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Percutaneous Dilatational Tracheostomy in Patients with Hematologic Cancers: A Retrospective Cohort Analysis of Safety and Clinical Outcomes

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Abstract

Critically ill patients with hematologic malignancies (HM) frequently present with blood-related complications such as thrombocytopenia, coagulopathy, anemia, and leukopenia, which can considerably elevate the risk of both procedural and post-procedural adverse events. This study investigates the safety profile and clinical outcomes of percutaneous dilatational tracheostomy (PDT) in this high-risk population. We conducted a retrospective cohort study of HM patients who underwent PDT at a tertiary academic hospital from 2012 to 2023. The primary endpoint was the occurrence of bleeding complications within the first 7 days post-procedure. Secondary outcomes included procedure-related mortality and overall mortality at 7 days, thirty days, and one year. Propensity score matching was employed to adjust for baseline differences and allow accurate comparison with non-HM patients.

Among 1,627 patients included, 65 (4 percent) had HM. Patients with HM exhibited a higher Charlson comorbidity index and a markedly greater prevalence of thrombocytopenia (platelets <100,000/mcL) than patients without HM (8.0 [IQR 5.0–11.3] vs. 5.0 [IQR 2.0–7.0], $p < 0.001$; and 49.2 percent vs. 5.0 percent, $p < 0.001$, respectively). After matching, 7-day mortality was significantly elevated in the HM cohort (23.4 percent vs. 4.3 percent, $p = 0.007$), yet rates of intraoperative complications, early bleeding, and 1-year mortality were comparable between groups. PDT can be performed safely in critically ill HM patients; however, they remain at higher risk of early mortality following the procedure.

Keywords: Hematological malignancies, Intensive care unit, Percutaneous, Dilatational, Tracheostomy, Complications

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Introduction

Hematologic malignancies (HM) represent a broad spectrum of cancers originating from bone marrow and lymphatic cells. In the United States, roughly 1.4 million individuals are either living with HM or in remission. In 2019 alone, approximately 176,200 new HM cases were reported, accounting for 10 percent of all newly diagnosed cancers [1–3].

Recent therapeutic advances and improvements in supportive care have enhanced survival among HM patients [4]. At the same time, these improvements have resulted in more patients experiencing critical complications requiring ICU admission [5–7]. About 14 percent of patients with HM are admitted to the ICU within one year of diagnosis [7]. Historically, ICU mortality rates in this population reached up to 90% [8–10], though modern studies from specialized centers suggest mortality rates are now closer to 50% [8].

Acute respiratory failure is one of the most frequent and severe complications in HM, accounting for 60–80% of ICU admissions in this population [11]. Among patients

with lymphoma or leukemia, 10–20% experience respiratory failure, whereas this rate rises to around 50% in patients with neutropenia or following bone marrow transplantation [12, 13]. Mortality remains high, particularly in mechanically ventilated patients and allogeneic transplant recipients [14, 15]. While nearly half of these patients may not survive, recent data indicate a trend toward improved survival [16]. Some survivors develop chronic respiratory failure, often requiring prolonged ventilatory support due to neuromuscular weakness or lung damage.

Tracheostomy is indicated in 10–20 percent of patients requiring extended mechanical ventilation, with its utilization increasing over the past two decades [17, 18]. Though the prevalence of tracheostomy specifically among HM patients has not been well documented, it is likely higher than in the general ICU population because HM increases the likelihood of prolonged weaning [19].

Percutaneous dilatational tracheostomy (PDT), first introduced in 1955 [20], has become the preferred approach for ICU patients needing long-term respiratory support. Compared to traditional surgical tracheostomy, PDT offers advantages such as bedside performance, fewer complications, reduced costs, and avoidance of operating room delays [21]. Studies have demonstrated its safety in high-risk populations, including patients with morbid obesity, coagulopathy, cirrhosis, and those on dual antiplatelet therapy [22–26].

Patients with HM often have thrombocytopenia, anemia, leukopenia, and coagulopathy, which heighten their risk for procedural and post-procedural complications, including bleeding, airway injury, and infections [27]. Despite these risks, comparative data on PDT safety in HM versus non-HM critically ill patients are lacking. This study aims to evaluate PDT-associated bleeding risk and overall safety in HM patients, hypothesizing that their unique hematologic profiles may result in different clinical outcomes compared to other ICU patients.

