Tracheostomy Complications as a Trigger for an Airway Rapid Response: Analysis and Quality Improvement Considerations

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Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

Abstract
Objective. To analyze the subset of airway rapid response (ARR) calls related to tracheostomy identified over a 46-month period from August 2011 to May 2015 to determine proximate cause, intervention, and outcome and to develop process improvement initiatives.


Setting. Tertiary care academic medical center in a large urban setting.

Subjects. Hospital inpatients with an in situ tracheostomy or laryngectomy who experienced an ARR.

Methods. Detailed review of operator, hospital, and patient records related to ARR system activations over a 46-month period.

Results. ARR was activated for 28 patients with existing tracheostomy. The cohort included open tracheostomy (n = 14), percutaneous tracheostomy (n = 8), laryngectomy stoma (n = 3), and indeterminate technique (n = 3). The most frequent triggers for emergency airway intervention were decannulation (n = 16), followed by mucus plugging (n = 4). The mean body mass index of ARR patients was higher than that of a comparator tracheostomy cohort (32.9 vs 26.3, \( P < .001 \)). BMI was \( > 40 \) in 9 ARR patients. There was 1 mortality in the series.

Conclusions. Tracheostomy is a major trigger for ARR with potential fatal outcome. Factors that may contribute to tracheostomy emergencies include high body mass index, surgical technique for open tracheostomy or percutaneous tracheostomy, tracheostomy tube size, and bedside tracheostomy management. Results have triggered a hospital-wide practice improvement plan focused on tracheostomy awareness and documentation, discrete process changes, and implementation of guidelines for emergency management.

Keywords
Tracheostomy, difficult airway, rapid response teams, surgical airway

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Loss of an airway in the hospital setting is an anxiety-provoking event for the health care team, with potential for severe morbidity. Airway emergencies typically encompass either an unexpected loss of airway in the intubated patient or the inability to mask ventilate or intubate after induction of anesthesia for planned intubation. Rescue of the latter situation necessitates a needle cricothyroidotomy, surgical tracheostomy, or surgical cricothyroidotomy. Rapid response teams increasingly feature in the hospital response to patients experiencing clinical deterioration on the inpatient wards.¹ The airway rapid response (ARR) team at the Hospital University of Pennsylvania was developed in 2009 as a response to several “can’t intubate/can’t ventilate” scenarios that required placement of an emergent surgical airway. The intent of the ARR team was to rapidly gather at the bedside, through a single activation pathway, the surgical expertise and equipment necessary to perform a surgical airway or manage a tracheostomy emergency (see Figure 1). In an effort to assess utilization of the ARR system and identify opportunities for system improvement, we undertook a review of activations during the most recent period for which data were available. Our review demonstrated that >1 in 5

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activations of the ARR system involved a patient with an in situ surgical airway. We undertook an analysis of this subset of ARR activations to document the nature of these particular events in an effort to identify risk factors and areas for process and quality improvement. We hypothesized that accidental decannulation, percutaneous tracheostomy, and obesity (body mass index [BMI] >30) would be the most common attributes associated with ARR events in tracheostomized patients.

Methods
The Institutional Review Board of the Perelman School of Medicine at the University of Pennsylvania approved the study. We manually reviewed the operator call logs for notation of ARR activation. Archival records prior to mid-2011 were unavailable. Three logged operator events identified a clinical location but could not be linked to a patient. Relevant hospital documentation was reviewed for each event. We collected data on 129 patients, and detailed review identified a subset of 28 patients who had a surgical airway in place at the time of the ARR. Additional data were collected on this subset of patients. Data abstracted included the following: the indication for the surgical airway, the interval from surgical airway to ARR, the type of tracheostomy (percutaneous, open, or stoma), the specifics of the technique of open tracheostomy (incision, management of the thyroid, technique of entry, management of the tracheal cartilage, method of securing the tracheotomy tube, and postoperative management). ARR data were evaluated for issue that triggered the ARR. Triggers were divided into 3 categories: mucus plug, bleeding, and decannulation (accidental or planned). The data were reviewed and analyzed by all authors. Mean BMI of tracheostomy patients who did not experience an ARR was calculated by dividing the tracheostomy procedures by the pulmonary service in academic year 2014-2015 (n = 26) and open procedures billed under Current Procedural Terminology code 31600 or 31610 during the third quarter of 2014 (n = 58, all departments). The 2-tailed Student’s t test with unequal variances was used to determine statistical significance (P < .001)

