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S.I. : AUTISM INPATIENT COLLECTION - STUDYING THE SEVERELY AFFECTED

Behavioral Outcomes of Specialized Psychiatric Hospitalization in the Autism Inpatient Collection (AIC): A Multisite Comparison

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Abstract

Psychiatric hospitalization of children with autism spectrum disorder (ASD) is relatively common and occurs at a higher rate than in non-ASD youth. This study compared changes in the severity of serious problem behaviors in 350 youth with ASD enrolled in the autism inpatient collection during and after hospitalization in six specialized child psychiatry units. There was a significant reduction in serious problem behaviors from admission (aberrant behavior checklist—irritability subscale $M = 29.7$, SD 9.6) to discharge ($M = 15.0$, SD 10.3) and 2-month follow-up ($M = 19.3$, SD 10.3). Between discharge and 2-month follow-up, tantrum-like behaviors but not self-injurious behaviors increased slightly. Improvement in the severity of problem behaviors was not uniform across sites, even after controlling for measured site differences.

Keywords Autism spectrum disorder (ASD) · Psychiatric inpatients · Crisis · Autism inpatient collection (AIC) · Externalizing problem behaviors · Self-injurious behavior · Tantrum-like behavior

Introduction

Children and adolescents with autism spectrum disorder (ASD) are psychiatrically hospitalized at a much higher rate than non-ASD youth (Croen et al. 2006), primarily due to serious emotional and behavioral problems including aggression, self-injury, and tantrum-like behaviors (Siegel et al. 2012). Psychiatric hospitalization of children with ASD is relatively common, with up to 11% of youth reported to be hospitalized by age 21 and a 1-year prevalence ranging from 1.3 to 7% in the United States (U.S.) (Mandell 2008; Croen et al. 2006). Over the past decade, the number of inpatient psychiatric units in the U.S. designed specifically to serve the unique needs and symptoms of children with ASD and other neurodevelopmental disorders (specialized child psychiatry units) has doubled and continues to grow (Siegel et al. 2012).

Compared to general child psychiatry units, specialized child psychiatry units have a longer average length of hospital stay, utilize larger multi-disciplinary treatment teams, and employ a combined pharmacologic and intensive behavioral treatment approach (Siegel et al. 2012). Within general child psychiatry units, staff may have limited experience with the ASD population, and the treatment approach and therapeutic milieu is not specifically tailored for children with ASD. For

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example, general child inpatient units typically use verbal interventions, such as individual, family and group therapies, programming with high social demands, and group reinforcement schedules and choices (McGuire et al. 2015). These types of interventions can be less effective with children with ASD, who typically have impairments in social communication, may have rigid routines and preferences, and may also be cognitively disabled and/or non- or minimally verbal. As such, specialized child psychiatry units utilize a multi-disciplinary, bio-behavioral approach with a higher staff to patient ratio than is found in most general child psychiatry units (Siegel and Gabriels 2014).

However, to our knowledge there have been no large prospective studies of specialized inpatient treatment of children with ASD or comparisons of outcomes between specialized units. As the demand for acute psychiatric services for children with ASD increases and consumes a larger proportion of healthcare dollars (Nayfack et al. 2014), it is increasingly important to attempt to identify characteristics of effective treatment programs, which can either be replicated in other specialized child psychiatry units or potentially applied as best practices in general child psychiatry units (McGuire et al. 2015). The purpose of the current study was to begin to address this knowledge gap by assessing differences in behavioral outcomes (specifically aggressive, self-injurious and tantrum-like behaviors) across six specialized child psychiatry inpatient units.

Recent reports from two specialized child psychiatry inpatient units provided preliminary evidence for a reduced readmission rate and improvement in serious behavioral problems after specialized hospitalization (Gabriels et al. 2012; Siegel et al. 2014). In a retrospective study, Gabriels et al. (2012) reported a markedly lower 1-year hospital readmission rate (33 vs.12%) for children with ASD by comparing two eras: the first when children with ASD were being admitted to a general child psychiatry unit and the second when a specialized unit had been established in the same facility. They also reported a significant reduction in problem behaviors from hospital admission to discharge during the specialized unit era, although comparative information on problem behaviors was not available from the general unit era. In a single-site prospective study, Siegel et al. (2014) found that treatment in a specialized psychiatric inpatient unit was associated with a significant reduction in aggressive, self-injurious, and tantrum-like behaviors in children with ASD, which was sustained at 2 months post-discharge.

Other studies have examined the effects of both general and specialized psychiatric units for people with neurodevelopmental disorders on psychotic symptoms and mental illness severity, although most of these studies were retrospective designs focused on adults with intellectual disability (ID) and were not specific to ASD (Ballinger et al. 1991; Hurst et al. 1994; Palucka and Lunsky 2007; Chaplin 2004; Chaplin et al. 2011). The paucity of research specific to behavioral outcomes of children with ASD admitted to specialized inpatient units motivated the primary objective of this study.