Materials and Methods

Study design and setting

We conducted a single-center retrospective cohort study at Rambam Health Care Campus, a 1,000-bed university-affiliated tertiary referral center and the only Level I trauma and burn facility in northern Israel (serving >2 million people). The protocol was approved by the local Institutional Review Board (approval no. 0143-21-RMB), and the requirement for informed consent was waived due to the retrospective design.

All adult critically ill patients who underwent bedside percutaneous dilatational tracheostomy (PDT) for prolonged mechanical ventilation between January 2012 and March 2023 were screened through electronic medical records and manual chart verification. Emergent tracheostomies, procedures performed for airway obstruction from tumors or maxillofacial trauma, and surgical (open) tracheostomies were excluded.

Patients with an active hematologic malignancy (HM) at the time of PDT—identified by ICD-10 codes, confirmed by the Hematological Malignancy Research Network diagnostic criteria, and verified during chart review—formed the exposure cohort. These patients were further classified into three prognostic subgroups according to expected 5-year overall survival: favorable (>70%), intermediate (30-70%), and unfavorable (<30%) [28]. Patients without any documented hematologic malignancy (confirmed by the same rigorous chart review) constituted the control cohort.

Percutaneous dilatational tracheostomy technique

All procedures were performed at the bedside by board-certified intensivists, otolaryngologists, or cardiothoracic surgeons with a minimum prior experience of 30 PDTs, in line with international society recommendations [29, 30].

A single-step modified Ciaglia technique was used throughout the study period, employing either the Blue Rhino kit (Cook Medical, Bloomington, IN, USA) or the Portex Ultraperc kit (Smiths Medical, Hythe, Kent, UK) and 7.5- or 8.0-mm cuffed tracheostomy tubes [21].

Sedation and analgesia were achieved with intravenous propofol (1.5 mg/kg) or midazolam (5–10 mg) plus fentanyl (50–100 μg); neuromuscular blockade with rocuronium (0.6–1.2 mg/kg) was added when judged necessary by the anesthesiologist. Patients were ventilated on volume-controlled mode with FiO_2 1.0 and PEEP 5 cmH_2O. Neck hyperextension was achieved with a shoulder roll unless contraindicated by cervical spine instability.

Following local anesthesia with 2% lidocaine, a short vertical midline skin incision was made. Blunt dissection was carried down to the trachea, and the endotracheal tube was withdrawn under direct laryngoscopy until the cuff lay just below the vocal cords. Tracheal puncture was performed with a 14-gauge needle; intraluminal position was confirmed by effortless air aspiration. A J-wire was inserted, followed by progressive dilatation was performed, and the tracheostomy tube was advanced over the dilator using standard Seldinger technique.

Tube position was confirmed by auscultation and capnography; the tube was then sutured and tied in place. A chest X-ray was obtained routinely after the procedure. Bronchoscopy or real-time ultrasound guidance was used selectively in anatomically challenging cases.

Anticoagulation was managed as follows: prophylactic heparin was stopped 12 hours and therapeutic anticoagulation at least 24 hours before PDT; both were restarted 12 and 24 hours afterward, respectively. Pre-

procedure correction with platelets (if count <50 × 10⁹/L) or fresh frozen plasma (if INR >1.5) was performed at the treating physician's discretion. Patients receiving dual antiplatelet therapy were not included in this analysis.

Outcome measures and data collection

The primary endpoint was early bleeding within 7 days after PDT, classified as:

- Minor: bleeding controlled by local pressure, gauze change, or bedside suturing
- Major: bleeding requiring surgical exploration in the operating room, urgent bronchoscopy for airway obstruction, hemoglobin drop ≥2 g/dL, or transfusion of ≥2 units of packed red blood cells [31, 32].

Secondary endpoints included procedure-related death, as well as all-cause mortality at 7 days, 30 days, and 1 year.

The following variables were extracted from electronic medical records: age, sex, body mass index (BMI), Charlson Comorbidity Index, primary admission diagnosis, duration of invasive mechanical ventilation before tracheostomy, use of antiplatelet drugs, and the most recent laboratory values (platelet count, partial thromboplastin time [PTT], and international normalized ratio [INR]) obtained 24–48 hours prior to the procedure. Mortality at the predefined time points was also recorded. The Charlson Comorbidity Index, a validated weighted score that predicts 1-year mortality based on the number and severity of comorbid conditions, was calculated for each patient [33].

