Visual Quality of Life in Veterans With Blast-Induced Traumatic Brain Injury

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IMPORTANCE Traumatic brain injury (TBI) is an important cause of morbidity worldwide, with increasing awareness of the role of blast exposure in military and civilian casualties. Visual problems have been reported in TBI and may affect functioning and quality of life.

OBJECTIVE To evaluate the 25-item National Eye Institute Visual Functioning Questionnaire and Neuro-Ophthalmic Supplement for utility in assessing the effect of blast exposure on perceived visual functioning among veterans with TBI.

DESIGN, SETTING, AND PARTICIPANTS Observational cohort study from a tertiary care Veterans Health Administration hospital. Reported visual quality of life was compared with existing norms, and relationships between perceived visual quality and ocular injury, diplopia, visual performance, and blast exposure characteristics were examined. Participants included inpatients with blast-induced TBI who underwent baseline examination between December 7, 2006, and January 11, 2012, at a multiple-trauma rehabilitation center and who had at least 1 intact eye and were able to undergo psychometric testing and ocular examination. Among 64 sequentially eligible patients, 60 completed visual quality testing, 1 declined study participation, and 3 were evaluated prior to inclusion of visual quality testing in the protocol. Thirty-nine patients returned for outpatient follow-up, with a median test-retest interval of 11 months.

EXPOSURE Combat blast exposure with documented TBI.

MAIN OUTCOMES AND MEASURES Composite and subscale scores on the 25-item National Eye Institute Visual Functioning Questionnaire and Neuro-Ophthalmic Supplement.

RESULTS Both tests had high test-retest reliability. Blast-exposed veterans reported significantly poorer visual quality compared with healthy samples and some patient samples with known eye disease. Scores tended to be worse for participants with identified visual performance deficits (poorer visual acuity or spatial contrast sensitivity, visual field depression or defects). Scores were not related to the extent of ocular injury or to blast exposure characteristics such as use of protective eyewear or TBI severity level.

CONCLUSIONS AND RELEVANCE Individuals with blast-induced TBI reliably completed both tests and reported significant decrements in their subjective visual experiences. Measures of subjective visual quality may be useful to identify patients needing additional visual or neurologic evaluation and to monitor the effect of visual rehabilitation on patients with blast-related visual disabilities.

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raumatic brain injury (TBI) is an important public health issue, with 1.4 million patients with TBI receiving care annually in the United States and up to 10 million annual casualties worldwide. Since 2000, the Defense and Veterans Brain Injury Center has identified more than 280,000 cases of TBI in US service members, many resulting from combat blast exposure. During blast exposure, blast waves and acceleration forces can produce brain injury; these same forces can affect the eyes, orbital tissues, and ocular adnexa. Visual performance can be impaired through damage to cortical, brainstem, cranial nerve, or ocular structures. Closed globe injuries, visual field defects, and other visual performance deficits have been described in combat blast survivors with TBI. However, in the absence of open globe (penetrating) eye injury, visual problems may be unrecognized. In 2008, the Veterans Health Administration mandated comprehensive eye examinations for all inpatients with TBI in multiple-trauma rehabilitation centers in an effort to diagnose TBI-related eye disorders. However, to our knowledge, the role of subjective visual quality of life (vQoL) questionnaires in the evaluation of patients with neurotrauma has not been previously examined or reported.

The 25-item National Eye Institute Visual Functioning Questionnaire (VFQ-25) was developed to assess the effect of common eye disorders (eg, glaucoma, cataract) on the patient's visual experience. Normative data include patient groups and a reference group with no known eye disorder. The VFQ-25 has been applied to other eye conditions, neurologic and ophthalmic disorders, to our knowledge, the role of subjective visual quality of life (vQoL) questionnaires in the evaluation of patients with neurotrauma has not been previously examined or reported.

