An Update on Substance Use and Treatment following Traumatic Brain Injury

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Traumatic brain injury (TBI) is a leading cause of mortality and morbidity among young adults. Substance abusers constitute a disproportionate percentage of these patients. A history of substance abuse predicts increased disability, poorer prognosis, and delayed recovery. While consensus in the literature indicates that substance-abuse rates decline following injury, conflicting literature shows a significant history of brain injury in addicts. We reviewed the literature on substance abuse after TBI to explore the state of knowledge on TBI as a risk factor for substance abuse. While recent reviews regarding substance abuse in TBI patients concur that substance-abuse rates decline even after mild TBI, an emerging literature suggests mild TBI may cause subtle impairments in cognitive, executive, and decision-making functions that are often poorly recognized in early diagnosis and treatment. When combined with difficulties in psychosocial adjustment and coping skills, these impairments may increase the risk for chronic substance abuse in a subset of TBI patients. Preliminary results from veterans indicate these patterns hold in a combat-related post-traumatic stress disorder population with TBI. This increasingly prevalent combination presents a specific challenge in rehabilitation. While this comorbidity presents a challenge for the successful treatment and rehabilitation of both disorders, there is sparse evidence to recommend any specific treatment strategy for these individuals. Mild TBI and substance abuse are bidirectionally related both for risks and treatment. Further understanding the neuropsychiatric pathology and different effects of different types of injuries will likely improve the implementation of effective treatments for each of these two conditions.

Key words: **traumatic brain injury; substance abuse; prevalence; treatment outcome; review**

Introduction

Traumatic brain injury (TBI) encompasses a broad category of psychological, cognitive, motor, and other impairments that result from externally inflicted trauma to the brain. Estimated at an incidence of 1.5 to 2 million new cases/year,[1] TBI imposes large economic burdens. Direct costs of acute care and rehabilitation for new cases are estimated between $9 and $10 billion in the United States.[1] Since the highest prevalence is among persons aged 15 to 24, the average lifetime costs for care of single individuals with severe TBI are estimated to be as high as $1.8 million.[1] These direct cost estimates do not include costs of social services or loss of earnings to patients or primary

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caregivers and thus underestimate total societal burdens of TBI.[1] On the other hand, mild uncomplicated TBI (mTBI), usually defined as concussion, brief loss of consciousness, or Glasgow Coma Scale ratings of 13–15, may account for more than 85% of all TBIs.[2] Mild TBI, being initially uncomplicated and straightforward in its treatment, represents a disproportionately small percentage of total acute treatment costs. However, the subtle neuropsychological effects of mTBI are likely to be currently underappreciated as a significant source of later neurocognitive difficulties, costs, and suffering.[3]

Substance abuse, impairing motor, cognitive, and judgment performance is a demonstrated risk factor for TBI. This is, perhaps, most memorably demonstrated by case reports describing odd or remarkable behaviors leading to TBIs while inebriated. Examples range from the anonymous, such as the fatal head injury in a MDMA ("Ecstasy") user after attempts at "car surfing"[4] and the report of a 5-cm wooden fragment lodged in the left frontal lobe of a patient found semiconscious with a full syringe of high purity amphetamine,[5] to the famous, as in the speculated link between American author Ernest Hemingway's well-known struggles with substance abuse and his resulting "remarkably accident-prone" history, with at least five well-documented TBIs, likely both complicating factors in the course of his bipolar illness and eventual suicide.[6]

These case reports reflect a consistent and quantifiable risk relationship described across several systematic investigations. Kraus and colleagues found that of 1155 TBI cases tested for blood-alcohol levels (BAL) in 1981 in San Diego County, 58% tested positive. Of these positive results, 84% were at or above the 100 mg/dL level that was commonly used as a limit of legal intoxication.[7] Follow-up investigations throughout the next decade concurred with these initial reports, indicating that BAL at admission correlated with the likelihood of pre-injury abuse and various measures of recovery.[8–11] In 1991, Kreutzer and colleagues reported a preinjury moderate-to-heavy alcohol use rate of 66%.[8] In two larger samples, reported in 1995[9] and 1996,[10] Kreutzer and colleagues found similar patterns. In a study of substance abuse and crime patterns, 327 patients with various severities of TBI reported a high preinjury incidence of moderate and heavy drinking; 81% and 47% among those with and without arrest histories, respectively. Bombardier and colleagues reported similar results. Examining preinjury use rates, they reported a high percentage (59%) of "at-risk" drinkers and high rates of illicit substance use by self-report (34%), similar to a subset with available toxicology results (37%).[11]

