Safe (re)tracheostomy in critically ill patients with previous neck surgery using the minimally-invasive tracheostomy approach

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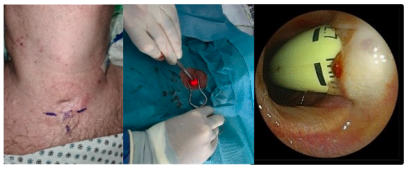
ABSTRACT

Background: Published clinical data on minimally invasive tracheostomy (MIT) techniques in critically ill patients with prior neck surgery—particularly in the context of retracheostomy following surgical tracheostomy—remain limited. Generally, conventional percutaneous dilatational tracheostomy has not been recommended for such high-risk patients, owing to the potential for critical complications.

Methods: This study presents data on MIT performed in 11 high-risk patients with previous neck surgery treated in a university hospital intensive care unit (ICU) specializing in hepatic and gastrointestinal diseases. Of note, all procedures were performed directly at the patient's bedside.

Results: Eleven critically ill patients (age 56-75 years; 8 males and 3 females) with a previous history of neck surgery, including surgical tracheostomy (n = 7), neck dissection (n = 2), pharyngectomy (n = 1), and thymectomy (n = 1), underwent (re)tracheostomy to enable prolonged ventilation for inappropriate arousal or delayed weaning. Tracheostomy was performed exclusively via the MIT approach, the mainstay tracheostomy technique in our ICU. Specific risk factors for tracheostomy involved obesity (morbid obesity in 2 patients, with a body mass index of 43.0 and 71.0), cutaneous and tracheal scarring (n = 5), dense pretracheal vasculature (n = 3), postradiotherapy skin fibrosis (n = 1) and the presence of goiters (n = 2). In all patients, MIT was performed without complications, showcasing the safety of the MIT approach even in cervically preoperated high-risk patients.

Conclusions: MIT could be used as a nonsurgical tracheostomy in ICUs in a wide spectrum of patients, including high-risk patients previously deemed ineligible for nonsurgical tracheostomy. (JTCVS Techniques 2026;35:102171)



Minimally invasive tracheostomy after previous neck surgery.

CENTRAL MESSAGE

This study presents data on minimal-invasive tracheostomy (MIT) performed in 11 high-risk patients with previous neck surgery. MIT could be used for nonsurgical tracheostomy in a wide spectrum of critically ill patients.

PERSPECTIVE

In aggregate, minimal-invasive tracheostomy (MIT) demonstrated safety in enabling (re)tracheostomy in high-risk patients with prior neck surgery traditionally considered ineligible to non-ST. Thus, we provide further evidence supporting the use of MIT as a universal approach for nonsurgical bedside tracheostomy in intensive care units.

Tracheostomy is a key technique performed in intensive care units (ICUs) to enable extended mechanical ventilation in critically ill patients.[1] the number of critically ill patients requiring extended mechanical ventilation has been continuously rising over the last decade,[2] and thus refinements in tracheostomy procedures are attracting increasing attention.

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This retrospective study was approved by the Ethics Committee of University Regensburg (Ethics Statement 25-4256-104; approved 30 June 2025), and written informed consent including publication of study data was obtained from all patients prior to tracheostomy.

Received for publication Sept 15, 2025; revisions received Nov 11, 2025; accepted for publication Nov 23, 2025; available ahead of print Dec 3, 2025.

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2666-2507

https://doi.org/10.1016/j.xjtc.2025.102171

Abbreviations and Acronyms
BMI = body mass index
hTS = hybrid tracheostomy
ICU = intensive care unit
MIT = minimal invasive tracheostomy
PDT = percutaneous dilatational tracheostomy
ST = surgical tracheostomy

Generally, 3 main tracheostomy approaches have been used broadly, with surgical tracheostomy (ST) and percutaneous dilatational tracheostomy (PDT) representing the gold standard, complemented by the novel hybrid tracheostomy (hTS) technique combining features from ST and PDT.[3-6]

ST poses certain issues, however, particularly for ICU specialists, such as the dependence on the availability of surgeons or otolaryngologists, frequent occurrence of cutaneous scar tissue, and time and labor consumption.[7-9] In contrast, PDT as first described by Ciaglia and colleagues[6] allows for swift bedside tracheostomy without the aid of a surgeon, establishing PDT as the primary tracheostomy technique for ICU specialists. Nevertheless, in high-risk patients with challenging anatomic characteristics (eg, obesity associated or pretracheal vasculature) or coagulation alterations (eg, liver cirrhosis), PDT has been widely avoided, owing to a substantially elevated risk of serious complications, such as bleeding and tracheal damage.[7,9-11] While hTS offers a fast tracheostomy procedure for the majority of patients, including patients with coagulation disorders, the risk of serious complications, such as paratracheal placement of the tracheostomy tube, argues against the use of hTS in high-risk patients with challenging anatomy.[4,12]

We recently published a novel tracheostomy approach, termed minimally-invasive tracheostomy (MIT), developed specifically for bedside tracheostomy in high-risk patients with challenging anatomy or coagulation disorders by ICU specialists.[13] The MIT procedure is predicated on the standard PDT approach optimized via the use of ultrasound to choose between a median or an anterolateral puncture trajectory, an initial skin incision, blunt tissue dissection, a probe puncture supported by diaphanoscopy, and continuous bronchoscopic guidance. In high-risk patients with large necks, prominent vessels, or bleeding disorders, tracheostomy is traditionally limited to surgeons. Adding such elements as skin incision, blunt dissection, and diaphanoscopy-guided probe puncture could improve the safety of the procedure. Furthermore, a novel anterolateral technique enables MIT in patients with dense pretracheal vasculature or atypical anatomy.

