

Posttraumatic Stress Following Acute Medical Trauma in Children: A Proposed Model of Bio-Psycho-Social Processes During the Peri-Trauma Period

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Abstract Millions of children worldwide experience acute medical events. Children's responses to these events range from transient distress to significant posttraumatic stress disorder symptoms (PTSS). While many models suggest explanations for the development and maintenance of PTSS in adults, very few have focused on children. Current models of child PTSS are primarily restricted to the post-trauma period, thus neglecting the critical peri-trauma period when screening and preventive interventions may be most easily implemented. Research on PTSS in response to pediatric medical trauma typically examines predictors in isolation, often overlooking potentially important interactions. This paper proposes a new model

utilizing the bio-psycho-social framework and focusing on peri-trauma processes of acute medical events. Understanding the relationships among bio-psycho-social factors during peri-trauma can inform early identification of at-risk children, preventive interventions and clinical care. Recommendations for future research, including the need to examine PTSS in the context of multiple influences, are discussed.

Keywords Child PTSD · Child PTSS · Medical traumatic stress · Peri-trauma · Acute medical trauma · Bio-psycho-social model

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Introduction

Events related to injury, acute medical illness and medical treatment are among the most common potentially traumatic events in childhood (Murray and Lopez 1996). In the USA alone, twenty million children suffer unintentional injuries each year (Grossman 2000), with many more children facing sudden illnesses (Marks and McQueen 2001). An acute medical event is defined as a sudden, unexpected and new medical event for a child. This includes injuries or sudden illnesses (excluding chronic illnesses). Unique to medical trauma, the peri-trauma period typically includes physical trauma (i.e., discomfort and/or pain due to injury, illness, or medical treatment), interaction with medical treatment providers and medical interventions; all components of this experience can contribute to the child's emotional reactions to his or her injury or illness. The peri-trauma period in children exposed to acute medical events is also unique from other acute trauma in presenting the opportunity for implementation of systematic screening and preventive interventions while

children are interfacing with the medical system for physical care. Children facing acute pediatric medical events (e.g., injury, ICU admission) frequently exhibit significant posttraumatic stress symptoms (Balluffi et al. 2004; Kean et al. 2006; Mintzer et al. 2005; Walker et al. 1999). More specifically, a meta-analysis found that 19 % of children with injuries and 12 % of children with illnesses develop persistent PTSS (Kahana et al. 2006). The consequences of PTSS extend beyond the psychological symptoms to also include poorer functional health outcomes and greater use of health services (Holbrook et al. 2005; Landolt et al. 2009; Mintzer et al. 2005; Zatzick et al. 2008). Thus, the major impact of PTSS on children demands clinically relevant research to support recovery after potentially traumatic acute medical events.

In general, posttraumatic stress disorder (PTSD) requires exposure to a potentially traumatic event (i.e., experiencing an event which involved the possibility of death or serious injury to the individual or to others) and includes symptoms of re-experiencing or intrusion, avoidance, arousal, changes in mood or cognitions, and impaired daily functioning (American Psychiatric Association 1994, 2010). For both clinical and research purposes, it is important to note that significant PTSS, regardless of PTSD diagnostic status, are associated with negative outcomes (Holbrook et al. 2005; Stoddard and Saxe 2001). In children with PTSS related to medical events, reexperiencing can take the form of dreams (e.g., nightmares about a car crash) or can be displayed in play (e.g., drawing pictures of a surgery). Arousal can be demonstrated as an increased startle response or activation of physiological responses following a trauma trigger (e.g., heart rate elevated at a follow-up appointment). Avoidance can be observed in a variety of ways such as refusing to take medications, not wanting to talk about the injury or illness, or refusing to return to the hospital. With the new DSM-5 criteria, prevalence rates for PTSD in adult trauma victims are expected to remain the same (Calhoun et al. 2012). It is unclear how the prevalence of PTSD/PTSS will change in children. However, given that depressive symptoms can also be a result of exposure to acute trauma in children (Kassam-Adams et al. 2010), it is possible that the changes to DSM-5 regarding mood criteria will result in higher rates of PTSD/PTSS in children exposed to acute medical events.

Specific to PTSS due to medical events, Kazak et al. (2006) explained that families are best served when medical teams apply an integrative model to understanding, preventing and treating medical traumatic stress. Their proposed framework highlights the importance of recognizing the systems (e.g., school) with which the child and family interact and examining children's responses to the medical event using a trauma phase approach (pre-, peri-,

post-). Research should include information on all phases of the medical trauma and consider developmental context and environmental influences (Kazak et al. 2006).

In children, research has focused on the post-trauma phase of acute events. Data during the peri-trauma period are particularly sparse. In acute medical trauma, the peri-trauma period can be defined as the time from which the potentially traumatic event (e.g., a child is injured in a motor vehicle crash) begins through the child's medical treatment (i.e., including the medical treatment as part of the potentially traumatic event such as emergency transport, surgery and/or hospitalization). In medical populations, peri-trauma factors are of special importance. Applying a bio-psycho-social framework to the prevention of PTSS, biological markers during peri-trauma have the potential to serve as readily available screeners, while psycho-social factors can serve as potential mechanisms of action to prevent or reduce sustained PTSS. Understanding markers and mechanism of action provides a unique opportunity for prevention of PTSS during the child's medical treatment.

