-3 hours, and the frequency should be increased when there is a lot of secretion.[21]	1b
	17. A combination of postural drainage and expectorant medications to promote expectoration is recommended.[19]	5b

(*Continued*)

Table 6 (Continued).

Category	Evidence Content	Evidence Level
Tracheotomy Tube Fixation	18. Suture immobilization is possible in the early postoperative period (within 7 days), and suture integrity needs to be checked daily; the later period relies on tethered fixation.[13,18,21] Obese patients need to strengthen immobilization to prevent trocar displacement.[19]	5b
	19. Daily inspection of the fixation tape is recommended to prevent displacement of the cannula. The trocar material is recommended to be silicone (to reduce mucosal irritation)[19], and the inner diameter needs to match the patient's airway diameter.[15]	Ia
	20. When using the fixation tape to secure the tracheal tube, it should be ensured that the tightness of the fixation tape is moderate, preferably easy to insert with 1 to 2 fingers, to avoid over-tightening that may cause patient discomfort or skin damage.[22,24] If the cannula is accidentally dislodged, blind reinsertion is prohibited.[18]	5b
Selection and Replacement of Tracheal Tubes and Tethers	21. Cannula with balloon: for patients at high risk of mechanical ventilation or aspiration. Dual-lumen cannula: for easy cleaning of the inner cannula to minimize blockage. Adjustable length cannula: for obese or swollen neck patients; Montgomery T-tube (tracheal softening).[18,21]	Ib
	22. Cotton tethers are used in the early postoperative period to minimize skin damage. Nylon ligatures are used for long-term use and need to be checked regularly for tightness.[18] Alternatively, foam collars or hook-and-loop ties (e.g. Velcro) may be used instead of traditional gauze ties to reduce friction and pressure.[22,24]	Ia
	23. Tie replacement should be performed by at least 2 healthcare professionals, at least 1 of whom has experience in tracheostomy care: one to secure the tracheal cannula and the other to replace the tie.[18]	5b
Inner sleeve replacement	24. Clean daily (non-disposable) or change every 24 hours (disposable) for those with internal cannulae. Increase frequency of cleaning (e.g., every 4-6 hours) when secretions are heavy.[13,16,18]	5b
	25. The first replacement of the inner cannula needs to be done 7-10 days postoperatively (after sinus formation), and the long-term cannula is replaced every 28-30 days[13,19], and immediately in case of contamination or breakage; the recommended cleaning procedure is to remove the inner cannula and soak it in sterile saline. Use a soft-bristled brush to remove secretions and reinsert after drying1.[18]	Ia
	26. Have emergency equipment (e.g., tracheostomy kit, laryngoscope) available before replacement.[15] Monitor oxygen saturation continuously for 4 hours after replacement.[18] Change the tube with the patient in the supine position with the shoulders elevated to avoid pseudotracheal formation.[19]	Ib
Oral health care	27. Oral care twice daily with chlorhexidine mouthwash (to reduce oral colonization of bacteria); oropharyngeal secretions need to be attracted before deflating the airbag.[13,16,21]	Ib
	28. Intubated patients need to be checked regularly for oral mucosal injury.[18] Drainage of oral secretions in the lateral position, combined with swallowing training to reduce retention; use moisturizing gel for dry oral mucosa.[19]	Ia
Skin care around the incision	29. Use sterile 0.9% sodium chloride solution and gauze to clean the skin around the stoma, and use chlorhexidine solution (0.05%-0.1%) for disinfection in patients at high risk of infection, but it should be implemented in accordance with the hospital infection control policy [18,21]; avoid the use of hydrogen peroxide and hypochlorite for disinfection.[22]	Ib
	30. It is recommended that the skin around the incision be cleaned at least twice daily, increasing the frequency when there is a lot of secretion. Using sterile cotton balls or gauze, disinfect in a circular pattern centered on the incision opening (>5 cm in diameter). Allow to dry after disinfection and then cover with a sterile dressing.[13,19]	5b
	31. Monitor for granulomas or infection; obese patients need to prevent erosion of the skin folds in the neck.[13,21] Retain cultures when redness, swelling, or oozing is present around the incision.[13] Use silver nitrate cauterization or surgical trimming in case of granulomatous overgrowth.[18] Use antimicrobial dressings (e.g., silver ion-containing dressings) if breaks or infections are present, but avoid concomitant use with oxidizing cleansers.[22]	5b
	32. It is recommended to choose different dressings according to the local conditions of different incisions: aseptic open gauze dressing is used for 0 degree incision, new open foam dressing is used for I degree incision, silver ion dressing + aseptic open gauze dressing is used for II degree incision, and alginate silver ion dressing + aseptic open gauze dressing is used for III degree incision. In the early postoperative period, foam dressings were used to absorb exudate, hydrocolloid dressings were used to protect the incision, and the dressing was changed to hydrophilic foam dressing after 3 days [22]; the use of moist dressings can reduce the risk of incision infection and pressure ulcers, which is superior to traditional gauze.[17,23] Long-term tube carriers need to prevent peristoma dermatitis and use skin protectants if necessary.[19]	Ia

(*Continued*)

Table 6 (Continued).