In the current study, we examined changes in the severity of serious problem behaviors from admission to 2-month follow-up in 350 children with ASD who were admitted to six specialized child psychiatry units and prospectively enrolled in the autism inpatient collection (AIC) study. An early goal of the AIC study was to test the feasibility of using the specialized inpatient setting to perform systematic autism research and to begin to characterize the population of children and adolescents with ASD who are admitted for inpatient psychiatric care (see Siegel et al. 2015, for details of AIC study methods). In this study, our first objective was to describe the specialized inpatient population by examining both demographic (age, sex, ethnicity, race) and clinical factors (expressive communication, level of adaptive functioning, problem behaviors), and to test for differences across the six sites, for both participant and site characteristics. Our second objective was to examine changes in serious problem behaviors over time (admission, discharge, and 2-month follow-up) for the full sample and between sites. We hypothesized that the sample would show a significant reduction in serious problem behaviors between admission and 2-month follow-up (Hypothesis 1), which would be similar across inpatient sites (Hypothesis 2). Greater understanding of the factors that contribute to variations in behavioral outcomes may enhance treatment for this population and reduce cost and morbidity for the affected youth, their families, and the health care system.

Methods

Participants

Three-hundred-fifty children and adolescents aged 4–21 years were prospectively enrolled in the autism inpatient collection (AIC) study with an ASD diagnosis confirmed by research-reliable administration of the autism diagnostic observation schedule, second edition (ADOS-2; Lord et al. 2012) (see Siegel et al. 2015 for a full description of study methods). The average age of study subjects was 12.9 years ($SD = 3.3$, range 4–21), 79% were male, 79% were Caucasian, and 93% were non-Hispanic/non-Latino. The average length of hospitalization was 25.6 days ($SD = 23.8$, range 3-163). The average nonverbal IQ score was 76.4 ($SD = 29$, range 30–145) (Roid et al. 2013), the mean vineland adaptive behavior scale II (VABS-II) composite score was 57.5 ($SD = 15.1$, range 25–118) (Sparrow et al. 2005), and the mean VABS-II expressive communication subscale score was 7.1 ($SD = 4.5$, range 1–24), which

is almost 3 standard deviations below the population mean. Twenty-two percent of subjects exhibited daily self-injurious behavior during their hospital stay (see Table 1). At the time of admission, the great majority of children (95.3%) resided in their family home.

Three-hundred-twenty-three consistent parents/guardians (i.e., the same parent/guardian completed the surveys at each time point) completed study measures in person within 7 days of hospital admission, at hospital discharge, and again by telephone at 2-month follow-up. Ninety-five percent were the child's parent (biological, step, foster, or adoptive), of which 84% were mothers, 10.8% fathers, 3.4% grandparents, and 1.5% other relatives. Average parent age was 42 years ($SD = 11.4$), and a slight majority were married (58%). For education, the largest group of mothers (39%) had completed "some college or associate's degree," and for fathers, the largest group consisted of those who had "finished some high school (or high school equivalent)" (32%); 55% of the families reported an annual household income ≤ $50,000.

Data Collection and Measures

Data for this study were drawn from a longitudinal study (the Autism Inpatient Collection; see Siegel et al. 2015) which examined phenotypic, behavioral, and genetic data of children with ASD in a large cohort recruited from six specialized inpatient psychiatric hospital units in the United States including: Bradley Hospital (Brown University; RI), Cincinnati Children's Hospital (University of Cincinnati; OH), Children's Hospital Colorado (University of Colorado, CO), Sheppard Pratt Health Systems (University of Maryland, MD), Western Psychiatric Institute and Clinics (University of Pittsburgh, PA), and Spring Harbor Hospital/Maine Medical Center Research Institute (Tufts University; ME) which also serves as the AIC coordinating site with data and analytic cores. The units specialize in the assessment and treatment of children with ASD and other developmental disorders and admissions are funded by public and private health insurance.

Data were collected at hospital admission (Time 1), discharge (Time 2), and 2-month follow-up (Time 3) between March 2014 through January 2016. The six specialized child psychiatric units in this study treat children with autism and problem behaviors with a similar multidisciplinary bio-behavioral approach. Target problem behaviors, most frequently physical aggression, self-injurious behavior (SIB) and tantrums, are defined and tracked and individualized positive behavioral support plans are utilized to effect a reduction in the target behaviors. In conjunction, targeted medication and communication and occupational therapy supports and interventions are utilized to treat problem behaviors and co-occurring psychiatric disorders. Family psychoeducation and supportive therapy are provided. Follow-up care is highly variable after discharge, and was not measured. This study was approved by the Institutional Review Board (IRB) at all participating sites, and all families gave permission for their data to be used in publications related to this study.