Compared to conventional PDT, this optimized MIT technique is safer, avoids severe complications, and is faster and more efficient than ST.[13] Given the consistent safety of MIT across all patients in this series, the technique has become the standard bedside tracheostomy procedure in our ICU, with no absolute patient-related contraindications to its use.

Apart from anatomic challenges and coagulation disorders, a history of previous neck surgery, including prior ST, represents an independent caveat for the use of nonsurgical tracheostomy approaches.[14] Detailed reports focused on nonsurgical tracheostomy approaches in patients with previous neck surgery are limited. A paucity of single-case studies and case series analyzing retracheostomy via PDT following prior surgical or nonsurgical tracheostomy provide seminal evidence for the feasibility of retracheostomy via nonsurgical approaches[14-16]; however, reports on (re)tracheostomy in critically ill patients with additional risk factors, such as obesity or pretracheal vasculature, have not been shared so far.

The goal of the present study was to establish MIT as a safe and efficient bedside procedure for (re)tracheostomy in critically ill patients with previous neck surgery. Remarkably, the MIT technique proved especially suitable for (re)tracheostomy in patients with prior neck surgery and concomitant additional relevant risk factors, such as morbid obesity and dense pretracheal vasculature. In sum, we highlight MIT as a tracheostomy approach universally applicable to large numbers of critically ill patients, including patients previously regarded as ineligible for nonsurgical tracheostomy.

METHODS

Patients

We retrospectively evaluated 11 critically ill patients from the ICU of a German university hospital who underwent MIT between November 2023 and July 2025. All patients in this cohort requiring prolonged mechanical ventilation had a history of prior neck surgery. The novel MIT approach has been the mainstay tracheostomy technique in our ICU since 2023. We compiled demographic, clinical, laboratory, and procedural data from the medical records. This retrospective study was approved by the Ethics Committee of the University Regensburg (Ethics statement 25-4256-104, approved 30 June 2025), and written informed consent including publication of study data was obtained from all patients prior to tracheostomy.

Inclusion and Exclusion Criteria

Generally, patients requiring mechanical ventilation for longer than 14 days were subjected to tracheostomy. Tracheostomy was performed exclusively using the MIT care bundle without predefined inclusion or exclusion criteria. Criteria for conversion to ST included uncontrolled bleeding and failure to establish airway access. Moreover, patients with large neck tumors may be more suitable for ST, especially in centers inexperienced with MIT.

MIT Technique

MIT was performed at the bedside as described in detail previously.[13] In short, the first steps included proper neck

extension, skin incision with a disposable scalpel, blunt skin dissection with a scissors, and retraction of skin and pretracheal tissue with a spreader (3/4 teeth), followed by a probe puncture with a 20G, 7-cm-long injection needle. Next, tracheal access was established, followed by cannulation using the Tracoe Experc Dilation Set (Tracoe Medical), comprising a 14G tracheostomy catheter, a guidewire, a small dilator (14 Fr), a large dilator (Tracoe Experc dilator), and a size 8 tracheal cannula. Bleeding from the skin was stopped by applying local pressure, and the tracheostomy was fixed with a circular tape. The first cannula change was scheduled after 2 weeks. Wound care involved inspection of the tracheostomy site once daily, followed by cleaning with sodium chloride–drenched gauze and application of a precut sterile, nonwoven tracheostomy dressing. An autonomous monitoring device was used to maintain cuff pressure between 20 and 30 cmH_2O during and after tracheostomy.

To maintain airway patency while minimizing mucosal trauma and infection risk after tracheostomy, regular suctioning was performed once per shift during the first week, followed by on-demand suctioning thereafter. MIT was performed after hand hygiene, with sterile gloves, sterile gowns, sterile drapes, and precise sterilization of the tracheostomy area. Regular cannula exchanges were performed with sterile gloves.

Periprocedural Imaging

Directly before tracheostomy, targeted color flow Doppler ultrasound assessment was performed to detect pretracheal vasculature or goiters. In addition, an initial bronchoscopic examination was performed to eliminate any significant bronchial obstructions, followed by continuous bronchoscopic monitoring throughout the entire procedure. At the end, the correct placement of the tracheal cannula was confirmed via bronchoscopy. Thereafter, a bedside chest X-ray was performed to verify cannula position and rule out pneumothorax or pneumomediastinum.