Category	Evidence Content	Evidence Level
Daily assessment of incisions	33. Cannula position, cannula pressure, nature of secretions and frequency of suctioning were checked every 8 h. Ventilator waveforms, peak airway pressure and carbon dioxide monitoring were assessed[16,20,21]; suggested that sputum assessment should be graded according to viscosity (I-III degree), and color and volume should be recorded. As well as the effect of humidification, observation of line condensation, patient tolerance (cough, SpO_2).[13,15,17]	Ia
	34. Auscultate breath sounds daily and monitor for stridor or respiratory distress. Observe the patient's conscious state and be alert for altered consciousness due to hypercapnia.[18]	Ia
	35. It is recommended to observe whether the patient's skin and dressing at the tracheostomy site are clean and dry. If the incision site is red, tender, swollen, appears to be inflamed, has an odor, and the skin temperature is high; or if there is yellowish-green discharge near the incision accompanied by fever, it must be reported to the physician immediately, and specimen cultures are required if there are obvious signs of infection[13,18,19,21]	5b
Rehabilitation exercise	36. Early respiratory muscle training in postoperative awake patients[19]; e.g., abdominal breathing training: instruct patients to promote lung expansion for 10 minutes three times daily, or cough training (encourage active coughing during airbag deflation, supplemented by manual pressure on the suprasternal fossa)[13] or the use of an expiratory resistance device (threshold 25-30 cmH_2O), for 5-10 minutes three to four times daily. Inspiratory resistance training (abdominal weight bearing 2.5-5 kg) strengthens the diaphragm.[19]	Ib
	37. Passive joint mobilization is initiated in awake patients within 24 hours postoperatively to prevent deep vein thrombosis. Gentle neck stretching exercises can be started on the 3rd postoperative day to avoid cannula displacement. Gradually increase shoulder rotation and arm lifting exercises to prevent muscle atrophy[24]. Early activities out of bed, such as stretching and sitting up, escalator exercise, and aerial treadmill, 2-3 times a day for 5-10 minutes each time. Reduce ICU-acquired debility.[13,15,18,19]	5b
	38. Swallowing function training (e.g., cold stimulation, active swallowing) is recommended to reduce secretion retention.[13,16,19,24]	5b
	39. Early use of speaking valves (e.g., Passy-Muir valve) to promote speech and swallowing recovery[13,18,24] or use TCM acupuncture to promote swallowing recovery (e.g., Fengchi and Lianquan points).[19]	Ib
Complication prevention	40. Pain: Postoperative pain is relieved with acetaminophen or low-dose opioids.[13]	Ib
	41. Bleeding: Tracheotomized patients with bleeding on metal cannulae should be guarded against hemorrhagic asphyxiation, and their respiration and sputum color changes should be closely observed.[13,19]	Ib
	42. Misaspiration: to reduce the risk of pneumonia associated with aspiration, keep the head of the patient's bed elevated to 45° during nasogastric feeding after tracheostomy.[19,21]	5b
	43. Infection: Use a trocar with a balloon upper drain after surgery to minimize lower respiratory tract infections caused by aspiration of secretions under the vocal folds. Or use Chinese medicine methods, such as Chinese medicine acupoint patch (e.g., Angelica dahurica, Rhizoma coptidis) to assist in anti-infection.[19]	5b
	44. Swallowing dysfunction: use of VFSS (video fluoroscopic swallowing examination): to clarify the risk of aspiration; FEES (fiberoptic endoscopic evaluation of swallowing): to observe swallowing function dynamically.[13,20]	5b
	45. Pressure injuries: assess the patient's skin risk using the Braden Scale, focusing on the neck and back of the shoulders, or use the NPIAP staging tool[18,21] to check for skin pressure every 4 hours; avoid excessive neck recumbency, and protect the skin at the bony prominences with a pressure-reducing dressing (e.g., silicone pads).[13] Obese patients need to check the skin at the neck crease daily and use barrier cream (e.g. zinc oxide) to prevent maceration.[17] Regularly adjust the position of the trocar to avoid long-term pressure on the same area.[21]	Ia
	46. Contact dermatitis: avoid dressings containing adhesive components, wetting fluid leakage needs to be cleaned up in time to avoid chemical irritation leading to dermatitis, recommended use of hypoallergenic hydrocolloid or silicone dressings; if erythema or itching occurs, immediately discontinue use of the current dressing and apply hydrocortisone ointment locally.[13,17]	Ib
Quality of care improvement	47. Establish a tracheostomy database to track complications (e.g., infection rate, extubation rate); analyze adverse events at regular multidisciplinary meetings to optimize the nursing process.[13] Develop a tracheostomy care flow chart, including emergency treatment plan (e.g., extubation first aid).[17]	Ib
	48. Document quality of care using standardized assessment tools (e.g., TRACH scale, PDCA cycle optimization process).[15]	Ia
	49. It is recommended that a standardized tracheostomy procedure (e.g., staffing, equipment requirements, patient positioning, and sedation and analgesia protocols) be developed within the ICU.[20]	5b