Data abstraction followed standardized methodology for retrospective cohort studies [34]. Three trained abstractors, blinded to the study hypothesis, independently reviewed all charts using a structured, pilot-tested data collection form. Outcome assessment was performed by a separate investigator. The study adhered to the STrengthening the Reporting of OBservational Studies in Epidemiology (STROBE) guidelines [35].

Statistical analysis

Categorical data are presented as numbers and percentages; continuous data are reported as medians with interquartile ranges (IQR). Between-group comparisons were performed using the χ^2 test or Fisher's exact test for categorical variables and the Mann–Whitney U test for continuous variables. Statistical significance was set at two-sided $p < 0.05$.

Missing data were handled by listwise deletion. To minimize confounding, propensity score matching was applied using admission diagnosis, Charlson Comorbidity Index, and platelet count as covariates. Matching was performed with a caliper width of 0.2 of the standard deviation of the logit of the propensity score.

All analyses were conducted with IBM SPSS Statistics, version 26.0 (IBM Corp., Armonk, NY, USA).

Results and Discussion

Between January 2012 and March 2023, a total of 1911 critically ill patients underwent tracheostomy for prolonged mechanical ventilation. Of these, 225 patients (11.8%) were judged unsuitable for percutaneous dilatational tracheostomy due to difficult neck anatomy (short or thick neck, morbid obesity, cervical mass, or large goiter) and were referred for open surgical tracheostomy. Another fifty nine patients (3.1 percent) were excluded because they were receiving dual antiplatelet therapy.

After exclusions, 1627 patients who underwent bedside PDT were included in the final analysis. Among them, 65 patients (4.0%) had active hematologic malignancy and formed the HM cohort, whereas the remaining 1562 patients (96.0%) without hematologic malignancy served as controls **(Figure 1)**.

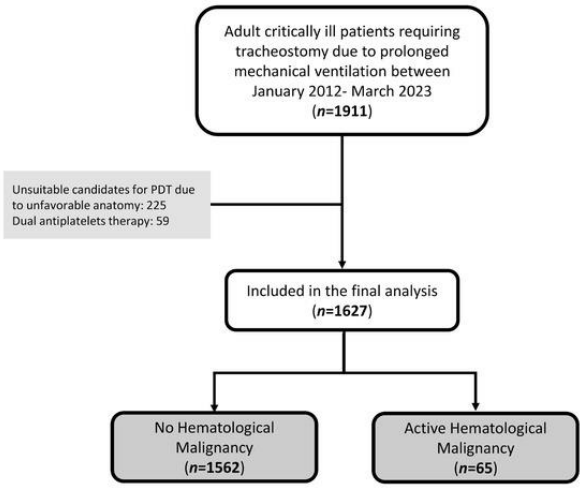

Figure 1. Patient inclusion flow diagram.

The types and characteristics of hematologic malignancies among the included patients are summarized in **Table 1**.

Table 1. Classification of hematological malignancies in the study cohort (n = 65) according to 5-year survival probabilities, based on the Hematological Malignancies Research Network [8].

Prognostic Category	Number of Patients (%)
High survival likelihood (5-year survival >70%)	15 (23.1%)
Intermediate survival likelihood (5-year survival 30–70%)	32 (49.2%)

Low survival likelihood (5-year survival <30%)	18 (27.7%)

Although baseline characteristics were generally similar between the two groups, patients with hematological malignancies presented with notably higher Charlson comorbidity index scores (median 8.0, IQR 5.0–11.3 versus 5.0, IQR 2.0–7.0, $p < 0.001$) and a markedly greater frequency of thrombocytopenia (platelet count <100,000/mcL) (49.2% versus 5.0 percent, $p < 0.001$). Admission diagnoses varied between groups **(Table 2)**, and one patient in the hematologic group required FFP transfusion prior to the procedure. Most patients in both cohorts received tracheostomy later than 10 days after initiating invasive mechanical ventilation, with early tracheostomy performed in 26.2 percent of the hematologic patients and 28.0% of those without hematologic disease ($p = 0.74$).

Table 2. Demographic, clinical, and laboratory profiles of the study population (n = 1627).