Anesthesia and Ventilation for MIT

Common anesthesia regimens included propofol, midazolam, ketamine, and sufentanyl. In addition, a 100 mg dose of rocuronium was injected 5 minutes prior to tracheostomy to achieve muscle relaxation. Pressure-controlled ventilation with 100% oxygen fraction was maintained during the procedure.

Safety Assessment Following Tracheostomy

Pneumothorax and pneumomediastinum were excluded on X-ray performed immediately after tracheostomy. Tracheal cannula misplacement was ruled out by bronchoscopy and X-ray. Bleeding from the cannulation site was classified as a complication if it occurred within 2 weeks after tracheostomy or if it necessitated further intervention apart from local compression.

RESULTS

Patient Characteristics

For more than 2 years, we have exclusively performed a recently published MIT technique for the bedside tracheostomy of critically ill patients requiring prolonged mechanical ventilation. Even in high-risk patients usually recommended for the ST owing to coagulopathy or difficult anatomy of the neck, MIT has proven be safe and efficient. Thus, we extended the MIT approach to patients with a previous history of neck surgery, which is commonly considered a vital risk factor for an MIT approach. As of November 2023, 11 adult patients (3 females and 8 males) with a previous history of neck surgery underwent MIT during treatment in our ICU. Patient characteristics are summarized in Table 1. The median patient age was 61 years (range, 56-75 years). Comorbidities necessitating ICU treatment and mechanical ventilation encompassed intracranial bleeding (n = 1), septic shock (n = 5), upper gastrointestinal bleeding (n = 3), myasthenia gravis (n = 1), spinal shock (n = 1), and acute-on-chronic liver failure (n = 1). Additional comorbidities included seizures (n = 2), head and neck cancer (n = 4), type 2 diabetes (n = 1), terminal kidney failure (n = 2), liver cirrhosis (n = 2), pneumonia (n = 3), and graft-versus-host disease after stem cell transplantation (n = 1). Ten of the 11 patients had a history of prior tracheostomy, which was performed surgically in 8 patients and via MIT in 2 patients. In contrast, 2 patients received first-time tracheostomy using the MIT technique. For both initial tracheostomy and retracheostomy, delayed weaning from mechanical ventilation was the primary cause. Retracheostomy was performed exclusively via the MIT approach relying on a skin incision, blunt skin dissection with a scissors, and retraction of skin and pretracheal tissue with a spreader to allow for diaphanoscopy-guided puncture and cannulation of the trachea (Figure 1, *A*). Bronchoscopic monitoring of the entire MIT procedure, especially the tracheal puncture, dilation, and cannulation, is an integral aspect of MIT (Figure 1, *B*).

MIT in High-Risk Patients With Previous Neck Surgery

Up to now, patients with previous neck surgery have been regarded as high-risk patients for nonsurgical tracheostomy approaches owing to difficult modified anatomy originating from cutaneous or tracheal scarring. Our study was focused specifically on establishing MIT as a feasible bedside tracheostomy procedure in patients with previous neck surgery. Hence, after corroborating that MIT is safe and efficient in high-risk patients with difficult anatomy, such as morbid obesity or pretracheal vasculature, we assayed MIT in patients with prior neck surgery. In our study, each patient was initially assessed for risk factors associated with complications of

TABLE 1. Patient characteristics

ID	Age, y	Sex	Comorbidity	Reason for first TT	Technique for first TT	Reason for second TT
1	67	M	Intracranial bleeding, seizures	Inappropriate arousal	Surgical	Inappropriate arousal
2	56	M	Septic shock, head and neck cancer, type 2 diabtetes	Pharyngectomy	Surgical	Delayed weaning
3	69	M	Head and neck cancer, upper GI bleeding	Delayed weaning	Surgical	Delayed weaning
4	58	F	Myasthenia gravis, terminal kidney failure	Delayed weaning	MIT	NA
5	75	M	Septic shock, upper GI bleeding, terminal kidney failure	Inappropriate arousal	Surgical	Inappropriate arousal
6	62	M	Septic shock; seizures; liver cirrhosis	Dysphagia	Surgical	Delayed weaning
7	61	F	Septic shock; acute myeloid leukemia; GVHD	Inappropriate arousal	MIT	Delayed weaning
8	67	M	Pneumonia; spinal shock; head and neck cancer	Delayed weaning	Surgical	Delayed weaning
9	60	F	Septic shock; cholangitis; pneumonia	Delayed weaning	Surgical	Delayed weaning
10	56	M	Acute on chronic liver failure; liver cirrhosis; pneumonia; COPD	Delayed weaning	Surgical	Delayed weaning
11	68	M	Upper GI bleeding; head and neck cancer	Delayed weaning	MIT	Delayed weaning

TT, Tracheostomy; *GI*, gastrointestinal; *MIT*, minimally invasive tracheostomy; *NA*, not applicable; *GVHD*, graft-versus-host disease; *COPD*, chronic obstructive pulmonary disease.

tracheostomy, especially previous neck surgery, elevated body mass index (BMI), altered coagulation, and challenging anatomy as evidenced by clinical inspection, ultrasound imaging, or bronchoscopy (Table 2). All patients undergoing MIT had a history of prior neck surgery, which constituted an essential inclusion criterion. Nine patients had previously undergone surgical tracheostomy, and 1 patient had a transcervical thymectomy for myasthenia gravis. In addition to surgical tracheostomy, 3 patients diagnosed with head and neck cancer were already subjected to pharnygectomy with concomitant neck dissection, radiochemotherapy, or isolated neck dissection. Moreover, liver cirrhosis (n = 2), prior allogeneic stem cell transplantation (n = 1), postradiotherapy skin fibrosis (n = 1), and obesity (n = 3), including morbid obesity with a BMI >30 in 2 patients (one with a BMI of 43.0 and the other with a BMI of 71.0), were identified as additional risk factors for tracheostomy-related complications in general.