equipment (eg, resuscitation kits, suction devices, and ventilators) to ensure rapid response in emergencies, real-time monitoring of patients' vital signs via a centralized monitoring system, and the provision of a stable and reliable respiratory support environment. Maintaining and managing medical equipment is important in terms of compliance with technical specifications, patient and user safety, and improving the efficiency of healthcare services.[29,30] A systematic evaluation study[31] pointed out that the availability and preparedness of medical equipment are crucial for ensuring patient safety. Equipment that is aging or malfunctioning can have an impact on the effectiveness of healthcare services, so contingencies need to be addressed through spare equipment and regular maintenance to guarantee service continuity. In addition, a 12-year microbiological surveillance of ICUs by Daniela et al[32] showed an increase in the rate of surface contamination from 15.6% to 41.3%, suggesting that the ICU environment may be a potential reservoir for (opportunistic) strains of pathogenic microorganisms,[33] which are capable of medical equipment and surroundings to survive and multiply.[34] Rigorous equipment maintenance and scientific environmental management not only reduce the risk of infection but also provide stable and safe treatment conditions for patients, which plays a key role especially in emergencies or long-term care. Reducing the risk of transmission of pathogenic microorganisms through continuous monitoring and optimization of the ICU environment can significantly improve the safety and prognosis of tracheostomy patients.

ICUs experience a high rate of HAIs. This elevated incidence is mainly attributed to the presence of immunocompromised patients and the frequent performance of invasive operations.[35] As a result, closely monitoring HAIs in ICUs is of exceptional importance. Timely monitoring, along with providing feedback, enables the swift identification of high-risk patients. Once identified, targeted infection control measures can be implemented. These measures include emphasizing hand hygiene among healthcare workers, instituting isolation procedures, and maintaining a high standard of environmental cleanliness.[36] Such steps are crucial for halting the spread of pathogens and form the core of an effective infection prevention and control program. As indicated in evidence 7, It is a strict requirement for healthcare workers to carry out hand hygiene before any operation and to scrupulously follow aseptic techniques. In particular, during the COVID-19 outbreak, N95 masks and face screens were required to be worn, along with the use of closed suction systems; contaminated instruments after tracheostomy should be disposed of in accordance with medical waste specifications, and environmental surfaces should be wiped down with chlorine-containing disinfectants. These measures can effectively block the transmission pathway of pathogens, reduce the risk of respiratory infection and cross-infection, and provide a solid guarantee for infection prevention and control of tracheostomy patients.

Furthermore, daily assessment, as a key link in the maintenance and protection of tracheostomy patients, can promptly identify potential problems (such as trocar displacement, incision infection, or insufficient wetting) and provide a scientific basis for dynamic adjustment of the nursing program, thus effectively minimizing complication risks, safeguarding patient safety, and ensuring the unhindered progression of the rehabilitation process. Evidence 32–35 requires that the position of the trocar, trocar pressure, and the nature of secretions be checked every 8 hours, and the effect of wetting be assessed; the patient's respiratory sounds should be auscultated every day, and the incision should be observed to see if there is any redness, swelling, or seepage of fluids, and culture specimens should be taken in a timely manner. The systematic monitoring mechanism can detect potential abnormalities (such as hypercapnia or granulomatous hyperplasia) at an early stage and provide a scientific basis for subsequent interventions.

In summary, maintenance and protection measures have a crucial role in the care of tracheostomy patients. Environmental optimization, infection prevention and control, equipment management, and dynamic monitoring are key lines of defense in reducing complication rates. Only by integrating maintenance and protection throughout the treatment process can we provide tracheostomy patients with a solid foundation of safety and ensure the continuity and effectiveness of treatment, thereby maximizing recovery and minimizing risk. The importance of this system cannot be overlooked and is fundamental to achieving high quality care.

Scientific and Refined Care for Tracheostomy Patient Care Practices

Tracheostomy patient care focuses on directly improving the patient's physiological status, promoting rehabilitation and preventing complications, involving immediate postoperative care, airway wetting, suction care, management of cannula and incision, oral care, skin care, rehabilitation exercises and complication prevention. Immediate postoperative care is

