Predictors of Long-Term Risky Driving Behavior in the Multimodal Treatment Study of Children with Attention-Deficit/Hyperactivity Disorder

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Abstract

Objective: This study examines predictors of later risky driving behavior in children with attention-deficit/hyperactivity disorder (ADHD).

Methods: Stepwise logistic regression and receiver operating characteristic (ROC) analysis were used to explore baseline predictors of risky driving behavior for adolescents who completed the 8-year follow-up assessment in the Multimodal Treatment Study of Children with Attention-Deficit/Hyperactivity Disorder (MTA).

Results: Stepwise logistic regression analysis explained 19% of the total variance in risky driving behavior. Increased likelihood of risky driving behavior was associated with parental history of conduct disorder, low parental monitoring and supervision, and increased age. ROC analysis identified discriminative predictors for adolescents older and younger than 16 years of age at follow-up. The most discriminative predictors of later risky driving behavior were parental stress at baseline (for children 16 years or older) and increased child-rated parental protectiveness (for children less than 16 years old).

Conclusion: Risky driving behavior was significantly predicted by baseline characteristics for the MTA cohort. Aspects of parenting behavior (or the child's perception of them), including parental stress levels, parental protectiveness, and parental levels of monitoring and supervision, were most informative in predicting these outcomes. Our results suggest that interventions to reduce high-risk behaviors in these high-risk children with ADHD might involve targeted parenting interventions.

Keywords: attention-deficit/hyperactivity disorder, risky driving, long-term outcomes

Introduction

CHILDREN WITH ATTENTION-DEFICIT/HYPERACTIVITY disorder (ADHD) are at increased risk of engaging in risky and dangerous behavior as adolescents and young adults (Murphy and Barkley 1996). ADHD is associated with an increased likelihood of later engaging in risky driving behavior, resulting in receiving a driving citation, being cited for speeding, and having a license suspended (Barkley et al. 1993, 1996, 2002; Nada-Raja et al. 1997). ADHD is also associated with an increased likelihood of being involved in automobile accidents, being at fault for the accident, or having bodily injuries as a result of those accidents (Barkley et al. 1993, 1996, 2002; Nada-Raja et al. 1997; Groom et al. 2015).

Although previous research has been dedicated toward identifying concurrent behaviors associated with risky driving in adults with substance use, conduct disorder [CD], and worse ADHD symptoms, little research has examined predictors among children with ADHD for later risky driving behaviors (Thompson et al.

2007). Identifying children with ADHD at high risk for experiencing later risky driving behavior may be useful in targeting or developing interventions designed to reduce risky driving behaviors before these children obtain their driving licenses.

The Multimodal Treatment Study of Children with ADHD (MTA) was a 14-month randomized clinical trial that investigated the efficacy of various treatments, including (1) medication management, (2) behavioral treatment, and (3) combined treatment (medication management with an added behavioral intervention), compared with community care (MTA 1999). The MTA was critical in establishing the current evidence base of treatments for childhood ADHD. Results demonstrated that for the first 14 months of treatment, evidence-based pharmacological treatment, primarily with psychostimulant medication, was superior to behavioral treatment.

Secondary analyses went on to suggest that medication management with an additional behavioral intervention added small, but significant, improvements compared with medication alone (Conners et al. 2001; Swanson et al. 2001). After the initial 14

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months of treatment, children in the MTA were followed for over a decade so that longitudinal outcomes of childhood ADHD could be examined (Molina et al. 2009).

While the association between ADHD and risky driving behavior has been demonstrated, little research has examined whether this relationship can still be seen for individuals diagnosed with ADHD in childhood. Furthermore, there is a lack of insight into possible childhood predictors of later risky driving behavior for those diagnosed.

Analysis of risky driving behaviors seen later in children of the Pittsburgh ADHD Longitudinal Study revealed that ADHD probands were four times more likely than controls to have ever driven without a license or permit 8 years later (Thompson et al. 2007). Additionally, the number of accidents reported in the last 6 months, the number of tickets received in a lifetime, and the number of tickets received in the last 6 months were higher for children with ADHD compared with controls. Increased risky driving behaviors were associated with increased symptoms of CD as well as ADHD severity (specifically, hyperactivity, and impulsivity) in late adolescence and early adulthood when driving behaviors were assessed (Thompson et al. 2007).