Clinical inspection revealed cutaneous scar tissue caused by prior neck surgery, such as previous surgical tracheostomy (Figure 2, *A-C*) or transcervical thymectomy (Figure 2, *D*). The target site for (re)tracheostomy was chosen adjacent to the old scar but without direct contact, to bypass potentially unstable scar tissue. A short and broad neck constitutes another important risk factor for tracheotomy, especially in cases of morbid obesity with distances of 60 to 85 mm from the skin to the tracheal wall, which underscores the relevance of blunt tissue dissection before tracheal puncture in MIT (Figure 2, *A* and *D*). Fragile skin with a propensity for bleeding was evident in 2 patients with advanced liver cirrhosis and in 1 patient with previous allogeneic stem cell transplantation causing chronic graft-versus-host disease of the skin. Ultrasound supported by color flow Doppler of the neck conducted right before the start of MIT revealed the presence of goiters in 2 patients and dense pretracheal vasculature in 3 patients (Figure 3, *A*).

The MIT technique involves both a median and an anterolateral puncture approach specifically designed to circumvent pretracheal hindrances, such as vasculature or goiters, by puncturing both the skin and tracheal wall off the midline. In our MIT approach, bronchoscopic assessment prior to tracheostomy is mandatory. Correspondingly, all patients included in our study underwent bronchoscopy prior to tracheostomy. While tracheal stenosis was not observed, bronchoscopy showed tracheal scarring originating from the index tracheostomy in 8 patients (Figures 1, *B* and 3, *B*), allowing for the bronchoscopy-guided selection of a new puncture site for re-tracheostomy to avoid the potentially unstable tracheal scar tissue. Four patients underwent MIT with full heparin-based anticoagulation, which was paused 6 hours before MIT and resumed 12 hours after MIT. Pancytopenia (n = 1), thrombocytopenia (n = 1), and impaired plasmatic coagulation were observed in 4 patients undergoing MIT, which was managed with substitution of thrombocyte concentrates or fresh frozen plasma. In general, coagulation alterations together with anatomic challenges can cause intraprocedural and also significant postprocedural bleeding in the days after tracheostomy, with fatal jeopardy arising from bronchial obstruction owing to blood or clots. Collectively, patients with previous neck