Aberrant Behavior Checklist—(ABC) (Aman et al. 1985)

Our primary outcome, serious child problem behaviors, was measured using the Aberrant Behavior Checklist (ABC) Irritability subscale. The ABC is a 58-item questionnaire developed and validated as a treatment-sensitive outcome measure for children with developmental disabilities. We utilized the ABC Irritability (ABC-I) Subscale score (15 items) to examine change in behavioral severity over time

Table 1 Comparison of demographic and clinical variables by child sex

	Overall sample (N = 350)		Males (N = 275, 79%)		Females (N = 75, 21%)		*p* value
Age (years) [*M* (*SD*), range]	12.9 (3.3)	4–21	12.9 (3.4)	4–21	12.8 (2.9)	6–18	0.76
Ethnicity (N = 314) (Non-Hispanic/Latino) (N/%)	292 (93%)		228 (92%)		64 (96%)		0.36
Race (Caucasian) (N/%)	276 (79%)		217 (79%)		59 (79%)		0.96
Length of hospital stay [*M* (*SD*), range]	25.6 (23.8)	3–163	25.9 (22.2)	3–130	24.7 (29.0)	4–163	0.69
Non-verbal IQ (N = 287) [*M* (*SD*), range]	76.4 (29)	30–145	76.8 (29)	30–145	75.1 (30)	30–141	0.60
Intellectual disability (NVIQ < 70) (N/%)	116 (42%)		94 (44%)		22 (38%)		0.44
Expressive communication subscale (Vineland-2) (N = 256) [*M* (*SD*), range]	7.1 (4.5)	1–24	7.2 (4.7)	1–24	6.9 (3.7)	1–17	0.67
Adaptive behavior composite (Vineland-2) (N = 220) [*M* (*SD*), range]	57.5 (15.1)	25–118	57.8 (15.3)	25–118	56.1 (14.4)	28–87	0.49
Self-injurious behavior (SIB) present (N = 76) (N/%)	76 (22%)		58 (21%)		20 (27%)		0.40

Statistical analyses: continuous comparison (ANOVA), categorical comparison (Chi square)

(admission, discharge, 2-month follow-up). The ABC-I is a self-report questionnaire (completed by parents) and the items are rated on a 4-point Likert scale ranging from (0) "not at all a problem" to (3) "the problem is severe in degree" with higher scores indicating more severe problem behaviors. The ABC-I subscale was utilized because it taps the problem behaviors we were most interested in (primarily aggression, self-injurious behavior and tantrums), and it is the most common outcome measure in studies of problem behavior in ASD. The ABC-I has also shown sensitivity to change in hospitalized youth with autism in a prior single-site study (Siegel et al. 2014). Previous literature has examined the ABC-I as a multidimensional construct consisting of the following two subdomains: self-injurious behavior (SIB), 3 items, and tantrum-like behaviors (TLB; physical aggression and tantrums), 12 items (Aman et al. 2010). Internal reliability estimates (Cronbach's α) were 0.89, 0.96, and 0.88 at admission, 0.93, 0.95, and 0.93 at discharge, and 0.92, 0.95, and 0.93 at follow-up, for ABC-I, ABC-I SIB, and ABC-I TLB scores, respectively. Although the TLB subdomain contains more items than the SIB subdomain (12 vs. 3 respectively), which can influence the reliability of scales, Cronbach's alpha scores for each subscale were high (all above 0.88) at admission, discharge, and 2-month follow-up.

Statistical Analyses

Descriptive Statistics

Descriptive statistics were calculated using means and standard deviations for continuous variables and proportions for categorical variables. Analysis of variance (ANOVA) and Chi square tests were performed to analyze sex differences between children's demographic and clinical variables as continuous and categorical variables respectively. Pearson correlation coefficients (r) were estimated to examine associations between demographic and clinical variables and behavioral outcomes. All measures used in this study have been previously reported to be valid and reliable in the ASD patient population. All analyses were conducted using SPSS version 21.0 (IBM 2012) with statistical significance determined at $p \leq 0.05$, two-tailed tests.

Repeated Measures Analysis of Variance (RMANOVA)

Repeated measures analysis of variance (RMANOVA) were conducted to compare overall changes in observed scores (ABC-I, ABC-I SIB, ABC-I TLB) across all three time points (admission, discharge, and 2-month follow-up). Overall problem behavior (ABC-I), self-injurious behavior (ABC-I SIB), and tantrum-like behavior (ABC-I TLB) were modeled separately. Mean differences (MD) in problem behavior scores were calculated by subtracting scores at earlier time points from scores at later time points including: (1) admission—discharge, (2) admission—2-month follow-up, and (3) discharge—follow-up. A negative mean difference indicated a reduction in problem behavior scores between time points, whereas a positive mean difference was an increase in problem behavior scores.