Previous work in the same MTA cohort demonstrated that children with ADHD were at increased risk of driving illegally, receiving citations, and having a driver's license or permit suspended or revoked. Furthermore, positively biased self-perceptions of competence in childhood were associated with increased risk of dangerous driving behaviors 8 years later (Hoza et al. 2013).

To our knowledge, no studies have systematically investigated potential baseline childhood predictors of risky driving behavior at 8-year follow-up for the MTA cohort using data-driven approaches. Predictors for risky driving behavior at 8-year follow-up for the MTA cohort will be explored using stepwise regression techniques and receiver operating characteristic (ROC) analysis.

Methods

Study overview

The reasoning, design, purpose, and methods of the MTA have been described previously (Richters et al. 1995; Arnold et al. 1997; MTA 1999). All subjects who participated in the MTA and their guardians provided informed consent and assent. The local ethics committee approved the study, a written informed consent was obtained, and the study was registered at ClinicalTrials.gov (identifier: NCT00000388).

Subjects

Children between the ages of 7 and 9 were recruited from 6 sites across the United States and Canada for the initial 14-month treatment trial. Participants needed to meet the Diagnostic and Statistical Manual of Mental Health Disorders (DSM-IV) criteria for ADHD combined type, using the Diagnostic Interview Schedule for Children (DISC), version 3.0 (Shaffer et al. 2000). Children were excluded if they met any of the following criteria: physical inability to participate in all aspects of the study (i.e., non-English-speaking guardian or hospitalization), intolerance to MTA medications in the past, or participation in treatments that were incompatible with any MTA treatment assignments (i.e., bipolar disorder and Tourette syndrome treatments or neuroleptic medications in the last 6 months). To be included in the follow-up analysis, participants needed to participate in an 8-year follow-up interview that included a driving behavior questionnaire.

Assessment of risky driving

Participants were assessed at baseline and various other time points throughout the study, including an assessment at 8 years.

Risky driving behavior was assessed using both a parent and an adolescent version of the Driving Behavior Questionnaire, which was created for the MTA to evaluate driving behavior (Donovan et al. 1983; Jessor et al. 1991). The following items were included in our risky driving behavior outcome variable: "Have you ever driven illegally?" "Were you ever in a car or motorcycle accident, regardless of fault, *while you were the driver*?" and "Have you ever been ticketed for any traffic violations such as speeding and illegal parking?" The resulting outcome variable was a dummy, coded as one if any of the items were positive and coded zero otherwise.

Details on predictor variables are provided in the data analysis subsection. More specific details regarding the assessment procedures and measures used in the MTA have been described previously (Richters et al. 1995; Arnold et al. 1997; MTA 1999).

Intervention

Children were randomized to 1 of 4 treatment groups for 14 months, which included (1) medication management, (2) behavioral treatment, (3) combined treatment (medication management with an added behavioral component), and (4) community care. Treatment groups were designed to be flexible for each patient's individual clinical needs throughout the period of treatment. Information regarding treatment administration has been described elsewhere (Greenhill et al. 1996; MTA 1999; Wells et al. 2000). After 14 months of randomized treatment, treatment was no longer controlled, but subjects participated in semiregular assessments administered by study staff.

Data analysis

The data utilized in this analysis were obtained from the NIMH-supported MTA data set. Data preparation and analysis were conducted using Statistical Analysis System (SAS, version 9.2) and used for stepwise regression models. Microsoft Excel was also used to conduct data analysis. Regression models and signal detection methodology were used to establish the best prediction model. ROC analysis was conducted using software available online from Ruth O'Hara at Stanford University (www.stanford.edu/~yesavage/ROC.html).