key to securing the patient's transition. Evidence 8–10 requires that the patient's vital signs and incisional bleeding be closely monitored for 24 hours postoperatively and the first balloon pressure adjustment be completed within 1 hour postoperatively and maintained at 25–30 cmH_2O. These measures reduced the risk of postoperative bleeding and aspiration through early intervention and positional management. After tracheostomy, the patient's respiratory mucosa loses its normal heating, humidification and filtration functions, resulting in mucosal dryness, sputum becomes viscous and is prone to form sputum crusts, which in turn triggers respiratory obstruction, increases the risk of lung infection, and in severe cases may even cause asphyxia, which is life-threatening.[37,38] The formation of sputum crusts is particularly common in patients not receiving mechanical ventilation, which may lead to partial or complete blockage of the artificial airway. According to the existing literature, the incidence of artificial airway sputum crusts ranges from 16.13% to 41.94%, with partial occlusion rates ranging from 9.68% to 32.26%,[39] and complete occlusion rates of 4%.[40] And through the airway wetting and effective suction, can dilute sputum, promote the timely discharge of sputum, so as to maintain a smooth airway, and significantly reduce the incidence of related complications. Evidence 11–13 clearly standardize the wetting parameters and recommend that patients on mechanical ventilation or with viscous secretions are advised to use a heated humidifier for wetting, meanwhile, patients who are breathing on their own are advised to achieve passive wetting through a heat and humidity exchanger, so as to make sure the temperature of the inhaled gas remains at 37°C while the relative humidity attains 100%. Moreover, Evidence 14–17 clearly defines the indications for sputum suctioning, the operation specifications, and the combination of positional drainage and expectorant medications. These measures reduce airway damage and secretion retention through precise humidification and standardized sputum aspiration, and significantly improve the quality of ventilation in patients.

The management of trocars and incisions is a core component in the care of tracheostomy patients. Evidence 18–26 regulate in detail the fixation method, material selection, replacement frequency, elasticity adjustment of tracheal cannulae and tethers, as well as the replacement requirements of the inner cannulae, providing a scientific basis for clinical practice. According to the NSW ACI guidelines,[22] the direct pressure, shear and friction exerted by tracheal cannulae and tethers on the local skin are the main causes of trachea-related pressure injuries (TRPI). Therefore, choosing the appropriate tracheal tube and tether, regularly adjusting the position and tightness, and maintaining the stability of the tracheal tube are key measures to prevent TRPI. In terms of material selection, cotton tethers are commonly used in the early postoperative period because of their softness and low elasticity, which can effectively minimize skin damage; while for long-term use, nylon tethers or Velcro (eg, Velcro) are recommended, which are especially suitable for patients with little ability to extubate on their own, but the degree of looseness needs to be closely monitored to avoid compression injury. In addition, a Meta-analysis showed that the use of foam neck collars or hook-and-loop tethers significantly reduces friction and localized pressure, thus further reducing the risk of TRPI.[28] At the time of replacement, the replacement operation is done collaboratively by at least two healthcare professionals to prevent unplanned extubation or extubation events.[22]

In terms of oral care for tracheostomy patients, Evidence 27–28 specifies a series of standardized operational requirements aimed at reducing the risk of infection and enhancing patient comfort. Specifically, chlorhexidine mouthwash care is required twice daily to effectively reduce the number of colonized bacteria in the oral cavity. This, in turn, decreases the likelihood of ventilator-associated pneumonia (VAP) among patients undergoing mechanical ventilation.[41] Prior to deflating the airbag, it is essential to completely suction out the patient's oropharyngeal secretions to avoid the accidental inhalation of these secretions into the airway, which can trigger lung infection or other complications. In addition, a positional management strategy that combines drainage in the lateral position can further promote secretion discharge.

Available studies have shown that approximately 10% of tracheostomy patients develop TRPI.[42] Such injuries are usually caused by tissue ischemia due to continuous pressure applied by medical devices and humid environments.[43] Patients are more likely to be at high risk for pressure injuries due to prolonged skin contact with equipment during tracheostomy, coupled with moist conditions from secretions and humidified oxygenation. Therefore, skin care is particularly important in the management of tracheostomy patients. Evidence29-32 points to daily cleansing and disinfection of the skin around the incision and the selection of appropriate disinfectants and dressings (eg, chlorhexidine solution or silver-ion dressings) based on the risk of infection. These measures are effective in reducing the growth of

pathogenic microorganisms and lowering the risk of infection through standardized procedures and regular assessment, cleansing and disinfection of the skin around the stoma. Meanwhile, choosing appropriate dressings (eg, absorbent and breathable foam dressings or antibacterial dressings) can reduce local pressure, absorb excess secretions, and keep the skin dry, which effectively reduces the occurrence of trocar displacement, skin injury, and incisional infections, and lays the foundation for patients' long-term recovery. A cohort study effectively reduced the incidence of tracheotomy-related pressure ulcers and injuries by implementing multidisciplinary collaborative tracheostomy care measures.[44] Prior to the implementation of the comprehensive care program, 9 (10.6%) of 85 patients developed TRPI; whereas, no new cases of TRPI were identified in the 20 months after the program was implemented. This result suggests that a systematic, multidisciplinary nursing intervention can significantly improve patient prognosis and effectively prevent complications.