To date, preventive PTSS interventions for pediatric medical populations have produced mixed results (Berkowitz et al. 2011; Cox and Kenardy 2010; Kramer and Landolt 2011; Stallard et al. 2006; Zehnder et al. 2010). For example, two preventive interventions have shown promise in preventing PTSS during the post-trauma period following acute medical events: Kids and Accidents (psycho-education with a web-based component for children and a booklet for parents) and the Child and Family Traumatic Stress Intervention (four-session in-person psycho-educational and skills based intervention) (Cox and Kenardy 2010; Berkowitz et al. 2011). In contrast, though not specific to pediatric medical events, some efforts to prevent during the peri-trauma or early post-trauma period (e.g., via debriefing) have produced no effect or worsened symptoms by interfering with the normal recovery process (McNally et al. 2003; Rose et al. 2002). Given these results, it is unclear what intervention components or mechanisms of action are most effective and what factors should be targeted in developing or improving preventive interventions. In addition, most children exposed to acute medical events do not have contact with behavioral health providers; thus, screening and intervening by medical providers during the peri-trauma period have the potential to significantly extend the reach of secondary prevention programs. Recognizing and working to prevent PTSS in the peri-trauma period can help improve children's care, promoting full emotional and physical recovery.

This paper provides a narrative review, synthesizing current research and theory regarding the development and maintenance of PTSS in children exposed to acute medical events. Extending current theory, we propose a new model

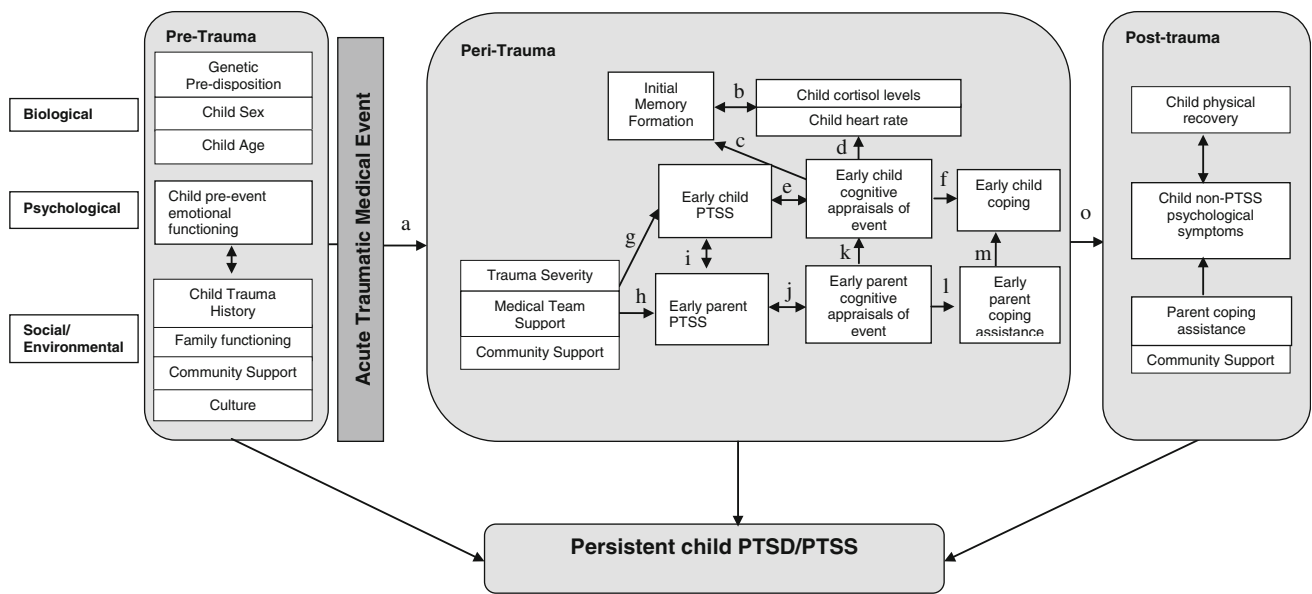


Fig. 1 Theoretical model for the development of child PTSD/PTSS following acute medical trauma. This model does not include every factor influencing the development of PTSS following acute medical trauma. Rather, we suggest including pre, peri and post-trauma factors

in future research and highlight specific understudied paths during the peri-trauma period. See text for supporting evidence for individual paths as labeled by letters (a–o)

that integrates key biological, psychological and social processes during the peri-trauma phase that may contribute to the development and maintenance of PTSS. Specifically, we summarize factors across each trauma phase (pre-, peri-, post-) using the biological, psychological and social/environmental framework. We focus the discussion on the peri-trauma time period, given its importance in acute medical trauma and current gaps in the literature. See Fig. 1 for a summary of the relationships in the proposed model.