Logistic regression models assessed the association of the baseline characteristics with risky driving behavior at 8-year follow-up. To make better use of the available data, two complementary statistical techniques were used: stepwise regression and ROC analysis. These two separate methods were chosen for exploratory data analysis as they not only provide ways to minimize false-positive error but also allow for two distinct data-driven approaches to analyze potential predictors. The advantages of each approach are described in the Methods section and the limitations discussed in depth in the Discussion section.

The regression technique used followed an approach developed by Fournier et al. and has been applied to both linear and logistic regression in previous studies (Fournier et al. 2009; Powers et al. 2014). This method was chosen not only to allow for exploratory examination of a large number of potential predictor variables but also to minimize the possibility of false-positive error and to limit problems with collinearity (since only a few variables are included from each domain). Before analysis, predictor variables were rationally divided into seven domains (demographic, trial factors, cognitive functioning, comorbid psychopathology, family history of psychiatric disorders, parent-child relationship, and parental variables).

The following steps were carried out in each individual domain separately: Step 1 tested a full model, including all variables and

their interactions with treatment. Step 2 repeated the analysis retaining predictors with $p < 0.20$ from step 1. Step 3 repeated the analysis retaining predictors with $p < 0.10$ from step 2. Step 4 repeated the analysis retaining predictors with $p < 0.05$ from step 3. Step 4 was repeated until all predictors in the model are significant at $p < 0.05$. Significant predictors across all domains were then included into a combined model. The same 4-step procedure was then repeated for the variables included in the combined model. Continuous predictors were centered at the grand mean and dichotomous predictors were coded as -0.5 and 0.5 (Kraemer et al. 2002).

The following baseline characteristics were entered by domain for regression analysis:

The demographic domain included sex, race, age, size of city most lived in, and parental welfare and income status. Information about medical history was also included, specifically neonatal history (pregnancy length, birth weight, and nicotine exposure).

The trial factor domain included study site, randomized treatment assignment, and the interaction between site and treatment assignment.

The cognitive domain consisted of various neuropsychological measures, including the Continuous Performance Task (CPT) (impulsivity, inattention, and dyscontrol) (Riccio 2004) and the Wechsler Intelligence Scale for Children (WISC) III (verbal, performance, and full scale) (Kaufman 1994).

The comorbid psychopathology domain included DISC 3.0 [anxiety (separation and generalized), phobia (simple and social), panic disorder, tics (chronic and transient), Tourette syndrome, and depression] (Shaffer et al. 1996, 2000), Multidimensional Anxiety Scale for Children (MASC) (March et al. 1997), total number of self-reported antisocial behaviors and subscales (destruction of property, physical aggression, and stealing behaviors) (Loeber et al. 1989), Child Behavior Checklist (CBCL) total score and subscales (social problems, internalizing, and externalizing) (Achenbach and Edelbrock 1983), Social Skills Rating System (SSRS) total scores (social skills and problem behavior) and subscales (cooperativeness, responsibility, social conduct, internalizing, externalizing, and hyperactivity) (Gresham and Elliott 1990), and Aggression and Conduct Problems Scale (ACPS) total score and subscales (aggression and CD symptoms) (American Psychiatric Association 2000).

The family history domain included a family history of ADHD, alcohol or substance abuse, tics, Tourette syndrome, anxiety, depression, obsessive-compulsive disorder, psychiatric hospitalization, and previous incarceration (Shaffer et al. 2000).

The parental variable domain included information on parental marital status, education level and employment status, parental knowledge about behavior principles, Parental Stress Index (PSI) total score and subscales (defensive responding, parental distress, parent-child dysfunctional interaction, and difficulty of child) (O'Dell et al. 1979), the Beck Depression Index (BDI) (Beck 1961), and a history of CD as measured by the Antisocial Personality Scale (APS) for the Structured Clinical Interview for the DSM-IV (SCID-II) (First 1997). To avoid collinearity issues, both the PSI total score and its subscales were entered into separate regression models. If either model had any factors that remained significant, the model with the higher R^2 value was retained and entered into the combined model.