Characteristic	Active Hematologic Malignancy (n = 65)	No Hematologic Malignancy (n = 1562)	p-Value
Age, years, median (IQR)	64.9 (55.9–70.1)	64.1 (49.2–74.0)	0.97
Male sex, n (%)	40 (61.5%)	1045 (66.9%)	0.37
Charlson comorbidity index, median (IQR)*	8.0 (5.0–11.3)	5.0 (2.0–7.0)	**<0.001**
Admission diagnosis, n (%)			**<0.001**
Medical	41 (63.1%)	618 (39.6%)	
Neurological	5 (7.7%)	254 (16.3%)	
Surgical	4 (6.2%)	103 (6.6%)	
Trauma	2 (3.1%)	400 (25.6%)	
Other	13 (20.0%)	186 (11.9%)	
BMI, kg/m², median (IQR)	26.0 (22.00–29.19)	26.0 (23.11–30.75)	0.07
Duration of mechanical ventilation before tracheostomy, median (IQR)**	12.0 (9.0–15.0)	12.0 (9.0–17.0)	0.26
Early tracheostomy (<10 days of ventilation), n (%)	17 (26.2%)	438 (28.0%)	0.74
Recent aspirin use (≤5 days before procedure), n (%)	6 (9.2%)	211 (13.5%)	0.32
Recent clopidogrel use (≤5 days before procedure), n (%)	0 (0.0%)	23 (1.5%)	0.32
Platelet count, K/mcL, median (IQR)	100.0 (50.8–242.3)	282.0 (197.0–402.0)	**<0.001**
Thrombocytopenia (platelets <100 K/mcL), n (%)***	32 (49.2%)	78 (5.0%)	**<0.001**
INR, median (IQR)	1.07 (1.01–1.19)	1.07 (0.99–1.16)	0.88
aPTT, sec, median (IQR)	27.7 (25.5–31.1)	28.7 (26.1–31.5)	0.38
Intraoperative complications, n (%)	0 (0.0%)	23 (1.5%)	0.32
Early bleeding, n (%)			
Minor	5 (7.7%)	75 (4.8%)	0.29
Major	0 (0.0%)	5 (0.3%)	0.65
Late bleeding, n (%)	0 (0.0%)	4 (0.3%)	0.68
PDT-related mortality, n (%)	1 (1.5%)	9 (0.6%)	0.33
7-day all-cause mortality, n (%)	13 (20.0%)	85 (5.4%)	**<0.001**
30-day all-cause mortality, n (%)	32 (49.2%)	363 (23.3%)	**<0.001**
1-year all-cause mortality, n (%)	48 (73.8%)	765 (49.0%)	**<0.001**

*Charlson comorbidity index missing in 10 patients (0.6 percent) in the control group.

**Mechanical ventilation duration missing in 22 control patients (1.4 percent) and 1 patient in the HM group (1.5%).

***Thrombocytopenia was defined as platelet count <100 K/mcL

BMI: Body Mass Index; INR: International Normalized Ratio; aPTT: Activated Partial Thromboplastin Time; PDT: Percutaneous Dilatational Tracheostomy. Statistically significant values ($p \leq 0.05$) are highlighted in bold and italics.

In the hematological malignancy group, 5 patients (7.7 percent) experienced early bleeding, all classified as minor, whereas the control group reported 80 bleeding events (5.1 percent), including 75 minor and five major cases (p = 0.36). PDT-related mortality occurred in one patient with HM (1.5 percent) compared to nine patients (0.6 percent) in the control group (p = 0.33). Nevertheless, mortality at 7 days, 30 days, and 1 year was notably higher in the HM cohort.

Following adjustment using propensity scores and matching for admission diagnosis, Charlson comorbidity index, and platelet count, only the 7-day mortality remained significantly elevated in patients with hematologic malignancies (23.4 percent vs. 4.3 percent, p = 0.007), while bleeding complications and 1-year mortality rates were similar between the two groups **(Table 3)**.

