Emergency department predictors of tracheostomy in patients with isolated traumatic brain injury requiring emergency cranial decompression

Clinical article


Section of Neurosurgery, Department of Surgery, Aga Khan University Hospital, Karachi, Pakistan

Object. Patients with severe traumatic brain injury (TBI) frequently require a tracheostomy for prolonged mechanical ventilation and/or pulmonary toilet. It is now proven that the earlier the procedure is done, the more beneficial it is to the patient. The present study was carried out to determine if the requirement of a tracheostomy can be predicted on arrival of a patient to the emergency department. The prediction can potentially aid in combining the procedure with cranial decompression. In this study, the authors’ aim was to determine the emergency department predictors of tracheostomy in patients with isolated TBI requiring emergency cranial decompression.

Methods. The authors performed a retrospective chart review of all patients who underwent surgery for isolated TBI and required more than 4 days of mechanical ventilation. Multivariate logistic regression analysis was used for predictive indicators.

Results. In patients with isolated severe TBI, a patient age of 31–50 years, the presence of preexisting medical comorbid conditions, a delay in emergency department arrival exceeding 1.5 hours, an abnormal pupil response on arrival, and a preoperative neurological worsening during hospital stay were independent predictors of the requirement for tracheostomy. These findings were validated in a small cohort of patients and were found to be significant.

Conclusions. Requirement of a tracheostomy can be predicted in patients with severe TBI on arrival to the emergency department. These results were validated in a small cohort of patients, and it was found that the positive predictive value of requirement of tracheostomy was directly proportional to the number of predictors present. Larger prospective studies with appropriate control groups are further recommended to validate the authors’ findings. (DOI: 10.3171/2011.7.JNS101829)

Key Words • traumatic brain injury • tracheostomy • mechanical ventilation

Tracheostomy has an important role in the airway management of patients with TBI. Early and late tracheostomy procedures have both been practiced widely, and there are now overwhelming data for patients with TBI and other critically ill patients to support the advantages of performing the procedure earlier rather than later. However, very few investigators have studied the predictors of tracheostomy, that is, the factors that can help determine which patients with TBI will ultimately require a tracheal diversion procedure to facilitate airway management, especially those with severe TBI. If the likelihood of requiring a tracheostomy can be predicted with reasonable accuracy at the time of the patient’s arrival in the emergency department, the procedure can potentially be combined with the cranial decompression procedure. The current study was performed to enable neurosurgeons to predict at the time of admission which patients with TBI would require a tracheostomy for airway management, so that the procedure may be performed early in the course of management, or even combined with the decompression procedure.

Methods

A retrospective case-control study was conducted at Aga Khan University Hospital, and data regarding patients treated for TBI between 2004 and 2009 were retrieved by ICD-9. Our institution is a privately run university hospital with a Level I trauma center and serves as a...
The hospital runs a neurosurgery residency program that deals with patients of all age groups, without subspecialty sections for pediatric and adult TBI. The intensive care teams for pediatric and adult patients, however, are separate. All patients who required a supratentorial decompressive procedure for TBI, followed by postoperative ventilation for 4 days or longer, were included in the study. Patients were divided into 2 groups, those patients who required a tracheostomy any time during the hospital stay (DST group) and those patients who were extubated uneventfully (DSO group). Patients with missing data, maxillofacial and cervical injuries, history of surgery outside our institution, and severe associated systemic injuries were excluded. Also excluded from the study were patients who underwent posterior fossa decompressions, those who only required CSF diversion procedures, and those who were either extubated or died prior to Day 4 postsurgery.

As an institutional protocol, every patient with a TBI arriving to the emergency department with a GCS score of 8 or less immediately receives endotracheal intubation; the remaining patients are managed without intubation. We do not routinely perform intracranial pressure monitoring for patients with TBI. Patients with mass lesions such as extradural or subdural hematoma, fulfilling Brain Trauma Foundation guidelines, are brought to the operating room for decompressive surgery with or without replacement of the bone flap, depending on intraoperative findings. Patients without obvious mass lesions but with intracranial hypertension and persistently low GCS scores undergo ventilation in the ICU and are treated on the basis of Lund protocol and undergo serial neurological examinations and neuroimaging. In cases of medically refractory intracranial hypertension, worsening neurological status, development of a mass lesion such as flared contusions, or expanded hematoma causing midline shift, the patients are taken for a decompressive craniectomy, either bilateral or unilateral, depending on the individual case. After decompressive surgery, all patients are given a chance of gradual weaning from ventilator support. After 4 days of unsuccessful weaning or a persistently low GCS score precluding safe airway protection, the attending neurosurgeon, the attending intensivist, and the patient’s family discuss the need for a tracheal diversion procedure; if consent is given, it is usually performed within the next 24 hours, depending on the availability of the operating room. All tracheotomies are performed in the operating room with open technique by the attending neurosurgeon, neurosurgery fellows, or residents.