Results
We analyzed data from 129 patients. The larger group (n = 101) consisted of patients requiring emergent intubation for either unplanned extubation or acute respiratory distress who had high-risk features (Figure 1). Here we report results for the smaller cohort of 28 patients (21.7%) who had both ARR activation and a surgical airway in place at the time of the ARR event. Most of the 28 patients had a single ARR event, but the ARR was activated multiple times for 2 patients during the same admission. For patients with multiple ARR activations, the first ARR was considered to be the primary event. Most events took place in the intensive care units (n = 16, 57.1%). Most of others (n = 10, 35.7%) occurred on general medical/surgical inpatient wards. One event occurred during transport from an intensive care unit, and 1 occurred in the postanesthetic care unit. The proximate causes of are summarized in Table 1. More than half (n = 16, 57.4%) were decannulation related. These were divided into planned (n = 3) or accidental decannulation (n = 13). Mucus plugging was the cause in 7 patients (25%) and required tube change in 4 patients (14.3%). Active hemorrhage was the cause in 4 patients (14.3%), with 3 of these being minor. The interval from tracheostomy to ARR varied markedly. The mean for open tracheostomy was 24.4 days (range, 0-84), and the mean for percutaneous tracheostomy was 11.75 days (range, 0-20). There were 3 events on patients with fresh tracheostomy. One of them resulted from accidental decannulation. Twenty-four patients had the surgical airway procedure performed at our institution and 4 at outside hospitals. Data related to the surgical technique for tracheostomy are summarized in Table 2. The procedures included open (n = 14, 50%) and percutaneous (n = 8, 28.5%) tracheostomies, as well as tracheostomies in laryngectomized patients (n = 3, 10.7%). In 3 patients (10.7%), the surgical approach to the existing tracheostomy could not be definitely established. Bronchoscopic guidance was used to facilitate percutaneous tracheostomy in all but 1 patient, for which it was not clearly documented. In the open tracheostomy group, there were many different management techniques and nearly as many surgeons as there were patients. The thyroid isthmus was divided (n = 5), “partially divided” (n = 1), absent due to thyroidectomy (n = 1), elevated or retracted superiorly (n = 5), or not clearly documented (n = 2).

### Table 1. Airway Rapid Response Trigger in Order of Frequency and BMI (n = 28).

<table>
<thead>
<tr>
<th>Trigger</th>
<th>Mean BMI (Range)</th>
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</thead>
<tbody>
<tr>
<td>Dislodge/decannulation (n = 16)</td>
<td>36.6 (22-47.1)</td>
</tr>
<tr>
<td>Mucus plug requiring trach change (n = 4)</td>
<td>39.6 (40-53.4)</td>
</tr>
<tr>
<td>Minor bleeding only (n = 3)</td>
<td>24.85 (23-29.1)</td>
</tr>
<tr>
<td>Mucus plug suction only (n = 3)</td>
<td>23.5 (21-26)</td>
</tr>
<tr>
<td>Tracheoinnominate fistula (n = 1)</td>
<td>30.4</td>
</tr>
<tr>
<td>Minor ventilator problem (n = 1)</td>
<td>22</td>
</tr>
</tbody>
</table>

Abbreviation: BMI, body mass index.
The management of the trachea was as follows: T incision (n = 2), trapdoor/Bjork flap (n = 2), excision of the third tracheal ring (n = 3), cruciate incision (n = 1), and incision between first and second rings with 22-modifier for difficult tracheostomy (n = 1). In 1 patient, a vertical incision was made in the second ring, and in 1 patient, percutaneous tracheostomy was converted to open tracheostomy. In 1 open tracheostomy, the operation was described as performed with bronchoscopy. Complications subsequent to the ARR are presented in Table 3. One patient died after accidental decannulation, false passage, and bag mask ventilation prior to the arrival of the ARR team. Details are elaborated in the Discussion section. We identified 4 cases of very difficult tracheostomy tube reinsertion that were rescued with orotracheal intubation. Two of these cases were subsequent to percutaneous tracheostomy. One patient required open tracheostomy revision in the operating room. The tracheostomy tubes in these patients included Shiley cuffed No. 6 (n = 2), Portex No. 7.5 (n = 1), and proximal extra long tube (XLT; n = 1). In 2 patients, XLTs were initially installed (proximal, n = 1; distal, n = 1), but both of these were removed due to poor fitting at the time of the procedure. In the 1 patient who did leave the operating room with an XLT, it was changed to a standard-length tube at postoperative day 15. An ARR was activated on postoperative day 16 after accidental decannulation into a false passage. Excluding the total 1 patient who did leave the operating room with an XLT, 1 patient required suction only. Two of these cases were assumed to be mucus plugging or minor malpositioning of the tracheostomy tube. One patient (BMI, 22) required suction only. From a No. 4 to a No. 6, which resolved the problem. The values (P < .001).