Aspects of the relationship between TBI at all levels and substance-abuse history have been systematically reviewed. Corrigan reported on the state of the literature in 1995,[12] and Taylor and coworkers[13] and Parry-Jones and colleagues[14] updated this report with more recent results in two extensive reviews in 2003 and 2006, respectively. However, most of these previous reports have relied on heterogeneous groups of TBI patients. Alcohol use rates post-TBI are negatively correlated with disability ratings; that is, continued use is correlated with higher functional status.[15] The relationship between mTBI and abuse of substances other than alcohol has been less extensively explored. Substance abusers presenting for treatment report a significant history of TBI; those with such a history show a "coherent pattern of seeking an emotionally dampening [drug] experience" through significantly increased use of both marijuana and sedatives.[16] Amphetamine[17] and other stimulants[18,19] have been reported to be useful in TBI treatment. There are reported changes in response to morphine.[20] Opiates are often needed for pain management in trauma patients, and the risks/benefits of using these medications early in management are relatively unclear.[21] With these considerations, we specifically review the literature regarding the two following questions:

(1) How does TBI act as a risk factor for substance abuse and compulsive behaviors?

(2) What is currently known about treatment of substance abuse in persons with TBI?

We thus now report results of multiple searches of PubMed database from 1983 to present that examine TBI and substance abuse. We identified studies meeting inclusion criteria that included English language and reports of rates, treatment, or predictive values of substance abuse/compulsive behavior post-TBI and/or screening for TBI history in substance abusers/compulsive behaviors. Efforts were made to identify all relevant articles involving any post-TBI substance use prevalence rates or post-TBI substance use treatment evaluations. All abstracts in the final search results were reviewed, and the selected articles' literature was also reviewed to double check that the search criterion was not missing any material. Further, the final selected articles were checked through the ISI Web of Knowledge database (http://apps.isiknowledge.com) to evaluate any more-recent articles that had cited our selections. The search terms, inclusion criteria, and articles identified are summarized in Tables 1 and 2.

TBI as a Risk Factor for Substance Abuse

Many of the studies that reported pre-TBI substance abuse also examined rates following TBI.[8,9,22] Other studies examined motivations for change in substance use after TBI.[23] While the literature regarding alcohol use rates is extensive, the literature is generally lacking in studies that address other substances with specificity, often reporting all illicit substance abuse as a single category.

Alcohol

While many of those studies describing premorbid alcohol abuse mentioned above also reported on the prevalence of continued alcohol abuse post-TBI, this number is often reported in the context of other specific questions. Specifically, Kreutzer and colleagues reported a decline in postinjury alcohol abuse rates from 66% to 28%, as reported by primary caregivers of 74 consecutive referrals to a supported employment service, with a similar decline (36% to 4%) in drug use rates.[8] In their larger study of criminal behavior and substance abuse post-TBI, these researchers reported a decline postinjury in both those with and without arrest histories, to 58% and 27%, respectively.[9] In a separate study, 87 young persons (ages 16 to 20) were surveyed at about 8 and 28 months postinjury. While overall abstinence rates remained high throughout follow-up, drinking patterns in patients classified as moderate to heavy drinkers returned to preinjury baselines at the later follow-up.[10]

In two studies of patients hospitalized and rehabilitated for various levels of TBI, Bombardier and colleagues examined postinjury changes in drinking behavior and motivation to change alcohol use. Similar to above reports, they reported a substantial decrease from preinjury to postinjury drinking, with moderate and heavy drinking rates of 64.9% to 36.2%, respectively.[22] Bombardier and associates also reported that, compared to a general medical sample, motivation to change—as manifest by the percent of patients in contemplation or action stages of the "stages of change" model[24]—was increased in a sample of 50 TBI cases, with a 64% rate of alcohol involvement.[11] Furthermore, this variable correlated positively with both lifetime alcohol problems and BAL on admission.[23] This sample, however, was disproportionately composed of severe cases (63% of those with Glasgow Coma Scores available) and thus may overestimate contemplation compared to more mild cases.

