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Children's post-traumatic stress and the role of memory following admission to intensive care: A review

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Key words
children, intensive care, memory, paediatric illness, post-traumatic stress.

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Abstract

Although our understanding of children's psychological outcomes following intensive care lags significantly behind advances in medicine, there is a growing awareness that intensive care admission impacts children beyond the boundaries of physical well-being. Intensive care presents a variety of disease-related, treatment-related, and environment-related stressors that may place children at risk of post-traumatic stress (PTS), particularly as children may have limited resources to understand and cope with aspects of the admission, its consequences, or treatment events. This article summarises the current literature on children's PTS responses following intensive care admission with emphasis on: (1) children's experience of intensive care; (2) the prevalence of PTS in children following intensive care admission; (c) factors associated with vulnerability to PTS; and (d) the role of memory and appraisal in the development of children's PTS. Existing research does have methodological limitations, and future studies utilising larger sample sizes and developmentally appropriate diagnostic measures are warranted. Furthermore, longitudinal studies investigating the aetiology and course of PTS following paediatric intensive care unit admission, particularly with further investigation of memory and cognitive factors, may lead to advances in screening, prevention, and early intervention strategies for children.

Key Points

1 A significant minority of children experience adverse post-traumatic outcomes following intensive care admission, and symptoms may persist over several months without intervention.
2 Acute post-traumatic stress symptoms may be difficult to distinguish from responses to medical and treatment-related events within intensive care.
3 Factors related to processing, understanding, appraisal, and recall of events may be important in the aetiology of children's post-traumatic stress responses following intensive care admission.

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The past decade has seen a growing awareness that paediatric intensive care unit (PICU) admission impacts children and families beyond the boundaries of physical well-being. Critical illness and associated medical care expose children to an array of extreme psychological stressors, including threat to life and physical integrity, painful, invasive and/or frightening treatment procedures, and distressing events occurring within the environment. Children do experience adverse psychological responses following a stay in the PICU, most notably post-traumatic stress disorder (PTSD) or symptoms of post-traumatic stress (PTS) that fail to meet full diagnostic criteria but nonetheless result in high levels of distress and impairment (see Davydow, Richardson, Zatzick, & Katon, 2010 for a review of a wider range of psychological trauma responses). Symptoms may persist over time and lead to long-term emotional dysfunction, adverse physical health outcomes, and poorer health-related quality of

life (Landolt, Buehlmann, Maag, & Schiestl, 2009; Seng, Graham-Bermann, Clark, McCarthy, & Ronis, 2005; Zatzick et al., 2008).

The identification of factors that increase vulnerability to PTS following PICU admission is of particular current interest for the development of screening tools, prevention and intervention strategies to promote holistic recovery. Pre-admission, injury/illness-related, treatment-related, and environment-related variables are of interest, and preliminary research appears consistent with the wider paediatric injury and illness literature. Adult intensive care unit (ICU) literature demonstrates that patient's subjective experience, understanding, and recall of ICU are aetiologically important, which is consistent with recent cognitive conceptual models that stress the importance of memory and appraisal for trauma in PTSD development (Brewin, Dalgleish, & Joseph, 1996; Ehlers & Clark, 2000). Children's experience, understanding, appraisal, and recall of PICU are not well understood and require particular attention as they are undergoing cognitive, emotional, and psychological development; children may have fewer resources than adults to make sense of their experience and acute responses.

Despite recent progress, significant gaps remain in our current understanding of the epidemiology, aetiology, course, impact on physical, emotional, psychological, social and academic developmental trajectories, assessment, and intervention needs of children who develop clinically significant PTS following a PICU admission. With the aim of reviewing the current scientific standing on children's PTS following PICU admission and encouraging further research, this article reviews the literature with emphasis on: (1) children's experience of PICU; (2) the prevalence of PTS in children following PICU admission; (3) factors associated with vulnerability to PTS; and (4) the role of memory and appraisal in the development of children's PTS.

PTS and PICU

Admission to PICU, for many patients, presents a threat to life and/or physical integrity that constitutes a high-risk event for the development of PTSD. Many elements of the PICU experience may be traumatic for children. PICU patients are exposed to more potentially frightening, painful and traumatic diagnosis and treatment-related procedures than general care ward patients (Rennick, Johnston, Dougherty, Platt, & Ritchie, 2002). Procedures may include, but are not limited to, intubation, ventilation, suctioning, arterial or central venous lines, continuous infusions of fluid or medicines, bronchoscopy, urinary catheterisation, arterial stabs, and burn dressing changes. Some of these procedures are associated with a range of potentially serious complications, increased mortality rates, and pain and discomfort (Morrow, 2008). Sedatives (most commonly benzodiazepines) and analgesic agents (most commonly opiates and ketamine) are administered to reduce potential distress and discomfort. However, adverse reactions have been documented in adults and children following sedation, including nightmares, acute anxiety, phobias, depression, perceptual disorders, alteration in consciousness, paranoia, irritability, and rage (Bennett, 1999; McGraw & Kendrick, 1998; Voepel-Lewis, Mitchell, & Malviya, 2007).

