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Predictors of Swallowing Outcomes in Patients with Combat-Injury Related Dysphagia

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Abstract

Background: Traumatic injuries, such as those from combat-related activities, can lead to complicated clinical presentations that may include dysphagia. *Methods:* This retrospective observational database study captured dysphagia-related information for 215 US military service members admitted to the first stateside military treatment facility after sustaining combat-related or combat-like traumatic injuries. A multidimensional relational database was developed to document the nature, course, and management for dysphagia in this unique population and to explore variables predictive of swallowing recovery using Bayesian statistical modeling and inferential statistical methods. *Results:* Bayesian statistical modeling revealed the importance of maxillofacial fractures and soft tissue loss as primary predictors of poor swallowing outcomes. The presence of traumatic brain injury (TBI), though common, did not further complicate dysphagia outcomes. A more detailed examination and rating of videofluoroscopic swallow studies from a subset of 161 participants supported greater impairment for participants with maxillofacial trauma and no apparent relationship between having sustained a TBI and swallow functioning. *Conclusion:* These analyses revealed that maxillofacial trauma is a stronger indicator than TBI of dysphagia severity and slower or incomplete recovery following combat-related injuries. *Level of evidence:* Therapeutic/Care Management study, level IV.

Keywords: traumatic brain injury, combat, maxillofacial trauma, swallowing, dysphagia, database

One of many potential sequelae of traumatic injuries, dysphagia has particular impact in terms of level of care, quality of life, and a landmark on the recovery path for patients and family members. Combat-related injuries can cause complicated neurological and structural problems that are expected to contribute to dysphagia. Blast injuries, including the internal compression effects from the primary pressure wave, impact injuries from being physically displaced, or penetrating injuries from shrapnel and debris, can cause neurologic damage. Blast victims may also sustain strokes and intracranial swelling related to compromised neurovascular systems.[1–3] Furthermore, head and neck trauma, including facial fractures, soft-tissue ablations, avulsions, and cranial nerve injuries can result from bullet fragmentation and blast injuries.[4–7] The presenting problems range from reduced consciousness as a result of polytrauma, brain injury, pain medication, and sedation to restricted movement from skeletal stabilizers, such as a halo or mandibular-maxillary fixation devices. Although these trauma mechanisms can lead to swallowing dysfunction, limited reports exist in the literature, making it difficult to predict the occurrence, severity, and course of dysphagia in combat-related injuries.

To better understand the military patient population and factors that impact recovery from dysphagia, this project involved developing and populating a multidimensional relational database that tracked demographic, injury, and dysphagia-specific variables over the course of hospitalization. Specifically, the primary objective of this study was to identify factors that are predictive of functional swallowing at the time of hospital discharge in patients with combat-related injuries. A preliminary report described the development of the database to achieve this goal.[8] The analysis involved several iterations of predictive modeling using Bayesian Belief Network (BBN) machine-learning algorithms as the database grew in size. Each iteration involved adding cases, operationally refining definitions, and selectively identifying clinically relevant variables. This article reports the final iteration of the analysis based on this research effort involving 215 inpatients. The BBN analysis was determined to be the most appropriate approach for this dataset because it manages incomplete, uneven data sets; in addition, the machine-learning approach does not rely on a priori assumptions, thus allowing the model to identify associations among variables that may not be expected.[9]

Results from the BBN analysis led to more specific hypotheses regarding primary injuries that complicated dysphagia recovery. These predictors of dysphagia outcomes were subjected to inferential statistical analysis to evaluate the reliability and strength of their influences. Specifically, the secondary objective of this study was to compare swallowing outcomes between groups of patients with and without maxillofacial trauma (MFT) and those with and without traumatic brain injury (TBI).

Methods

Participants

Inpatients admitted to (former) Walter Reed Army Medical Center (WRAMC) andWalter Reed National Military Medical Center (WRNMMC) between January 2004 and October

2014 were eligible for inclusion in this chart review if they were wounded or injured in a combat zone or combat-related activity and subsequently referred for dysphagia evaluation. The project was conducted according to the rules and regulations provided by the institutional review board at WRNMMC. If patients were admitted after institutional review board approval of the protocol, they or their legally approved representative provided informed consent for inclusion in the chart review; prior cases were approved for retrospective inclusion and were exempt from informed consent.