Data were collected using a detailed 2-page form by a neurosurgery resident after reviewing patient charts. Collected data included details regarding sociodemographic factors (age, sex, comorbidities, clinical factors including mechanism of injury, clinical examination on arrival, radiological findings, associated injuries, and so on), management-related time intervals (incident to arrival delay, arrival to operating room delay, and so on), and surgical variables (type and duration of surgery, estimated blood loss, and postoperative course). Special emphasis was placed on preoperative variables, as the objective was to analyze the predictors from these variables. Continuous variables were analyzed as means ± SDs, and the Student t-test was used to compare the 2 groups. Categorical variables were analyzed as the proportion and percentages, and the chi-square test was used to compare the 2 groups.

Predictive variables were analyzed using logistic regression. Continuous predictive variables (age, incident to arrival delay, delay in arrival to the operating room, and GCS score on arrival) were tested for linearity by plotting the quartile values against their coefficients. If linearity was not found, then they were categorized by examining the frequency distribution. Initially, smaller groups were made, and the groups with homogeneous risk were clumped to form larger groups. Univariate logistic regression was run for each variable, and the significant variables at the 5% level of significance were further analyzed using multivariate regression. An association of exposure with outcome was represented as odds ratios with 95% CIs. These findings were validated in a cohort of patients and checked for sensitivity, specificity, and positive and negative predictive values.

Results

Ninety-eight patients fulfilled the inclusion criteria, of whom 58 underwent tracheostomy (DST group). The male to female ratio was 9:1. The most common mechanism of injury was motor vehicle accident in 70 patients (71.4%). The mean GCS score on arrival was 6.66 ± 2.8, and 67 patients (68.4%) had severe TBI (GCS score ≤ 8). The remaining patients (31 [31.7%]) had an arrival GCS score of 9 or higher; however, these scores worsened during hospital stay and the patients required decompressive surgery. Neuroimaging features were classified according to Marshall classification and showed unevacuated mass lesions in 75 patients (76.5%) and diffuse injury pattern in the remaining patients. The injuries were on the left side in 44 patients (44.9%), on the right side in 32 patients (32.7%), and bilateral in 22 patients (22.4%). The mean incident to arrival time was 6.49 ± 12.8 hours, and the mean interval between arrival time and time of incision was 7.1 ± 14.5 hours. Baseline comparison of some of the arrival factors of both groups is summarized in Table 1. The 2 groups were comparable at baseline, with the exception of age and incident to arrival time.

The type of surgical decompression included craniectomy and clot evacuation with replacement of bone flap in 45 patients (45.9%), unilateral decompressive craniectomy in 31 patients (31.6%), and bilateral decompressive craniectomies in 22 patients (22.4%). No patient underwent more than one operative procedure. The mean decompression to tracheostomy time was 4.88 days. The mean duration of postoperative ventilation was 6.6 ± 2.4 days, and the mean ICU stay was 8.36 ± 3.21 days. Of the commonest infectious complications during admission, 43 patients had upper or lower respiratory tract infections, 10 patients had urinary tract infections, and 11 patients had sepsis. Causative organisms included Acinetobacter in 19 patients (19.4%); methicillin-resistant Staphylococcus aureus, Pseudomonas, and Klebsiella in 9 patients...
Emergency department predictors of tracheostomy

The findings from this study were validated by applying them to a fresh cohort of patients with isolated severe TBI who underwent emergency cranial decompression. The predictions were cross-checked with the requirement of tracheostomy. A total of 28 patients fulfilled the inclusion criteria and were analyzed. The sensitivity, specificity, positive predictive value, and negative predictive value of each significant predictive factor derived from previous multivariate analysis were calculated and are mentioned in Fig. 1. We then also checked the cumulative probability by plotting a linear graph with the presence of one or more predictive factors against the probability of requiring a tracheostomy (Fig. 2). The graph shows a linear correlation with the positive predictive value of requiring a tracheostomy being directly proportional to the number of predictive factors present. The presence of all 4 variables was found to be associated with 100% positive predictive value of requirement of tracheostomy.

Discussion

Early tracheostomy in critically ill patients, including those with TBI, has been shown to reduce the duration of ventilation, ICU length of stay, incidence of ventilator-associated pneumonia, and cost, as well as a likely improvement in overall mortality. Several of these studies were carried out in patients with TBI. An early prediction of patients likely
to require a tracheal diversion procedure for long-term airway management is the key to avail the benefits of an early tracheostomy. Only a few investigators have attempted to determine these predictors, and most of these studies have examined critically ill patients in general, of which a very small proportion comprise those with TBI. All of these studies have mainly studied factors arising during hospital stay typically on admission Day 4 or later for prediction of tracheostomy. However, this cannot be termed as an “early” prediction. In contrast, our study has attempted to explore factors present on arrival in the emergency department, so not just an early tracheostomy, but an immediate tracheostomy may be performed. The fact that we have chosen patients undergoing surgery potentiates the combination of tracheostomy with cranial decompression, thus reducing an extra operating room visit. At centers in which bedside tracheostomies are performed, this is essentially a non-issue. It is, however, of considerable importance in a setup such as ours in which operating rooms are limited, operating room time is costly, and a few days’ wait may be required for an elective procedure. Similarly, the availability of ventilators is also an issue, and each extra day that the patient occupies the ventilator waiting for a tracheostomy has to be considered.