Current Theoretical Models of PTSD/PTSD Development in Children

Below, we provide a brief history of the bio-psycho-social framework and three primary theories which influenced the model proposed in this paper.

Bio-Psycho-Social Framework

As understanding of psychological disorders and symptoms has progressed, it has become increasingly clear that the onset of symptoms does not have a single cause. Rather, psychological symptoms should be assessed and treated within the context of the individual and his or her situation. Engel proposed using a bio-psycho-social framework to guide medicine (including psychiatry) in the 1970s (Engel 1977). Thirty years later, Fava and Sonino (2008)

summarized how the bio-psycho-social framework has been applied to patient care. They noted that while the evidence base for the bio-psycho-social framework has grown over time, actual implementation of this framework in patient care has been slow (Fava and Sonino 2008). In the field of psychology, Suls and Rothman (2004) suggested that the application of bio-psycho-social framework has yet to be utilized to its full potential and should be considered in emerging theories of health psychology and clinical practice. Research has identified biological, psychological and social (environmental) contributors to the onset and persistence of PTSD/PTSS (Alisic et al. 2011; American Psychiatric Association 2014; Cox et al. 2008; Kahana et al. 2006), and using the bio-psycho-social framework to inform treatment of PTSD/PTSS has been suggested (Finkelhor et al. 2009). Despite current research and recommendations for clinical practice, the bio-psycho-social framework has yet to be described clearly as it relates to the conceptualization of the development of PTSD/PTSS and has not been integrated into standard clinical care.

Biological Model

Schwartz and Perry (1994) suggested that neurobiology plays a primary role in the development of PTSS: Physiological symptoms maintain hyper-arousal and influence the formation of memories. When faced with an acute potentially traumatic stressful event, the body’s natural

reaction is to activate systems, which create the fight-or-flight response. As this response is initiated, changes in the brain occur to promote survival. In some individuals, this response continues beyond the duration of the stressor or at a higher frequency or intensity. Thus, rather than the fight-or-flight response enhancing survival as intended, the response may create PTSS (Schwartz and Perry 1994). Schwartz and Perry suggest that several factors contribute to this process: genetics, family factors, the developing brain (i.e., how developed the brain is when a trauma exposure occurs) and malignant memories. Genetics play a role in how a child develops arousal symptoms and how a child learns; thus, genetic predisposition indirectly impacts the development of PTSD. The family environment can impact how the child processes traumatic events, and memories have a stronger impact on the developing brain than the adult brain. During periods of high stress, neurobiological processes can disrupt the process of memory consolidation resulting in the formation of “malignant memories,” which are related to the later development of trauma symptoms (particularly those related to arousal; Schwartz and Perry 1994). Though not specific to acute pediatric medical events, research supports the role of malignant memories in that heightened peri-trauma physiological responses (e.g., elevated heart rate, release of hormones) are associated with aberrant memory function (Pitman and Delahanty 2005; Pitman et al. 2012).

Schwartz and Perry (1994) were among the first to highlight how physiological changes in the brain interact with memory/cognition and the child’s social environment to affect the development and maintenance of PTSD. While they allude to the interactions among these specific biological, psychological and environmental processes, they place heavy emphasis on the biological processes involved in memory formation and neglect more specific child and parent psychological processes (e.g., appraisals, coping behavior). This theory focuses on the post-trauma phase and chronic PTSD, rather than processes occurring during the peri-trauma phase, restricting the extent to which this theory can inform preventive efforts.

Psychological Model

A model proposed by Meiser-Stedman (2002) suggests the application of cognitive behavioral theory (CBT) toward understanding and treating PTSD in children. His rationale highlights the role of children’s cognition and memory in the maintenance of PTSS. Meiser-Stedman offers support for a CBT model based on modifications of theories offered to explain the maintenance of PTSD in adults. He suggests that this allows for (1) consideration of a developmental framework, (2) inclusion of the role of the family, (3)

examination of the child’s pre-trauma functioning, (4) attention to the increase in comorbid psychological disorders, (5) examination of the child’s ability to verbalize memories and cognitions and (6) consideration of the role of maladaptive cognitions, particularly cognitive avoidance. Meiser-Stedman et al. (2007, 2009) present evidence to support the theory that children’s memories and cognitions play a role in the maintenance of PTSS (Meiser-Stedman et al. 2009; Meiser-Stedman et al. 2007). More specifically, in children exposed to physical assaults or motor vehicle accidents, maladaptive appraisals mediated the relationship between initial PTSS and PTSS 6 months later (Meiser-Stedman et al. 2009).

Meiser-Stedman’s CBT model has positively influenced the field by encouraging researchers and clinicians to recognize similarities and differences in PTSS maintenance among adults and children and by bringing attention to the importance of children’s cognitions. This model suggests consideration for psychological factors (e.g., pre- and post-trauma symptoms) and the environment (i.e., family roles). Yet, the model does not account for variability in biological factors nor does it include child and parent coping behaviors. Further, his model focuses on the pre- and post-trauma phases, again leaving out the potentially critical peri-trauma phase.