Table 2. Airway Rapid Response in Existing Tracheostomy (n = 28).

<table>
<thead>
<tr>
<th>Approach to Tracheostomy</th>
<th>Mean BMI (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open (n = 14)</td>
<td>33.9 (22-47.1)</td>
</tr>
<tr>
<td>Percutaneous (n = 8)</td>
<td>31.6 (23-44.6)</td>
</tr>
<tr>
<td>Laryngectomy (n = 3)</td>
<td>23 (21-26)</td>
</tr>
<tr>
<td>Uncertain* (n = 3)</td>
<td>42 (30.4-53.4)</td>
</tr>
</tbody>
</table>

Abbreviation: BMI, body mass index.
*Tracheostomy performed at outside institution and details of technique not available.

Table 3. Subsequent Complications in Airway Rapid Response Patients with Existing Tracheostomy.

<table>
<thead>
<tr>
<th>Complication</th>
<th>Patients, n</th>
<th>Trach Type</th>
<th>Mean BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td>1</td>
<td>O</td>
<td>40.4</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>1</td>
<td>P</td>
<td>40.9</td>
</tr>
<tr>
<td>Failure to reinsert tracheostomy tube*</td>
<td>5</td>
<td>O (4), P (1)</td>
<td>39.3</td>
</tr>
<tr>
<td>Tracheoinnominate fistula</td>
<td>1</td>
<td>P</td>
<td>30.1</td>
</tr>
</tbody>
</table>

Abbreviation: BMI, body mass index; O, open; P, percutaneous.
*One patient in this group developed pneumothorax after the tracheostomy tube was reinserted following orotracheal intubation. One patient was the single mortality in this population. The other 3 patients required a return to the operating room following orotracheal intubation.

Table 4. BMI in ARR Group Compared with Tracheostomy Controls without an ARR.

<table>
<thead>
<tr>
<th>Tracheostomy Group</th>
<th>Patients, n</th>
<th>Mean BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARR: study group</td>
<td>28</td>
<td>32.9 ± 9.1a</td>
</tr>
<tr>
<td>No ARR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open tracheostomy</td>
<td>58</td>
<td>27.1 ± 5.8b</td>
</tr>
<tr>
<td>Percutaneous tracheostomy</td>
<td>26</td>
<td>24.7 ± 6.8</td>
</tr>
<tr>
<td>Open + percutaneous tracheostomy</td>
<td>84</td>
<td>26.3 ± 6.2b</td>
</tr>
</tbody>
</table>

Abbreviations: ARR, airway rapid response; BMI, body mass index.
**Different-lettered citations indicate significant difference between BMI values (P < .001).

Comparative BMI data are presented in Table 4.

Mucus plugging triggered the ARR in 7 patients. The mean BMI of ARR associated with mucus plugging was lower than that for accidental decannulation (Table 2), although the small sample size precludes statistical analysis. Two patients with a BMI >50 required a tracheostomy tube change to treat a mucus plug. Patients with BMI <30 were treated with suction.

The bleeding cohort included 1 tracheoinnominate fistula that required operative intervention. Three patients experienced “minor” bleeding, and 1 patient experienced bleeding and accidental decannulation.

Two events involved “diminished ventilation” of unclear etiology. These were assumed to be mucus plugging or minor malpositioning of the tracheostomy tube. One patient had a BMI >30 and required a change of tracheostomy tube from a No. 4 to a No. 6, which resolved the problem. The other patient (BMI, 22) required suction only.