Medical records were reviewed and extracted for 215 patients from a pool of 557 potentially eligible candidates identified by hospital data-coders as being between the ages of 18 years and 55 years and referred for swallow evaluation. Research staff prioritized cases for whom videofluoroscopic swallow study (VFSS) images were available for reanalysis and then reviewed as many cases as was practical given time and funding constraints. Detailed information about patient history, injuries and procedures, airway and diet status, medication, swallow evaluations, and speech-language pathology (SLP) management was entered into a multilayered and multivariate database as described previously.[8] In brief, data were entered for time points corresponding to hospital admission, hospital discharge, and any intervening encounters involving a consult by a speech-language pathologist (SLP) or a change in swallowing-related status. The SLP consults were documented with special attention to swallow evaluation procedures and therapeutic recommendations. For the study's second objective, patients with available VFSS recordings were reanalyzed by the research team according to current standard clinical rating scales (Penetration-Aspiration Scale [PAS][10]; Modified Barium Swallow Impairment Profile [MBSImP]).[11]

Bayesian Data Analysis

For objective 1, BBN analysis was used to identify connections between variables and clusters of variables that contribute to predictions regarding swallowing outcomes at the time of hospital discharge. Variables with more than 20% missing data were eliminated from analysis. The BBN modeling used optimized machine-derived learning algorithms. The machine-learning tool used (FasterAnalytics) uses the evidence available in the database to link correlated variables and determine how they are distributed. Models were trained on 80% of the data and were independently validated using receiver operating characteristic analysis on the remaining 20%. BBN determined conditional probabilities between variables assessed upon initial examination, and provided outcome predictions that can be used to estimate prognosis in future clinical situations.

Preliminary models derived from the partially populated database were published previously.[8] Sequential versions of the model included increasingly more data, which allowed for greater detail and discernment of meaningful relationships between variables. The most relevant outcome measure for this study is the level of swallowing independence at the time of hospital discharge. Earlier models relied on a bilevel dichotomy for this outcome variable, but this fourth and final iteration of the model comprised an adequate sample size to use a three-tiered outcome variable.

To assign an appropriate swallowing-independence level, researchers analyzed hospital records, including SLP reports and discharge reports to determine the appropriate score on the American Speech-Language-Hearing Association National Outcome Measures

System (ASHA NOMS) for swallowing.[12] This is a seven-point scale that ranks swallowing along a continuum of complete dependence on enteral hydration and nutrition to complete independence of swallowing with no strategies, cues, or time allowances. Our analysis simplified the assigned ASHA NOMS scores into to three tiers: levels 1–2, NPO (*non per os*); levels 3–5, PO (*per os*) with restrictions and/or compensations; and levels 6–7, independent PO.

When recordings of VFSSs conducted by a clinical SLP during hospitalization were available, they were reviewed and scored subsequently by a research SLP (A.M.D., K.D.B.) according to the MBSImP system. This standardized system scores six different component movements associated with the oral phase of swallowing, 10 with the pharyngeal phase, and 1 with the esophageal phase. Each item receives a rating from 0 to 2, 0 to 3, or 0 to 4, where 0 is normal; composite scores by swallowing phase range from 0 to 22 for oral, 0 to 29 for pharyngeal, and 0 to 4 for esophageal. The MBSImP ratings were assigned for each trial and for each overall VFSS comprising swallows of a variety of bolus viscosities and volumes. The overall ratings reflected the most severe impairment observed on each swallowing component during any trial from that VFSS. Three components were omitted from further analyses because they were frequently unscorable from the clinical VFSS recordings: Component 1 (lip closure) was often not observable in the videofluoroscopic frame; component 3 (bolus preparation/mastication) requires a solid bolus that may not have been administered for clinical reasons; and component 13 (pharyngeal contraction) can be observed only in the anteroposterior view, which was not routinely captured. The MBSImP scores were not included in the BBN analysis because they were unavailable for more than 20% of total cases. However, these data were critical for the inferential analyses that followed. For those analyses, the oral phase of swallowing included ratings for components 2, 4, 5, and 6, for a total score from 0 to 15. The pharyngeal phase included components 7 to 12 and 14 to 16, for a total score from 0 to 26.