Rehabilitation exercises are key to improving the long-term prognosis of tracheostomy patients. Evidence 36–39 suggests that early postoperative respiratory muscle training (abdominal breathing, cough training), passive joint mobilization, and swallowing function training can also be combined with traditional Chinese medicine to promote the recovery of respiratory and swallowing functions. A prospective cohort study showed[45] that the improvement rate of the patients' muscle strength in the intervention group (76.92%), which implemented pulmonary rehabilitation training measures, was significantly higher than that in the control group (39.02%), while diaphragm mobility also increased significantly (control group: 1.86±0.64 cm; observation group: 1.44±0.57 cm). This shows that the importance of rehabilitation exercise for tracheostomy patients should not be ignored. Through early and scientific rehabilitation exercise, it can not only enhance the strength and endurance of respiratory muscles but also significantly improve the ventilation function of patients, reduce sputum retention, and lower the risk of infection.

Complication prevention in tracheostomy patients is an important aspect of patient safety and promotion of recovery, which covers a wide range of aspects such as pain management, bleeding monitoring, aspiration prevention, infection control, and skin protection. Evidence 40–46 has developed prevention strategies for complications such as pain, bleeding, aspiration, and infection. Postoperative pain can be effectively relieved by the use of acetaminophen or low-dose opioids;[17] for the risk of bleeding, the respiratory status and sputum color changes need to be closely observed, especially when using metal cannulae to prevent asphyxiation from bleeding.[17,23] Some studies have indicated that the incidence of aspiration among patients who have undergone tracheostomy and have an indwelling tracheostomy cannula ranges from as high as 30% to 50%, of which 75%–82% of aspiration cases do not have obvious clinical symptoms,[46,47] which poses a greater challenge for early identification and intervention.

In order to lower the risk of aspiration-induced pneumonia, during nasogastric feeding, the head of the patient's bed ought to be elevated to 45°; swallowing function can be assessed by VFSS or FEES to clarify the risk of aspiration.[23,25] For incisional infections, the use of trocars with balloon upper drains is recommended, combined with TCM methods such as herbal acupoint patches to assist in anti-infection.[23] For the prevention of pressure injury, NSW ACI guidelines[22] require that nurses should observe the integrity, temperature and humidity, indentation, and edema of the skin around the incision and below the tethered band on every shift, especially in the early stage of tracheostomy, which is susceptible to subcutaneous emphysema and other swelling of the neck. And the skin risk is assessed by Braden scale or NPIAP staging tool, focusing on the protection of vulnerable areas such as the neck and back of the shoulder, using pressure-reducing dressings (eg, silicone pads) and regular adjustment of trocar position to avoid long-term compression.[28] In addition, obese patients need to pay special attention to the skin in the neck folds and use barrier creams in a timely manner to prevent maceration.[21] Management of contact dermatitis requires avoidance of dressings containing adhesive components, prompt cleanup of wetting fluid leaks, and selection of hypoallergenic dressings.[17,21]

This shows that the prevention of complications in tracheostomy patients needs to start from various aspects, and the risk of complications can be minimized through scientific and refined nursing measures and dynamic monitoring. At the same time, modern medical technology and Chinese medicine auxiliary therapy can be combined, which can further optimize the nursing effect, protect the safety of tracheostomy patients and promote their early recovery. In summary, the care of tracheostomy patients encompasses a variety of aspects including immediate postoperative care, airway wetting, suction care, cannula and incision management, oral care, skin care, rehabilitation exercises and complication prevention. The listed evidence covers the whole process of tracheostomy patient care and provides a scientific and standardized

operational basis for clinical practice through evidence-based summary of evidence. It provides a scientific guarantee for patient safety and rehabilitation.

The Importance of Multidisciplinary Collaboration and Quality Improvement of Care in the Management of Tracheostomy Patients

The management of tracheostomy patients is a complex healthcare task requiring not only routine care but synergistic multidisciplinary collaboration and quality improvement. Evidence 1–3 indicates that forming specialized tracheostomy teams and multidisciplinary teams (MDTs) significantly reduces complication rates and hospital stays. These teams—comprising intensivists, respiratory therapists, speech therapists, and nurses—coordinate care plans through weekly reviews, jointly engaging in preoperative decision-making, postoperative management, and extubation assessments to deliver comprehensive, individualized care.

Meanwhile, Evidence 47–49 underscores the need to track complications via tracheostomy databases, develop standardized flowcharts/emergency protocols, and continuously refine nursing processes using the TRACH scale and PDCA cycle. The GTC exemplifies quality improvement critical role. Boasting the largest prospectively collected global dataset on tracheostomy care, GTC has established evidence-based guidelines and partnered with the National Tracheostomy Safety Project to lead international quality improvement initiatives. Existing research has demonstrated that the use of the improvement methods advocated by GTC in quality improvement projects at four different hospitals can significantly improve the safety and quality of care for tracheostomy patients.[48]

Multidisciplinary collaboration and quality improvement are indispensable cornerstones of tracheostomy patient management. They provide a robust foundation for holistic patient care through continuous optimization of nursing quality and safety. Future efforts should further advance these frameworks to build safer, more efficient care systems, ultimately enhancing patient recovery outcomes and healthcare service quality.

