Twelve-month recovery of medical decision-making capacity following traumatic brain injury

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ABSTRACT

Objective: To investigate recovery of medical decision-making capacity (MDC) over the first year following traumatic brain injury (TBI).

Methods: A total of 177 participants (111 persons with TBI and 66 healthy controls) were recruited from an inpatient/outpatient TBI rehabilitation unit and outpatient neurology department. Participants with TBI were classified by injury severity into subgroups: mild TBI (mTBI; $n = 28$), complicated mild TBI (cmTBI; $n = 23$), and moderate/severe TBI (msevTBI; $n = 60$). Control and TBI groups were compared at 1 month (t1), 6 months (t2), and 12 months (t3) postinjury using the Capacity to Consent to Treatment Instrument (CCTI), which evaluates MDC using 5 consent standards: expressing choice, reasonable choice, appreciation, reasoning, and understanding.

Results: Relative to controls, no TBI group displayed impairment on CCTI expressing choice or reasonable choice at any timepoint. Those with mTBI had reduced appreciation and understanding at t1, which resolved by t2. The cmTBI and msevTBI groups were impaired on all 3 complex consent standards at t1. While patients with cmTBI improved to a level similar to controls by t3, those with msevTBI remained impaired on reasoning and understanding. Across all TBI groups, notable MDC improvement only occurred over the first 6 months postinjury.

Conclusions: Over 1 year, most individuals with mTBI or cmTBI regain MDC, while many individuals with msevTBI have lingering deficits in reasoning and comprehension of treatment information. Clinical recovery of MDC occurs primarily during the first 6 months post-TBI regardless of injury severity. Clinicians can therefore identify MDC outcomes in TBI at 6 months postinjury.

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GLOSSARY

CCTI = Capacity to Consent to Treatment Instrument; **cmTBI** = complicated mild traumatic brain injury; **GCS** = Glasgow Coma Scale; **GEE** = generalized estimating equations; **GOAT** = Galveston Orientation and Amnesia Test; **MDC** = decision-making capacity; **msevTBI** = moderate/severe traumatic brain injury; **mTBI** = mild traumatic brain injury; **TBI** = traumatic brain injury; **UAB** = University of Alabama at Birmingham.

Following traumatic brain injury (TBI), individuals are confronted with numerous medical problems and treatment decisions during acute hospitalization, rehabilitation, and over the course of long-term recovery. Medical issues may include managing medications, following advance directives, or treating orthopedic injuries and secondary complications.^{1,2} Therefore, it is of clinical importance to determine whether the cognitive and emotional deficits associated with TBI impair a person's medical decision-making capacity (MDC),³ which includes the ability to comprehend and recall pertinent information and then make logical decisions based upon that information.

Previous studies by our group have investigated MDC using the Capacity to Consent to Treatment Instrument (CCTI) in patients with uncomplicated mild TBI (mTBI), complicated mild TBI (cmTBI), and moderate/severe TBI (msevTBI).^{1,4-6} These studies found impairments at time of injury in MDC in cmTBI and msevTBI groups, with partial recovery of MDC at 6 months. However, to date, longitudinal studies of longer-term recovery of MDC in TBI have not been conducted.

Supplemental data
at Neurology.org

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In the present study, we longitudinally investigated MDC over a 12-month period in healthy controls and in persons with TBI representing a range of TBI severity: mTBI, cmTBI, and msevTBI. We hypothesized that persons in all 3 TBI groups would show MDC impairment at baseline. Given that many people who sustain a TBI improve cognitively over the course of the first year, we hypothesized that improvements in MDC would occur over the course of the 12-month study period. However, we expected recovery to be limited for those who sustained msevTBI.

METHODS **Participants.** In total, 177 participants were included: 111 persons who sustained a TBI and 66 healthy controls. Participants were prospectively enrolled between 2007 and 2011 from the University of Alabama at Birmingham (UAB) School of Medicine as part of a NIH-funded longitudinal study examining MDC after TBI (Recovery of Lost Abilities in Medical Decision-Making [RECLAIMED]).