The parent-child relationship domain included parent and child ratings from the Alabama Parenting Questionnaire (APQ) scales [parental involvement, positive parenting, discipline subscales (inconsistent, harsh, and appropriate), and low monitoring and supervision] (Essau 2006) and the Parent-Child Relationship Questionnaire (PRQ) subscales (rationale, praise, possessiveness, affection, quarreling, prosocial, similarity, dominance, intimacy, physical pun-

ishment, admiration of and by parent, deprivation of privileges, nurturance, verbal and physical punishment, companionship, guilt induction, and shared decision-making) (Furman and Gierson 1995).

ROC analysis was used as an alternative nonparametric method that operates through recursive partitioning. It aims to identify subgroups of children who have a differential probability of achieving a particular binary outcome and has been utilized in many previous studies to examine predictors of dichotomous outcomes (Kraemer 1992; Jakubovski et al. 2015). Across all predictor variables, the cutoff point that yields the best prediction is then used to divide the total sample in two subsamples. The same procedure is repeated systematically in each subsample. This iterative process continues until a subgroup contains less than 10 individuals or the group difference is not significant at an alpha level of 0.05. The analysis was also stopped at the 3-way interaction level. ROC analysis was stratified into two groups according to age (being older or younger than 16 years) at follow-up since chronological age was a strong predictor of risky driving behaviors.

ROC analysis has advantages over traditional regression analyses: it has improved power and flexibility when examining higher-order interactions—ROC analysis, in contrast to regression, can analyze all possible interactions, rather than only those specified *a priori*, and can analyze interactions even when the main effect terms are not included in the model. ROC analysis can also sort through missing data without discarding all other prognostic data. Subjects with missing data on predictor variables were excluded from the regression analysis and from the ROC analysis only for the analyses involving the missing predictor variable. We did not attempt to impute missing data for predictor variables.

Results

Subjects

A total of 579 participants completed the baseline assessment, of which 430 had information on risky driving behavior at follow-up 8 years later and were included in the analysis. Of those with available data, 44.7% of adolescents reported risky driving behavior.

Table 1 compares participants and nonparticipants at 8-year follow-up for all predictor variables. Participants were less likely to be male ($t = 4.98$, $p = 0.03$) and have parents who received welfare ($t = 3.96$, $p = 0.05$), but more likely to be Caucasian ($t = 8.06$, $p = 0.005$), and have comorbid GAD ($t = 4.16$, $p = 0.04$) at childhood baseline assessment. Participants were less likely to have a family history of drug use ($t = 4.26$, $p = 0.04$), tics ($t = 5.71$, $p = 0.02$), and depression ($t = 3.98$, $p = 0.05$), but more likely to have a family history of anxiety ($t = 9.65$, $p = 0.002$) or OCD ($t = 16.32$, $p < 0.0001$). Participants had a higher income ($t = -2.66$, $p = 0.008$) and more educated parents [mother ($t = -3.32$, $p < 0.001$) and father ($t = -3.09$, $p = 0.002$)], as well as a higher full scale IQ ($t = -2.91$, $p = 0.004$).

Risky driving behaviors at follow-up

The results of regression analysis are depicted in Table 2. Significant baseline predictors of risky driving behaviors were found in six domains (demographic, trial, cognitive, comorbid psychopathology, parental, and parent-child relationship). The final combined model explained 19.0% of the variance.

A higher age (RR = 1.31, 95%CI = 1.16–1.47, $p < 0.0001$), a higher likelihood of being at site three (RR = 2.27, 95%CI = 1.36–3.77, $p = 0.002$), a lower likelihood of being at site four (RR = 0.65, 95%CI = 0.53–0.79, $p < 0.0001$), a higher CBCL externalizing subscore (RR = 1.02, 95%CI = 1.01–1.03, $p < 0.001$), a lower CBCL social