As alluded to above, subject selection is a significant concern for generalizing these results to the population at large. With exceptions that include data from the San Diego emergency department[7] and one report from Bombardier and colleagues,[22] these studies were aimed at answering specific questions, not at characterizing general rates of abuse, and therefore were

TABLE 1. Search Criteria used and Initial Abstracts Identified for Post-TBI Substance Use

Subject	Terms Used*	Search Result	Articles Identified*
1. TBI[1]	"Brain Injuries"; "Brain Injury, Chronic"; "Head Injuries, Penetrating"; "Diffuse Axonal Injury"; "Head Injuries, Closed"; "traumatic brain injury"		
2. Alcohol Abuse	"Alcoholism"; "National Institute on Alcohol Abuse and Alcoholism (U.S.)"; "alcohol abuse"	61,755	
3. Other Drug Abuse	"Amphetamine"; "Amphetamine-Related Disorders"; "Dextroamphetamine"; "Marijuana Abuse"; "Cannabis"; "Marijuana Smoking"; "Cocaine"; "Cocaine-Related Disorders"; "Crack Cocaine"; "Toluene"; "Hallucinogens"; "Methoxydimethyltryptamines"; "Analgesics, Opioid"; "Narcotics"; "Opiate Alkaloids"; "Opioid-Related Disorders"; "Thebaine"; "Opium"; "Morphine"; "Analgesics, Opioid"; "3,4-ethylenedioxyamphetamine"; "3,4-methylenedioxyethamphetamine"; "nepenthe"; "cocaine N-oxide"; "cyclohexyl nitrite"	141,337	
4. Nonspecific Addiction or Abuse Behavior	"Substance-Related Disorders"; "Behavior, Addictive"; "Compulsive Behavior"; "addiction"; "drug abuse"; "substance abuse"	189,985	
1 AND 2		182	27
1 AND 3		200	36
1 AND 4		575	60

* Significant overlap exists between the abstracts identified in each combination search.
[1]TBI, traumatic brain injury.

sampled from specific populations that were not selected to provide representative data. However, even the most potentially representative sample, recruited from consecutive admissions to a level 1 trauma center with board inclusion criteria by Bombardier and colleagues,[22] may in fact provide only limited representativeness, because there was a suboptimal (69%) recruitment rate for those offered participation. Since the studies by Kreutzer and colleagues[8,9] recruited from among patients who attended an employment service, there may be selection based on injury severity, economic situation, psychological comorbidity, or a combination of these factors. The final report from the Kreutzer group is specific to a younger age range (16–20 yrs),[10] selecting for a population with shorter histories of substance abuse and perhaps other criteria.

In spite of these limitations, these results concur with those of many others discussed in the recent reviews mentioned above.[12–14] Taken together, the data portray an overall pattern of decreased substance abuse postinjury. Individuals who continue to abuse represent a high-risk group with extensive premorbid histories and a compromised prognosis.

Other Drugs

There is little literature that allows us to produce separate analyses for abusers of specific substance classes. General categories such as "other" or "illicit" drugs are most often available, often for investigations of the effects of continued substance abuse on various neuropsychological measures.[25,26]

Cannabis

One case report describes cannabis use post-TBI, in the context of comorbid depression.[27] In this patient, followed over a course of 19 weeks of treatment for the mood disorder, it

TABLE 2. Search Criteria used and Initial Abstracts Identified for Post-TBI Substance-Use Treatment Evaluations

Subject	Terms Used	Search Result	Articles Identified*
1. Treatment	"rehabilitation"; "outcomes"; "treatment"	5,700,829	
2. Post-TBI	"Brain Injury, Chronic"; "Brain Injuries"; "Head Injuries, Penetrating"; "Head Injuries, Closed"; "Diffuse Axonal Injury"; "Traumatic Brain Injury"; "TBI"; "Acquired Brain Injury"; AND "post-injury"	41,229 Post-TBI: 4709	
3. 1 AND 2		2351	
4. Non specific Addiction or Abuse Behavior and Alcohol Abuse or Treatment	"addiction"; "substance use"; "substance abuse"; "Alcoholism"; "National Institute on Alcohol Abuse and Alcoholism (U.S.)"; "alcohol abuse"; "alcohol"; "beer"; "wine"; "spirits"; "alcoholism"; "ethanol"; "alanon", "twelve step program"; "residential program"	1,185,265 Search 3 AND 4: 73	27 of 73
5. Cannabis	"Marijuana Abuse"; "Cannabis"; "Marijuana Smoking"; "Pot"; "Grass"; "Hash", "Weed" with limits as #5	13,237 Search 3 AND 5: 3	3 of 3
6. Cocaine	"Cocaine"; "Cocaine-Related Disorders"; "Crack Cocaine"; "Cocaine N-oxide" with limits	12,914 Search 3 AND 6: 2	2 of 2
7. Stimulants	"Amphetamine"; "Amphetamine-Related Disorders"; "Dextroamphetamine"; "Ecstasy"; "Speed"; "diet-pills"; "3,4-ethylenedioxyamphetamine"; "3,4-methylenedioxyethamphetamine" with limits	32,898 Search 3 AND 7: 31	24 of 31
8. Inhalants	"cyclohexyl nitrite"; "Toluene"; "inhalant"; "nitrous"; "glue"; "paint thinner"; "petrol"; "gasoline" with limits	14,086 Search 3 AND 8: 3	3 of 3
9. Hallucinogens	"Hallucinogens"; "Methoxydimethyltryptamines"; "LSD"; "PCP"; "Acid"; "Mushrooms"; "Ketamine"; "special K" with limits	479,952 Search 3 AND 9: 44	7 of 44
10. Opiates	"Analgesics, Opioid"; "Narcotics"; "Opiate Alkaloids"; "Opioid-Related Disorders"; "Thebaine"; "Opium"; "Morphine"; "nepenthe"; "heroin"; "methadone"; "codeine"; "Narcotics anonymous", "Thebaine" with limits	43,525 Search 3 AND 10: 9	5 of 9