Patients were excluded if they had received substance abuse treatment within 1 year of enrollment (per patient/family report) or had a preexisting diagnosed CNS disorder, developmental disorder, or severe psychiatric disorder. Individuals with a prior mTBI or cmTBI were included if their previous injury occurred at least 1 year before enrollment. Persons with a previous msevTBI were excluded.

Healthy controls were recruited through local advertisements and selected to match participants with TBI on demographic variables of age, sex, ethnicity, and education. Controls were excluded if they had been diagnosed with a psychiatric disorder (except mild depression), substance abuse, cerebrovascular disease, or other neurologic disease. None of the controls was taking medications known to affect cognition.

Procedures. TBI severity level (i.e., mTBI, cmTBI, msevTBI) was assigned using diagnostic criteria from TBI Model Systems (table e-1 at Neurology.org) and has been well-described previously.^{7–14} All TBIs resulted from a closed head injury and individuals with penetrating brain injuries (e.g., gunshot wound) were excluded from the study.

Consistent with the TBI Model System protocol,¹⁵ the average time from date of brain injury to baseline assessment was 32 days (SD 12 days). Participants were also assessed at 6 and 12 months postinjury. Sixteen of the controls and 26 of the patients with TBI did not complete all 3 visits due to the following reasons: scheduling problems (6%), not interested in participating (25%), skipped visit caused by being outside of study window for follow-up (6%), illness (6%), excluded for poor effort (6%), and unknown (50%).

At all 3 visits participants completed the CCTI and a comprehensive battery of neuropsychological and psychological measures. Cross-sectional results from the neuropsychological test battery have been reported separately.¹⁶

Standard protocol approvals, registrations, and patient consents. We obtained written informed consent from each participant or in some cases their legal representative or a family member. The study procedures followed protocol and accord with the ethical standards of the UAB Institutional Review Board, which approved this study.

Measures. **Consent capacity measure.** The CCTI¹⁷ is a psychometric instrument with established reliability and validity used to assess MDC.^{17,18} The CCTI contains 2 clinical vignettes that are presented in both oral and written formats. Each vignette presents a hypothetical medical problem (A, neoplasm; B, cardiovascular disease) and symptoms followed by the presentation of the risks and benefits of 2 alternative treatment options. After vignette presentation, the written format is removed, and participants respond to standardized oral questions designed to assess the following 4 core consent standards derived from the legal and medical literature^{17,19}: expressing a treatment choice (expressing choice), appreciating the personal consequences of a treatment choice (appreciation), providing rational reasons for a treatment choice (reasoning), and understanding the treatment situation, available treatment choices, and respective risks/benefits of the treatment choices (understanding).

A fifth standard measures the ability to make a reasonable treatment choice (reasonable choice).¹⁷ As the term “reasonable” is interpreted with some degree of subjectivity, reasonable choice is not a clinically accepted consent standard and is considered to be experimental.

Trained research assistants administered and scored the CCTI according to well-operationalized criteria.¹⁷ Responses to the CCTI questions were recorded on audiotape and transcribed to ensure scoring accuracy. Research assistants who scored the protocols were blinded to participant group status and the study investigators were not involved in either CCTI administration or scoring.

Data analysis. Demographic variables were analyzed using one-way analysis of variance (age, years of education, Glasgow Coma Scale [GCS] score, Galveston Orientation and Amnesia Test [GOAT] score) or Pearson χ^2 tests (sex, race). Significant omnibus tests were followed with Games-Howell or $2 \times 2 \chi^2$ tests.

We employed generalized estimating equations (GEE) with independent correlation matrices to assess the longitudinal effects of TBI severity on performance on the appreciation, reasoning, and understanding CCTI standards at baseline, 6 months, and 12 months following injury. GEE is an extension of generalized linear model approaches that accounts for the correlated nature of longitudinal data.²⁰ Moreover, GEE utilizes data from all participants (rather than just completers) and provides more robust estimates in the presence of missing data.²¹ For ordinal variables (appreciation, reasoning), a cumulative logistic link function was used, and for normally distributed, continuous variables (understanding), an identity link was used in the model. The main effects of TBI severity and time were explored along with their interaction, using the healthy control group and baseline visit as the reference. Almost the entire study sample (approximately 95%) obtained perfect scores on CCTI expressing choice and reasonable choice. Due to this lack of variability, formal statistics were not conducted on these standards.