Methods

Our study was designed to evaluate vQoL using standard questionnaires in patients with documented blast-induced TBI. It was approved by the Stanford University Institutional Review Board and the VA Palo Alto Research and Development Committee. All participants or their legally authorized representative gave written informed consent. Data were obtained during initial and follow-up evaluations in a longitudinal cohort study of inpatients in a multiple-trauma rehabilitation center at a tertiary care Veterans Health Administration hospital, with baseline testing occurring between December 7, 2006, and January 11, 2012. Participants were recruited from patients who met the following inclusion criteria: documented TBI from combat blast exposure, at least 1 eye with measurable visual acuity and no evidence of open globe injury, and willingness and ability to undergo ocular and visual examination. Some study participants, including most of those with diagnoses of mild TBI, were admitted to the center some time after the initial blast exposure to conduct a more complete evaluation of their TBI status than had been carried out at the time of injury. Of 64 patients who met eligibility criteria during the study period, 60 provided data for the present analyses, 1 refused study participation, and 3 were recruited prior to use of vQoL questionnaires as standard protocol. To assess the reliability of these measures, the VFQ-25 and NOS were readministered approximately 1 year later (median test-retest interval, 11 months) in 39 patients who returned for outpatient follow-up assessment.

Measures

The TBI severity levels (mild, moderate, severe, or penetrating) were assigned by the Defense and Veterans Brain Injury Center local manager based on duration of unconsciousness, duration of posttraumatic amnesia, Glasgow Coma Scale scores, history of penetrating head injury, and results of structural neuroimaging. Information on use of protective eyewear and location at the time of the blast was obtained from medical record review and history.

An experienced research team member administered the VFQ-25 and NOS questionnaires in interview format. The VFQ-25 includes a general health item and 24 vision items with 10 subscales: general health (5 items), vision-related role (3 items), mental health (3 items), physical health (3 items), social functioning (3 items), environmental (3 items), driving (1 item), and symptoms (3 items). The NOS was developed to assess the effect of visual sequelae not covered by the VFQ-25 but relevant to neuro-ophthalmic disorders. The NOS items are averaged to obtain a single summary score. For both measures, item responses (5- or 6-point scale) are translated into percentage scores, with 0 representing the worst possible score and 100 the best. Perception of double vision in various gaze positions was assessed in binocular patients with the Diplopia Questionnaire and scored according to published directions.

Baseline psychometric visual testing was performed when the attending team, patient, and family felt that such examinations were feasible; testing was not attempted or was discontinued if the patient was tired or unable. Ocular trauma examination, performed by subspecialist ophthalmologists, is described elsewhere. Injuries were identified by specific type as well as by anatomical classification zone. Tympanic membrane rupture, a marker for concussive brain injury from blast overpressure, was determined from the medical records.

Each study eye was tested for best spectacle-corrected visual acuity with high-contrast (100%) Sloan optotypes in an illuminated cabinet (Precision Vision). Spatial contrast sensitivities were recorded at 3, 6, 12, and 18 cycles per degree after instruction with a test object for each frequency (VectorVision). Scores at these frequencies were highly intercorrelated and were therefore averaged after conversion to standard scores based on published norms. Automated perimetry was performed with visual correction if needed with a Humphrey Field Analyzer 750i using the 30-2 Swedish interactive thresholding algorithm standard format (Carl Zeiss Meditec). Reliability of visual fields was determined based on published...
indices. Unreliable visual fields were generally repeated; all unreliable fields were excluded from analysis. Two independent reviewers recorded mean deviation, pattern standard deviation, and the presence of a field defect consistent with a neurologic injury of the visual pathways (hemianopia or quadrantanopia). Discrepancies were resolved by mutual agreement.

Statistical Analysis

Because scores on the VFQ-25 and NOS are highly skewed toward the maximum, we used nonparametric statistical tests to evaluate the relationships between these scores and measures of visual performance. To compare scores with published norms, where only means and standard deviations (or standard errors of means) were available, we used t tests with unequal variance; this test is considered relatively robust in terms of violations of the normal distribution. Specific statistical tests are reported in the tables. We used PASW Statistics 18 statistical software (SPSS Inc) for analysis.