Social/Environmental Model

Finally, Kazak’s (2006) application of the Pediatric Psychosocial Preventative Health Model (PPPHM) for assessment and treatment of children in healthcare settings reinforces the concept of a bio-psycho-social model for preventive health. She brings together the influence of social factors on children by using the PPPHM. The PPPHM highlights the bi-directional influence between a child’s health and their multilayered systems (e.g., medical, school and family systems). For example, a child’s illness may affect parenting techniques and school attendance, which then, in turn, affects the child. Kazak suggests that this model can be particularly helpful in determining the level of preventive care needed to facilitate a child’s recovery. Research has supported using the PPPHM to determine child risk and level of care needed (Kazak 2006).

While PPPHM reinforces the idea of implementing the bio-psycho-social framework for PTSS related to medical events and highlights the importance of a child’s social environment, it does not clearly delineate specific factors that may be important during each trauma phase. Because this model focuses more generally on preventive health rather than specifically on PTSD/PTSS, specific factors associated with PTSD/PTSS are not discussed (e.g., trauma history, appraisals).

Table 1 Summary of meta-analyses examining predictors of PTSD/PTSS in children

	Kahana et al. (2006)	Cox et al. (2008)	Alisic et al. (2011)	Trickey et al. (2012)
Meta-analysis characteristics				
Traumatic events	Injury and illness	Injury	Various	Various
Number of studies	26	14	34	62
Designs of studies	Cross-sectional	Cross-sectional and longitudinal	Longitudinal	Cross-sectional
Age in samples	6–19	5–18	1–18	6–18
PTSD Measures	Included all PTSD symptoms	Validated/psychometrics provided	Included at least avoidance and intrusion	Validated/include intrusion, avoidance, hyperarousal
Model	Fixed effects	Fixed effects	Random effects	Random effects
Predictors assessed		Effect sizes		
Pre-trauma factors				
Biological				
Sex (female)		0	Small	Small
Age (younger)		0—medium	0—small	0
Minority status		–	Small	0
Psychological				
Pre-trauma psychopathology		–	Small	–
Pre-trauma low self-esteem		–	–	–
Social (environmental)				
Low SES		Small	–	0
Prior trauma exposure		–	Small	–
Other life events		–	–	–
Parent psychological problem		–	–	–
Peri-trauma factors				
Biological				
Heart rate at hospital		–	–	Small
Psychological				
Perceived life threat		Large	Small–medium	–
Peri-trauma fear		–	–	–
Appraisal		Small	–	–
Social (environmental)				
Trauma severity		Small–large	0—Small	0
Time since trauma (shorter)		–	–	–
Days in hospital		–	–	Small
Involvement of family/friend in trauma		–	0—small	–
Bereavement		–	–	–
Post-trauma factors				
Biological				
No factors addressed		–	–	–
Psychological				
Co-morbid psych problem		–	–	–
Acute stress		Large	–	Medium
Depressive symptoms		Large	–	Medium
Anxiety symptoms		Large	–	Medium
Dissociation		Large	–	–
Internalizing symptoms		Large	–	–
Conduct problems		–	–	–

Table 1 continued

Predictors assessed	Effect sizes			
Coping: blaming others	–	–	–	Medium
Coping: distraction	–	–	–	Medium
Coping: thought suppression	–	–	–	Medium
Social (environmental)				
Parental distress	–	0—medium	Small	Small
Poor family functioning	–	–	–	Medium
Social impairment	Small	–	–	–
Social support (low)	Small	–	–	Small
Social withdrawal	–	–	–	Small

Summary

Taken together, these three models support the concept of applying the bio-psycho-social framework to the development of PTSD/PTSS in children exposed to acute medical events. While drawing from each of these models, the current proposed model is innovative in several ways. The proposed model (1) brings together bio-psycho-social factors and their interaction into a single overarching model, (2) focuses on pediatric acute medical trauma and (3) highlights the importance of the peri-trauma phase in medical events (Table 1).

Proposed Model and Supporting Evidence

Overview

Influenced by the models above and based on evidence described below, we propose a model which applies a bio-psycho-social framework to the development of PTSD/PTSS in children experiencing acute medical trauma. The proposed model suggests factors across each trauma phase, with particular focus on the peri-trauma phase. As noted, the peri-trauma phase of acute medical trauma may be an ideal time for screening and intervention and has often been neglected in current research and practice. See Fig. 1 for an illustration of the proposed relationships between variables in the model.