TABLE 1. BASELINE CLINICAL CHARACTERISTICS OF PARTICIPANTS AND NONPARTICIPANTS IN 8-YEAR MTA FOLLOW-UP

Variable	Participants at 8-year follow-up (N = 430)	%/ SD	Nonparticipants at 8-year follow-up (N = 149)	%/ SD	t	p-value
Sex						
Male (N,%)	336.0	78.1%	129.0	86.6%	4.98	0.03
Race						
Caucasian (N,%)	276.0	64.2%	76.0	51.0%	8.06	0.005
Age, years	7.8	0.8	7.8	0.8	0.93	0.35
Parental welfare (N,%)	72.0	16.7%	36.0	24.2%	3.96	0.05
Income (tens of thousands)	5.0	2.5	4.3	2.5	-2.66	0.008
Continuous performance task totals						
Inattention	9.4	7.1	10.5	7.6	1.53	0.13
Impulsivity	7.7	8.2	11.3	10.2	3.78	<0.001
Dyscontrol	20.1	28.7	27.4	35.6	2.22	0.03
WISC III						
Full Scale	102.0	14.6	98.0	14.5	-2.91	0.004
DISC 3.0						
Separation anxiety disorder (N,%)	49.0	11.4%	18.0	12.1%	0.06	0.81
GAD (N,%)	36.0	8.4%	5.0	3.4%	4.16	0.04
Simple phobia (N,%)	54.0	12.6%	18.0	12.1%	0.02	0.89
Social phobia (N,%)	75.0	17.4%	20.0	13.4%	1.27	0.26
Chronic tics (N,%)	24.0	5.6%	7.0	4.7%	0.17	0.68
Major depressive disorder (N,%)	18.0	4.2%	4.0	2.7%	0.70	0.40
Family history (N,%)						
ADHD (N,%)	163.0	37.9%	49.0	32.9%	1.01	0.32
Drug use (N,%)	162.0	37.7%	42.0	28.2%	4.26	0.04
Tics (N,%)	32.0	7.4%	3.0	2.0%	5.71	0.02
Anxiety (N,%)	46.0	10.7%	30.0	20.1%	9.65	0.002
Depression (N,%)	174.0	40.5%	46.0	30.9%	3.98	0.05
OCD (N,%)	9.0	2.1%	14.0	9.4%	16.32	<0.0001
Psychiatric hospitalization (N,%)	76.0	17.7%	17.0	11.4%	2.97	0.08
Maternal education	4.3	1.1	3.9	1.0632	-3.32	<0.001
Father's education	4.2	1.2	3.8	1.3611	-3.09	0.002
Parent knowledge of Behavior principles (% Correct)	0.4	0.2	0.4	0.2	-2.3	0.020
Parental history of conduct disorder (N,%)	11.0	2.6%	9.0	6.0%	4.10	0.04

t-tests and chi-square tests conducted to examine differences between groups are displayed.

Bold values indicate characteristics that were significantly different in participants compared to nonparticipants.

SD, standard deviation; WISC, Wechsler Intelligence Scale for Children; DISC, diagnostic interview schedule for children; ADHD, attention-deficit/hyperactivity disorder; GAD, generalized anxiety disorder; OCD, obsessive-compulsive disorder.

problems subscore (RR=0.96, 95%CI=0.92–1.00, $p=0.04$), a higher SSRS internalizing subscore (RR=1.09, 95%CI=1.04–1.15, $p=0.001$), a higher BDI total score (RR=1.02, 95%CI=1.01–1.04, $p=0.005$), a higher child-reported APQ low monitoring/supervision subscore (RR=1.03, 95%CI=1.01–1.04, $p<0.001$), a lower child-reported PRQ praise subscore (RR=0.89, 95%CI=0.80–0.99, $p=0.03$), and a higher child-reported PRQ nurturance subscore (RR=1.18, 95%CI=1.06–1.32, $p=0.003$) predicted an increased likelihood of risky driving behaviors.

Figure 1A depicts the empirically derived hierarchical prognostic subgroups for risky driving behavior at 8-year follow-up for children older than 16 years at the time of follow-up. The overall likelihood of risky driving behavior was 52.5%. Baseline clinical characteristics were able to identify subgroups with as low as 6.7% likelihood of risky driving behavior (a PSI total score <106, a full scale IQ <97, and a CBCL social problems subscore ≥ 4 or sometimes true or more) to as high as 86.0% likelihood of risky driving behavior (a PSI total score ≥ 106 and a child-reported PRQ deprivation of privileges subscore ≥ 2.5). The most discriminative predictor of risky driving behavior was the PSI total score.