Conclusion

This paper systematically summarizes 49 key evidences for the care of tracheostomy patients, covering the three major themes of maintenance and protection, nursing measures, and multidisciplinary collaboration and quality improvement. In terms of maintenance and protection, it focuses on the importance of equipment management, environment optimization, and infection prevention and control to provide patients with a safe and stable treatment environment through standardized equipment configuration, regular maintenance, and strict infection control measures. In terms of nursing measures, comprehensive standardization is carried out from immediate postoperative care, airway wetting and suction care to trocar and incision management, oral care, skin care, rehabilitation exercises and complication prevention, aiming to improve patients' physiological condition and boost recovery through meticulous operations. Eventually, the quality of care is continuously optimized through the formation of a professional tracheostomy team and the development of quality improvement programs.

A limitation of this study is that it only incorporated published English and Chinese literature, excluding research in other languages, which may pose certain geographic and cultural adaptation constraints. When applying this evidence to clinical practice guidelines, healthcare professionals should comprehensively assess patient factors like condition severity, nutritional status, immune function, and sedation-analgesia level. This will help create more customized tracheostomy care plans for optimal patient outcomes.

Future research can further focus on the study of outcome assessment of tracheostomy patients under the multidisciplinary collaboration model, especially the value of the application of TCM rehabilitation means (eg, acupuncture, tuina, etc.) in combination with other disciplines to provide more comprehensive rehabilitation support for patients. At the same time, we can also establish a feedback mechanism on the application of evidence for tracheostomy patients, enabling continuous improvement of care strategies based on real-world outcomes and making these strategies more clinically relevant.

Data Sharing Statement

The datasets that were either generated or analyzed throughout the present study can be obtained from the corresponding author upon a reasonable request.

Ethics Approval and Consent to Participate

An ethics statement is not applicable because this study is based exclusively on published literature.

Funding

This study was supported by 2021 Zhongshan Third Batch of Social Welfare and Basic Research Projects (Major and Key Projects in Medical and Health Care) (Project No. 2021B3014). The funders were not involved in study design, data collection, analysis, or manuscript preparation.

Disclosure

The authors declare no conflicts of interest in this work.