We also examined capacity impairment ratings (no impairment, mild/moderate impairment, severe impairment) for each participant with TBI by comparing their performance to that of healthy controls. For appreciation, reasoning, and understanding standards, a no impairment rating was defined as a score no more than 1.5 SDs below the control mean on that standard; a mild/moderate impairment rating as a score between 1.5 SDs and 2.5 SDs below the control mean; and a severe impairment rating as a score more than 2.5 SDs below the control mean. For expressing choice, a no impairment rating was defined as a score of 4, a mild/moderate impairment rating as a score of 3, and a severe impairment rating as a score of ≤ 2 . For reasonable

choice, the only 2 possible impairment ratings were no impairment (1) and impairment (0).

Assignment of ratings is useful in categorizing the extent of MDC impairment and has been implemented in previous studies assessing capacity in clinical samples.^{17,22,23} While these impairment ratings have scientific and clinical value, they are used experimentally for scientific purposes and are not representative of participants' actual legal or clinical competency status.

The assigned significance level for analyses was $p < 0.05$.

RESULTS Demographic and sample characteristics.

Table 1 lists the causes of TBI for the patient sample. Table 2 presents demographic/clinical variables for healthy controls and all TBI groups. Although the omnibus test for age revealed a significant group difference, subsequent post hoc analyses did not reach significance despite cmTBI participants being older by approximately a decade. Additionally, the mTBI group had a greater proportion of nonwhite participants than those with cmTBI ($\chi^2 = 4.791$, $p = 0.029$) or msevTBI ($\chi^2 = 8.759$, $p = 0.003$). As expected, the msevTBI group had lower baseline GCS and GOAT scores than both mTBI and cmTBI groups (all $p < 0.001$).

TBI group and control performance on the CCTI. Table 3 presents the means and SDs for the 5 CCTI standards at each timepoint across TBI severity group. Results of the GEE analysis revealed interactions between TBI group and time for appreciation (Wald $\chi^2 [6, 464] = 19.05$, $p = 0.004$), reasoning (Wald $\chi^2 [6, 464] = 21.00$, $p = 0.002$), and understanding (Wald $\chi^2 [6, 464] = 49.16$, $p < 0.001$). Table 4 presents the odds ratios (appreciation, reasoning) or differences in raw scores (understanding) to compare the TBI group and healthy controls at each timepoint.

Mild TBI. In comparison to healthy controls, patients with mTBI had poorer appreciation and understanding immediately following injury. However, by 6 months postinjury, those with mTBI did not differ from controls on either standard. The ability to

provide a rational reason for treatment choice was not impaired in patients with mTBI in the first year following injury relative to those without head injury.

Complicated mild TBI. At baseline, those with cmTBI perform worse than controls on appreciation, reasoning, and understanding. Six months after injury, only understanding was impaired relative to controls. The 2 groups do not differ on any standard 12 months postinjury. Moreover, the mTBI and cmTBI groups do not differ from each other on appreciation, reasoning, or understanding at any timepoint (all $p > 0.05$).

Moderate/severe TBI. Compared to healthy controls, patients with msevTBI have poorer appreciation, reasoning, and understanding at baseline and at 6 months following injury. Although appreciation is similar to that of healthy controls by 12 months, those with msevTBI continue to demonstrate impaired performance relative to controls on reasoning and understanding with little to no improvement in scores between months 6 and 12.

Of note, the repeated measures analyses were conducted with and without covariates for race and age. Inclusion of these covariates did not appreciably change the results. Thus, only results from the unadjusted analyses are reported.

Capacity impairment ratings. Table 5 presents capacity impairment ratings (intact, mild/moderate impairment, severe impairment) by TBI group across the CCTI consent standards of appreciation, reasoning, and understanding at all 3 timepoints. Although approximately 18% of people with msevTBI exhibited an impaired ability to make a reasonable treatment choice at baseline, impairment on either expressing choice or reasonable choice did not exceed 10% for any other TBI group or at any other timepoint. Thus, these 2 CCTI consent standards were not included in table 5.