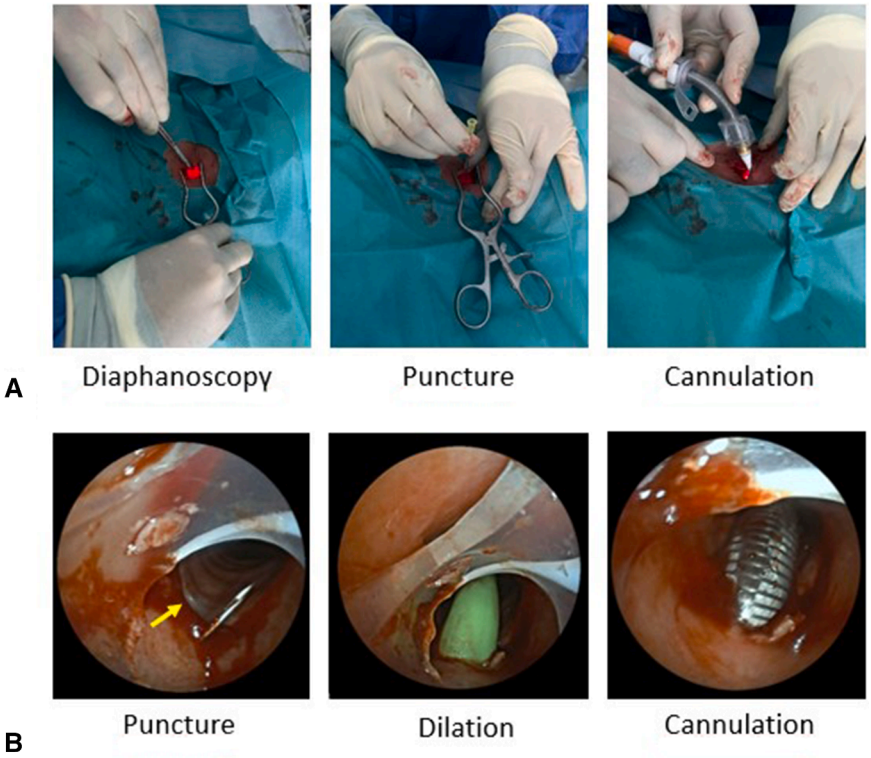

FIGURE 1. Minimally invasive tracheostomy (*MIT*) procedure. A, Following skin incision and blunt tissue dissection, the skin incision margins were retracted using a spreader, and the trachea was identified by diaphanoscopy. Under bronchoscopic surveillance and guided by diaphanoscopy, an initial probe puncture of the trachea was carried between 2 tracheal rings with a thin 20G injection cannula. The *arrow* is indicating the previous tracheostomy site. Then a second tracheal puncture with the tracheostomy catheter was performed in close proximity to the probe puncture. Next, a guidewire was inserted, and 2 successive dilations with 2 dilators of incremental size were performed before the tracheostomy tube was placed over the guide wire. B, Bronchoscopic surveillance was used throughout the whole procedure to confirm correct tracheal puncture, dilation, and cannula position.

surgery are commonly excluded from nonsurgical tracheostomy approaches, especially in the case of additional risk factors, such as morbid obesity, scar tissue, pretracheal vasculature, and coagulation disorders. In this study, we demonstrated the feasibility of MIT in such high-risk critically ill patients with previous neck surgery and additional risk

TABLE 2. Risk factors related to complications of (re)tracheostomy

ID	Medical history	BMI	Anatomy	Imaging	Coagulation
1	Previous ST	22.9	Scar tissue	Tracheal scarring*	Anticoagulation
2	Previous ST; previous pharyngectomy; previous neck dissection; head and neck cancer	24.3	Scar tissue	Tracheal scarring*	Anticoagulation
3	Previous ST; head and neck cancer treated with radiochemotherapy	21.5	Scar tissue	Tracheal scarring*	Normal
4	Myasthenic crisis; thymectomy; morbid obesitiy	43.0	Scar tissue; thick neck	Goiter†	Thrombocytopenia
5	Previous ST; obesity	29.0	Thick neck	Dense vasculature†	Anticoagulation
6	Previous ST; liver cirrhosis	17.8	Scar tissue; fragile tissue	Tracheal scarring*	Impaired
7	Previous ST; GVHD (skin); allogeneic HSCT‡	26.5	Fragile tissue	Goiter†	Pancytopenia
8	Previous ST; previous neck dissection; head and neck cancer	20.3	Scar tissue	Tracheal scarring*	Normal
9	Previous ST; morbid obesity	71.0	Thick neck	Dense vasculature†	Anitcoagulation
10	Previous ST; liver cirrhosis	22.8	Fragile tissue	Dense vasculature†	Impaired
11	Previous cervical radiotherapy; head and neck cancer	23.9	Fibrotic skin	NA	Normal

BMI, Body mass index; *ST*, surgical tracheostomy; *GVHD*, graft-vs-host disease; *HSCT*, hematopoietic stem cell transplantation; *NA*, not applicable. *Visible on bronchoscopy. †Visible on ultrasound. ‡Hematopoietic stem cell transplantation.