Figure 1B depicts the empirically derived hierarchical prognostic subgroups for risky driving behavior at 8-year follow-up for children below the age of 16 at the time of follow-up interview. The overall likelihood of risky driving behavior was 34.7%. Baseline clinical characteristics identified subgroups with as low as 8.3% likelihood of risky driving behavior (a child-reported PRQ protectiveness subscore <3.3 and a CPT dyscontrol subscore ≥ 11) to as high as 87.0% likelihood of risky driving behavior (child-reported PRQ protectiveness subscore ≥ 3.3 , a performance IQ <96, and being male). The most discriminative predictor of risky driving behavior was the child-reported PRQ protectiveness subscore.

Discussion

Exploratory analyses of the MTA cohort at 8-year follow-up identified several baseline characteristics evaluated when children were 7–9 years of age and were associated with later risky driving. Baseline characteristics explained 19% of the variance in risky driving behavior 8 years later. Parenting style (e.g., low monitoring/supervision), aspects of the parent–child relationship, and parental stress levels appear quite informative in predicting later risky driving behavior.

TABLE 2. BASELINE PREDICTORS OF RISKY DRIVING BEHAVIORS AT 8-YEAR MTA FOLLOW-UP

Variable	Driving behaviors		
	RR	95% CI	p-value
Demographic domain			
Age	1.31	(1.16–1.48)	<0.0001
R-Square			0.040
Trial factor domain			
Site 3	0.540	(0.33–0.87)	0.01
Site 4	1.513	(1.23–1.86)	<0.0001
R-Square			0.060
Cognitive domain			
CPT			
Dyscontrol	0.99	(0.99–1.00)	0.03
R-Square			0.055
Comorbid psychopathology domain			
CBCL			
Externalizing	1.02	(1.01–1.03)	<0.001
Social problems	0.93	(0.89–0.98)	0.003
SSRS			
Internalizing	1.07	(1.01–1.13)	0.02
R-Square			0.087
Family history domain			
No significant variables			
Parental domain			
BDI total score	1.02	(1.01–1.04)	0.005
R-Square			0.053
Parent–child relationship domain			
APQ			
Low Monitoring/Supervision	1.02	(1.01–1.04)	<0.001
Praise	0.87	(0.78–0.97)	0.01
Nurturance	1.21	(1.08–1.36)	0.002
R-Square			0.088
Combined model			
Age	1.31	(1.16–1.47)	<0.0001
Site 3	2.27	(1.36–3.77)	0.002
Site 4	0.65	(0.53–0.79)	<0.0001
CBCL			
Social Problems	0.96	(0.92–1.00)	0.04
SSRS			
Internalizing	1.09	(1.04–1.15)	0.001
APQ			
Low Monitoring/Supervision	1.03	(1.01–1.04)	<0.001
PRQ child-rated			
Praise	0.89	(0.80–0.99)	0.03
Nurturance	1.18	(1.06–1.32)	0.003
R-Square			0.190

Stepwise logistic regression models are displayed.

RR, relative risk; CPT, Continuous Performance Task; CBCL, Child Behavior Checklist; SSRS, Social Skills Rating System; BDI, Beck Depression Index; APQ, Alabama Parenting Questionnaire; PRQ, Parent–Child Relationship Questionnaire.

Several modifiable risk factors for dangerous driving behaviors were identified. Low monitoring/supervision by parents and increased parental stress were particularly important in predicting increased risky driving behavior. These findings are consistent with conclusions derived in previous studies that positive parental involvement in driving of their children and a healthy parent–child relationship improve driving behaviors (Simons-Morton et al. 2003; Taubman-Ben-Ari and Katz-Ben-Ami 2012).