*Overlap existed between each combination search; these were the articles retained for closer investigation and review for appropriateness; TBI, Traumatic Brain Injury.

Limits: Applied search limits of English, Humans, and from 1/1/1983 to present.

appeared likely that moderate cannabis use (up to 1/16 ounce per week) exacerbated his depressed mood. The author also reported significant effects of cannabis use on cognitive function, though she ascribed this to an indirect effect through effects on the patient's mood. It is worth noting that this patient initially abstained completely from use upon starting treatment and resumed use 12 weeks into treatment at levels that he reported to be decreased compared to those that he used pretreatment.

Cocaine, Stimulants, and Opioids

We identified no articles specifically addressing post-TBI abuse or dependence of other specific drugs, including cocaine, stimulants, or opioids.

Preliminary Data

As part of an initial review of over 1800 initial mental health evaluations from returning Iraq and Afghanistan veterans, we have obtained histories of TBI. Data from the first 346 screened subjects have been extracted, allowing us to divide the screened veterans into four groups. Veterans with and without posttraumatic stress disorder (PTSD) and with and without TBI, as screened using the approach noted below.

Of the initial 346 individuals extracted, 213 (61.6%) completed their TBI screen. This TBI screen consists of two parts, with the second part consisting of four sections. Part 1 asks if the veteran has already been diagnosed with a TBI during their military service.

Part 1: Has the veteran already been diagnosed as having TBI during Operation Iraqi Freedom (Iraq)/Operation Enduring Freedom (Afghanistan) OIF/OEF deployment? No. Continue to Section 1. Yes. This is a positive screen and completes the screening questions.

If so, they are given a positive screen and labeled "TBI." Nine of the 213, 4.2% of the sample, were so diagnosed.

If not, the screen proceeds to Part 2. The questions of the screen are listed as follows.

- Section 1: The veteran experienced the following events during OIF/OEF deployment: Blast or Explosion IED (improvised explosive device), RPG (rocket-propelled grenade), Land Mine, Grenade, etc. 2) Vehicular accident/crash (any vehicle, including aircraft). 3) Fragment wound or Bullet wound above the shoulders. 4) Fall. 5) Blow to the head (head hit by falling/flying object, head hit by another person, head hit against something, etc.). 6) Other injury to head.

If none, negative screen; if yes for one or more, continue to section 2.

- Section 2: The veteran had the following symptoms immediately afterwards: 1) Losing consciousness/"knocked out." 2) Being dazed, confused, or "seeing stars." 3) Not remembering the event. 4) Concussion. 5) Head injury.

If none, negative screen; if yes for one or more, continue to section 3.

- Section 3: The veteran states the following problems began or got worse afterwards: 1) Memory problems or lapses. 2) Balance problems or Dizziness. 3) Sensitivity to Bright Light. 4) Irritability. 5) Headaches. 6) Sleep problems.

If none, negative screen; if yes for one or more, continue to section 4.

- Section 4: The veteran relates he/she is currently having or has had the following symptoms within the past week: (same 6 options as section 3).

If none, negative screen; if yes for one or more, this is a positive screen.