Multilevel Modeling Repeated Measures Analysis of Covariance (RMANCOVA)

Multilevel models with a first-order covariance structure to perform repeated measures analysis of covariance (RMANCOVA) were conducted to compare overall changes in observed scores (ABC-I, ABC-I SIB, ABC-I TLB) as well as changes between the six sites over time, controlling for covariates (listed below). Overall problem behavior (ABC-I), self-injurious behavior (ABC-I SIB), and aggression and tantrum-like behavior (ABC-I TLB) were each modeled separately. We first tested three unadjusted models examining primary predictors (time, site, and time by site interaction) without covariates. We then tested three adjusted models which included our primary predictors as well as continuous demographic and clinical covariates that were significantly correlated with behavioral outcomes at discharge and 2-month follow-up (age, ABC-I admission score) or that differed between sites at baseline (non-verbal IQ, expressive communication, length of stay), as failure to control for these variables might produce spurious results in the multilevel models. Because it is recommended that covariates in ANCOVA models be continuous, race (Caucasian, yes/no), and ethnicity (non-Hispanic, yes/no) were not included as covariates in the models due to their restricted binary level of measurement (Tabachnick and Fidell 2007). An interaction effect would be observed if the effect of one factor (time) was dependent on what happened to another factor (site). Testing for interactions allowed us to examine whether changes in serious problem behaviors varied by sites over time.

Results

Descriptive Statistics

There were no significant differences between males and females in this sample on demographic (age, ethnicity, and race) or clinical variables (length of stay, non-verbal IQ, expressive communication, adaptive behavior, and self-injurious behavior) (see Table 1). Site differences were found for children's ethnicity ($p \leq 0.001$), race ($p \leq 0.001$), non-verbal IQ ($p \leq 0.001$), expressive communication ($p = 0.012$), and hospital length of stay ($p \leq 0.001$) (see Table 2).

Table 2 Comparison of demographic and clinical variables by six specialized psychiatric inpatient sites between admission, discharge, and 2-month follow-up

	Overall (n = 350)	Site 1 (n = 81)	Site 2 (n = 40)	Site 3 (n = 34)	Site 4 (n = 67)	Site 5 (n = 84)	Site 6 (n = 44)	*p* value
Age (years) (*M*/*SD*)	12.9 (3.3)	12.4 (3.4)	13.3 (3.6)	12.3 (3.6)	13.1 (3.2)	13.5 (3.0)	12.5 (3.3)	0.22
Sex (males) (*N*/%)	275 (79%)	66 (82%)	30 (75%)	30 (88%)	54 (81%)	61 (73%)	34 (77%)	0.47
Ethnicity (n = 314) (Non-Hispanic/Latino) (*N*/%)	292 (93%)	80 (100%)	35 (92%)	26 (84%)	52 (96%)	66 (92%)	33 (85%)	0.001*
Race (Caucasian) (*N*/%)	276 (79%)	75 (93%)	35 (88%)	26 (77%)	50 (75%)	51 (61%)	39 (89%)	0.001*
Non-verbal IQ (n = 287) *(M/SD)*	76.4 (29)	72.8 (26.6)	65.2 (28.5)	65.1 (27.4)	70.9 (30.8)	83.8 (27.9)	93.6 (25.9)	0.001*
Expressive communication subscale (Vineland-2) (N = 256) *(M/SD)*	7.1 (4.5)	6.9 (4.5)	4.6 (3.1)	7.2 (5.0)	7.0 (4.6)	7.7 (4.6)	8.8 (3.8)	0.012*
Adaptive behavior composite (Vineland-2) (N = 220) *(M/SD)*	57.5 (15.1)	55.8 (13.3)	47 (9.7)	55.3 (15)	58.3 (17.9)	59.2 (14.9)	61.3 (16.3)	0.2
Aberrant behavior checklist irritability subscale *(M/SD)*								
Admission	29.7 (9.6)	31.5 (7.5)	33.8 (7.8)	26.5 (14.0)	30.5 (10.9)	28.2 (9.8)	24.8 (11.4)	0.54
Discharge	15.0 (10.3)	12.9 (10.3)	19.6 (8.4)	20.0 (11.3)	15.8 (12.7)	14.1 (10.4)	12.4 (11.1)	0.68
2 month follow-up	19.3 (10.3)	18.8 (8.0)	20.3 (13.7)	17.5 (3.5)	26.2 (10.1)	17.6 (10.6)	16.6 (10.7)	0.64
Length of stay (n = 334) (*M*/*SD*)	25.6 (23.8)	46.8 (27.8)††	5.2 (0.83)†	23.5 (19.3)	24 (27.1)	18.8 (12.1)†	19.7 (12)†	0.001*
Short (< 13 days) (*N*/%)	121 (36%)	2 (3%)	38 (95%)	9 (29%)	29 (45%)	31 (37%)	12 (28%)	0.001*
Moderate (14–24 days) (*N*/%)	107 (32%)	17 (24%)	1 (3%)	13 (42%)	20 (31%)	37 (44%)	19 (44%)	
Long (> 25 days) (*N*/%)	106 (32%)	53 (74%)	1 (3%)	9 (29%)	15 (23%)	16 (19%)	12 (28%)	

*$p < 0.05$

†Sites 2, 5, and 6 are significantly different from site 1 (††)

We found correlations between hospital length of stay and mean ABC-I score at admission and ($r = .13$, $p = 0.02$), non-verbal IQ and ABC-I at discharge ($r = -.18$, $p = 0.01$), VABS-II expressive communication subscale score and ABC-I at discharge ($r = -.16$, $p = 0.02$), and child age and ABC-I at 2-month follow-up ($r = -.17$, $p = 0.01$). We included these as covariates in our multilevel model in order to provide statistical control for their influence on the outcomes of interest. Our final adjusted models included ABC-I at admission, non-verbal IQ, expressive communication, age, and length of stay as covariates.