Results

Participants included 57 men and 3 women, with a median age of 25 years (range, 19-45 years). Severity of TBI was rated as mild in 22 participants (37%), moderate or severe in 23 (38%), and penetrating in 15 (25%). At initial testing, the median interval since injury was 8.7 months (range, 2-82 months). Most participants (n = 42 [74%]) were wearing ballistic eyewear. Thirty-four participants (58%) were in a vehicle at the time of blast exposure, while 25 (42%) were dismounted. Evaluation of tympanic membranes was documented for 50 participants; 18 (36%) showed evidence of rupture.

The VFQ-25 composite scores for participants with TBI were significantly lower across all subscales than those of the original reference sample and of several patient groups previously described in the literature, namely individuals with diabetes mellitus, dry eye, glaucoma, and macular degeneration (Table 1). The VFQ-25 composite scores were similar to those
found in the macular telangiectasia and cataract groups. Additional comparisons (Table 2) indicate that the TBI group scored significantly lower on the VFQ-25 and NOS than did disease-free adults or patients with multiple sclerosis and not significantly different on either measure from individuals with other neuro-ophthalmic disorders.

Measure Reliability

Both the VFQ-25 and NOS demonstrated good reliability. Across an 11-month interval, the test-retest reliability was \( r = 0.79 \) (\( P < .001 \)) for the VFQ-25 and \( r = 0.70 \) (\( P < .001 \)) for the NOS. The average change in scores was 0% on the VFQ-25 and –3% on the NOS. Among 6 participants with the largest improvement in VFQ-25 scores, none moved into the normal range but 3 showed improved visual acuity or contrast sensitivity at follow-up. The 3 participants with the largest declines in scores at follow-up had scored in the normal range at baseline. Although their visual acuity was stable, subjective visual complaints including photophobia worsened and resulted in lower scores on both vQoL measures, and 1 participant experienced reduced contrast sensitivity. The VFQ-25 and NOS scores were highly correlated (Spearman \( r = 0.85; P < .001 \)), another indicator of test reliability.

Relationships With Ophthalmic Examination Results

We compared the VFQ-25 and NOS composite scores for subgroups of participants with TBI based on findings from the ocular trauma examination and visual performance measures (Table 3). All participants had at least 1 intact eye with some level of visual acuity. Nine eyes had been enucleated for open globe injury, and 3 had no light perception due to optic nerve damage. The VFQ-25 scores were marginally worse for monocular participants than for binocular participants (\( P = .06 \)), but the NOS scores did not differ significantly for these groups.

### Table 3. Scores on the 25-Item National Eye Institute Visual Functioning Questionnaire and the Neuro-Ophthalmic Supplement for Subgroups of the Traumatic Brain Injury Sample Based on Visual Functioning

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>VFQ-25 Score</th>
<th>NOS Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median ( x^2 ) Statistic ( P \text{ Value} )</td>
<td>Median ( x^2 ) Statistic ( P \text{ Value} )</td>
</tr>
<tr>
<td>Eye loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Binocular</td>
<td>89</td>
<td>3.63 ( .06 )</td>
</tr>
<tr>
<td>Monocular</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>Level of ocular injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>83</td>
<td>1.90 ( .39 )</td>
</tr>
<tr>
<td>1-2 Types</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>≥3 Types</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>Diplopia Questiona</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No symptoms</td>
<td>97</td>
<td>15.07 ( .001 )</td>
</tr>
<tr>
<td>Moderate</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>Severe</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>Visual acuity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20/20 or better</td>
<td>89</td>
<td>9.26 ( .01 )</td>
</tr>
<tr>
<td>20/25-20/40</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Worse than 20/40</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Contrast sensitivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>95</td>
<td>10.95 ( .004 )</td>
</tr>
<tr>
<td>−1 to −2 SDs</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>&lt;−2 SDs</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>Mean deviation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>96</td>
<td>8.63 ( .003 )</td>
</tr>
<tr>
<td>Significant</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>Pattern standard deviation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>96</td>
<td>11.56 ( .001 )</td>
</tr>
<tr>
<td>Significant</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>Neurologic field abnormality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>87</td>
<td>1.99 ( .37 )</td>
</tr>
<tr>
<td>Hemianopia</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>Quadrantanopia</td>
<td>90</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: NOS, Neuro-Ophthalmic Supplement; VFQ-25, 25-item National Eye Institute Visual Functioning Questionnaire.