Therefore, a negative TBI screen suggests (1) no injury was incurred, (2) the veteran had an injury but no immediate symptoms, or (3) the veteran had an injury with immediate symptoms but no long-term sequelae. Only those veterans who sustained an injury, had

TABLE 3. Preliminary Data from 213 Consecutively Screened Iraq and Afghanistan Veterans at Time of Initial Mental Health Screening Evaluation, an Early Part of an Ongoing Retrospective Clinical Chart Review

Variable	+PTSD, +TBI	+PTSD, −TBI	−PTSD, +TBI	−PTSD, −TBI
% Sample	19.2%	16.4%	10.8%	53.6%
Mean (SD) Age	27.4 (6.0)	30.2 (6.3)	29.7 (9.3)	30.4 (8.6)
% Male	95.1%	88.6%	82.6%	83.3%
% White	58.5%	54.3%	56.5%	46.5%
% Married	36.6%	48.6%	52.2%	40.4%
% ≤ HS Education	39.0%	40.0%	30.4%	31.6%
Past Alcohol Use	65.9%	62.9%	73.9%	68.4%
Current Alcohol Use	53.7%	45.7%	52.2%	60.5%
Past Cannabis Use	17.1%	28.6%	21.7%	18.4%
Current Cannabis Use	2.4%	5.7%	4.3%	5.3%
Past Cocaine Use	2.4%	11.4%	0.0%	5.3%
Current Cocaine Use	2.4%	0.0%	0.0%	0.9%
% Depressive Disorder	75.6%	62.9%	43.5%	36.3%
% Panic Disorder	22.0%	11.4%	8.7%	4.4%

HS, high school.

immediate symptoms, had symptoms that got worse afterward, and are continuing to have prolonged problems are screened positive. For purposes of this study, only those veterans with a positive screen are being considered to have a TBI. Those who may have had an injury but have no residual symptoms (a negative screen at part 2, section 4) are not complicating the diagnostic process and have been placed in the non-TBI group.

Table 3 provides the demographics of the preliminary sample. The percentages of those having used or currently using alcohol, cannabis, or cocaine, and the percentages having a comorbid depressive disorder, a comorbid panic disorder, are also listed. No group contained any diagnosed comorbid psychotic disorder.

Data from this sample show a rate of TBI at 30.0%. The majority are due to blast exposure and subsequent motor vehicle accidents. The TBI groups tend to be younger than the non-TBI groups by an average of approximately 2 years. Both PTSD and TBI were associated with a trend toward lower levels of education. All four groups showed a decrease in alcohol use from past to current. The largest fractional decrease was found in the TBI-only group. Confirmation of these preliminary data in additional samples might indicate effects of more education on adverse consequences of alcohol on PTSD treatment. There were overall low rates of current cannabis use, with all groups at less than 6%. However, all four groups reported higher rates prior to military service. Prospective studies will be required to determine if these data are due to reporting bias during the clinical interview. Similarly, cocaine showed slightly higher past rates of use, but overall almost none was reported by the sample. Overall panic disorder was slightly higher in the TBI groups than the non-TBI groups. Depressive disorders were more associated with PTSD than with TBI status. Not surprisingly, these preliminary results indicate that alcohol is the dominant drug being used in the returning veteran population. However, the legality of this substance may be influencing reporting. We do see a drop in self-report as the question changes from use of alcohol to cannabis to cocaine.

Undiagnosed TBI History in Substance Abusers

We have also identified articles that address this question from the opposite perspective:

When screening populations of substance abusers, what are the reported rates of TBI history? In three separate recent reports, Walker and colleagues[28] have investigated this question. Initial findings in 2001[28] indicated that, among medium- and minimum-security prison inmates, those with histories of head injury had greater utilization of healthcare resources including hospital stays, admissions, and ER visits. Following up in 2003, Walker and coworkers[29] analyzed self-reported health and mental health histories of individuals with no, one, or two or more TBIs from a sample of 661 drug-abusing inmates. They found a significant association between number of TBIs and alcohol and marijuana use histories and with mental health problems that included depression, anxiety, and suicidal ideation.[29] In a larger and more representative sample of 7784 adult substance abusers who were entering a treatment facility, these authors found that nearly a third (31.7%) reported histories of at least one TBI that resulted in loss of consciousness.[16] Patients with histories of TBI reported more months of substance abuse, even when levels of depression and anxiety were controlled using statistical techniques.