Repeated Measures Analysis of Variance (RMANOVA)

In our sample, problem behavior severity (ABC irritability subscale) scores decreased significantly between admission and discharge, ABC-I ($MD = -14.7$, $p \leq 0.001$), ABC-I SIB ($MD = -2.0$, $p \leq 0.001$), and ABC-I TLB ($MD = -9.6$, $p \leq 0.001$), and between admission and 2-month follow-up, ABC-I ($MD = -10.4$, $p \leq 0.001$), ABC-I SIB ($MD = -1.8$, $p \leq 0.001$), and ABC-I TLB ($MD = -6.0$, $p \leq 0.001$). Interestingly, problem behavior severity scores increased slightly between discharge and 2-month follow-up for ABC-I ($MD = 4.3$, $p \leq 0.001$), and ABC-I TLB scores ($MD = 3.6$, $p \leq 0.001$), but not ABC-I SIB scores ($MD = 0.21$, $p = 1.0$) (see Fig. 1a, b, c).

Multilevel Modeling Repeated Measures Analysis of Covariance (RMANCOVA)

Due to the correlation between ABC-I admission score with hospital length of stay as well as ABC-I discharge and 2-month follow-up scores, we included the ABC-I admission score as a covariate in the models. Thus, time in the multilevel model RMANCOVA was measured between discharge and 2-month follow-up only. After controlling for differences between sites at admission, we found similar changes in problem behaviors between discharge and 2-month follow-up. We observed a significant increase in both ABC-I and ABC-I TLB problem behavior scores between discharge and 2-month follow-up in the ABC-I unadjusted ($F = 100.5$, $p \leq 0.001$) and adjusted models ($F = 5.8$, $p = 0.02$) and ABC-I TLB unadjusted ($F = 91.9$, $p \leq 0.001$) and adjusted models ($F = 7.5$, $p = 0.007$). There was also a significant site effect for the ABC-I, ABC-I SIB, and ABC-I TLB unadjusted ($F = 4.5$, $p \leq 0.001$; $F = 2.3$, $p = 0.04$; and $F = 4.0$, $p = 0.002$, respectively) and adjusted ($F = 5.3$, $p \leq 0.001$; $F = 2.6$, $p = 0.03$; and $F = 5.5$, $p \leq 0.001$, respectively) models indicating variations in child problem behavior severity