During the pre-trauma phase of the event, specific biological factors (child genetic predisposition, sex, age), psychological factors (emotional functioning) and social factors (child trauma history, family functioning, community support, culture) ought to be considered in determining risk for subsequent PTSS to allocate resources to those likely to have the most need. In addition to contributing

directly to PTSS, pre-trauma variables also contribute to the processes during the peri-trauma period (Fig. 1, path a). For example, girls report more early PTSS, and parents of younger children use more coping assistance (Gold et al. 2008; Marsac et al. 2013). While we do not provide an exhaustive list of specific potential relationships between pre- and peri-trauma variables, we suggest these relationships should be considered in future research. During the peri-trauma period, the intra- and inter-relationships among biological (initial memory formation, hormone response, cardiovascular reactions), psychological (early child PTSS, appraisals, coping) and social/environmental framework (trauma severity, medical team support, community support, parent PTSS, parent appraisals, parent coping assistance) may affect the development and maintenance of PTSD/PTSS. To date, most research has focused these variables in isolation of one another, particularly during the peri-trauma period. Table 2 provides a summary of the evidence to date to support the independent role of each of these variables in contributing to PTSS. In addition to the independent contributions of these factors, we suggest examining these variables together as described below (see *Peri-Trauma Period: Integrating Biological, Psychological and Social Factors*). During post-trauma, factors contributing to PTSS include biological (physical injury recovery), psychological (non-PTSS emotional reactions) and social (parent coping assistance, community support) components. Again, in addition to their independent contribution to PTSS, pre and peri-trauma variables may influence these factors (Fig. 1, path o). For example, physical recovery from injury is associated with preexisting emotional health, child gender (females at risk for worse recovery) and severity of physical trauma (Polinder et al. 2005; Zonfrillo et al. 2013). While it is beyond the scope of this paper to detail every potential relationship across time points, we include these post-trauma factors to

encourage future research to improve understanding of the development of PTSS and to increase screening and intervention effectiveness.

Peri-Trauma Period: Biological Factors and PTSS

Acute physiological responses, including elevated stress hormone levels and heart rate, may serve as early predictors of PTSS in children. Cortisol levels have been examined in PTSD research, although the direction of alterations in cortisol related to PTSD/PTSS outcomes has been mixed in adults (Klaassens et al. 2012; Meewisse et al. 2007). The inconsistencies in the relationships between cortisol levels and PTSD may be due in part to the large range of PTSD symptom presentations in individuals as well as the length of time that has lapsed between the traumatic event and the collection of cortisol in the research studies (Miller et al. 2009; Weems and Carrion 2007). In children, there has been greater consistency regarding the direction of the relationship between early peri-trauma stress hormone levels and PTSD, especially in boys (Carrion et al. 2002; Delahanty et al. 2005; Ostrowski et al. 2007). For example, Ostrowski et al. (2007) assessed urinary cortisol levels in 54 children admitted for injuries at baseline, six weeks and seven months. At baseline, levels of stress hormones were measured in urine samples with collection initiating upon admittance to the hospital. PTSS were assessed at 6 weeks and 7 months. At both follow-ups, higher cortisol levels predicted PTSS only in boys.

Perhaps the most consistently observed biological risk factor for PTSD is heart rate assessed within the first 24 h of hospital admission for injury. In-hospital heart rate levels have been found to predict PTSD at 6 weeks (Nugent et al. 2006b), 3 months (Kassam-Adams et al. 2005), and 6 months post-injury (Bryant et al. 2007a; De Young et al. 2007; Nugent et al. 2006b), even after controlling for age, sex and injury severity. A single measurement (earliest available heart rate) has been shown to be a stronger predictor of PTSD than heart rate averaged over the first 20 min post-admission (Nugent et al. 2006a). For example, Nugent et al. (2006a) collected heart rate for 82 children who were admitted to the emergency department for treatment of an injury, and collected PTSS data at 6 weeks and 6 months. Heart rate was collected during EMS transport, upon arrival to the emergency department, for the first 20 min of the emergency department visit, and at discharge. After controlling for demographic factors and depressive symptoms, the first recorded heart rate and heart rate averaged over the first 20 min following admission both predicted PTSS at 6 weeks; however, only the first recorded heart rate predicted PTSS at 6 months (Nugent et al. 2006b). The role of heart rate in medical trauma other

Table 2 Support for potential peri-trauma phase predictors of subsequent PTSS/PTSD

Predictors	Supporting study citations
Biological	
Memory formation	Pitman and Delahanty (2005) ^a , Pitman et al. (2012) ^a
Elevated cortisol (boys only)	Carrion et al. (2002), Delahanty et al. (2005), Ostrowski et al. (2007)
Elevated heart rate	Nugent et al. (2006a), Kassam-Adams et al. (2005), Bryant et al. (2007a, b), De Young et al. (2007), Nugent et al. (2006b)
Psychological	
Child PTSS	Ostrowski et al. (2011)
Child cognitive appraisals	Kahana et al. (2006), Cox et al. (2008), Trickey et al. (2012), Ehlers et al. (2003), McDermott and Cvitanovich (2000), Stallard and Smith (2007), Bryant et al. (2007a, b), Aaron et al. (1999)
Child coping	Stallard and Smith (2007), Zehnder et al. (2006), Marsac et al. (2013, 2014), Landolt et al. (2002)
Social (environmental)	
Trauma severity	Kahana et al. (2006), Cox et al. (2008), Trickey et al. (2012)
Medical team support	Kazak (2006) ^b , Kassam-Adams et al. (2013) ^b
Community support	Kazak (2006) ^b , Kassam-Adams et al. (2013) ^b
Parent PTSS	Balluffi et al. (2004), Alisic et al. (2011), Cox et al. (2008), Trickey et al. (2012)
Parent appraisals	Barrett et al. (1996b) ^c , Dadds et al. (1996) ^c
Parent coping assistance	Marsac et al. (2013), Barrett et al. (1996b) ^c , Dadds et al. (1996) ^c