Inferential Data Analysis

After identifying predictors of swallowing outcomes based on BBN analysis, inferential statistical analysis further examined the specific contributions of MFT and TBI to swallowing outcomes for objective 2. MFT was identified if the patient sustained a fracture of the mandible or lower two thirds of the facial bones, missing or damaged teeth, or loss of soft tissue involving the neck, lower face, or oral cavity. TBI was identified if the patient was diagnosed with moderate or severe TBI (2–3 on the VA/DoD TBI Severity Scale[13]), positive neuroimaging results, or physician's notes confirming brain injury.

Two-way analyses of variance (ANOVAs) examined differences between groups defined by presence or absence of MTF and TBI for oral phase, pharyngeal phase, penetration-aspiration, and functional swallowing during initial assessments according to MBSImP and PAS ratings, and ASHA NOMS. Repeated-measures ANOVA examined changes in condensed tri-level ASHA NOMS ratings between the time of the first swallow examination and the score assigned at hospital discharge. Significance levels were set a priori at .05.

Results

Participants

Patients included in this database study were 211 men and 4 women. Ages ranged from 19 years to 46 years (median, 25.9 years) at the time of injury. The primary injuries resulted from blast explosions (n = 137), gunshot wounds (n = 46),motor vehicle accidents or rollovers (n = 19), and other causes (n = 13). Patients were transferred to WRAMC/WRNMMC from field and/or regional hospitals within 1 day to 193 days postinjury (median, 4 days), and the first SLP visit occurred from 0 day to 391 days after admission (median, 6.5 days).

BBN Modeling

The Bayesian model is illustrated graphically in Figure 1. The tri-level outcome variable, adapted from the ASHA NOMS for swallowing at the time of hospital discharge, is shown with a thick outline. First-degree associates, that is, the input variables that were most closely associated with dysphagia outcome, were

(1) solid-food restriction based on the first swallow evaluation;
(2) presence of a tracheotomy before admission; and
(3) presence of a maxillofacial fracture.

Second-degree associates were

(1) receiving nonoral nutrition at the time of the first swallow evaluation;
(2) liquid restriction based on the first swallow evaluation;
(3) damage to cranial nerves V, VII, IX, X, and/or XII;
(4) presence of orofacial soft-tissue lacerations;
(5) damaged or missing teeth;
(6) having a tracheotomy at the time of the first swallow evaluation; and
(7) rating on the TBI Severity Scale.

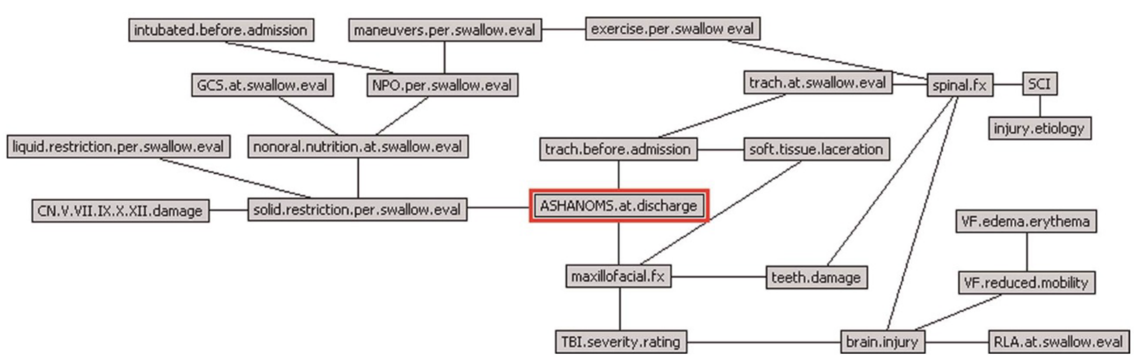

Figure 1. BBNmodel illustrating variables from the time of admission or initial assessment that are predictive of functional swallowing at the time of discharge ("ASHANOMS .at.discharge" indicated with a thick black outline). Functional swallowing was rated according to a modified tri-level version of the ASHA NOMS for dysphagia.

