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Longitudinal outcome and recovery of social problems after pediatric traumatic brain injury (TBI): Contribution of brain insult and family environment

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ABSTRACT

Pediatric traumatic brain injury (TBI) can result in a range of social impairments, however longitudinal recovery is not well characterized, and clinicians are poorly equipped to identify children at risk for persisting difficulties. Using a longitudinal prospective design, this study aimed to evaluate the contribution of injury and non-injury related risk and resilience factors to longitudinal outcome and recovery of social problems from 12- to 24-months post-TBI. 78 children with TBI (injury age: 5.0–15.0 years) and 40 age and gender-matched typically developing (TD) children underwent magnetic resonance imaging including a susceptibility-weighted imaging (SWI) sequence 2–8 weeks post-injury ($M = 39.25$, SD = 27.64 days). At 12 and 24-months post- injury, parents completed questionnaires rating their child's social functioning, and environmental factors including socioeconomic status, caregiver mental health and family functioning. Results revealed that longitudinal recovery profiles differed as a function of injury severity, such that among children with severe TBI, social problems significantly increased from 12- to 24-months post-injury, and were found to be significantly worse than TD controls and children with mild and moderate TBI. In contrast, children with mild and moderate injuries showed few problems at 12-months post-injury and little change over time. Pre-injury environment and SWI did not significantly contribute to outcome at 24-months, however concurrent caregiver mental health and family functioning explained a large and significant proportion of variance in these outcomes. Overall, this study shows that longitudinal recovery profiles differ as a function of injury severity, with evidence for late-emerging social problems among children with severe TBI. Poorer long-term social outcomes were associated with family dysfunction and poorer caregiver mental health at 24-months post injury, suggesting that efforts to optimize the child's environment and bolster family coping resources may enhance recovery of social problems following pediatric TBI.

1. Introduction

Traumatic brain injury (TBI) is a common cause of childhood death and disability. In Australia alone, 219–345 cases per 100,000 are reported each year, with this highly conservative estimate based on hospital presentations only (Crowe et al., 2009). In contrast to the well documented physical, cognitive and behavioral sequelae of such injuries, the impact of pediatric TBI on post-injury social development is less well understood (Anderson et al., 2005; Anderson and Moore, 1995; Rivara et al., 1993; Taylor et al., 2002). Of particular concern, preliminary reports suggest that social impairments may be among the most profound and disabling con-

Abbreviations: ANZSCO, Australian and New Zealand Standard Classification of Occupations; CBCL, Child Behavior Check List; GCS, Glasgow Coma Scale; MRI, Magnetic Resonance Imaging; SES, Socioeconomic Status; SWI, Susceptibility-weighted Imaging; TBI, Traumatic Brain Injury.

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sequences of pediatric TBI, however clinicians are poorly equipped to identify children at risk for persisting difficulties (Anderson and Beauchamp, 2012; Beauchamp and Anderson, 2010; Gerring and Wade, 2012; Wade et al., 1998; Yeates et al., 2004).

Social skills emerge relatively early in development and illustrate protracted maturation, mediated by an anatomically distributed "social brain" network that comprises the corpus callosum, superior temporal sulcus, fusiform gyrus, temporal pole, medial prefrontal cortex, orbitofrontal cortex, amygdala, temporoparietal junction, and inferior parietal cortex (Adolphs, 2009; Kennedy and Adolphs, 2012). While both pediatric and adult studies suggest that regions of the social brain are commonly vulnerable to the effects of TBI (Wilde et al., 2005), it may be that social skills are at elevated risk for disruption among children and adolescents, in whom neural networks are undergoing rapid functional and structural maturation (Blakemore, 2008; Choudhury et al., 2006).

In line with this hypothesis, several cross-sectional studies have linked pediatric TBI to higher levels of aggressive and maladaptive behavior, less social engagement (Andrews et al., 1998; Bivona et al., 2014; Dooley et al., 2008; Hawley, 2012; Kosty and Stein, 2013; Landry et al., 2004; Rosema et al., 2012) reduced social participation and poorer social adjustment (Anderson et al., 2013). Not unexpectedly, studies have shown an association between injury severity and some aspects of social function. For example, compared to children with mild and moderate TBI, children with severe TBI show greater decline in post-injury social function with minimal improvement by one year post injury (Rivara et al., 1993). Similarly, recent reports have linked severe TBI to poorer social adjustment and participation (Anderson et al., 2013), as well as poorer functioning in more specific domains of social competence, including social cognition (Dennis et al., 2012; Janusz et al., 2002; Ryan et al., 2014) and maintenance of peer friendships (Prigatano and Gupta, 2006). While this body of research supports the deleterious impact of TBI on social function, recovery trajectories for these skills remain poorly characterized, and few studies have examined the respective contribution of injury and non-injury related risk and resilience factors to variability in long term social outcomes.