^a Studies conducted during post-trauma period only; based on theory, we expect findings to be similar during peri-trauma; ^b suggested by theory; no empirical evidence to date; ^c studies were conducted to study how appraisals and coping were influenced by parents in relation to anxiety as an outcome. While samples were not children presenting with trauma exposure, we suggest that results specific to how parents influence child appraisals and coping will apply to families in which children have been exposed to medical trauma

than injury is more complicated due to the potential effects of medication and disease processes and warrants further investigation. Heart rate upon admission has potential public health relevance as a readily available and easily implemented screener of PTSD/PTSS risk, requiring no additional procedures. Mechanisms through which heart rate is associated with PTSD/PTSS remain unclear, though it is suggested that when an individual appraises the situation as more stressful, he or she has stronger physiological responses (e.g., increased heart rate; Fig. 1, path d; Olff et al. 2005).

Peri-Trauma Period: Psychological Factors and PTSS

Folkman and Lazarus (1985, 1991) were the first to suggest an essential role for cognitive appraisals in evaluating an individual's coping responses to stress (Folkman and Lazarus 1985; Lazarus 1991), positing that a primary appraisal occurs when the individual interprets the event as threatening. Following primary appraisal, the individual selects a coping technique (Folkman and Lazarus 1985). Drawing from literature examining the manifestation of anxiety, maladaptive cognitive appraisals (e.g., nothing will be normal again) after a difficult event lead to behavioral strategies (i.e., coping) that directly produce PTSS and/or prevent the development of realistic and adaptive appraisals (Ehlers and Clark 2000; Meiser-Stedman 2002). Though these theories were not posed specifically to pediatric medical trauma, they can be applied. For example, after a frightening medical event, a child may be naturally exposed to potential trauma triggers (e.g., follow-up appointments requiring return to the hospital). This exposure to a reminder of the event can promote realistic appraisals and help to diminish emotional distress. However, if a child has appraised their injury or illness as particularly traumatic, this may lead to avoidant coping strategies (Fig. 1, path f). Avoidant coping may then reduce exposure to reminders and divert the natural recovery process.

Research has supported the independent roles of appraisals and coping in children facing acute medical trauma. Specific to appraisals, children's cognitions (e.g., perception of threat during the traumatic event, negative appraisals about vulnerability to future harm, and negative interpretation of intrusive memories, alienation from others, anger and rumination) are related to worse PTSS (Bryant et al. 2007b; Ehlers et al. 2003; McDermott and Cvitanovich 2000; Stallard and Smith 2007). Amount and type of child coping with acute medical events post-trauma are also related to PTSS, though peri-trauma coping and PTSS have yet to be examined (Alisic et al. 2014; Marsac et al. 2014; Stallard and Smith 2007; Zehnder et al. 2006). In a study of 243 children with injuries, Marsac et al. (2014) found that worse PTSS during the peri-trauma period were associated with later use of distraction, social withdrawal, problem-solving and blaming others (Marsac et al. 2014). In children with newly diagnosed diabetes ($n = 38$) or an injury or newly diagnosed chronic disease ($n = 161$), use of active coping and support-seeking coping was weakly related to PTSS, and use of religious coping predicted fewer PTSS 1 year later (Landolt et al. 2002; Zehnder et al. 2006). These studies suggest a probable role for the interaction among peri-trauma PTSS, coping and appraisals in predicting later PTSS. However, more research is necessary to better understand these relationships.

Peri-Trauma Period: Social (Environmental) Factors and PTSS

Findings for the relationship between severity of trauma exposure for acute medical events and later PTSS have been mixed, ranging from no effect to large effect sizes (Alisic et al. 2011; Cox et al. 2008; Kahana et al. 2006; Trickey et al. 2012). More research is needed to understand whether the differences in findings could be explained by other peri-trauma factors serving as moderators. While support from medical teams (e.g., delivering trauma-informed care) and support from the community has been recommended, empirical evidence is not available on the impact of this type of support during the peri-trauma period (Kassam-Adams et al. 2013; Kazak et al. 2006). Based on research during the post-trauma period, we expect community support (including the medical community) during the peri-trauma period could also help prevent PTSD/PTSS (Kahana et al. 2006; Trickey et al. 2012).