Summary statistics for the outcome variable reflect that 33 patients remained NPO (ASHA NOMS levels 1–2), 127 had some level of dietary or behavioral restrictions (levels 3–5), and 55 were independent with swallowing at the time of hospital discharge (levels 6–7). Validation of the model based on 20% of the data yielded acceptably robust AUC values from receiver operating characteristic analysis of 0.80, 0.84, and 0.86 for these three levels, respectively.

Inferential Analyses

Of the 215 participants in the dysphagia database, 102 were classified as having MFT and 151 had TBI; 78 had both MFT and TBI, and 40 had neither (Table 1). Trained and certified SLPs rated VFSS recordings from 161 participants with the MBSImP and PAS; 2 of these were unanalyzable for oral phase ratings. Figure 2 illustrates the summary statistics for oral-phase impairments, pharyngeal phase impairments, and penetration-aspiration scores at the time of initial VFSS according to the presence or absence of MFT and TBI. The ANOVA results, listed in Table 2, revealed that oral-phase impairments were significantly greater in patients with MFT as compared with those without MFT. The oral phase did not differ significantly according to presence or absence of TBI. Pharyngeal-phase swallowing and PAS tended to reveal greater impairments in the MFT group, but these did not meet criterion for statistical significance. These variables did not differ significantly according to presence or absence of TBI. There were no significant interactions between MFT and TBI on any of these variables.

Table 1. Numbers of Patients Classified According to the Presence or Absence of MFT and TBI

Total N	MFT	No MFT	Total
TBI	78	73	151
No TBI	24	40	64
Total	102	113	215
N with VFSS	MFT	No MFT	Total
TBI	58	56	114
No TBI	20	27	47
Total	78	83	161

Total N includes all participants; N with VFSS includes those participants with available VFSS recordings that were rated with the MBSImP and PAS.