References

1. Madero Pérez J, Vidal Tegedor B, Abizanda Campos R, Cubedo Bort M, Alvaro Sánchez R, Micó Gómez M. Traqueostomía percutánea en pacientes ventilados [Percutaneous tracheostomy in ventilated patients]. *Med Intensiva*. 2007;31(3):120–125. doi:10.1016/s0210-5691(07)74789-7
2. Prieto-González M, López-Messa JB, Moradillo-González S, et al. Resultados de un protocolo de manejo sobre la vía aérea artificial en pacientes críticos sometidos a ventilación mecánica [Results of an artificial airway management protocol in critical patients subjected to mechanical ventilation]. *Med Intensiva*. 2013;37(6):400–408. doi:10.1016/j.medin.2012.07.003
3. Freeman BD, Kennedy C, Coopersmith CM, Buchman TG. Examination of non-clinical factors affecting tracheostomy practice in an academic surgical intensive care unit. *Crit Care Med*. 2009;37(12):3070–3078. doi:10.1097/CCM.0b013e3181bc7b96
4. Susanto I. Comparing percutaneous tracheostomy with open surgical tracheostomy. *BMJ*. 2002;324(7328):3–4. doi:10.1136/bmj.324.7328.3
5. Park H, Kent J, Joshi M, et al. Percutaneous versus open tracheostomy: comparison of procedures and surgical site infections. *Surg Infect*. 2013;14(1):21–23. doi:10.1089/sur.2011.059
6. Vargas M, Sutherasan Y, Antonelli M, et al. Tracheostomy procedures in the intensive care unit: an international survey. *Crit Care*. 2015;19(1):291. doi:10.1186/s13054-015-1013-7
7. Cipriano A, Mao ML, Hon HH, et al. An overview of complications associated with open and percutaneous tracheostomy procedures. *Int J Crit Illn Inj Sci*. 2015;5(3):179–188. doi:10.4103/2229-5151.164994
8. Halum SL, Ting JY, Plowman EK, et al. A multi-institutional analysis of tracheotomy complications. *Laryngoscope*. 2012;122(1):38–45. doi:10.1002/lary.22364
9. Brenner MJ, Pandian V, Milliren CE, et al. Global tracheostomy collaborative: data-driven improvements in patient safety through multidisciplinary teamwork, standardisation, education, and patient partnership. *Br J Anaesth*. 2020;125(1):e104–e118. doi:10.1016/j.bja.2020.04.054
10. Twose P, Jones G, Lowes J, Morgan P. Enhancing care of patients requiring a tracheostomy: a sustained quality improvement project. *J Crit Care*. 2019;54:191–196. doi:10.1016/j.jcrc.2019.08.030
11. Zhu Z, Hu Y, Xing W, Zhou Y, Gu Y. Composition of the different types of evidence-based problems. *J Nurse Training*. 2017;32(21):1991–1994. doi:10.16821/j.cnki.hsjx.2017.21.025
12. AGREE Enterprise. Appraisal of guidelines for research & evaluation II (AGREE II): users manual and 23-item instrument. 2017. Available from: https://www.agreetrust.org/about-the-agree-enterprise/. Accessed February 18, 2025.
13. The Joanna Briggs Institute. Critical Appraisal Tools. 2024. Available from: https://joannabriggs.org/critical-appraisal-tools. Accessed Feb 18, 2025.
14. Shea BJ, Grimshaw JM, Wells GA, et al. Development of AMSTAR: a measurement tool to assess the methodological quality of systematic reviews. *BMC Med Res Methodol*. 2007;7(1):10. doi:10.1186/1471-2288-7-10
15. Shea BJ, Reeves BC, Wells G, et al. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomized or non-randomized studies of healthcare interventions, or both. *BMJ*. 2017;358(sep21 16):j4008. doi:10.1136/bmj.j4008
16. Gu Y, Zhang HW, Zhou YF, Hu Y, Xing WJ. Quality assessment tools of JBI evidence-based health care center for different types of research - quality assessment of analytical studies (I). *J Nurs Train*. 2018;33(05):400–403. doi:10.16821/j.cnki.hsjx.2018.05.005
17. Intensive Care Society. Guidance for: tracheostomy care. 2020. Available from: http://www.ics.ac.uk/Society/Guidance/PDFs/Tracheostomy_care_guidance. Accessed March 14, 2025.
18. Intensive Care Society. Respiratory support units: guidance on development and implementation. 2020. Available from: http://www.ics.ac.uk/Society/Guidance/PDFs/Tracheostomy_care_guidance. Accessed March 14, 2025.
19. Mussa CC, Gomaa D, Rowley DD, Schmidt U, Ginier E, Strickland SL. AARC clinical practice guideline: management of adult patients with tracheostomy in the acute care setting. *Respir Care*. 2021;66(1):156–169. doi:10.4187/respcare.08206
20. Blakeman TC, Scott JB, Yoder MA, Capellari E, Strickland SL. AARC clinical practice guidelines: artificial airway suctioning. *Respir Care*. 2022;67(2):258–271. doi:10.4187/respcare.09548
21. Xiangzhi L, Lijun H, Yamin W, Shouzhen C. Expert consensus on artificial airway humidification care in adult critical patients. *Modern Clin Nurs*. 2023;29(11):1. doi:10.3969/j.issn.1671-8283.2023.11.001
22. New South Wales Agency for Clinical Innovation. Care of adult patients in acute care facilities with a tracheostomy: clinical practice guide. 2021. Available from: http://www.aci.health.nsw.gov.au/__data/assets/pdf_file/0004/685300/ACI-CPG-Tracheostomy.pdf. Accessed March 14, 2025.