In a study that interviewed 550 adults who were entering substance-abuse treatment, Felde and colleagues[30] examined childhood predictors of TBI and substance-abuse severity. As noted by Walker and colleagues,[28,29] these authors found that TBI was associated with more severe substance-abuse histories, both by self-report (Modified Michigan Alcohol-Drug Screening Test, MAST/AD) and psychiatric interviews (Substance Abuse Problems Scale, MN-SAPS). Interestingly, however, these correlations did not extend to significant differences in problems caused by substance abuse. They found that patients with histories of TBI were more likely to have had childhood behavioral problems, loss of parents, and chronic health problems in either themselves or a parent. Since the TBI history pertained only to injuries during adulthood, this study is an interesting demonstration of childhood risk factors that predict comorbid substance abuse and TBI. The authors thus interpret their data to describe a psychological profile of this patient population where "childhood behavior problems seem to set the stage for adult behaviors that increase risk of trauma."[30] Neuropsychological profile from TBI in substance abusers was tested by Hestad and associates[31] in a group of Scandinavian intravenous drug users. They reported a significant decline in neurocognitive functioning associated with a history of multiple TBIs, but not with a single TBI.[31]

This consistent finding of a significant TBI history in substance abusers is, perhaps, not surprising. The retrospective design of these studies is not intended to differentiate causative factors. Correlations could be explained simply by the aforementioned high risk of TBI secondary to substance abuse. However, consideration of a number of findings indicates a more complex relationship. These data include Felde and colleagues'[30] findings that describe how specific predictive childhood experiences and behaviors predispose to comorbid substance abuse and TBI. In concordance with this idea and the report of Hestad and colleagues[31] report, a large literature describes a myriad of neuropsychiatric sequelae to TBI. Impulse control and motivated behavior are both generally understood to involve frontal lobe function. A parallel between the pattern of symptoms in severe TBI and focal frontal damage can be understood to arise from an observed sensitivity of the frontal lobes to contusional damage.[32] While it is beyond the scope of this paper to review this area extensively, we briefly mention several relevant observations.

Donovan and Barry[33] described a patient who developed frank compulsive behaviors after frontal TBI, resulting in stereotyped, ritualistic behaviors. The authors comment specifically on the presentation of compulsions devoid of anxiety or obsessive elements which are otherwise common in frontal lobe syndromes. Reports such as this describe specific symptom clusters of compulsive behaviors known to involve circuits that are also implicated in substance abuse and addiction.

Support for this link to compulsive behaviors resembling addiction comes from reports by Regard and colleagues[34] on EEG abnormalities and TBI histories in pathologic gamblers (PGs) who do not abuse substances. Although the exclusion of substance abuse (except tobacco) resulted in small sample sizes, these investigators also reported significant increases in TBI history compared with a group of healthy controls matched for age, gender, and socioeconomic status. Histories of TBI in this PG sample were thus increased over 3-fold (52% vs. 16%); two of the PGs with positive TBI developed their gambling behavior only after an injury in adulthood. This significant history of TBI was accompanied by increased neurological and psychiatric symptoms, various neuropsychological test abnormalities, and focal EEG abnormalities in 65% of PGs.

Rehabilitation of Substance Abuse Post-TBI

The National Institutes of Health made a recommendation for the inclusion of substance-abuse evaluation and treatment in rehabilitation programs for TBI in 1999.[35] However, little work has been done to determine if interventions that are effective in the general population are effective for persons with TBI.[36] In fact, one study suggested that traditional methods of substance-abuse treatment are often ineffective due to the cognitive, behavioral, physical, and emotional deficits that occur after brain injury.[37] It is suggested that more effective care may be provided by matching patients with appropriate treatments.[38] However, issues that still need clarification include (1) the difficulties engaging and retaining individuals in treatment and (2) which interventions have been evaluated in persons with TBI who are participating in substance-abuse treatment programs. This information is important, particularly given that two studies[39,40] have documented an inability to differentiate individuals with mild or uncomplicated TBI (defined as no CT scan abnormalities at the time of the trauma) from persons without TBI in substance-abuse treatment. These groups provided similar results on an extensive battery of neuropsychological measures including tasks involving concentration, memory, and information processing speed.

Treatment Retention Strategies

Two studies[41,42] detail some information about treatment retention in substance-abuse treatment. No studies specifically targeted treatment retention for abusers of specific substances that include cannabis, stimulants, cocaine, hallucinogens, inhalants, and opioids.

Corrigan and Bogner[41] reported on a randomized, controlled, clinical trial that compared two methods for improving retention in substance abuse treatment for persons with TBI. They enrolled 74 individuals, who were randomized to one of three treatment conditions: financial incentive, barrier reduction, or attention control. Financial incentives were single $20 gift certificates for perfect first-month attendance. Barrier reduction targeted making appointment reminder calls, finding transportation, paying for parking or public transportation, child care during appointment times, and lunch money during attendance. Attention control only verified participant information and provided the date and time and place of the next scheduled appointment. Outcome measures evaluated included treatment attendance, perceived therapeutic alliance, and premature termination of treatment.