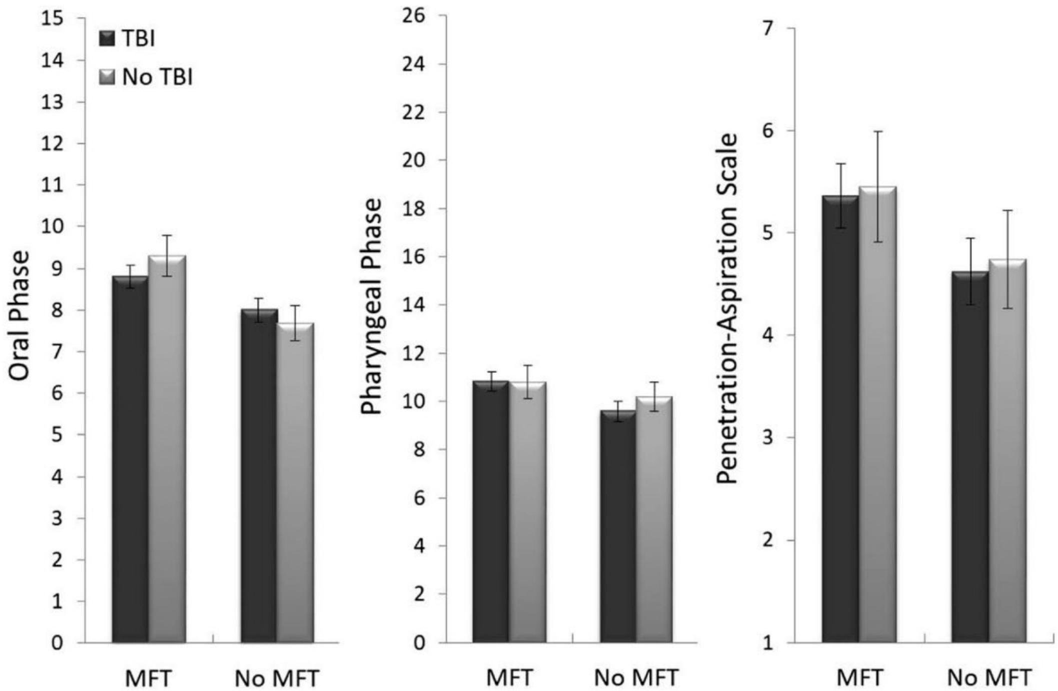

Figure 2. Scores for oral-phase impairment (left), pharyngeal-phase impairment (center), and penetration-aspiration (right) by the presence or absence of MFT and TBI. Higher scores reflect more disordered swallow function. There was a statistically significant improvement in the oral-phase of swallowing for participants with MFT compared to those without MFT ($p = 0.002$). Error bars = ±1 SE.

Table 2. ANOVA Results for VFSS Analysis from Initial Assessment According to the MBSImP (4 Components for Oral Phase; 9 Components for Pharyngeal Phase) and PAS

	Oral Phase			Pharyngeal Phase			PAS		
Effect	$F(1,155)$	p	Observed Power	$F(1,157)$	p	Observed Power	$F(1,157)$	p	Observed Power
MFT	10.249	0.002	0.889	2.639	0.106	0.365	2.896	0.091	0.394
TBI	0.064	0.800	0.057	0.297	0.586	0.084	0.057	0.811	0.057
MFT × TBI	1.147	0.286	0.186	0.318	0.574	0.897	0.001	0.974	0.061

At the time of initial testing, independence of functional swallowing was significantly greater for patients without MFT than those with MFT, $F(1,211) = 14.24$, $p = 0.0004$. The presence or absence of TBI did not have a significant effect on ratings of functional swallowing, $F(1,211) = 0.084$, $p = 0.772$. Table 3 lists the total number and percentage of patients at each level of functional swallowing at the time of initial evaluation and also at hospital discharge, thus illustrating the improvements in swallowing outcome over time as well as the persistence of some degree of dysphagia in most patients.

Table 3. Number (and Percentage) of Patients at Each Level of Functional Swallowing According to the ASHA NOMS at the First Instrumental Swallow Assessment and at Hospital Discharge

	First Study	Discharge
ASHA NOMS	n (%)	n (%)
1	41 (19.1)	12 (5.6)
2	19 (8.8)	21 (9.8)
3	26 (12.1)	34 (15.8)
4	45 (20.9)	51 (23.7)
5	40 (18.6)	42 (19.5)
6	21 (9.8)	29 (13.5)
7	23 (10.7)	26 (12.1)

The lines between sections indicate the tri-level scheme used for BBN modeling. ASHA NOMS 1–2, NPO; 3–5, PO with restrictions and/or compensations; 6–7, independent PO.

Functional swallowing improved significantly between the times of initial evaluation to hospital or SLP-service discharge, $F(1,211) = 16.405$, $p < 0.0001$ (Fig. 3). There was also a main effect of group, such that ASHA NOMS scores were lower (i.e., less swallowing independence) for participants with MFT, $F(1,211) = 14.244$, $p = 0.0002$, but not TBI, $F(1,211) = .084$, $p = 0.772$. Interactions between sessions and either group and both groups were not statistically significant [session × MFT: $F(1,211) = 0.027$, $p = 0.870$; session × TBI: $F(1,211) = 0.023$, $p = 0.878$; session × MFT × TBI: $F(1,211) = 1.287$, $p = 0.258$). The interaction between MFT and TBI was significant, $F(1,211) = 3.976$, $p = 0.047$, such that participants with MFT but no TBI demonstrated the lowest ASHA NOMS ratings and those without MFT or TBI had the highest ratings when collapsed over time. The time interval between these assessments was similar for patients with MFT (M = 26.7 days) and those without MFT (M = 27.4 days) but was substantially longer on average for patients with TBI (M = 30.9 days) than without TBI (M = 18.2 days). All but two participants were discharged from SLP services within 6 months. When these two outliers (11.2 and 19.0 months) were removed from analysis, the duration remained significantly longer for patients with TBI [25.4 days vs. 17.3 days, $F(1,209) = 4.24$, $p = 0.041$] and did not differ for patients with or without MFT [20.8 days vs. 21.8 days, $F(1,209) = 0.060$, $p = 0.807$].