Table 3. Demographic, clinical, and laboratory characteristics of the propensity score–matched cohort

Characteristic	Active Hematologic Malignancy (n = 47)	No Hematologic Malignancy (n = 47)	p-Value
Age, years, median (IQR)	66.2 (58.8–71.9)	65.1 (59.7–72.3)	0.89
Male sex, n (%)	26 (55.3%)	23 (48.9%)	0.54
Charlson comorbidity index, median (IQR)	7.0 (6.0–8.0)	7.0 (5.0–9.0)	0.58
Admission diagnosis, n (%)			1.00
Medical	32 (68.1%)	32 (68.1%)	
Neurological	4 (8.5%)	4 (8.5%)	
Surgical	2 (4.3%)	2 (4.3%)	
Trauma	1 (2.1%)	1 (2.1%)	
Other	8 (17.0%)	8 (17.0%)	
BMI, kg/m², median (IQR)	25.9 (22.9–29.4)	25.0 (23.5–31.0)	0.58
Duration of mechanical ventilation before tracheostomy, median (IQR)	12.0 (10.0–15.0)	15.0 (10.3–22.8)	***0.01***
Aspirin use within 5 days prior to procedure, n (%)	4 (8.5%)	10 (21.3%)	0.08
Clopidogrel use within 5 days prior to procedure, n (%)	0 (0.0%)	0 (0.0%)	1.00
Platelet count, K/mcL, median (IQR)	121.0 (81.0–244.8)	188.0 (73.0–268.3)	0.34
Thrombocytopenia (platelets <100 K/mcL), n (%)	19 (40.4%)	19 (40.4%)	1.00
INR, median (IQR)	1.07 (1.02–1.20)	1.05 (0.97–1.13)	0.31
aPTT, sec, median (IQR)	29.3 (26.0–31.8)	27.9 (24.2–30.5)	0.16
Intraoperative complications, n (%)	0 (0.0%)	1 (2.1%)	0.32
Early bleeding, n (%)			
Minor	3 (6.4%)	4 (8.5%)	0.69
Major	0 (0.0%)	0 (0.0%)	1.00
Late bleeding, n (%)	0 (0.0%)	0 (0.0%)	1.00
PDT-related mortality, n (%)	0 (0.0%)	0 (0.0%)	1.00
7-day all-cause mortality, n (%)	11 (23.4%)	2 (4.3%)	***0.007***
30-day all-cause mortality, n (%)	23 (48.9%)	14 (29.8%)	0.06
1-year all-cause mortality, n (%)	35 (74.5%)	38 (80.9%)	0.46

BMI: Body Mass Index; INR: International Normalized Ratio; aPTT: Activated Partial Thromboplastin Time; PDT: Percutaneous Dilatational Tracheostomy. Statistically significant differences (p < 0.05) are highlighted in bold and italics.

Our findings indicate that percutaneous dilatational tracheostomy (PDT) can be conducted safely in critically ill patients with hematological malignancies (HMs) who require extended mechanical ventilation. After controlling for comorbidities and other confounding factors, PDT was not associated with increased early bleeding in this group. Nevertheless, patients with HMs experienced higher short-term mortality at seven and thirty days, although these outcomes were not directly related to the tracheostomy procedure, and 1-year mortality did not differ significantly between groups.

Patients with HMs admitted to intensive care units are at high risk of death, a risk that is further amplified when invasive mechanical ventilation becomes necessary [36]. Managing respiratory failure in this population is particularly complex and demands close coordination among hematologists, intensivists, pulmonologists, infectious disease experts, and other specialists to ensure optimal ICU care as a bridge to anticancer therapy [11]. Supporting this, a multinational study by Bris *et al*. reported a 90-day mortality rate of 64.4% among HM patients admitted for acute respiratory failure [37]. These patients often face numerous complications, including infections, sepsis, metabolic imbalances, and heightened risks of both bleeding and thrombosis [27]. Surgical interventions, even minor ones, are associated with elevated complication rates and mortality in HM patients [38–40]. For example, Forrester *et al*. reported a nearly threefold increased risk of death (standardized mortality ratio 2.9, IQR 2.2–3.8) following general surgical procedures in this population [38], while Nguyen *et al*. observed higher rates of postoperative complications after cardiac surgery, including increased transfusion requirements, respiratory failure, acute kidney injury, prolonged ICU and hospital stays, and numerically higher 30-day mortality [39, 41, 42].