Parents may influence the development of PTSD/PTSS through their own PTSS, cognitive appraisals and efforts to help their child cope (i.e., coping assistance; Barrett et al. 1996a; Blount et al. 1991; Power 2004; Salmon and Bryant 2002; Skinner and Zimmer-Gembeck 2007). A number of studies have identified a relationship between caregiver and child PTSS during the post-trauma period (Alisic et al. 2011; Cox et al. 2008; Trickey et al. 2012). While there has not yet been a focused effort to examine parents' distress during the peri-trauma period, Balluffi et al. (2004) found a relationship between parents' PTSS during their child's intensive care hospitalization and their child's PTSS 2 months later. Additionally, a recent study conducted by De Young et al. (2014) identified an association between child and parent PTSS 1 and 6 months following a burn injury. Though neither study (i.e., Balluffi et al. 2004, De Young et al. 2014) assessed for a potential association between peri-trauma child PTSS and peri-trauma parent PTSS, combining these results with others in the post-trauma phase suggests a potential relationship between peri-trauma parent PTSS and subsequent child PTSS (Alisic et al. 2011; Balluffi et al. 2004; Cox et al. 2008; Trickey et al. 2012).

Several studies have found that in children with PTSS related to medical events, early child PTSS predicts later PTSS (Dalgleish et al. 2008; Kassam-Adams and Winston 2004). For example, Kassam-Adams and Winston (2004) conducted a study to examine PTSS within 1 month following pediatric injury and again 3 months later (sample $n = 243$). Findings indicated that while a diagnosis of acute stress disorder was not the best predictor of post-traumatic stress disorder, a significant relationship emerged between PTSS severity ($r = .56, p < .0005$) (Kassam-Adams and Winston 2004). Similarly, Dalgleish et al. (2008) followed 367 children (ages 6–17 years old) for

6 months following an injury related to a motor vehicle crash; results indicated that PTSS 2–4 weeks post-injury significantly predicted PTSD 6 months later (Dalglish et al. 2008). No research to date suggests that parent appraisals or coping assistance has a direct relationship on child PTSS. These factors are potential mechanisms through which parents may influence their child's PTSS and are described below.

Peri-Trauma Period: Integrating Biological, Psychological and Social Factors

Very little empirical evidence exists to help explain the interactions among the bio-psycho-social factors addressed in this manuscript and how, when integrated, they may influence the onset or severity of child PTSS. Thus, the model proposed here aims to fuse together theory and empirical evidence above and highlights areas for new research to inform screening and preventive intervention.

As described above, physiological arousal is related to PTSS outcomes. Integrating this knowledge with the model of how biological, psychological and social processes contribute to PTSS, we can speculate on the nature of these relationships and examine the intra-relationships of the peri-trauma variables. For example, hormonal responses and cardiovascular levels are related to the formation of memories (Fig. 1, path b), which may in turn influence PTSS. Heart rate is also related to the psychological variable of appraisals (path d) (Nixon et al. 2010; Pitman and Delahanty 2005; Pitman et al. 2012); both heart rate and appraisals are related to PTSS (Meiser-Stedman et al. 2009; Nugent et al. 2006a). Thus, there may be a shared variance or moderated affect, with appraisals influencing heart rate (path d). Changing appraisals during peri-trauma (e.g., using cognitive behavioral techniques) may serve to also affect heart rate and memory formation. Elevated heart rate could serve as a screener to identify intervention need.

However, appraisals do not operate in isolation: Appraisals are related to both psychological variables of early PTSS (Fig. 1, path e) and coping (path f). Specifically, how children perceive an event while it is happening predicts PTSS (Ehlers et al. 2003; McDermott and Cvitanovich 2000). Extrapolating from research during the post-trauma period, in a study conducted by Stallard and Smith (2007) of cognitive appraisals and coping with concurrent PTSS in injured children ($N = 75$), appraisals and coping together accounted for 64 % of the variance in PTSS 8 months after injury. Interestingly, trauma memory did not significantly contribute to PTSS in this study, suggesting that the relationships between appraisals and memory (path c) need further exploration (Stallard and Smith 2007). Interventions during the peri-trauma period which focus on appraisals and coping together could be

more powerful than those aiming to change appraisals only. It is also possible that the relationship between appraisals and PTSS is partially accounted for by coping behaviors.

We propose that appraisals during the peri-trauma period are also influenced by the social variable parent appraisals (Fig. 1, path k) and coping by parent coping assistance (path m). Parental influence over child appraisals and coping has been most clearly established as related to child anxiety. Drawing from the larger appraisals and coping literature (i.e., beyond pediatric medical events and PTSS), direct observation of parent–child processes highlights parents' role in how children appraise situations. Parents of children with anxiety indicate that they have more threatening appraisals of events and maladaptive coping strategies than parents of children without anxiety (Barrett et al. 1996b; Micco and Ehrenreich 2008). For example, Barrett et al. (1996b) presented a series of hypothetical scenarios separately to 205 children and parents to elicit cognitive appraisals (threat versus neutral interpretations of ambiguous situations) and coping responses (adaptive versus maladaptive). In a subsequent family discussion task using these situations, anxious children and their parents generated more threat appraisals and more avoidant coping responses than non-anxious participants (Barrett et al. 1996b). Further, parents of anxious children were more likely to reciprocate and reward avoidant coping suggestions made by their children. When parents encouraged avoidant coping, children were more likely to sustain these strategies (Dadds et al. 1996). Specific to children exposed to trauma, parent coping assistance has been associated with child coping for community violence (Kliewer et al. 2006), pediatric injury (Marsac et al. 2014) and painful medical procedures (Blount et al. 1989). For example, injured children whose parents engaged in more coping assistance strategies used more social support as a coping strategy (Marsac et al. 2014). Evidence suggests a potential role for parent influence over appraisals and coping during the peri-trauma period (paths k, m), but investigations are warranted to clarify this role. Further understanding how children's appraisals develop by taking each factor into consideration has direct implications for preventive interventions and clinical care. For example, if parent appraisals strongly influence child appraisals, then parent appraisals can be targeted with cognitive behavioral treatment as well.