Discussion

The ARR system for airway emergencies has been a major development in our institution and is an emerging model for experiencing no emergencies (32.9 vs 26.3, P < .001).
emergencies involving difficult airways. The ARR is initiated when the criteria shown in Figure 1 are met, and these include patients with a known difficult intubation, fresh tracheostomy, recent airway or neck surgery, and other pharyngeal or airway pathology. The ARR team is distinct from the anesthesia stat response activated for urgent, routine intubation in the following ways: the ARR call mobilizes a trauma surgery attending, an otolaryngology–head and neck surgery resident, a battery-operated flexible fiberoptic bronchoscope, a tracheostomy set with the expectation that a surgical airway will be necessary, and a video laryngoscope. Currently, these personnel and equipment are not routinely available in our intensive care units. At the time of this review, the Hospital of the University of Pennsylvania was a level I trauma center. The hospital was staffed 24 hours a day with an attending-level traumatologist. Otolaryngology house staff (year 2 or senior) cover 2 adjacent hospitals in the evening, and attending-level ear-nose-throat staff provide coverage from home such that an otolaryngologist may not be immediately available to respond. For the many hospitals without trauma surgery coverage, an alternate approach with 24/7 ear-nose-throat coverage or competency of surgical, intensive care, or anesthesia staff in formal surgical airway techniques would be necessary.

The ARR system was primarily instituted to address the need for rapid surgical airway access in the “can’t intubate/can’t ventilate” scenario. While it was anticipated that a small fraction of ARR events would involve accidental decannulation of a fresh tracheostomy, we were surprised to discover that 21.7% of all activations were related to patients with in situ airways. Our study demonstrates that patients with chronic in situ airways are a significant contributor to airway-related emergencies in a tertiary academic hospital. Although we report known complications of tracheostomy, we are not aware of detailed reports in the literature of the prevalence, outcomes, and detailed characterization of these complications in the emergency in-patient setting. Our data may underestimate the magnitude of decannulation-related emergencies. The primary care team may have managed some of these. It is likely that tertiary hospitals without an ARR system are experiencing a similar profile of tracheostomy emergencies that may be underappreciated. Even though these events represent a small fraction of total tracheostomy patients, the potential for severe associated morbidity is significant and as evidenced by the patient death and other significant interventions and complications in our cohort. The data demonstrate the need for a well-equipped, well-trained multidisciplinary team to handle decannulation emergencies, and they point to the need to identify risk factors that may be modified to reduce the occurrence of these events. The majority occurred in the intensive care unit, but many were in the general ward and occasionally at a remote location. Our institution has 4 specialized intensive care units (neuro, surgical, computed tomography, and medical) with substantial variability of skill and experience managing or performing tracheostomies. This argues for a hospital-wide system that brings appropriately skilled staff and equipment to the event as many practitioners are unfamiliar with tracheostomy emergencies.

Retrospective chart reviews are inherently limited in the ability to delineate cause-and-effect relationships. However, such investigation provides important data to guide hypothesis generation in follow-up studies, as well as a foundation for directed process improvement pilots. The small sample size limits the ability to perform rigorous statistical analysis of subsets of the data. However, overall elevated BMI is associated with a risk of activation of the ARR in our system, and we have added BMI to our quality improvement sampling data on all of our tracheostomy patients.

We believe that the goal should be zero decannulation-related inpatient airway emergencies and the implementation of a well-structured emergency pathway for those that do occur. We have instituted a multidisciplinary Airway Safety Committee in our health system, cochaired by anesthesiology and otolaryngology faculty, which includes representatives from all departments involved in airway management and airway emergency responses. The committee serves as a central group for reporting and review of hospital-wide airway-related quality and safety issues and as the primary venue for the implementation of airway-related risk reduction initiatives, educational programs, technology assessments, and process changes.

As a direct result of the findings of this review, our Airway Safety Committee has begun initiatives toward improving tracheostomy care. The centralized reporting of airway events and the multidisciplinary nature of this committee are important to process change. We added existing tracheostomy designation to immediate postevent reporting of ARR events to the Airway Safety Committee to facilitate prompt and targeted review. We implemented annual multidisciplinary airway safety grand rounds with an initial focus on tracheostomy-related emergencies. We are adapting the UK National Tracheostomy Safety Project to our local environment (http://tracheostomy.org.uk/). This will include a detailed tracheostomy information sheet and emergency rescue algorithm at the bedside for all inpatients with a tracheostomy. We are in the process of implementing waveform capnography to confirm airway patency in tracheostomized patients during ventilator reconnections and as part of emergency airway interventions. We initiated a discussion on the role of perioperative fiberoptic bronchoscopic assessment of tracheostomy tube position as part of routine perioperative management. We hypothesize that this may serve to identify airways at risk of accidental decannulation and facilitate decision making with regard to primary XLT placement in appropriate cases.