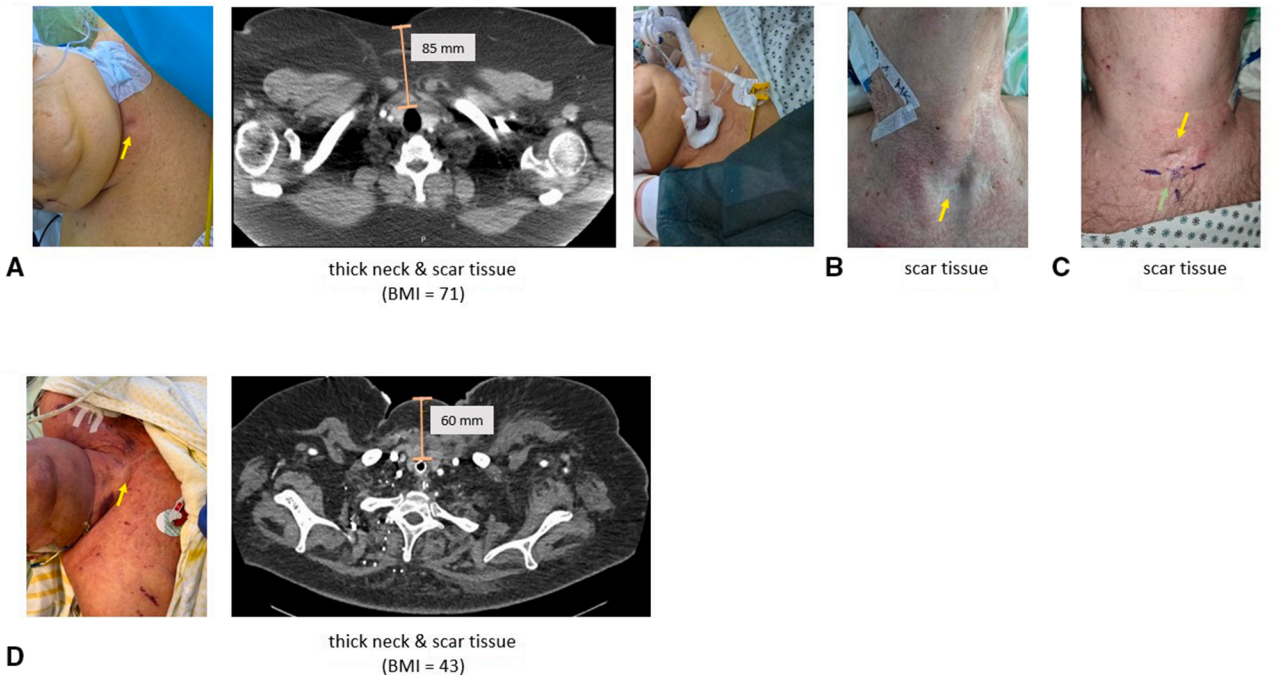

FIGURE 2. Prior neck surgery and morbid obesity as risk factors for (re)tracheostomy. A, (left) A massive neck originating from morbid obesity (body mass index [*BMI*], 71.0) together with a history of previous surgical tracheostomy (scar tissue from first tracheostomy marked by the *yellow arrow*) pose risk factors for retracheostomy in this patient; (middle) computed tomography (*CT*) scan with the distance from skin to trachea marked; (right) image obtained after safe and successful retracheostomy using the minimally invasive tracheostomy approach. B, Scar tissue (*yellow arrow*) owing to prior surgical tracheostomy. C, Scar tissue (*yellow arrow*) formed in response to prior surgical tracheostomy directly above the selected site for retracheostomy (*green arrow*). D, (left) A short and broad neck due to morbid obesity (BMI, 43) and a cervical scar (*yellow arrow*) caused by transcervical thymectomy as risk factors for tracheostomy in this patient; (right) CT scan with the distance from skin to trachea marked.

factors. The procedure time for MIT did not differ between first-time tracheostomy and retracheostomy. Regarding long-term outcomes, 6 of our 11 patients were alive at the time of this writing, none of whom had experienced decannulation failure or persistent stoma or required reintervention (Table E1). The remaining 5 patients had died from causes unrelated

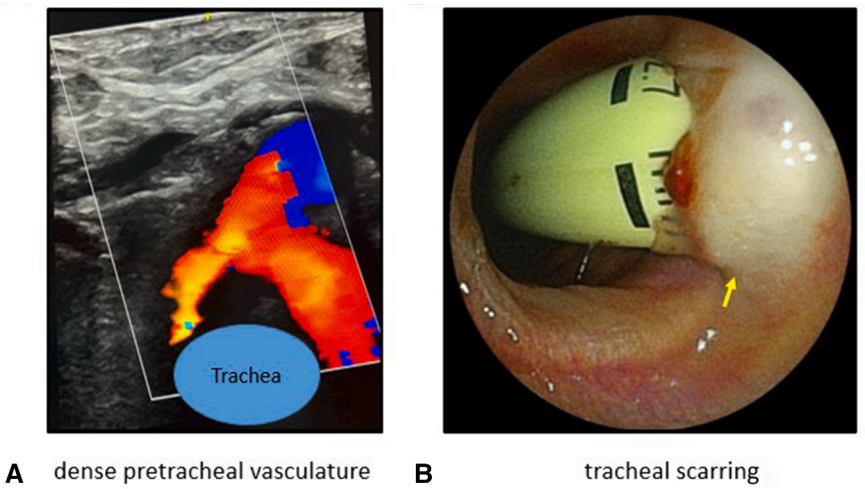

FIGURE 3. Dense pretracheal vasculature and tracheal scarring as risk factors for (re)tracheostomy. A, Prominent blood vessels located in the pretracheal tissue as revealed by ultrasound imaging. The blue ellipse represents the trachea. B, Bronchoscopic imaging showing tracheal scar tissue (*yellow arrow*) caused by previous surgical tracheostomy. Retracheostomy was performed right below the site of tracheal scarring under continuous bronchoscopic surveillance.

to the tracheostomy procedure, and none had been able to undergo intermittent decannulation (Table E1).

MIT is Safe in High-Risk Patients With Previous Neck Surgery

No serious complications associated with MIT were recorded (Table 3). Bleeding from the cannulation site was insignificant and was stopped by local compression. Significant hemorrhage or endotracheal bleeding was not observed after MIT. Tracheal laceration did not occur. X-ray performed immediately after tracheostomy excluded pneumothorax. In all, MIT interventions were successful the first time without events of tracheal perforation, laceration, or misplacement of the cannula. The first routine exchange of the tracheal cannula was performed after approximately 2 weeks without any problems.

Finally, we examined the occurrence of long-term complications associated with tracheostomy in the 6 surviving patients. Three patients experienced transient voice impairments, all of which resolved within 3 months. No airway symptoms (dyspnea or stridor), wound infections, or tracheal stenosis were reported (Table E2). Taken together, our results demonstrate that MIT can be safely performed without major complications in high-risk patients with prior neck surgery.