Mild TBI. At baseline, a third of participants with mTBI had impaired ratings (mild/moderate or severe) for appreciation and a fifth of participants had impaired understanding. However, less than 20% of participants with mTBI continued to demonstrate impairment at 6 and 12 months on these consent standards.

Complicated mild TBI. Less than half of the cmTBI group exhibited impaired appreciation (39%), reasoning (30%), and understanding (48%) at baseline. At 6 months, a quarter and a little over a third of the cmTBI group was still impaired on understanding and appreciation, respectively. However, impairment did not exceed 14% on any consent standard at 12 months.

Moderate/severe TBI. At baseline, over half of the msevTBI group exhibited impaired reasoning and appreciation, with impaired performance on understanding approaching 80%. Although msevTBI

Table 1 Causes of traumatic brain injury in the study sample (n = 111)

Cause	No. (%)
Motor vehicle accident	62 (55.9)
Falls	21 (18.9)
Motorcycle/moped/bicycle accident	13 (11.7)
Assault with blunt instrument	5 (4.5)
ATV/go-cart crash	3 (2.7)
Hit by falling or flying object	2 (1.8)
Sports	2 (1.8)
Other	2 (1.8)
Pedestrian	1 (0.9)

Abbreviation: ATV = all-terrain vehicle.

Table 2 Demographic and clinical characteristics of study participants

Variables	Range	Controls (n = 66)	mTBI (n = 28)	cmTBI (n = 23)	msevTBI (n = 60)	F/ χ^2	p ^a
Age, y	19–79	35.38 ± 12.4	35.39 ± 12.4	46.35 ± 18.0	36.17 ± 15.3	3.78	0.012 ^b
Sex						6.41	0.093
Men		40 (60.6)	15 (53.6)	13 (56.5)	46 (76.7)		
Women		26 (39.4)	13 (46.4)	10 (43.5)	14 (23.3)		
Race						9.84	0.020 ^b
White		48 (72.7)	15 (53.6)	19 (82.6)	50 (83.3)		
Other		18 (27.3)	13 (46.4)	4 (17.4)	10 (16.7)		
Education, y	8–20	12.85 ± 1.5	13.11 ± 1.9	13.83 ± 2.8	12.63 ± 2.4	1.90	0.132
GOAT score	0–100						
Baseline		NA	96.00 ± 4.9	95.05 ± 6.9	68.05 ± 34.4	15.45	<0.001 ^b
6 mo		NA	94.31 ± 5.8	96.40 ± 6.1	91.77 ± 12.7	1.63	0.202
12 mo		NA	93.08 ± 6.4	97.38 ± 3.8	93.86 ± 15.5	0.72	0.490
GCS score	3–15	NA	14.33 ± 1.9	14.67 ± 0.6	5.82 ± 3.0	137.12	<0.001 ^b

Abbreviations: cmTBI = complicated mild traumatic brain injury; GOAT = Galveston Orientation and Amnesia Test; GCS = Glasgow Coma Scale; msevTBI = moderate/severe traumatic brain injury; mTBI = mild traumatic brain injury; NA = not applicable.

Values are mean ± SD or n (%).

^ap Value for omnibus test of group differences. Subsequent post hoc tests for age only approached significance despite older participants in the cmTBI group. Post hoc testing also revealed that the mTBI group had a greater proportion of nonwhite participants. As expected, the msevTBI group had lower baseline GCS and GOAT scores.

^bSignificant.

participants improved on all 3 standards at 6 months, a large proportion remained impaired a year after injury: 17% for appreciation, 25% for reasoning, and 50% for understanding.