While immunosuppression from disease or therapy contributes to surgical risks, immediate procedural complications are often driven by bleeding tendencies. Although low platelet counts or prolonged coagulation times explain some of this risk, accurate biomarkers for predicting hemorrhage in critically ill HM patients remain limited [43]. In a cohort of 1,012 critically ill HM patients, Vigneron *et al*. reported that 10.8% suffered severe bleeding events (WHO grade 3–4), with more than half classified as grade 4, indicating life-threatening hemorrhage. These events were associated with longer ICU stays, increased ICU mortality, and higher needs for mechanical ventilation, vasopressors, renal replacement therapy, and transfusions [44].

Evidence regarding tracheostomy in cancer patients, particularly those with HMs, is limited. Angelberger *et al*. evaluated PDT and surgical tracheostomy in immunocompromised hematology patients, most of whom were thrombocytopenic. In 84 patients (63 receiving PDT), periprocedural complications occurred in three cases (4.6 percent) without fatalities, and only two patients (3.2%) experienced postprocedural bleeding, which was more frequent in the open surgery group [45]. Similarly, Kumar *et al*. demonstrated that tracheostomy can be safely performed in critically ill cancer patients, including those with comorbidities, thrombocytopenia, or COVID-19 infection, although short-term mortality remained high; no procedural deaths occurred, and 70 percent of patients had died within six months. In this study, the majority had solid tumors, with only 36% having HMs [46]. Previous research has also shown that PDT is feasible in other high-bleeding-risk populations, including patients with cirrhosis or those on dual antiplatelet therapy [24, 25], and even in a small cohort of 26 neutropenic patients, tracheostomy was well tolerated without major adverse events [47].

Our findings indicate that patients with hematological malignancies (HMs) undergoing percutaneous dilatational tracheostomy (PDT) experience relatively few procedural complications. In this cohort, there was only one instance of periprocedural death (1.5 percent) and five cases of minor early bleeding (7.7 percent). Despite the low procedural risk, short-term mortality was considerable, with up to 20 percent of patients dying within one week post-procedure. One-year mortality remained high in this group but was similar to rates observed in patients without HMs. The elevated early mortality likely reflects the severity of the underlying critical illness, though factors such as suboptimal timing of tracheostomy or an increased susceptibility to post-procedural infections may also play a role and warrant further investigation.

In our cohort, hematologic patients underwent tracheostomy after a median of twelve days of mechanical ventilation, with only about one-quarter receiving early tracheostomy, typically defined as placement within 7–10 days of ventilation. Previous studies have demonstrated that earlier tracheostomy can modestly reduce mortality, shorten ICU stays, decrease the duration of mechanical ventilation, and lower the incidence of pulmonary infections [48, 49]. Early tracheostomy is also associated with faster achievement of patient-centered milestones, including the ability to communicate, mobilize out of bed, and resume oral intake, while reducing the need for sedatives and analgesics [50]. Certain subgroups, such as patients with severe traumatic brain injury, stroke, acute spinal cord injury, multiple rib fractures, or severe polytrauma, may derive particular benefit from early intervention [41, 42, 51–53]. Notably, Blot *et al*. (1995) observed that in mechanically ventilated neutropenic patients, tracheostomy performed within forty eight hours of ventilation initiation was associated with a trend toward improved survival [54].

The optimal timing of tracheostomy has not been extensively studied in cancer patients or those with HMs. Given that these patients often have lower probabilities of successful ventilator weaning [19], early tracheostomy could be considered to potentially improve outcomes. Early intervention may allow for reduced reliance on continuous sedatives and inotropic agents, which are commonly used to manage hypotension but may contribute to immunosuppression, cytokine dysregulation, micro-aspiration, impaired gastrointestinal motility, microcirculatory changes, and increased infection risk

[55]. By facilitating earlier weaning, reducing ventilator-associated pneumonia, minimizing systemic infections, promoting alertness and mobility, and easing nursing care, early tracheostomy could support faster rehabilitation and hospital discharge [56].

This study has several limitations. Its retrospective design introduces potential biases, the relatively small size of the HM cohort may limit generalizability, and our analysis was restricted to bleeding complications, excluding other relevant outcomes such as ventilator-associated pneumonia or stoma infections.

Conclusion

In summary, PDT appears safe in critically ill patients with HMs, with no increase in early bleeding or procedure-related mortality. However, roughly one in four patients may die within the first week following the procedure. Future research should aim to confirm these findings, identify factors contributing to early mortality, and further evaluate the impact of tracheostomy timing on clinical outcomes in this high-risk population.

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