For TBI clients, the single-payment financial incentive provided the most robust method of increasing appointment attendance during the first month of treatment. There was an 81% reduction in missing appointments compared with the attention control condition. Barrier reduction did improve early attendance, yielding a 37% smaller chance of missing an appointment compared to attention control. This difference did not reach statistical significance. While neither the financial incentive

nor barrier reduction predicted the perceived therapeutic alliance, appointment attendance did predict the perceived therapeutic alliance. When the authors evaluated the relationships between treatment condition and likelihood of premature termination of treatment, they found the financial incentive group was equally likely to complete treatment as to end treatment early. The barrier reduction group had a 50% greater likelihood of ending treatment early, and the control group was almost three times as likely to end treatment early.

Additional studies[42] compared financial incentives, barrier reduction, and motivational interviewing with an attention control in 195 randomly assigned participants. The outcome measure was the proportion of each group that signed individualized treatment plans within 30 days. Financial incentive produced the highest rates (83%), followed by barrier reduction (74%). Motivational interviewing and the control condition each showed the least retention (45%). The financial incentive group had the fewest missed appointments—only 40% of participants missed one or more visits. Barrier reduction was similar, with 42% missing at least one visit. Motivational interviewing yielded 57% of participants who missed at least one appointment. The control condition resulted in 64% of participants missing at least one appointment.

Treatment Evaluations

Fourteen studies have evaluated treatments for substance abuse in persons with TBI. Nine[42–50] were reviewed in 2005.[36] Our focus will therefore be to discuss the remaining five studies[51–55] and place their findings in context of those previously reviewed. No specific information was located detailing treatment for persons with TBI for abuse or dependence on cannabis, stimulants, cocaine, hallucinogens, inhalants, or opioids.

Hibbard and coworkers[51] evaluated a peer-support intervention designed to match persons already experienced with TBI with individuals with TBI or their families. This peer support provided knowledge of resources, emotional support, and advocacy skills to address the acute and long-term needs of the persons with TBI and of their families. They reported that 82% of participants endorsed an increased sense of empowerment, 53% endorsed an enhanced quality of life, 54% improved coping with sadness, 45% improved coping with anger, and 36% improved coping with anxiety. Of all respondents, 82% endorsed improvements in knowledge about TBI and 54% endorsed improvements in quality of life, but only 18% endorsed improvements in family support.

Skills-based interventions were promoted by Vungkhanching and colleagues[52] with individual counseling. Delmonico and coworkers[53] used group therapy sessions to enhance skills-based interventions. These interventions are generally beneficial. Outcome data from individual counseling[52] sessions showed that at 9 months follow-up, the intervention group displayed a greater decrease in drug and alcohol use, more coping skills, and an increased likelihood of maintaining employment than did the control group. Skills-based interventions appear a worthwhile process to use when promoting abstinence from alcohol or drugs. Delmonico and colleagues[53] reviewed the literature supporting various aspects of group psychotherapy that have been shown to be beneficial in persons with TBI. The authors described improvement in concepts such as "universal issues," existential questions, interpersonal learning, anger, and frustration. They then went on to describe an evaluation of their group-therapy model for use in a drug and alcohol recovery group. These promising results are anecdotal and would benefit from more rigorous evaluation.

Hensold and colleagues[54] evaluated a program based on community inclusion. This program used positive and proactive methods to decrease substance use through a combination of individual and group sessions directed toward education and behavior self-monitoring. The treatment concept of "personal intervention" is based upon the theory that people who manage their life events successfully understand

their own behavior and how it relates to things that happen around them. The approach is grounded in a self-management frame, where individuals work for incentives based on their successfully management of their alcohol or substance issues. Treatment included management of mood and medical conditions, exploring alternative leisure or vocational placements, groups that explored education, relapse prevention, life impact, and monitoring of treatment progression. Staff training was an integral part of the program. Abstinence was strongly encouraged; incentives were supplied based on displays of progress. The investigators reported participant improvements in four of the five areas measured: residential status, level of independence, awareness, and productive involvement. There was no improvement in vocational activity; changes in alcohol consumption or substance use rates were not reported. The single largest area of improvement was in level of independence. The "majority of individuals" were reported to function independently for up to 10 h per day when discharged from the treatment program. The authors concluded no improvement was noted in vocational treatment because of the amount of time at work needed to show a change in the measure used. Overall, Hensold and colleagues[54] report on a multidisciplinary, community-based, substance-abuse treatment program with objective measures of outcome for persons with TBI. Maintenance of treatment gains was not assessed, however.