DISCUSSION We used a standardized performance measure and 5 consent standards to investigate MDC

over a 12-month period in persons with a range of TBI severity. Our study found that a great majority of all 3 TBI groups (mTBI, cmTBI, and msevTBI) were capable of expressing and making reasonable treatment choices (expressing choice, reasonable choice). In contrast, all 3 TBI groups exhibited significant impairment and differential

Table 3 Means and SDs for the 5 Capacity to Consent to Treatment Instrument standards at each timepoint across traumatic brain injury groups

Group	Visit	No.	Expressing choice	Reasonable choice	Appreciation	Reasoning	Understanding
Control	Baseline	66	3.99 ± 0.1	0.96 ± 0.2	7.47 ± 0.9	8.74 ± 2.6	63.64 ± 9.4
	6 mo	60	4.00 ± 0.0	0.95 ± 0.2	7.48 ± 0.8	8.75 ± 2.5	64.47 ± 9.1
	12 mo	50	3.96 ± 0.2	0.96 ± 0.2	7.42 ± 1.0	8.90 ± 2.5	64.72 ± 10.6
mTBI	Baseline	28	3.93 ± 0.3	1.00 ± 0.0	6.82 ± 1.3	8.18 ± 2.4	56.79 ± 11.2
	6 mo	27	3.85 ± 0.5	1.00 ± 0.0	7.19 ± 1.0	8.82 ± 2.5	60.93 ± 12.3
	12 mo	26	4.00 ± 0.0	0.96 ± 0.2	7.08 ± 1.4	8.81 ± 1.9	61.23 ± 14.5
cmTBI	Baseline	23	3.87 ± 0.5	0.96 ± 0.2	6.57 ± 1.7	6.91 ± 3.6	49.61 ± 17.4
	6 mo	20	3.90 ± 0.3	0.95 ± 0.2	6.95 ± 1.2	8.60 ± 3.3	57.25 ± 14.4
	12 mo	16	3.94 ± 0.3	1.00 ± 0.0	7.13 ± 1.2	8.13 ± 2.4	60.94 ± 9.4
msevTBI	Baseline	60	3.36 ± 1.4	0.83 ± 0.4	4.78 ± 2.9	4.41 ± 3.6	30.24 ± 21.2
	6 mo	48	4.00 ± 0.0	1.00 ± 0.0	6.52 ± 1.6	6.98 ± 3.1	48.04 ± 17.2
	12 mo	43	3.93 ± 0.3	0.98 ± 0.2	6.91 ± 1.4	7.37 ± 3.1	46.86 ± 16.5

Abbreviations: cmTBI = complicated mild traumatic brain injury; msevTBI = moderate/severe traumatic brain injury; mTBI = mild traumatic brain injury.

Values are mean ± SD.

Table 4 Traumatic brain injury vs control group performance on Capacity to Consent to Treatment Instrument appreciation, reasoning, and understanding standards

Standards	Baseline			6-mo follow-up			12-mo follow-up		
	Estimate	95% CI	p	Estimate	95% CI	p	Estimate	95% CI	p
mTBI									
Appreciation	3.01	1.33 to 6.76	<0.01 ^a	1.73	0.76 to 3.92	0.18	1.53	0.61 to 3.79	0.36
Reasoning	1.60	0.78 to 3.31	0.20	1.02	0.45 to 2.25	0.97	1.17	0.56 to 2.42	0.67
Understanding	−6.85	−11.51 to −2.19	<0.01 ^a	−3.54	−8.64 to 1.56	0.17	−3.49	−9.69 to 2.71	0.27
cmTBI									
Appreciation	3.32	1.30 to 8.46	0.01 ^a	2.33	0.92 to 5.83	0.07	1.58	0.53 to 4.72	0.41
Reasoning	3.16	1.26 to 7.92	0.01 ^a	0.94	0.36 to 2.49	0.92	1.80	0.71 to 4.52	0.21
Understanding	−14.03	−21.34 to −6.71	<0.01 ^a	−7.22	−13.79 to −0.64	0.03 ^a	−3.78	−9.12 to 1.55	0.16
msevTBI									
Appreciation	14.55	6.79 to 31.16	<0.01 ^a	3.33	1.62 to 6.84	<0.01 ^a	2.11	0.94 to 4.68	0.07
Reasoning	13.32	6.66 to 26.66	<0.01 ^a	3.12	1.58 to 6.17	<0.01 ^a	2.32	1.13 to 4.80	0.02 ^a
Understanding	−33.40	−39.20 to −27.59	<0.01 ^a	−16.43	−21.74 to −11.11	<0.01 ^a	−17.86	−23.53 to −12.19	<0.01 ^a

Abbreviations: CI = confidence interval; cmTBI = complicated mild traumatic brain injury; msevTBI = moderate/severe traumatic brain injury; mTBI = mild traumatic brain injury.