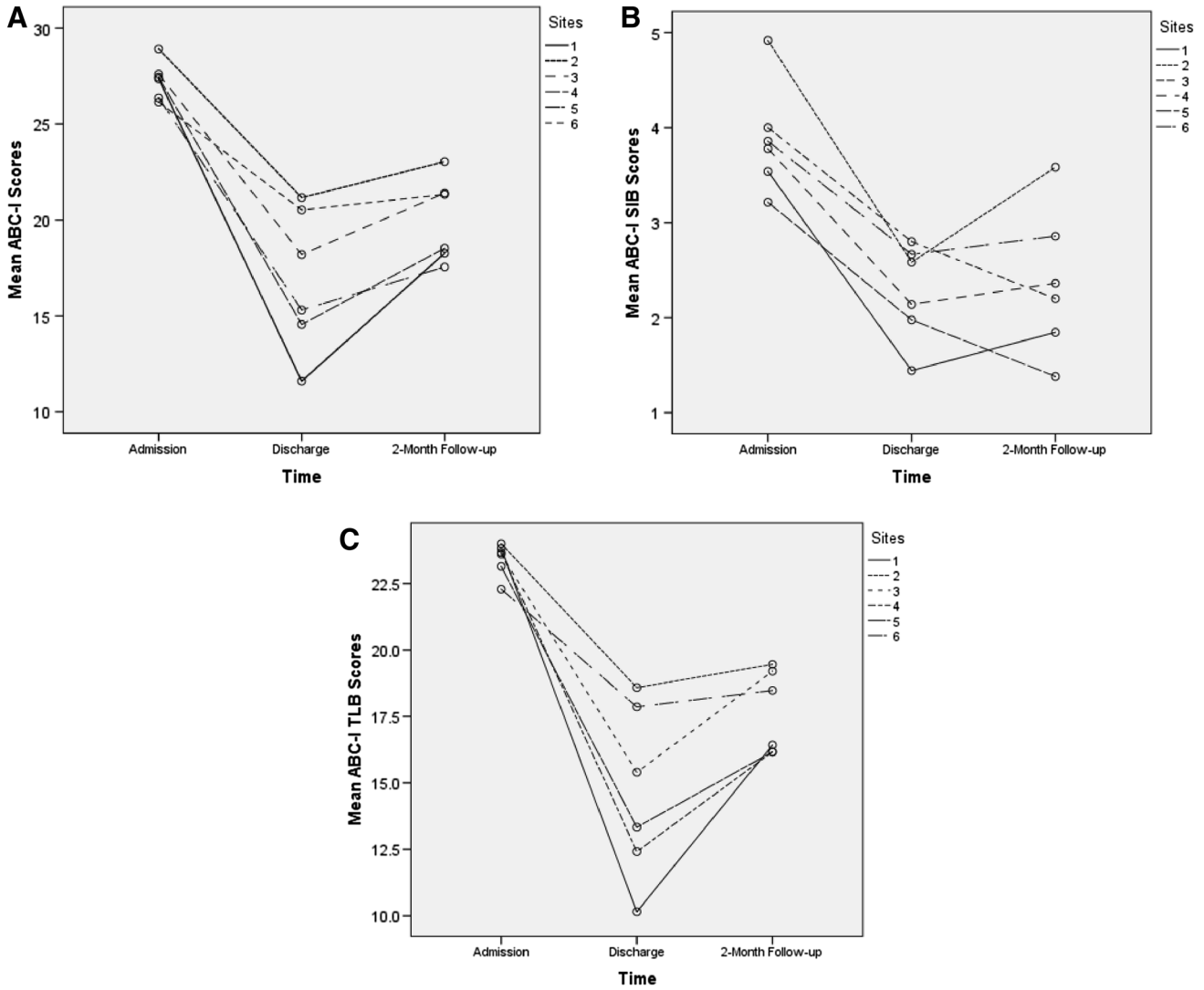

Fig. 1 **a** Comparison of aberrant behavior checklist irritability (ABC-I) subscale scores across specialized psychiatric inpatient sites between admission, discharge, and 2-month follow-up. **b** Comparison of aberrant behavior checklist irritability (ABC-I) self injurious behavior (SIB) subdomain scores across specialized psychiatric inpatient sites between admission, discharge, and 2-month follow-up. **c** Comparison of aberrant behavior checklist irritability (ABC-I) tantrum-like behavior (TLB) subdomial scores across specialized psychiatric inpatient sites between admission, discharge, and 2-month follow-up

scores across inpatient sites between discharge and 2-month follow-up. The time by site interaction effect was significant for both the unadjusted ($F=3.5$, $p \leq 0.001$); ($F=4.1$, $p \leq 0.001$) and adjusted ($F=2.3$, $p=0.04$); $F=2.7$, $p=0.02$) ABC-I and ABC-I TLB models respectively, but not for the ABC-I SIB unadjusted ($F=0.98$, $p=0.46$) or adjusted ($F=0.69$, $p=0.63$) models. The problem behavior score at admission was a significant covariate in each of the ABC-I ($F=51.3$, $p \leq 0.001$), ABC-I SIB ($F=102.7$, $p \leq 0.001$), and ABC-I TLB ($F=55.1$, $p \leq 0.001$) adjusted models. Expressive communication was a significant covariate only in the ABC-I SIB adjusted model ($F=4.5$, $p=0.03$) (see Table 3 for complete adjusted model results).

Discussion

This study sought to compare changes in the severity of serious problem behaviors in children with ASD during and after hospitalization in six specialized child psychiatry units in the United States. This is the largest prospective study to date investigating these outcomes in the ASD population in the inpatient setting. Our findings include significant improvement in child problem behaviors. This extends preliminary evidence provided by two distinct samples showing improvement in problem behaviors and reduced readmissions in youth admitted to two different specialized child psychiatry units (Siegel et al. 2014; Gabriels et al. 2012).

Table 3 Multilevel models examining changes in children's problem behaviors as measured by the aberrant behavior checklist irritability (ABC-I) subscale, ABC-I self-injurious behavior (ABC-I SIB) and ABC-I tantrum-like behavior (ABC-I TLB) subdomains between discharge, and 2-month follow-up

Model variables	ABC-I			ABC-I SIB			ABC-I TLB		
	F	Df	*p*	F	df	*p*	F	df	*p*
Time	5.8	1, 179	0.02*	0.05	1, 178	0.82	7.5	1, 181	0.007*
Site	5.3	5, 176	0.001*	2.6	5, 171	0.03*	5.5	5, 177	0.001*
Time by site interaction	2.3	5, 167	0.04*	0.69	5, 167	0.63	2.7	5, 169	0.02*
ABC-I admission score	51.3	1, 189	0.001*	102.7	1, 170	0.001*	55.1	1, 185	0.001*
Non-verbal IQ	1.3	1, 174	0.31	0.26	1, 167	0.61	1.6	1, 175	0.21
Expressive communication	0.02	1, 171	0.84	4.5	1, 166	0.03*	0.14	1, 172	0.70
Length of stay	0.31	1, 170	0.74	0.64	1, 163	0.42	0.23	1, 170	0.63
Age	2.6	1, 170	0.11	3.1	1, 166	0.08	2.0	1, 170	0.17