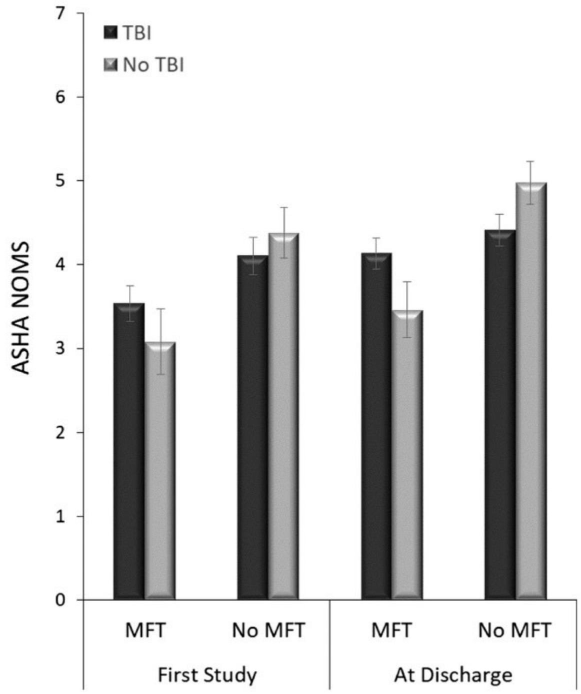

Figure 3. ASHA NOMS scores by group according to the presence or absence of MFT and TBI from the first swallow study to hospital discharge or discharge from SLP services. Higher scores reflect more independent swallow function. Swallowing independence improved significantly over time ($p < 0.0001$) and was better for participants without than with MFT ($p = 0.0002$); the interaction between MFT and TBI was also significant ($p = 0.047$). Error bars = ±1 SE.

Discussion

This multidimensional study of SMs with combat-related injuries examined injury characteristics and diagnostic information related to dysphagia to determine factors that best predicted swallowing outcomes. Bayesian modeling revealed that injuries involving MFT were most predictive of swallowing outcomes. This finding was expected given that fractures and lacerations involving the orofacial complex make it difficult to chew and prepare a bolus. Weaker associations were also found between TBI and dysphagia outcomes. In this population with polytraumatic injuries, we expected TBI to have a stronger impact on swallowing outcomes, especially when considered along with MFT-related variables in a multidimensional model. In fact, a previous retrospective review of patients admitted to an intensive care unit with blunt or penetrating neck injuries indicated that they were three times more likely to present with dysphagia if they also had TBI.[14]

To confirm the associations determined from the predictive modeling in the present study, each participant was classified according to whether or not they had MFT or TBI. Inferential analysis of functional swallowing ratings (ASHA NOMS) revealed more severe functional deficits in participants with than without MFT at the time of first study as well as at the time of discharge. Presence or absence of TBI did not influence ASHA NOMS scores at either time point. Interpretation of these data may be impacted by the even distribution of MFT but overrepresentation of TBI, particularly mild TBI, in this cohort. Interestingly, the degree of improvement was similar for all subgroups despite the longer hospital stays for the participants with TBI.

The VFSS recordings from a subset of participants (N = 161) were available for later analysis and were rated by trained and reliable research SLPs using standardized clinical rating methods to elucidate which phases of swallowing were affected by the presence of MFT and TBI. As suspected, these analyses confirmed the association between MFT and swallowing dependence from the time of the initial assessment, particularly deriving from the oral phase of swallowing. There were also tendencies for patients with MFT to demonstrate greater impairments during the pharyngeal phase of swallowing and to demonstrate penetration or aspiration of a bolus. The presence of TBI with or without concomitant MFT did not significantly impact dysphagia severity or characteristics based on these inferential analyses.