* Based on the k-sample Kruskal-Wallis test.

* Moderate indicates scores of 1 through 8; severe, scores of 9 through 25.
(P = .99). Ocular injury in at least 1 anatomical zone was present in 24 participants (40%), with a median of 3 injuries. (See the article by Cockerham et al7 for additional detail on the extent and nature of ocular injuries in a subsample of these participants.) Scores on the VFQ-25 and NOS were not related to the number of different ocular structures evidencing injury or to injury to any specific ocular zone (not shown).

Among 47 binocular individuals who completed the Diplopia Questionnaire, 17 (36%) reported diplopia, with a median score of 9 of 25 (a moderate level of double vision). Any report of double vision on the Diplopia Questionnaire was associated with lower VFQ-25 and NOS composites scores. (There is 1 item about double vision on the NOS but no item overlap with the VFQ-25.)

**Afferent Testing**

Among 57 participants with visual acuity testing at the initial assessment, 50 (88%) had visual acuity of 20/20 or better in at least 1 eye. Among 53 participants able to complete contrast sensitivity testing, 33 (62%) had normal values for at least 1 eye (values within 1 SD of the mean); 11 (21%) had values more than 2 SDs below the mean. Reliable visual field testing was completed for 52 participants: 32 (62%) of them had significant mean deviation for at least 1 eye, and 24 (46%) had significant pattern standard deviation (ie, values with probability ≤5%). Nine participants had visual field scotomas consistent with postchiasm (neurologic) injury (hemianopia or quadrantanopia).

Low scores on both the VFQ-25 and the NOS correlated with deficits in each of the afferent tests. Participants with deficits in visual acuity or contrast sensitivity tended to report poorer vQoL. Similarly, those with visual field defects (significant mean deviation or pattern standard deviation) reported poorer vQoL (Table 3). There were no significant differences in VFQ-25 and NOS scores in participants with neurologic hemianopic or quadrantanopic field defects vs other participants.

Despite these relationships, scores on the VFQ-25 and NOS were not always concordant with afferent visual performance results. Based on norms for individuals in this age range with no known eye disease,17 participants were classified as having average or below-average vQoL scores (ie, ≥1 SD below the mean). Ten of 24 individuals (42%) with normal VFQ-25 scores and 7 of 19 (37%) with normal NOS scores had abnormal visual performance results. Two of 35 individuals (6%) with below-average VFQ-25 scores and 3 of 39 (8%) with low NOS scores had incomplete or normal visual performance.

**Relationships With Characteristics of Blast Experience**

Scores on the VFQ-25 and NOS were not significantly related to any of the characteristics of the blast experience (Table 4). Scores were not affected by use or nonuse of ballistic eye-wear or location during blast (mounted vs dismounted). Similarly, neither TBI severity level nor presence of tympanic rupture was related to vQoL (Figure).