*Significant at $p \leq 0.05$. Multilevel modeling repeated measures analysis of covariance (RMANCOVA) was conducted separately for each of the three models

Our approach was to first examine demographic and clinical factors and to test for differences by gender and site. Our sample included a high proportion of children with intellectual disability (ID) (42%), minimally verbal status (48% ADOS module 1 or 2), and low adaptive functioning (mean VABS-II score of 57.5). Although there were no differences between males and females on any of our measures, differences were noted between inpatient sites for patient race, ethnicity, non-verbal IQ, expressive communication, and hospital length of stay. Differences in some demographics are likely related to variations in the population in each site's catchment area, such as the relatively racially and ethnically homogenous population of southern Maine versus the more diverse populations of the Baltimore and Pittsburgh areas. Site variation in mean length of hospital stay may reflect the complex interaction of child behavioral acuity, family goals and capabilities, and state- or site catchment area-specific insurance rules, post-discharge service options, and other unmeasured factors.

The patients in our sample displayed serious behavioral problems at admission, with a mean admission ABC-I score of 29.7 (*SD* 9.6) (for reference, a score of ≥ 14–16 is the usual clinical threshold for treatment studies in ASD). Though not directly measured here, children admitted to these specialized hospital units have typically been refractory to treatment at other levels of care, such as general psychiatric unit hospitalizations, day treatment programs, and outpatient use of multiple psychotropic medications (see Wink et al. 2017 in this issue). It is therefore notable that this severely affected, often treatment-refractory sample experienced both a statistically significant and clinically meaningful decrease in serious behavioral problems from admission (ABC-I $M = 29.7$, SD 9.6) to discharge (ABC-I $M = 15.0$, SD 10.3) that remained significant at home 2 months after discharge (ABC-I $M = 19.3$, SD 10.3). The clinical magnitude of the improvement observed in our sample during the inpatient stay was also substantial (an overall mean reduction of 14.7 points at discharge and 10.4 points at 2 months post-discharge).

Multilevel modeling revealed interesting findings both across study time points and between inpatient sites, as well as between the subdomains of problem behavior (i.e., self-injurious vs. tantrum-like behaviors). Interestingly, parents reported an increase in only one of the two problem behavior subdomains during the post-discharge period. While we found a decrease in both subdomains during hospitalization, in the post-discharge period we found an increase in tantrum-like behaviors (tantrums and aggression toward others) but not self-injurious behaviors. We considered several alternative explanations for the increase of total ABC-I scores from discharge to 2-month follow up including: (1) regression to the mean; (2) a treatment effect that moderates after inpatient treatment is over; and (3) the effect of returning the child to their home environment. However, because the increase in ABC-I score in the post-discharge period was only significant for the tantrum-like behavior subdomain, it may not be appropriate to apply these as general interpretations. Instead, it may be that hospitalization had a more enduring effect on behaviors captured by the self-injurious behavior subdomain, or that parents are more sensitive to the behaviors represented in the tantrum-like behavior subdomain once the child returns home, among other possibilities. As self-injurious behavior can often be treatment-refractory and present large challenges for children and their families, the finding of durable improvement in the self-injurious behavior subdomain post-hospitalization is notable.

Improvement in the severity of problem behaviors was not uniform across sites, even after controlling for significant site differences in our sample at admission. Examination of model covariates revealed that child problem behavior (ABC-I score) at admission was a significant predictor of child problem behavior, as well as self-injurious and tantrum-like behavior subdomains, at discharge and 2-month follow-up. Interestingly, length of stay was not found to be a significant predictor of behavioral outcomes, which was

surprising due to the notable differences in mean length of stay between inpatient sites. This can be partially explained by the correlation between the problem behavior scores at admission and length of stay, indicating that children with higher scores at admission were more likely to have a longer hospital stay.

Of course, the determinants of length of stay are many and varied and by no means limited to characteristics of the patient or of the treatment interventions employed. One of the major determinants, apart from health insurance rules and limitations, is the availability of adequate post-discharge follow-up services. A survey of nine specialized inpatient child psychiatric units in eight U.S. hospitals (Siegel et al. 2012) found that obtaining adequate follow-up services after discharge was rated as the single greatest challenge across all the units. This study also found that all the specialized units surveyed employed both a child psychiatrist and a psychologist or board certified behavior analyst (BCBA) and utilized both psychopharmacologic and behavior modification treatments, indicating a shared multi-disciplinary, bio-behavioral treatment approach. This is true of all the specialized units participating in the AIC study, regardless of their average length of stay. In our current healthcare system, the length of stay in acute psychiatric hospitalizations is primarily determined by the judgment of the medical insurer as to whether the patient meets medical necessity standards for continued inpatient level of care. These standards are interpreted variously by different insurers and applied subjectively to determine readiness for discharge. It has also been argued that these standards, developed for a verbal, neurotypical population, may not be appropriate when applied to youth with ASD, and can result in shortened lengths of stay that are sub-optimal (McGuire et al. 2015), which may serve neither the child nor the family well. There are many factors that likely affect length of stay which were not captured in the AIC data. Additional research examining the determinants of length of stay and other unmeasured factors within specialized psychiatric inpatient units may provide further insight into the relationship between length of hospital stay and behavioral outcomes in the setting of specialized child psychiatric inpatient units.