23. China Association of Medical Equipment. Recommendations for the management and rehabilitation of patients with a tracheostomy. *Chin J Tuberc Respir Dis*. 2023;46(10):965–976. doi:10.3760/cm.a.j.cn112147-20230331-00153.
24. Trouillet JL, Collange O, Belafia F, et al. Tracheotomy in the intensive care unit: guidelines from a French expert panel. *Ann Intensive Care*. 2018;8(1):37. doi:10.1186/s13613-018-0381-y
25. Hyzy RC, McSparron JI. Tracheostomy: postoperative care, maintenance, and complications in adults. 2022. Available from: https://sso.uptodate.com/contents/tracheostomy-postoperative-care-maintenance-and-complications-in-adults?search=Tracheostomy&source=search_result&selectedTitle=2%7E150&usage_type=default&display_rank=2. Accessed Feb 05, 2025.
26. Qiu W, Wu X, Han H, Huang R, Chen H. Application of foam dressing in tracheotomy: a meta-analysis. *Chin J Tissue Engine*. 2019;23(22):3599–3603. doi:10.3969/j.issn.2095-4344.1740
27. Yue M, Lei M, Liu Y, Gui N. The application of moist dressings in wound care for tracheostomy patients: a meta-analysis. *J Clin Nurs*. 2019;28(15–16):2724–2731. doi:10.1111/jocn.14885
28. Moser CH, Peeler A, Long R, et al. Prevention of tracheostomy-related pressure injury: a systematic review and meta-analysis. *Am J Crit Care*. 2022;31(6):499–507. doi:10.4037/ajcc2022659
29. Salim S, Mazlan S, Salim S. A conceptual framework to determine medical equipment maintenance in hospital using RCM method. *MATEC Web Conferences*. San Francisco. 2019;266:02011. doi:10.1051/matecconf/201926602011
30. Kutor J, Agede P, Ali R. Maintenance practice, causes of failure and risk assessment of diagnostic medical equipment. *J Biomed Eng Med Devices*. 2017;02:123. doi:10.4172/2475-7586.1000123
31. Zamzam AH, Abdul Wahab AK, Azizan MM, Satapathy SC, Lai KW, Hasikin K. A systematic review of medical equipment reliability assessment in improving the quality of healthcare services. *Front Public Health*. 2021;9:753951. doi:10.3389/fpubh.2021.753951
32. D'Alessandro D, Fabiani M, Appolloni L. Microbial environmental pollution in ICUs: results, trends, and suggestions from a long-lasting surveillance. *Atmosphere*. 2021;12(9):1174. doi:10.3390/atmos12091174
33. Russotto V, Cortegiani A, Raineri SM, Giarratano A. Bacterial contamination of inanimate surfaces and equipment in the intensive care unit. *J Intensive Care*. 2015;3(1):54. doi:10.1186/s40560-015-0120-5
34. Mora M, Mahnert A, Koskinen K, et al. Microorganisms in confined habitats: microbial monitoring and control of intensive care units, operating rooms, cleanrooms and the international space station. *Front Microbiol*. 2016;7:1573. doi:10.3389/fmicb.2016.01573
35. Salgado Yepez E, Bovera MM, Rosenthal VD, et al. Device-associated infection rates, mortality, length of stay and bacterial resistance in intensive care units in Ecuador: International Nosocomial Infection Control Consortium's findings. *World J Biol Chem*. 2017;8(1):95–101. doi:10.4331/wjbc.v8.i1.95
36. Zingg W, Holmes A, Dettenkofer M, et al. Hospital organisation, management, and structure for prevention of health-care-associated infection: a systematic review and expert consensus. *Lancet Infect Dis*. 2015;15(2):212–224. doi:10.1016/S1473-3099(14)70854-0
37. Freeman BD, Morris PE. Tracheostomy practice in adults with acute respiratory failure. *Crit Care Med*. 2012;40(10):2890–2896. doi:10.1097/CCM.0b013e31825bc948
38. Wen X, Li C, et al. Treatment of acute-onset-related convulsive intravenous infusion reactions: guidelines. *Am J Emerg Med*. 2021;8(1):95–101.
39. Hui WL, Jie JH. Research on the establishment of effective nursing methods for patients with artificial airways in ICU intensive care units. *Cardiovasc Dis Electro J Integrated Tradl Chin Western Med*. 2020;8(17):133+135. doi:10.16282/j.cnki.cn11-9336/r.2020.17.102
40. Ping RL, Song XL, Min HN, et al. Identification and management of airway obstruction in tracheostomy patients. *Med Inf*. 2011;24(09):4273–4274.
41. Nseir S, Di Pompeo C, Jozefowicz E, et al. Relationship between tracheotomy and ventilator-associated pneumonia: a case control study. *Eur Respir J*. 2007;30(2):314–320. doi:10.1183/09031936.06.00024906
42. O'Toole TR, Jacobs N, Hondorp B, et al. Prevention of tracheostomy-related hospital-acquired pressure ulcers. *Otolaryngol Head Neck Surg*. 2017;156(4):642–651. doi:10.1177/0194599816689584
43. Black J, Alves P, Brindle CT, et al. Use of wound dressings to enhance prevention of pressure ulcers caused by medical devices. *Int Wound J*. 2015;12(3):322–327. doi:10.1111/iwj.12111
44. Carroll DJ, Leto CJ, Yang ZM, et al. Implementation of an interdisciplinary tracheostomy care protocol to decrease rates of tracheostomy-related pressure ulcers and injuries. *Am J Otolaryngol*. 2020;41(4):102480. doi:10.1016/j.amjoto.2020.102480
45. Hua JW, Ling RG, Hong YT, et al. Effect of pulmonary rehabilitation training in patients with tracheostomy and non-mechanical ventilation: a prospective cohort study. *Chin Critical Care Med*. 2024;36(11):1153–1156. doi:10.3760/cma.j.cn121430-20240304-00189
46. Leder SB. Incidence and type of aspiration in acute care patients requiring mechanical ventilation via a new tracheotomy. *Chest*. 2002;122(5):1721–1726. doi:10.1378/chest.122.5.1721
47. Donzelli J, Brady S, Wesling M, Theisen M. Secretions, occlusion status, and swallowing in patients with a tracheotomy tube: a descriptive study. *Ear Nose Throat J*. 2006;85(12):831–834. doi:10.1177/014556130608501216
48. McGrath BA, Lynch J, Bonvento B, et al. Evaluating the quality improvement impact of the global tracheostomy collaborative in four diverse NHS hospitals. *BMJ Qual Improv Rep*. 2017;6(1):bmjqir.u220636.w7996. doi:10.1136/bmjquality.u220636.w7996