Psychological variables of early child PTSS and child coping are also influenced by the child's social environment (Fig. 1, paths g, i) such as trauma severity, support from the medical team, community support and parent PTSS (Alisic et al. 2011; Balluffi et al. 2004; Cox et al. 2008; Kahana et al. 2006; Kazak et al. 2006; Trickey et al. 2012). As mentioned previously, the relationship on trauma severity to PTSS has ranged from no effect to a large effect

across samples (Alisic et al. 2011; Cox et al. 2008; Kahana et al. 2006; Trickey et al. 2012). However, the reason in this variation is not well understood. It could be that some of the other peri-trauma variables are impacting this relationship. Additionally, to date, while it is recommended that medical teams deliver trauma-informed care, the effect of doing so is unknown (path g). Community support (e.g., peer, school) has been shown as a protective factor in the post-trauma period but has yet to be examined in the peri-trauma period (Kahana et al. 2006; Trickey et al. 2012), so the intra- and peri-trauma period relationships are unclear (path g). Finally, the relationship between parent and child PTSS is also complex (path i). For example, Ostrowski et al. evaluated 118 children admitted to hospital for an injury. Child avoidance symptoms in the hospital predicted PTSS 2 weeks later; an interaction between child and parent PTSS at 2 weeks predicted child six-week PTSS. Thus, the interaction between child and parent PTSS may be important in examining longer term outcomes (Ostrowski et al. 2011). It may be that if the medical team supports the parent and addresses parental symptoms, the parent may be better able to support the child's coping.

Limitations

A goal of proposing this new model is to stimulate future research focusing in on the peri-trauma time period of pediatric medical events that applies a bio-psycho-social framework. Thus, the current evidence to date to support this model is limited, and recommendations for clinical practice should be interpreted with caution. In addition, while biological markers of heart rate and cortisol levels have the potential to be noninvasive and easily obtainable, currently there is not a simple way for a clinician to "score" them, given individual variability. In the future, new technology may make this possible. In the evidence reviewed above, many of the studies identified findings with small effect sizes, which bring into question the confidence that we can have that these findings have significant clinical relevance. Additionally, with small effect sizes, it is difficult to determine the utility of individual risk factors for screening and intervention. Further, no study has examined the all (or most) of the relationships proposed in the model together. When these factors are brought together, the intra- and inter-relationships may change. This review also limited its scope to acute medical trauma rather than including all acute trauma; future work should examine how the model proposed here could be applied across acute trauma. Specifically, future research can highlight the similarities and differences in the bio-psycho-social variables across trauma types. Finally, to date, there is a paucity of research on the cross-cultural applications of these specific variables in relation to PTSD/PTSS. More

research is needed to support cross-cultural applications and/or need adaptations.

Summary

The need to support children exposed to acute medical events is clear, with millions of children worldwide experiencing acute medical events every year (Murray and Lopez 1996). Over the past 30 years, the field has significantly advanced our understanding of how the presentation of PTSD/PTSS in children differs from adults. However, ideal screening to predict sustained PTSS and efforts at preventive interventions are in their infancy and offer mixed results. The development and refinement of these preventive interventions can benefit from a better understanding of processes during the peri-trauma phase. Current models of PTSD/PTSS provide some guidance for factors to target moving forward; however, none of the current models of the development of child PTSD/PTSS bring together biological, psychological and social forces and their interactions. Further, to date, no models have focused on the peri-trauma period when screening and interventions can be delivered as part of medical care. The current model serves to fill both of these gaps and stimulate additional research to advance our understanding of the development of PTSS in children following acute medical trauma.

Adopting a bio-psycho-social model of PTSD/PTSS development and maintenance in children can serve to guide future research. Specifically, future research will significantly move the field forward by focusing on two main areas: (1) the intra- and inter-relationships among bio-psycho-social factors associated with PTSD/PTSS and how these relationships predict long-term outcomes in children, and (2) the processes involved during the peri-trauma phase. An important area of future research related to the inter-relationships among bio-psycho-social factors includes exploration of how peri-trauma physiological responses (bio) are related to early appraisals (psycho) and whether parental behavior (social) can mediate this relationship. Focusing on the peri-trauma phase will help improve understanding of how parents' own appraisals of the child's medical event and coping assistance may influence how children appraise and cope during the medical event. By improving understanding of these factors, preventive interventions can be better tailored and thereby more effective.

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