Estimates for ordinal outcome variables (appreciation and reasoning) have been exponentiated and represent the odds of achieving lower scores than controls. Estimates for continuous variables (understanding) represent the raw difference from control performance.

^a Significant.

improvement on the 3 more complex consent standards of appreciation, reasoning, and understanding over the first year following injury. Results are discussed separately for each TBI group.

As expected, we found that subtle impairments in cognitively complex aspects of MDC were present in many people with acute mTBI. However, most of these individuals exhibited intact consent capacity after 6 months. These results highlight the temporal

relationship between cognitive and MDC recovery in TBI. For example, previous studies have noted that people with mTBI perform commensurately to healthy controls on most cognitive measures within 3–6 months following injury.^{24–27} In addition, we noted in a previous study that the group effects of mTBI on MDC did not always transfer to the individual level.⁶ Although the mTBI group as a whole performed statistically equal to healthy controls,

Table 5 Number (%) of participants with traumatic brain injury (TBI) exhibiting impaired decision-making capacity across TBI group and time

	Baseline			6-mo follow-up			12-mo follow-up		
	Intact	Mild/moderate impairment	Severe impairment	Intact	Mild/moderate impairment	Severe impairment	Intact	Mild/moderate impairment	Severe impairment
mTBI									
Appreciation	19 (67.8)	4 (14.3)	5 (17.8)	22 (81.5)	3 (11.1)	2 (7.4)	22 (84.6)	1 (3.8)	3 (11.5)
Reasoning	26 (92.9)	2 (7.1)	0 (0)	25 (92.6)	2 (7.4)	0 (0)	25 (96.2)	1 (3.8)	0 (0)
Understanding	22 (78.6)	3 (10.7)	3 (10.7)	22 (81.5)	2 (7.4)	3 (11.1)	21 (80.8)	4 (15.4)	1 (3.8)
cmTBI									
Appreciation	14 (60.8)	4 (17.3)	5 (21.7)	13 (65.0)	5 (25.0)	2 (10.0)	13 (86.7)	1 (6.7)	1 (6.7)
Reasoning	16 (69.6)	5 (21.7)	2 (8.7)	18 (90.0)	0 (0)	2 (10.0)	14 (87.5)	2 (12.5)	0 (0)
Understanding	12 (52.1)	4 (17.4)	7 (30.4)	15 (75.0)	4 (20.0)	1 (5.0)	15 (93.8)	1 (6.3)	0 (0)
msevTBI									
Appreciation	23 (40.0)	7 (11.9)	29 (49.2)	28 (58.3)	8 (16.7)	12 (25.0)	35 (83.3)	3 (7.1)	4 (9.5)
Reasoning	25 (42.3)	14 (23.7)	20 (33.9)	36 (75.0)	8 (16.7)	4 (8.3)	32 (74.4)	7 (16.3)	4 (9.3)
Understanding	11 (18.6)	10 (16.9)	38 (64.4)	22 (44.8)	12 (25.0)	14 (29.2)	22 (51.2)	8 (18.6)	13 (30.2)

Abbreviations: cmTBI = complicated mild traumatic brain injury; msevTBI = moderate/severe traumatic brain injury; mTBI = mild traumatic brain injury.

a number of individuals who had sustained mTBI continued to show some level of MDC impairment a year after injury. This finding is also consistent with the literature on cognitive recovery in mTBI, as a subsample of those with mTBI may continue to experience cognitive impairment after most have recovered.^{24–28} Factors such as age, education, comorbid medical and psychiatric issues, and substance abuse history have been implicated as affecting cognitive recovery^{29,30} and, thus, likely influence individual differences in MDC recovery as well.