DISCUSSION

Traditionally, high-risk patients presenting with challenging anatomy or prior neck surgery have been exclusively recommended to undergo tracheostomy by surgeons or otolaryngologists.[9,10,17] We recently published the novel MIT approach to facilitate swift nonsurgical bedside tracheostomy in high-risk patients with morbid obesity or dense pretracheal vasculature.[13] In the present retrospective study, we investigated the feasibility and safety of MIT in high-risk patients with prior neck surgery. Even in patients with prominent cutaneous and tracheal scarring originating from previous surgical tracheostomy, MIT was performed without complications. While the majority of patients in this study had a history of previous neck surgery, a sizable proportion displayed additional risk factors, including morbid obesity, coagulation disorders, and dense pretracheal vasculature. Based on this study, we extend the applicability of MIT to the (re)tracheostomy of patients with previous neck surgery and corroborate the safety of the MIT approach in high-risk patients with challenging anatomy.

TABLE 3. Short-term complications associated with tracheostomy

Complication	Number of patients
Bleeding*	0
Pneumothorax	0
Mediastinal perforation of trachea	0
Tracheal laceration	0
Misplacement of TS tube	0
Failure to change tracheal cannula necessitating reintubation	0

*Requiring intervention beyond local compression or epinephrine injection.

In general, reports and retrospective studies of tracheostomy in patients with prior neck surgery, including surgical tracheostomy, are scarce. In a seminal case report describing for the first time a PDT approach secondary to ST, Kinnear and colleagues[14] shared their experience with a middle-aged male patient requiring prolonged ventilation for spinal shock. An early tracheostomy via PDT was performed on day 5 of mechanical ventilation. Remarkably, cannulation with a size 8 tracheostomy tube was complicated by a thick neck, requiring 2 attempts to place the cannula correctly. Accidental displacement of the tracheostomy tube 2 days later necessitated emergency endotracheal intubation owing to multiple failed attempts to reinsert the cannula. Due to tissue trauma from the recannulation attempts, a secondary tracheostomy to be performed surgically by an otolaryngologist was planned for the following day. Against the backdrop of excessive bleeding, the ST had to be aborted, and a new size 9 tube was successfully placed via endoscopic guidance provided by the blind insertion of a flexible optic through the old stoma. Several days later, the tracheal cannula was accidentally displaced once again, necessitating endotracheal intubation. Given an infection at the tracheostomy site, further surgical interventions to improve the tracheostoma were discarded in favor of a secondary PDT. Using the previous cannulation site for tracheal access, PDT was executed without compilations, marking the first reported case of PDT performed as revisional intervention after previous ST.

Whereas PDT might lead to complications in patients with thick necks and pretracheal vasculature, as exemplified by Kinnear and colleagues, our bedside MIT approach was specifically refined to deal with massive necks via an initial skin incision and blunt tissue dissection and with pretracheal vasculature via the ultrasound-guided selection of either a median or an anterolateral puncture trajectory, depending on blood vessel location. Of clinical relevance, by virtue of the skin incision and the blunt tissue dissection, reinsertion of the tracheal cannula following accidental cannula dislodgement is generally less difficult compared to conventional PDT. In contrast to the MIT approach, which is well suited for the retracheostomy of patients after previous ST with evident cutaneous or tracheal scar tissue, Kinnear and colleagues[14] performed the retracheostomy via PDT just several days after ST exploiting the old tracheal access site. This approach is feasible during the first month after ST, when excessive scar tissue has not yet formed. In cases of retracheostomy performed years after the initial procedure, as in most patients in our study, we recommend selecting a

new puncture site in close, but not identical, proximity to the old site owing to compromised stability and impaired wound healing often associated with fibrinous scar tissue. Importantly, off-midline tracheostomy is theoretically a risk factor for stenosis; however, previous studies have demonstrated the safety, efficacy, and uncomplicated perioperative course of this approach.[18-20]

Contrary to retracheostomy following ST or tracheostomy after prior neck surgery, several case studies on the safe repeat bedside PTD have been reported.[15,16,21] In one study, 14 patients with previous PDT performed between 10 days and 8 years earlier underwent successful retracheostomy via PDT.[16] Similar results from a second retrospective study were published showing the safe and successful repeated PDT in 12 neurocritically ill patients.[15] Nevertheless, none of these studies elaborated on the presence of additional risk factors, such as obesity, pretracheal vasculature, or coagulation disorders. Unlike ST, antecedent PDT usually is not associated with the formation of tangible scar tissue and anatomic distortions, making retracheostomy following PDT less complication prone. For high-risk patients following ST or other neck surgery, we highlight the MIT approach as a safe and feasible tracheostomy technique by presenting the first retrospective study to report on a nonsurgical secondary tracheostomy procedure after prior ST.