Our study suggests that patients with TBI in the 31- to 50-year age group are almost 5 times more likely to require a tracheostomy than those in other adult age groups and 16.5 times more likely to require a tracheostomy than pediatric patients (Table 2). Similarly, patients with an abnormal pupil response on arrival, patients arriving after a delay exceeding 1.5 hours, and patients with 2 or more underlying medical conditions were also found to be likely to require a tracheostomy.

In our study, the arrival GCS score was not a statistically significant independent predictor, perhaps due to the fact that 31 patients (31.7%) had mild or moderate TBI on arrival (GCS Score 9 or better), but worsened during hospital stay. Of these patients, 23 (74%) eventually required a tracheostomy. Although multivariate analysis showed that patients who have in-hospital deterioration are more likely to require a tracheostomy (p = 0.049), it cannot be termed as an “emergency department predictor.” A subgroup analysis carried out after excluding these patients did show a positive correlation between worsening arrival GCS and requirement of tracheostomy.

Our paper specifically addresses patients with TBI because studies performed on critically ill patients in general do not apply to such patients. This is due to the fact that patients with TBI require a tracheostomy for airway protection and pulmonary toilet and not necessarily prolonged ventilatory support; therefore, predictive factors applicable to the remaining critically ill patients do not always apply to TBI patients as well. To the best of our knowledge, only 2 other investigators in recent literature have attempted to address the topic specifically in TBI patients. Major et al. studied 64 individuals (30 cases and 34 controls). The mean day of tracheostomy was Day 11, but calculations were done for a possible tracheostomy on Day 4; patients with poor prognoses and those with penetrating injury were excluded. After studying postadmission and ICU-related factors such as APACHE (Acute Physiology and Chronic Health Evaluation) criteria, the authors concluded that GCS and SAPS

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Emergency department predictors of tracheostomy

(Simplified Acute Physiology Score) on Day 4 to be significant predictors. In 246 patients with TBI, Gurkin et al.\textsuperscript{9} studied various factors including those arising during the hospital stay. Only 35 of the patients had a tracheostomy with a mean time to tracheostomy of 13.3 $\pm$ 7.0 days. They identified a presenting GCS score $\leq$ 8, Injury Severity Score $\geq$ 25, and $>$ 7 days of ventilation as significant predictors for tracheostomy. Our study differs from these studies in that we only studied patients with predominant TBI, excluding those with concomitant systemic injuries (mean Revised Trauma Score 9.5 $\pm$ 1.5), which greatly reduced confounding factors. Also, instead of studying predictors on Day 4 or later (since we attempted to address only emergency department predictors for an earlier tracheostomy), predictors such as Injury Severity Score, SAPS, and number of ventilation days found significant by Major and Gurkin and colleagues,\textsuperscript{9,17} were not significant in our study.

We would like to mention a few weaknesses of the study. First, as with all studies based on retrospective chart review, our study has inherent weaknesses in terms of quality and details of recorded clinical information. For the purpose of this study, we only included patients with predominant TBI, excluding those with concomitant systemic injuries (mean Revised Trauma Score 9.5 $\pm$ 1.5), which greatly reduced confounding factors. Also, instead of studying predictors on Day 4 or later (since we attempted to address only emergency department predictors for an earlier tracheostomy), predictors such as Injury Severity Score, SAPS, and number of ventilation days found significant by Major and Gurkin and colleagues,\textsuperscript{9,17} were not significant in our study.

We decided to make 4 days of mechanical ventilation an inclusion criterion to exclude the potential bias introduced due to these conditions. The findings of our study are therefore not applicable to these specific groups of patients.

Also, despite best attempts at selecting a uniform cohort of patients by working with rigid inclusion criteria, a homogeneous group could not be obtained for the analysis, as is usually the case in clinical studies. Perhaps this is also the reason that despite introduction of complex mathematical models, prediction of outcome in TBI patients, especially those undergoing surgery, to date remains elusive.\textsuperscript{12,13} When we tested our findings from the multivariate analysis in a new cohort of patients, our results were validated with a 100% positive predictive value when all 4 predictive factors were present. The cohort was, however, very small and the study of a larger, multicenter, prospective cohort with appropriate control group prior to acceptance is required.

**Conclusions**

Our study suggests that in patients with TBI requiring emergency cranial decompression procedures, patient age between 31 and 50 years, presence of preexisting medical comorbid conditions, arrival to the emergency department exceeding 1.5 hours, abnormal pupil response on arrival, and preoperative neurological worsening during hospital stay are independent predictors of the need for a tracheostomy. These results were validated in a small cohort of patients and were found to be significant predictors of tracheostomy, their positive predictive value being directly proportional to the number of predictors present. Larger prospective, multicenter studies with appropriate control groups are further recommended to validate our findings.

**Disclosure**

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.
Author contributions to the study and manuscript preparation include the following. Conception and design: Shamim, Qadeer. Acquisition of data: Qadeer, Farooqi. Analysis and interpretation of data: Shamim, Qadeer. Drafting the article: Shamim. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Shamim. Statistical analysis: Qadeer, Murtaza. Administrative/technical/material support: Qadeer. Study supervision: Qadeer.

References

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