Another interesting finding was the emergence of expressive communication (as measured by the VABS-II expressive communication subscale score) as a significant covariate in the self-injurious behavior outcome model. Lower expressive communication scores were predictive of higher self-injurious behavior scores, but not tantrum-like behavior scores. To date, the research literature has reported conflicting findings on the relationship between expressive communication and problem behaviors in children with ASD (Chiang 2008; Duerden et al. 2012; Matson et al. 2009; see Williams et al. (2017) in this issue for detailed examination of the subject). One study examining risk factors associated with self-injurious behavior in children and adolescents with ASD found atypical sensory processing and insistence on sameness to explain most of the variance in the measures of self-injury, whereas functional communication was only a small contributor (Duerden et al. 2012). Another study found expressive communication to be significantly correlated with lower scores for both aggression and self-injurious behavior (Matson et al. 2009). Research examining augmentative and alternative forms of communication, such as graphic symbols and voice output communication aids, in the ASD inpatient population could lend greater insight into the relationship between expressive communication and self-injurious behavior.

Although all the inpatient units under study have the same basic bio-behavioral treatment model, there may be important unmeasured differences in the program environment of each site including the makeup of the multidisciplinary treatment teams (i.e., psychologists, occupational therapy, and speech therapy services), training of direct care staff, and provision of structured therapeutic and educational services, among other possible factors. There may also be unmeasured differences between sites in the type and availability of community follow-up services. These potential unmeasured differences produce an important limitation in terms of identifying predictors of change in our multivariate analyses. Further delineation of these characteristics could provide more information on elements of effective treatment. Due to the emergent nature of the index event for the study, acute psychiatric hospitalization, it was not possible to enroll a control group of youth who were not being hospitalized, which is another limitation of our study. Without a comparison group we can only describe the observed reduction in problem behavior for youth with ASD admitted to the specialized inpatient units. With this caveat in mind, tests of predictive models such as we have performed provide important information about the severely affected inpatient population, laying the groundwork for future studies.

Although follow-up data was collected post-discharge, a longitudinal study in which the observations occur at regular intervals did not occur during the course of inpatient treatment and a longer follow-up period would help to further our understanding of changes in behavioral outcome over time. As children's problem behaviors are highly predictive of caregiver/parent stress (Davis and Carter 2008), and parents of children with ASD frequently report great distress at watching their child engage in self-injurious and tantrum-like behaviors, it will be important to further study these two subdomains of problem behaviors in relation to parental mental health outcomes (i.e., stress and self-efficacy). Another possible limitation of our study is the low number of father participants (10.8%). If the focus is on how parents report the severity of their child's problem behavior, then it is important to recognize that differences between mothers

and fathers, including gender, may produce different results. It is also important to note that parents are not exposed to their children's problem behaviors as often while they are hospitalized and thus may not be the most accurate reporters of behavior change (tantrums compared to self-injury) during that time period. Thus, a relatively brief follow-up period and reliance solely on parent ratings of behavior were two additional important limitations of this study. Future research may benefit from engaging multiple informants, including both parents' perspectives, and behavioral staff on the unit, using a wider array of outcome measures to report changes in children's problem behavior during and after their inpatient stay (Cook and Goldstein 1993).

The methodological strengths of this study included a large sample size, subjects with the full spectrum of adaptive and cognitive abilities, and data collected from multiple sites over three points in time. This longitudinal design allowed us to test changes in behavioral outcomes from hospital admission to 2 months post-discharge. To our knowledge, this is the first study to examine changes in behavioral outcomes across multiple sites in a longitudinal inpatient sample of children with ASD and severe problem behaviors.

To conclude, hospitalization in specialized child psychiatry units appears to be effective in reducing the severity of serious problem behaviors in children and adolescents with ASD, even in a sample with a high proportion of minimally verbal subjects with ID and exposure to multiple prior treatments. There was a large decrease in the severity of problem behaviors during the inpatient stay, a small albeit statistically significant increase in tantrum-like problem behaviors from discharge to 2-month follow-up, and maintenance of the decrease in self-injurious behaviors at 2-month follow-up. Problem behavior scores at hospital admission were correlated with length of stay, indicating children with more severe problem behaviors at admission had longer lengths of hospital stay. Significant differences between inpatient sites were not explained by our study covariates and are thus likely due to unmeasured factors. Future studies could build upon these findings by examining the comparative effectiveness of hospitalization in specialized units and general child psychiatric units, matching for ASD symptom and behavioral severity and isolating for specific inpatient intervention elements, which would further inform public policy decisions on investing in hospital services for this growing, high-need population.

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Compliance with Ethical Standards

Conflict of interest The authors declare they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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