**Discussion**

Established vQoL instruments were used, for the first time to our knowledge, to determine the level of visual satisfaction in individuals with blast-related neurotrauma, and the resulting scores were compared with published data for visual and neurologic conditions. Despite documented blast-related TBI and, for some, cognitive deficits, participants responded reliably on both measures and showed significantly depressed scores compared with a disease-free reference group. These individuals with TBI reported substantial visual dissatisfaction, with group composite scores for both tests equivalent to or worse than visually disabling conditions, including cata-ract, thyroid eye disease, and optic neuropathy. Qualitatively, scores were most depressed for near and peripheral vision and for mental health, role functioning, and dependency.
The depressed VFQ-25 scores among those reporting double system, maybe a productive area of study in this population. Alignment, saccades, pursuits, vergences, and the vestibular efferent (oculomotor) system, which includes fixation and focused on relationship with afferent visual performance, but no appreciably reduced in participants with ocular injury. For those few participants with depressed vQoL but no discernable ocular damage or identified afferent defects, other testing methods may better capture visual dysfunctions. Our study focused on relationships with afferent visual performance, but the efferent (oculomotor) system, which includes fixation and alignment, saccades, pursuits, vergences, and the vestibular system, may be a productive area of study in this population. The depressed VFQ-25 scores among those reporting double vision suggest that efferent dysfunction may contribute to poor vQoL in some individuals with TBI. Further evaluation of these relationships is indicated. A substantial minority of participants had significant visual functioning deficits but reported essentially normal vQoL. Possible explanations include reduced awareness secondary to cognitive dysfunction or use of pain medications for associated injuries as well as military social taboos against “complaining.” Our study group had approximately equal numbers of mild, moderate to severe, and penetrating TBI, reflecting their recruitment from an inpatient unit. In contrast, mild TBI accounts for approximately 80% of neurotrauma in both civilian and military statistics.4-14 We found no difference in subjective visual experience between these subgroups, with low vQoL scores present at all severity levels (Figure). Because our mild TBI group may have been selected for inpatient evaluation based in part on continuing health concerns, our findings may not generalize to the broader population of individuals with mild TBI. Nevertheless, we note that although the terminology may suggest that mild TBI represents minor head trauma without anatomical findings (no radiologic evidence of brain injury by computed tomography or magnetic resonance imaging), numerous reports describe visual dysfunctions in blast survivors with mild TBI.8-14 Additionally, diffusion tensor imaging demonstrates axonal abnormalities in patients with blast-related mild TBI despite normal findings on computed tomography and magnetic resonance imaging.15 These findings raise concerns owing to the nature of blast injury encountered in insurgency warfare. The current military TBI classification system is based on a head trauma event of sufficient severity to cause unconsciousness, posttraumatic amnesia, reduced Glasgow Coma Scale score, and higher levels of abnormalities on standard neuroimaging. However, over time, combatants may be exposed to multiple blasts of low intensity before diagnosis of mild TBI. There is growing awareness of the neurologic and pathologic consequences of repetitive head injury in sports and combat, including behavioral changes and chronic traumatic encephalopathy.16-18 Our study was not able to evaluate a number of factors associated with rehabilitation of blast casualties that may affect psychometric testing, including cognitive impairment, mental health problems, and medication effects. Furthermore, we do not have information on the vQoL for veterans without blast exposure, so we cannot definitively link the reduced vQoL with blast exposure or head trauma. Our sample size hampers some comparisons, including use of multivariate modeling. Additional research is needed to validate our findings in a larger sample, which could include individuals with TBI from causes other than blast exposure. In preliminary work with 9 patients with non-blast-induced TBI, we have found median scores of 78 on the VFQ-25 and 67 on the NOS, similar to those obtained in this study of patients with blast-induced TBI. A larger, more diverse sample would permit systematic evaluation of the roles of blast exposure, cognitive impairment, posttraumatic stress disorder, other mental health problems, and medications in the reduced vQoL shown by blast-exposed patients with TBI.
All Veterans Health Administration multiple-trauma rehabilitation centers are required to evaluate patients’ visual acuity and visual fields. Both qVQI instruments provide useful additional information on the subjective effect of visual performance deficits. The VFQ-25 offers more detail about the specific problem areas, and the NOS offers a shorter questionnaire that correlates highly with the VFQ-25 composite score. In addition to identifying individuals who may benefit from additional afferent and efferent testing, these measures may provide a useful metric for the success of interventions, including visual and occupational rehabilitation. Many of the more than 2 million participants in the Iraq and Afghanistan conflicts have returned to civilian life without ocular examinations. We recommend that any patient with a history of combat blast exposure undergo a thorough visual and ocular examination, even in the absence of visual complaints.

REFERENCES

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Original Investigation Research