Advances in neuroimaging provide a unique opportunity to quantify the impact of TBI on the developing brain, and improve prediction of long-term social outcomes. One such technique, susceptibility weighted imaging (SWI), is a high resolution gradient-recalled echo (GRE) sequence that accentuates the magnetic properties of blood and blood product in the brain, rendering it particularly sensitive to micro-hemorrhagic lesions commonly associated with traumatic axonal injury (TAI) (Sehgal et al., 2005). Though SWI is shown to be more sensitive in detecting traumatic lesions than CT and conventional MR sequences (Beauchamp et al., 2011b) and demonstrates utility for prediction of cognitive outcomes after pediatric TBI (Beauchamp et al., 2013; Ryan et al., 2014), its value for prediction of long-term social functioning in this population remains unclear.

Though injury-related factors may increase risk for a range of social impairments after pediatric TBI (Yeates et al., 2007), several longitudinal studies suggest that the quality of the pre-injury environment may interact with the neurological consequences of injury to exert a cumulative negative influence on social outcomes. In particular, one recent study found that family functioning had a strong, but reducing, influence on social development over time post-injury (Yeates et al., 2010). Similarly, while post-injury social dysfunction has been linked to demographic factors such as socioeconomic status (Anderson et al., 2013; Li and Liu, 2013; McNally et al., 2013), the respective contribution of pre- versus post-injury environment is yet to be investigated.

The aims of this study were to (1) evaluate longitudinal outcome and recovery of social problems from 12- to 24-months post-injury and (2) explore the respective contribution of (i) number, volume and neuroanatomical location of micro-hemorrhagic lesions detected on susceptibility-weighted imaging (SWI), and (ii) pre- and post-injury family environment to 24-month social outcomes. In keeping with previous research, we predicted that recovery profiles would differ as a function on injury severity; that is, for children with severe injuries, social problems would increase over time, with evidence for late-emerging social problems at 24-months post-injury; and for those with milder injuries, social problems would not differ from typically developing controls and would show limited change across time. We also predicted that social problems at 24-months would be associated with (i) a greater number and volume of SWI lesions, as well as lesions in the corpus callosum, frontal and temporal cortices and (ii) poorer pre- and post-injury caregiver mental health and family functioning.

2. Method

2.1. Participants

This study comprised 118 children, 78 survivors of TBI (51 males) and 40 typically developing (TD) children (22 males). All participants were ascertained between 2007 and 2010, and were aged between 5.5 and 15.11 years at time of recruitment. As part of the larger longitudinal prospective study which aimed to investigate the psychosocial consequences of pediatric TBI (Anderson et al., 2013), children were recruited at time of injury, and represented consecutive admissions to The Royal Children's Hospital (RCH), Melbourne, Australia. TD children were recruited through local schools chosen to ensure a range of socio-economic backgrounds.

For the TBI group, inclusion criteria were: (i) 5.0 to 15 years of age at time of recruitment; (ii) documented evidence of closed head injury, including a period of altered consciousness or presence of at least two post-concussive symptoms; (iii) medical records sufficiently detailed to determine injury severity, including the Glasgow Coma Scale GCS, (Teasdale and Jennett, 1974) and neurological and radiological findings; (iv) no history of documented pre-injury neurological, developmental or psychiatric disorder, non-accidental injury, or previous TBI; and (v) no prior intervention for social impairment; (vi) English speaking; (vii) completion of 12 and 24 month assessments. The TD group were required to meet criteria (i), (iv), (v), (vi) and (vii) above.

For the TBI group, injury severity was classified into three groups: (i) mild ($n = 47$): GCS 13–15 on admission, loss of consciousness (LOC) < 1 h, and no abnormalities on CT or MRI scan; (ii) moderate TBI ($n = 20$): GCS 9–12 on admission, LOC 1–24 h, and/or evidence of intracranial pathology on CT or MRI scan; and (iii) severe TBI ($n = 11$): GCS ≤ 8 on admission, LOC > 24 h, and/or abnormalities on CT or MRI scan.

2.2. Outcome measures

2.2.1. General intelligence

The two-subtest version of the Wechsler Abbreviated Intelligence Scale (WASI) (Wechsler and Hsiao-pin, 2011) was administered at 6-months post-injury. The score used to describe the sample was the Full Scale Intelligence Quotient (FSIQ; mean [M] = 100, standard deviation [SD] = 15).

2.2.2. Social problems

The Child Behavior Checklist for ages 6–18 (CBCL/6–18) (Achenbach and Rescorla, 2001a) was completed by all families at the 12- and 24-month assessment time points. In addition, at the time of initial recruitment, primary caregivers of children and adolescents with TBI provided *pre-injury* retrospective ratings of social problems. Caregivers were asked to rate the frequency