Introduction

Several studies have examined the cognitive underpinnings of narrative discourse ability in acquired brain injury (ABI), revealing relationships between various measures of cognition and discourse production. Cognitive processes and domains, such as working memory (WM), declarative memory, executive functions (EF), and general intelligence have been shown to correlate or predict narrative ability at multiple levels of analysis (e.g., Cannizzaro & Coelho, 2012; Chapman et al., 2006; Coelho et al., in press; Kurczek & Duff, 2011). Two recent studies have proposed models of discourse production, emphasizing its cognitive bases. Duff and colleagues (2012) suggested a distributed cognition approach to the study of discourse in ABI populations. Coelho and colleagues (in press) implemented a statistical modeling approach to propose a preliminary model specific to narrative discourse, in which the direct path between IQ and story content served as the bridge between other cognitive processes and discourse measures. The latter study provided a basis for the current study and is discussed further.

In the Coelho et al. study, the participants with TBI had penetrating head injuries (PHI) caused by shrapnel projectiles. The lesions were relatively focal, but lesion size and distribution within the brain were heterogeneous across the group. Differences in discourse ability based on gross lesion location (i.e., left pre-frontal cortex (PFC), right PFC, bilateral PFC, left non-PFC, right non-PFC, and bilateral non-PFC) were unsubstantiated. Thus, alternative approaches to characterizing the nature of brain damage and the relationship to narrative discourse ability may be more insightful.

Measures of brain volume and brain volume loss offer a potential avenue for understanding the links between lesion characteristics and discourse production. Relationships between various brain volume measures and cognitive performance have a fairly consistent pattern in the literature. Gross measures, such as those involving total brain volume or total brain volume loss, typically correlate with general measures of cognitive function, such as intelligence (e.g., IQ; Farias et al., 2012, Grafman, Salazar, Weingartner, Vance & Amin, 1986). Fine-grained measures, such as tissue volume or loss in specific structures, generally correlate with more specific aspects of cognition, such as memory and processing speed (Ariza et al., 2006; Warner et al., 2010). Given that brain volume measures correlate with general and specific cognitive functions and that various cognitive processes have been found to correlate with a variety of narrative discourse measures, a logical next step would be to examine if brain volume measures also correlate with narrative discourse ability.

The present study of 167 individuals with TBI investigated how well total brain volume loss accounts for performance on cognitive tasks, including WM, immediate memory (IM), EF, and IQ, and on narrative discourse production measures at multiple levels (e.g., intra-sentential, inter-sentential, global) of analysis. An underlying goal of this study was to examine the prognostic potential of a brain lesion metric for outcomes in discourse production. It is hypothesized that brain volume loss will correlate significantly with the cognitive and narrative discourse measures.

Methods

Participants

All 167 participants were native English-speaking male Vietnam War veterans, 52-70 years of age, who sustained severe penetrating head wounds during the Vietnam War. Education ranged from 8-22 years. Scores ranged from 1-99 on the Armed Forces Qualification Test (AFQT), 25-60 on the Boston Naming Test (BNT), and 87-100 on the Token Test (TT).

Brain Volume Loss

Lesion volume was determined using axial CT scans without contrast using General Electric Medical Systems Light Speed Plus CT scanner and the Analysis of Brain Lesions (ABLe) software. The key measure of lesion volume was the percentage of brain volume loss (PVol).

Cognitive Measures

The Working Memory Primary Index Score from the Wechsler Memory Scale – Third Edition provided the WM metric (WMS-III; Wechsler, 1997). The WM score reflects performance on letter-number sequencing and spatial span tasks.

The Immediate Memory Primary Index Score, also from the WMS-III, is a measure of short-term declarative memory. The IM score reflects the ability to remember verbal and non-verbal information.

The Sorting Test composite score from the Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001) served as the EF measure. The Sorting Test requires multiple skills, including concept formation, problem-solving, and mental flexibility.

The IQ measure was the Wechsler Adult Intelligence Scale–III (WAIS-III; Wechsler, 1997) Full Scale IQ percentile. The Full Scale IQ is based on verbal and performance IQ scores.

Discourse Analysis Procedure

Task. Participants were shown a multi-frame picture story with no soundtrack on a computer screen. Upon completion, participants were instructed to retell the story. Retellings were video-recorded. Recordings were transcribed verbatim, segmented into T-units, and analyzed at multiple levels.

Sentence production. A T-unit is defined as an independent clause plus any attached subordinate clauses. The primary measures of sentence production were total number of T-units and the number of subordinate clauses per T-unit, which reflects grammatical complexity.

Cohesive adequacy. Cohesion pertains to how meaning is linked across utterances. In the analysis of cohesion, cohesive ties are judged to be complete, incomplete, or erroneous. Cohesive adequacy was the percent complete ties of total ties.

Coherence. Coherence refers to the thematic unity of a narrative. Each T-unit was rated for local (how an utterance thematically links back to a previous utterance) and global (how an utterance links to the overall theme of story) coherence (Van Leer & Turkstra, 1999).

Story grammar. Story grammar pertains to temporal and logical relationships between people and events in a story. The story grammar measure used was the proportion of T-units within episode structure, reflecting narrative organization.

Story completeness. Each narrative was rated for the presence of five critical components. The completeness score is the total number of components present in the story, reflecting narrative content.

Intra-rater and inter-rater reliability ranged from 92% to 98% and 84% to 96%, respectively across the discourse measures.

Data Analysis

Two Pearson correlational analyses were performed between the percentage of brain volume loss and the four cognitive measures and seven discourse measures.

Results

Correlations

Cognitive Measures. PVol had small but significant correlations with all cognitive variables, r = -.22 for WM, r = -.23 for IM, r = -.22 for the Sorting Test, and r = -.27 for IQ with $p < .01$ for all correlations (Table 1).

Discourse Measures. PVol had no significant correlations with any discourse variables, r = -.17 for the number of T-units, r = .12 for subordinate clauses per T-unit, r = -.09 for cohesive adequacy, r = -.06 for local coherence, r = -.01 for global coherence, r = .07 for the story grammar measure, and r = -.07 for story completeness (Table 2).

Discussion

Results will be discussed relative to the following:

1. Correlations for IQ and EF are generally consistent with reports in the literature for total brain volume measures. However, correlations for memory measures are comparable to those for IQ and EF, suggesting that specific cognitive processes may also be sensitive to overall loss of brain tissue.
2. Findings for the discourse measures suggest that PVol is not predictive of narrative discourse production.
3. Brain regions proposed to be involved in specific aspects of discourse processing/production.
4. Prognostic potential and limitations of lesion severity measures in TBI recovery.

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Table 1

Pearson Correlation Matrix between Percentage of Brain Volume Loss and Cognitive Measures

	Percentage of Brain Volume Loss
Working Memory Primary Index Score (WMS-III)	-.22*
Immediate Memory Primary Index Score (WMS-III)	-.23*
Sorting Test/Executive Functions (D-KEFS)	-.22*
IQ Percentile (WAIS)	-.26*

*$p < .01$

Table 2

Pearson Correlation Matrix between Percentage of Brain Volume Loss and Narrative Discourse Measures

	Percentage of Brain Volume Loss
Number of T-units	-.17
Subordinate clauses/T-unit	.12
Cohesive adequacy	-.09
Local coherence	-.06
Global coherence	-.01
Proportion of T-units in episodes (story grammar)	.07
Story completeness	-.07