Corrigan and Deutschle[55] reported initial findings from a multi disciplinary, integrated, community-based treatment program in which they compared participants with TBI to those without TBI. The authors noted that:

(1) TBI was associated with more affective disorders (depression, schizoaffective disorder, anxiety) and with fewer psychotic disorders (schizophrenia and psychosis). The investigators suggest these differences may require tailored pharmacological approaches to dosing and behavioral treatment approaches to accommodation to the cognitive impairments that occur with TBI.
(2) No non-TBI client was diagnosed with an Axis II disorder, while 25% of those with TBI were. The authors warn that many features of TBI may contribute to the Axis II diagnosis. They emphasize that care must be taken that the diagnoses are appropriate since Axis II diagnoses may preclude eligibility for some treatment programs.
(3) A history of greater numbers of past TBIs was associated with more psychiatric morbidity. Individuals displaying at least three TBIs typically started first substance use almost 5 years sooner than those without any TBI.
(4) The authors supported Timonen and colleagues'[56] prior work stating early TBI (before 12 years of age) doubled the likelihood of having an adult psychiatric diagnosis. Finally, the authors underscored the need for a validated method of identifying aspects of prior history of TBI, and explicitly stated that the methods developed need to identify more substantive information than the presence or absence of a history of prior TBI.

Placed in context of the prior nine evaluated studies,[36] the following main points can be seen.

(1) Community-based treatment for substance abuse for individuals with TBI is required. Inpatient or residential treatment for persons with TBI is seldom available or affordable.
(2) Motivational interviewing techniques are not sufficient when used in isolation. Skills-based interventions show more promise for improved outcomes.
(3) Inclusion of financial incentives and, to a lesser extent, barrier reduction helps to retain participants in treatment for at least the first month.
(4) Peer-based support is generally well received by persons with TBI and their

families, and has shown to benefit participants in a variety of ways (knowledge, a sense of empowerment, and coping capabilities).

(5) Treatment has been shown to be effective using both individual counseling and group psychotherapy modalities in outpatient community settings.

Conclusions and Future Research

The literature shows a clear decrease in substance abuse post-TBI, likely motivated by significant influences on lifestyle choices and functional status. Conflicting reports also reveal the possibility of complex interactions that lead to unanswered questions regarding the relationships between TBI and substance abuse. Interacting factors appear to be involved in the likelihood that patients will continue to abuse substances after TBI (or other traumatic events). Some of these factors include mobility and functional status, contemplation of change and recognition of consequences, and severity of pre-TBI substance abuse. Less investigated factors are likely to include psychiatric conditions such as depression and anxiety as well as TBI-induced changes in executive function, impulse control, and motivation.

Rates of substance abuse post-TBI indicate that, in most patients, those motivators for positive change predominate. A subpopulation of patients displays continued or even new-onset substance abuse. It seems reasonable to suspect that the observed negative correlation between functional status and continued substance abuse fits this model of balancing factors. Less severe TBI may permit an insidious discounting of the implications of substance use and the association with dangerous behaviors. Given the complex relationships between severity of preinjury substance abuse and continued postinjury abuse, the patients most resistant to change in substance abuse may be the very patients at the highest risks from continued substance abuse. These are therefore those with most to gain from improved treatment models for comorbid substance abuse and TBI.

The individuals at greatest risk of changes in behavior and substance abuse are likely to be those with mild or undiagnosed TBI. Such individuals receive little to no treatment, have limited overt symptoms that appear to resolve over the short term, and are likely to have greater financial resources and mobility. Such relationships will likely become better defined with the emerging understanding of the functional consequences of mild injury.

There is a small but growing literature on treatment evaluation for substance-use treatment in the context of TBI. The general consensus is that a multidisciplinary team approach, community based and involving a variety of treatment modalities, is optimal. Skills-based interventions and peer-based support systems appear beneficial. Motivational interviewing alone is not highly effective for promoting treatment retention, but financial incentives and barrier reduction methodologies have shown promise. While both individual and group treatments have been reviewed, a majority of the evaluations are based on data from small sample sizes with limited follow-up and do not yet allow us to make a more holistic evaluation.

Most work that focuses on prevalence rates and substance-use treatment continues to focus on alcohol, with less attention to other addictive substances. As opiate use is common in head-injured individuals, many of whom experience severe and often chronic pain, it is surprising that so little about opiate addiction risks is reported. Clearly, more targeted work is needed to document efficacies of treatments for alcohol as well as for cannabis, cocaine, and opiates.

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Conflicts of Interest

The authors declare no conflicts of interest.

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