Whenever possible, it is ideal to minimize the length of the airway affected by airway appliances to reduce the risk of tracheostomy-related scar formation and subsequent complications. In patients with previous PDT or MIT, we adhered to this principle by following the trajectory of the original tracheostomy; however, in patients who had undergone previous surgical tracheostomy, preprocedural bronchoscopy revealed significant fibrosis of the anterior tracheal wall at the previous tracheostomy site. Moreover, at the skin level, extensive scar tissue was observed. Tracheostomy scars are often depressed and adherent to the underlying trachea. Tracheocutaneous fistula may represent a complication.[22] In these patients, an alternative site was selected for the second tracheostomy to promote optimal wound healing within nonfibrotic tissue and to avoid such complications as tracheal rupture during dilation or the creation of a fistula after decanulation.

Limitations of this study arise from the small cohort and retrospective nature. In particular, the low patient number is a limitation, and we plan to evaluate the MIT approach in larger, multicenter cohorts. Nonetheless, seminal studies demonstrating the safety and feasibility of a potentially high-risk procedure are critical, as they lay the foundation for larger follow-up trials. Another limitation is that all procedures were performed by highly experienced MIT operators, which may limit the generalizability and real-world applicability of our findings. Thus, follow-up studies across different sites are needed. To aid decision making, we have developed an algorithm to recommend the most appropriate tracheostomy approach based on patient risk factors and operator experience (Figure 4).

In aggregate, MIT has demonstrated safety to enable (re)-tracheostomy in high-risk patients with prior neck surgery usually considered ineligible for nonsurgical tracheostomy. Thus, we add further evidence to support the use of MIT as a universal approach for nonsurgical bedside tracheostomy in ICUs.

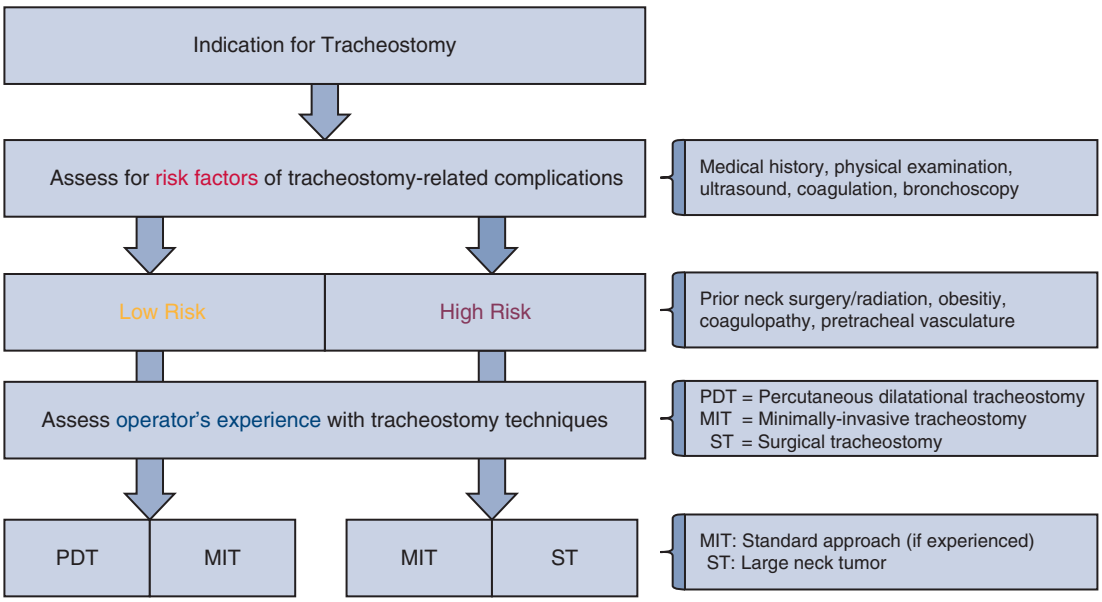

FIGURE 4. Decision making algorithm for tracheostomy based on patient risk factors and operator experience.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

Availability of Data and Materials

Original datasets are available from the corresponding author on reasonable request.

We thank the staff of our ICU for fruitful discussions and valuable input and gratefully acknowledge our patients for participating in this study.

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Key Words: tracheostomy, minimally invasive tracheostomy, surgical tracheostomy, critical care, weaning, intensive care unit

TABLE E1. Long-term outcomes

Patient	Status	Cause of death	Decannulation	Persistent stoma	Reintervention
1	Alive	NA	Yes	No	No
2	Alive	NA	Yes	No	No
3	Alive	NA	Yes	No	No
4	Dead	Septic shock, pneumonia	No	NA	No
5	Alive	NA	Yes	No	No
6	Dead	Septic shock, ACLF	No	NA	No
7	Dead	SAH	No	NA	No
8	Alive	NA	Yes	No	No
9	Dead	Septic shock, cholangitis	No	NA	No
10	Dead	ACLF; liver cirrhosis	No	NA	No
11	Alive	NA	Yes	No	No

NA, Not applicable; *ACLF*, acute on chronic liver failure; *SAH*, subarachnoid hemorrhage.

TABLE E2. Long-term complications associated with tracheostomy

Complication	Number of patients
Airway symptoms*	0
Transient voice impairment†	3
Persistent voice impairment	0
Pressure injury from cannula	0
Wound infection	0
Tracheal stenosis	0

*Dyspnea or stridor. †Lasting no longer than 3 months.