Teens who perceive and report high levels of parental monitoring and supervision are less likely to engage in risky driving behaviors such as driving too fast or driving aggressively (Beck et al. 2001) and to report violations and car crashes than those with fewer restrictions and less monitoring (Hartos et al. 2000). A low level of parental monitoring, greater parental permissiveness, and a weaker social bond between parents and the child have been previously seen to characterize developmental trajectories of young adult risky drivers (Bingham and Shope 2004; Beck et al. 2005). Given that these previous studies were not restricted to children with ADHD, it suggests that many modifiable risk factors identified in ADHD children may not be specific to the ADHD population.

The extension of the relationship between parenting and subsequent adolescent risky driving behavior to individuals with ADHD can be seen in a study observing parenting practices for adolescent drivers. Schatz et al. revealed that for teen drivers with ADHD, positive parenting strategies were low regardless of whether teens drove safely or engaged in dangerous driving behaviors (Schatz et al. 2014). Furthermore, when teens were driving in a risky manner, parents of these teens engaged in significantly more criticism and were rated by an observer to appear angrier, compared with when teens were driving safely (Schatz et al. 2014).

The Supporting Effective Entry to the Roadway program was evaluated in a trial to investigate its potential role as a mediator of family functioning and subsequent risky driving behavior for teens with ADHD (Fabiano et al. 2016). At post-treatment and 6-month follow-up, parents were observed to be less negative and teens reported lower levels of risky driving behaviors (Fabiano et al. 2016). However, at 12-month follow-up, these improvements were no longer seen. Furthermore, treatment did not decrease risky driving or citations or accidents.

Psychostimulant medication use in adulthood has demonstrated to improve driving safety in adults with ADHD (Cox et al. 2012; Randell et al. 2016). Estimates from analysis of commercial health insurance claims for 2, 319, 450 individuals indicate that up to 22.1% of motor vehicle crashes among individuals with ADHD could have been avoided if they were treated with a psychostimulant during the entire follow-up (Chang et al. 2017).

Several childhood predictors of risky driving behavior may be at least partially mediated through the decreasing likelihood of ADHD medication use in adulthood. For instance, parents who experience greater stress, display parenting problems, or have a more negative relationship with their child may be less likely to encourage their child to continue ADHD medications into adulthood. Future studies should investigate the impacts of parental stress, parenting strategies, and the parent–child relationship on both the likelihood of continuing pharmacological treatments for ADHD into late adolescent and early adulthood and subsequent risky behaviors.

A limitation to our analysis is that the results were empirically driven (exploratory) rather than hypothesis driven. A number of statistical tests were conducted without correction for multiple hypothesis testing. However, the data-driven approaches that were selected were chosen to minimize false positives associated with multiple hypothesis testing. In addition, older age is highly correlated with risky driving behavior and therefore a likely predictor of these outcomes. Age was controlled for in the regression analyses and separate ROC analyses were conducted for adolescents younger than 16 and adolescents older to control for age. However, age was not completely covaried for in ROC analysis given limitations in this statistical technique.

Given the hierarchical nature of the models used, there is also a strong possibility that several informative predictors of risky driving behaviors were not detected. Additionally, the stepwise logistic

FIG. 1. Empirically derived prognostic subgroups for risky driving behaviors at 8-Year MTA follow-up. **(A)** Displays empirically derived prognostic subgroups for risky driving behaviors at 8-year MTA follow-up for adolescents 16 years of age or older. **(B)** Displays empirically derived prognostic subgroups for risky driving behaviors at 8-year MTA follow-up for adolescents younger than 16 years of age. Boxes are shaded based on the *p*-value of discriminator in the analysis (dark gray, $p < 0.001$; light gray, $p < 0.01$; white, $p < 0.05$). PSI, Parental Stress Index; WISC, Wechsler Intelligence Scale for Children; PRQ, Parent-Child Relationship Questionnaire; CV, child-rated; CBCL, Child Behavior Checklist; SSRS, Social Skills Rating System; CPT, Continuous Performance Task; BDI, Beck Depression Index.

regression techniques likely overestimate the significance level and the proportion of variance explained by significant predictors. Therefore, future confirmatory analysis in prospective studies is needed to replicate our findings. Furthermore, participants in the follow-up sample are not necessarily representative of the baseline participants in the MTA.