The current results demonstrate that the cmTBI subgroup experiences more initial MDC impairment and slower recovery than those with mTBI, but over 1 year approaches full recovery. These results are consistent with previous literature that has noted that structural brain abnormalities seen in complicated mild head injuries are associated with worse cognitive and functional outcome than those with mTBI, despite the fact that these 2 patient groups share similar clinical characteristics (Glasgow Coma Scale score, loss of consciousness, and post-traumatic amnesia).^{31,32} Although our study found subtle differences in MDC between groups over the first 6 months, by 1 year postinjury, the cmTBI and mTBI groups are virtually indistinguishable from each other or from healthy controls, with fewer than 20% of patients in both groups demonstrating impairment on any CCTI standard at this timepoint.

As outlined in our previous study,⁵ the msevTBI group demonstrated the most severe MDC impairments at baseline. Although the majority of MDC recovery in the msevTBI group took place over the first 6 months following recovery, all 3 complex consent standards remained below the level of control performance. There appeared to be some individuals who continued to recover past 6 months on the appreciation standard, but this group experienced little to no improvement on reasoning or understanding and remained impaired for a year following injury. These findings support the results from our earlier longitudinal study with a separate msevTBI group and indicate a need for continual monitoring of MDC in those with more severe head injuries for at least a year postinjury.¹ However, cognitive improvement has been found to occur in a subset of individuals with msevTBI more than a year after their injury.³³ Thus, it remains possible that some people who sustained msevTBI will continue to show MDC recovery after the initial year following injury.

It is important to consider the underlying neuropsychological and neurobehavioral correlates of the MDC changes we have described. Although an assessment of neuropsychological predictors of

MDC outcome at 12 months postinjury is beyond the scope of the current study, previous work by our group¹⁶ has demonstrated that performance on measures of verbal memory (list and story learning), academic skills (word reading and written arithmetic), and verbal fluency (letter and category fluency) predicted performance on appreciation, reasoning, and understanding at 1 month postinjury. These cognitive predictors varied slightly by injury severity. Practitioners should note that diminished abilities in these cognitive domains, particularly verbal memory, might serve as a red flag for impaired medical decision-making ability in persons with TBI.

A significant proportion of patients with TBI are impaired in their capacity to make medical decisions 1 month after injury, with partial or full recovery during the first year. Recovery generally appears to stabilize after 6 months with limited MDC improvement between 6 and 12 months following injury in all groups. MDC outcome varied according to injury severity. The greatest amount of improvement occurred in patients with msevTBI. However, the msevTBI group still had the worst longitudinal outcome, as they remained impaired in their reasoning and understanding consent abilities at 12 months. Although CCTI performance for the mTBI and cmTBI groups approached that of controls by 6 months, approximately 18% of individuals with mTBI and 13% of those with cmTBI still demonstrated some level of impaired MDC 12 months postinjury. Clinically, the current findings underscore the importance of evaluating MDC soon after injury and over time in all individuals with TBI.

There were several limitations to the current study. First, we were unable to compare individuals with moderate and severe TBI due to insufficient number of moderate injuries. Second, approximately a quarter of our participants did not complete all 3 visits. Although GEE analysis is relatively robust to missing data, future investigations into MDC recovery using larger samples that can better absorb the statistical effect of attrition are needed. Third, studies in this population examining MDC over a longer duration of observation would also provide useful information about long-term outcomes. Finally, individuals may respond differently to the CCTI's hypothetical clinical vignettes than to real-life, personal medical situations, which may trigger emotional aspects of MDC not captured by this measure.

AUTHOR CONTRIBUTIONS

Kayla Steward: drafting/revising the manuscript for content, analysis or interpretation of data, statistical analysis. Adam Gerstenecker: drafting/revising the manuscript for content, analysis or interpretation of data.

Kristen Triebel: drafting/revising the manuscript for content, analysis or interpretation of data, study concept or design. Richard Kennedy: drafting/revising the manuscript for content, analysis or interpretation of data, development of figure for short-form article. Thomas Novack: drafting/revising the manuscript for content, study concept or design, acquisition of data, analysis or interpretation of data. Laura E. Dreer: drafting/revising the manuscript for content, study concept or design. Daniel Marson: drafting/revising the manuscript for content, study concept or design, analysis or interpretation of data, acquisition of data, study supervision or coordination, obtaining funding.

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