Factors regarding MFT may contribute to our understanding of the impact of these injuries on eating and swallowing. Certain fractures require surgical stabilization of the facial skeleton with mandibular-maxillary fixations, with or without open reduction internal fixations. Surgical stabilization often results in initially impaired mandibular range of motion, limiting the options for oral nutrition to liquid or pureed diets delivered via straw, syringe, or spoon. In addition, edema of the oral, pharyngeal, and laryngeal structures can occur from the primary blast wave, trauma, or postsurgically and may impede movement necessary for swallowing.[15]

Translating our results to a civilian population is complex because of the differences in the nature of typical injuries. Combat injuries are often complicated by multidirectional impacts from blast exposure, which may cause diffuse and difficult-to-quantify soft tissue damage. In contrast, civilian facial injuries, most often due to motor vehicle accidents or interpersonal violence, may be more focal.[16] Outcome predictions for dysphagia following severe TBI reported by Mandaville et al.[17] revealed different predictive variables (age, cognitive ratings, tracheotomy tube placement, and aphonia) than those identified herein, probably reflecting TBI severity. Only 25% of our patients with TBI (18% of the overall sample) were classified as having severe TBI. Borders et al.'s.[14] predictive variables (injury severity, tracheostomy, TBI, and cervical spinal bracing) for dysphagia in patients admitted to the intensive care unit of a civilian Level I trauma hospital with head/neck trauma also differed from those reported here. Their injuries almost entirely resulted from motor vehicle accidents (61%) or falls (33%), whereas our population was primarily affected by blast-related injuries (64%) or gunshot wounds (21%). Dysphagia characteristics following suicide attempts by gunshot[18] are difficult to compare because close-range facial gunshot injuries were relatively uncommon in the WRNMMC database. Overall, 21.4% of our population sustained gunshot wounds; of these, 75.5 (17.2% of our overall population) involved the neck, head, or face, with 8.7% specifically affecting the face. When a SM is in full-body protective gear, these are the only regions that are exposed, thus leaving them particularly vulnerable to injuries that could affect swallowing, speech, and survivability. In contrast, civilians involved in trauma may have more widely dispersed injuries.

The current findings highlight the complex relationship between swallowing function and artificial airways in persons with traumatic injuries. In our study population, the BBN analysis identified tracheotomy before admission as a primary associate for predicting swallow independence at discharge. It is possible that the presence of a tracheotomy in our cohort may have reflected the complexity and severity of injuries as appreciated by the medics and field surgeons. Previously, we examined swallowing mechanics related to artificial airways, bolus properties, and laryngeal trauma in selected cohorts of participants from this larger study.[19,20] Results indicated that tracheotomy repositions the larynx posteriorly, but these physiological changes were not necessarily predictive of those associated with aspiration. The extant literature on this topic is challenging to interpret due to conflicting results, a range of patient populations, and varying outcome variables. For example, Leder and Ross[21] failed to confirm a relationship between tracheotomy and aspiration in a group of mixed-etiology patients, whereas Borders et al.[14] identified patients with neck trauma to be seven times more likely to develop dysphagia if they had a tracheotomy. To further confound issues related to artificial airways, virtually all of the patients in the database were intubated at least once. Intubations have the potential to alter the sensation and mechanics of the upper aerodigestive tract,[22–24] although the effects appear to be consequential only when intubation exceeds 4 days to 5 days.[24,25] The literature is somewhat mixed regarding the relationship between intubation and dysphagia. Borders et al.[14] reported no relationship between intubation and dysphagia, but other investigators have reported prevalence of postextubation dysphagia as high as 84%.[25,26]

Other factors are clearly relevant to the interpretation of the current work and these studies. For example, many of our nontracheotomized patients required repeated endotracheal intubations with sedation for a variety of surgical procedures. Repeated intubations can increase the risk of inflammation and laryngeal trauma, both of which could contribute to swallowing dysfunction.[27] Additionally, dysphagia[28] and cognitive dysfunction,[29,30] both of which can exacerbate aspiration risk,[31] have been reported in vulnerable populations after a single episode of general anesthesia. Whether repeated sedation events would impact the current study population similarly is unknown. Finally, complex interactions between artificial airway status, bolus volume, bolus viscosity, and swallowing can introduce additional confounders to assessing and characterizing dysphagia.[20]