Reliance on self-report of risky driving behavior and positive bias self-perceptions in children with ADHD may have underestimated these outcomes within the ADHD sample. Our study specifically examines risky driving behaviors early in their driving career. Future studies should examine subsequent risky driving outcomes for children with ADHD in more experienced drivers. Last, although there was fairly high participation in the follow-up assessments of the MTA, participants and nonparticipants were different in many clinically important characteristics. Therefore, the MTA follow-up sample may not be completely representative of the initial MTA cohort or young ADHD patients in general.

Conclusions

Risky driving behavior was significantly predicted by baseline characteristics for children with ADHD 8 years earlier. Aspects of

parenting behavior, including low monitoring/supervision and parental stress levels, were most informative in predicting these outcomes. Our results suggest that interventions for these high-risk children with ADHD should be aimed at decreasing parental stress levels and increasing parental monitoring/supervision.

Clinical Significance

Childhood ADHD is associated with later risky driving behavior. Establishing predictors of risky driving behavior may aid in identifying high-risk children with ADHD. Data-driven analysis identified several modifiable risk factors associated with later dangerous driving behavior (parenting style, aspects of the parent-child relationship, and parental stress levels).

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The MTA was an NIMH cooperative agreement randomized clinical trial, continued under an NIMH contract as a follow-up study and finally under an NIDA contract. Collaborators from NIMH were Benedetto Vitiello, MD (Child and Adolescent Treatment and Preventive Intervention Research Branch), Joanne B. Severe, MS (Clinical Trials Operations and Biostatistics Unit, Division of Services and Intervention Research), Peter S. Jensen, MD (currently at REACH Institute and Mayo Clinic), L. Eugene Arnold, MD, MEd (currently at Ohio State University), and Kimberly Hoagwood, PhD (currently at Columbia); previous contributors from NIMH to the early phases were John Richters, PhD (currently at National Institute of Nursing Research), and Donald Vereen, MD (currently at NIDA). Principal investigators and coinvestigators from the sites are University of California, Berkeley/San Francisco: Stephen P. Hinshaw, PhD (Berkeley), and Glen R. Elliott, PhD, MD (San Francisco); Duke University: Karen C. Wells, PhD, Jeffery N. Epstein, PhD (currently at Cincinnati Children's Hospital Medical Center), and Desiree W. Murray, PhD; previous Duke contributors to early phases: C. Keith Conners, PhD (former PI), and John March, MD, MPH; University of California, Irvine: James Swanson, PhD, and Timothy Wigal, PhD; previous contributor from UCLA to the early phases: Dennis P. Cantwell, MD (deceased); New York University: Howard B. Abikoff, PhD; Montreal Children's Hospital/McGill University: Lily Hechtman, MD; New York State Psychiatric Institute/Columbia University/Mount Sinai Medical Center: Laurence L. Greenhill, MD (Columbia), and Jeffrey H. Newcorn, MD (Mount Sinai School of Medicine); University of Pittsburgh: Brooke Molina, PhD, Betsy Hoza, PhD (currently at University of Vermont), and William E. Pelham, PhD (PI for early phases, currently at Florida International University). Follow-up phase statistical collaborators were Robert D. Gibbons, PhD (University of Illinois, Chicago); Sue Marcus, PhD (Mt. Sinai College of Medicine); and Kwan Hur, PhD (University of Illinois, Chicago). The original study statistical and design consultant was Helena C. Kraemer, PhD (Stanford University). The collaborator from the Office of Special Education Programs/U.S. Department of Education was Thomas Hanley, EdD. The collaborator from Office of Juvenile Justice and Delinquency Prevention/Department of Justice was Karen Stern, PhD. This article reflects the views of the authors and may not reflect the opinions or views of the MTA 96 study investigators or the NIH.

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Disclosures

The authors have no conflicts of interest to disclose.

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