Our review highlighted the substantial heterogeneity of surgical practice for open tracheostomy. We are uncertain about the relationship of the tracheostomy approach and the risk of accidental decannulation or bleeding. We would like to evaluate a standard approach to the securing of the tracheotomy tube, the use of the Bjork flap, and the handling...
of the thyroid tissue.3,4 We are intrigued by the finding of a trend toward early decannulation events in the percutaneous tracheostomy population and delayed events in patients who underwent an open procedure, and we intend to explore this further.

The percutaneous procedure is an acceptable risk in the obese population,5 but the propensity for decannulation and the ease of emergent recannulation have not been adequately studied. We are reevaluating the risk of percutaneous tracheostomy in super morbidly obese patients (BMI >40) since 3 events occurred in this group. We note the inability to recannulate in 2 percutaneous patients. This necessitated transoral reintubation, which is a high-risk procedure in the super morbidly obese population. We are endeavoring to evaluate recannulation with the Blue Rhino introducer as a “best practice” for accidental percutaneous tracheostomy decannulation.

The patient death in this series highlights important process considerations for emergency rescue. In this case, an obese patient had an unrecognized placement of the tracheostomy tube in a false tract during reattachment to the ventilator. Prior to arrival of the airway response team, troubleshooting the resulting ventilator alarms and attendant hypoxemia included bag mask ventilation through the malpositioned tracheostomy tube and the development of pneumomediastinum. The patient was subsequently orotracheally intubated but died. The UK National Airway Audit identified tracheostomized patients as a risk factor for complications in the intensive care unit. More recently, the UK National Confidential Enquiry into Patient Outcome and Death revealed that inadequate provider knowledge and experience with tracheostomy-related emergencies was a primary risk factor for adverse outcomes in the United Kingdom.7 Our findings in this case series reinforce the UK conclusions. The United Kingdom established the National Tracheostomy Safety Project to serve as a major catalyst to the development and dissemination of algorithms and educational materials for the management of tracheostomy emergencies and has demonstrated harm reduction after implementation.1 In spite of this, tracheostomy emergencies, their causes, and quality improvement approaches to reduce event rates and associated morbidity have received scant attention in the US literature. The UK project emphasizes several critical points. First, waveform capnography has a prominent role at an early stage in emergency management. Second, oxygenation of the patient should be prioritized so that both the stoma and the oral airway should be used. Third, a potentially displaced or obstructed tube should not be given a trial of ventilation (as seen in our fatal case). Suction is attempted only after removing a blocked inner cannula, and if the suction does not pass, the tube should be replaced.

Other centers have established the importance of the multidisciplinary team2,8,9 and the role of the otolaryngologist10 and our ongoing experience demonstrates the value of the ARR team and the multidisciplinary Airway Safety Committee and further illustrates the importance of the otolaryngology-head and neck surgery team. Multidisciplinary education, in situ simulation of case-based emergencies, and the use of cognitive aids to manage acute emergencies are all likely to improve care. Principles of implementation science and rapid cycle improvement initiatives should be brought to bear on the important clinical issues raised by our study.

Conclusions

Existing tracheostomy was a frequent (21.7%) trigger for ARR in our institution. Decannulation was the most common trigger. BMI was a major risk factor for ARR with existing tracheostomy, and this particular subset of patients was at high risk for further complications. The data presented do not definitively demonstrate that a standardized tracheostomy technique, such as our preferred method of Bjork flap, improves the safety of open tracheostomy, yet none of the most serious events occurred in Bjork flap patients. Refinements in tracheostomy care within our institution continue with the aim to reduce the number of ARRs related to decannulation and to facilitate management when this life-threatening event does occur. This analysis provides useful information to surgical departments and hospital quality officers with regard to the care of tracheostomized patients and the preparedness and resource allocation for tracheostomy emergencies, while reinforcing the need for ongoing surveillance.

Author Contributions

Christopher H. Rassekh, design, drafting, analysis, acquisition approval, accountability; Jing Zhao, acquisition, revising, interpretation, approval, accountability; Niels D. Martin, acquisition, revising, approval, accountability; Ara A. Chalian, design, revising, approval, accountability; Joshua H. Atkins, design, drafting, analysis, revising, approval, accountability.

Disclosures

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References