Associations with TBI, although weaker than those with MFT, were identified with predictive modeling but did not appear to exacerbate functional swallowing when addressed inferentially. Nonetheless, neurologic deficits clearly can result from a blast's primary pressure wave, being propelled from the explosion, or penetrating head injury. Blast victims can experience neurological deficits secondary to varying degrees of brain injury or subsequent stroke.[32,33] Neurologic deficits may not only impair swallowing function, they may further inhibit treatment due to the inability to follow recommendations or perform given tasks.[34,35] More severe neurologic impairments can also adversely affect the clinician's ability to diagnose and treat swallowing disorders in blast injury victims. A primary hurdle is the multifactorial reduced level of consciousness secondary to polytrauma, brain injury, pain medication, and/or sedation.[33] Wounded service members are often sedated for the intercontinental flight to the United States and remain on medications that can alter awareness during initial assessments. The level of consciousness may be complicated further by posttraumatic stress, depression, and cognitive deficits that have an impact on the patient's ability to participate in a diagnostic swallow assessment, follow recommendations, or engage in a swallowing treatment protocol.[31] These impairments may mask sensorimotor swallowing deficits, delay swallowing intervention, and undermine swallowing independence.

Although management strategies were documented as part of this database, these factors were not examined for the current analysis. In a separate study, we trialed an intervention strategy with patients who were prospectively enrolled into this database. Based on results of the VFSS, the clinical SLP determined whether or not there was a sensory component to their dysphagia. For those with sensory deficits, plain 5-mL bolus samples and boluses with strong tastes including sweet, sweet-sour, and highly sour, were administered. Those that included a sour taste were found to enhance tongue-base retraction, hyoid elevation, and pharyngeal shortening as compared with unflavored boluses.[19] This and other management strategies were implemented in the course of participants' hospitalization as part of their dysphagia management. Therefore, the current results cannot be considered to simply be an unaltered representation of the natural history of dysphagia recovery.

Limitations of this study are those inherent of conducting retrospective chart reviews in that data may be missing, inconsistently collected and reported, and unreliable by nature of the number of clinical providers involved. Furthermore, data were collected over a 12-year period, and clinical management approaches likely changed across the course of the study. Some of these concernswere mitigated by a separate analysis by the research SLPs of all available VFSS recordings using consistent and reliable procedures. Another limitation is the complexity of data subjected to BBN analysis, which led to pruning of the model that may have eliminated interesting relationships. Also, data were extracted from multiple linked tables that addressed multiple aspects and stages of the hospitalization process. By selecting only the initial injury characteristics and assessments and using discharge disposition as the outcome variable, we were able to address initial characteristics that affected outcome but failed to appreciate the richness of other factors that may have contributed to improved function.

The primary clinical implication of these results is to highlight the importance of evaluating oral-phase dysphagia especially in patients with MFT, as well as the challenges of distilling meaningful predictors of recovery in highly heterogeneous patient populations. With complicated etiologies and wide variety of possible outcomes, our study reflects the consequences of complex injuries that result from combat situations. This foundational evidence regarding the expected course of recovery can guide clinical decision making and patient/family education for those facing dysphagia after traumatic injury.

In conclusion, this US Army–sponsored study addressed a gap in the literature regarding the nature and outcomes of dysphagia in combat-injured military service members with dysphagia. By implementing multidimensional analysis procedures to identify injury-related variables that had the strongest impact on recovery from swallowing disorders, this study revealed the relative importance of MFT over TBI as the basis of swallowing impairments. Specifically, patients who sustained MFT were more likely to demonstrate impairments with swallowing outcomes than those without such trauma, and the additional presence of brain injury did not significantly affect the results.

Authorship – All authors made significant and substantial contributions and are willing to take public responsibility for each aspect of this study, including study design, data acquisition, data analysis, and interpretation of findings. All authors contributed to the writing of this article: N. P. Solomon drafted the initial version of this article; A. M. Dietsch and K. Dietrich-Burns made major contributions and provided critical revisions. All authors approve this final version.

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