The PICU environment also presents children with potentially traumatic experiences. Children are exposed to ventilators, intravenous pumps, bright lights, strangers, and other sick children. Noise is generated by monitors, mechanical alarms from ventilators and other equipment, staff conversations, telephones, pagers, and other patients (Bailey & Timmons, 2005). The World Health Organization recommends that hospital noise levels not exceed 40dBA during the day and 35dBA at night (Berglund, Lindvall, & Schwela, 1999). However, average noise levels in the PICU reach 70dBA during the day, 59dBA at night, and maximum levels reach 120dBA (Carno & Connolly, 2005; Morrison, Haas, Shaffner, Garrett, & Fackler, 2003). Excessive noise can activate the sympathetic nervous system and interfere with usual sleep patterns, wound healing, sensitivity to pain, and heart rhythms in adults (Bailey & Timmons, 2005; Carvalho, Pedreira, & de Aguiar, 2005; Cureton-Lane & Fontaine, 1997; Fontaine, 2005). Sleep can also be severely disrupted by aspects of illness (e.g., pain), noise, light, staff interventions, or adverse effects of medications on sleep architecture (i.e., suppression of slow-wave and/or rapid eye movement (REM) sleep; Al-Samsam & Cullen, 2005; Cureton-Lane & Fontaine, 1997). Children may receive less than 5 hr total sleep during the night, and they may wake up to 40 times per night (Al-Samsam & Cullen, 2005; Cureton-Lane & Fontaine, 1997). Most sleep obtained are Stage 1 and 2 sleep (light sleep) with suppression of slow-wave and/or REM sleep (Carno, Hoffman, Henker, Carcillo, & Sanders, 2004; Corser, 1996). Disruption to sleep cycles affects the immune system and causes stress as slow-wave sleep inhibits cortisol secretion via the Hypothalamic-Pituitary-Adrenal (HPA) axis (Carno & Connolly, 2005). Children are also often separated from caregivers in PICU, and they may be witness to adverse events occurring to others in PICU.

Unfortunately, the PICU setting provides a challenging environment in which to identify intense fear and early post-traumatic responses in children. Children's initial fear responses may include disorganised and agitated

behaviour, crying, confusion, anger and aggression, or even detachment and absence of emotional responsiveness (children may appear quiet and withdrawn). Early symptoms of PTS in children may include distressing nightmares, intense emotional reactions when exposed to reminders, increased physical arousal including elevated heart rate and blood pressure, exaggerated startle reflex, irritability, anger, restlessness, and sleep disturbance. Early trauma responses may also include emotional numbing, detachment, reduced awareness in surroundings, and dissociative episodes where children appear frozen or stilled and unresponsive (American Psychiatric Association, 2000; Pynoos, 2009; Scheeringa, Zeanah, & Cohen, 2011). In an intensive care environment, particularly when staff members are on high alert for medical events, such symptoms could be misinterpreted as physical arousal secondary to a medical event, increased pain, behavioural responses to sedatives and other medications, or even delirium. Even when medical events are present, concomitant fear or trauma responses may be overlooked.

Prevalence of PTS Responses

Table 1 summarises the literature investigating prevalence of PTS/PTSD and associated risk factors in children following PICU admission. Clinically significant PTSD symptoms ("likely PTSD") were reported in 10% to 28% of children, and rates of subclinical symptoms were higher still. These rates are similar to those reported in adults' post-ICU admission (median point prevalence of 22% for self-report measures, 19% for clinician-administered interviews; Davydow et al. 2008). It appears that children experience short-term PTS as early as 24 hr post-discharge (Connolly, McClowry, Hayman, Mahony, & Artman, 2004; Muranjan, Birajdar, Shah, Sundaraman, & Tullu, 2008). Many children continue to experience significant PTS several months post-discharge, with little natural resolution of acute elevated distress (Bronner, Knoester, Bos, Last, & Grootenhuis, 2008; Rennick et al., 2002). There are mixed findings regarding the extent of PTS in children admitted to PICU compared with comparison groups. One group found that significantly more children admitted to PICU developed PTSD than children admitted to general care wards (Rees, Gledhill, Garralda, & Nadel, 2004). Another study found more intrusive thoughts among PICU patients than general care ward patients within the first 24 hr; no differences were evident between groups at 1-month follow-up (Muranjan et al., 2008). Other studies reported no difference in PTS between PICU patients and: (1) general care ward patients (Rennick et al., 2002) or (2) survivors of a fire disaster (Bronner et al., 2008).

Factors Associated with Vulnerability to PTS

The following section reviews our knowledge to date of pre-admission-related, injury and illness-related, treatment-related, and environment-related risk factors for PTS following PICU admission.

Pre-admission variables

Pre-admission psychopathology increases vulnerability to PTSD (Shears, Nadel, Gledhill, & Garralda, 2005). Age is not a consistent risk factor (one of six studies reported an association between age and parent report, but not child report, of child PTS; Bronner et al., 2008; Colville, Kerry, & Pierce, 2008; Connolly et al., 2004; Muranjan et al., 2008; Rennick et al., 2002; Shears et al., 2005; Vermunt et al., 2008). Variables not associated with PTS include gender (Bronner et al., 2008; Colville, 2008; Rennick et al., 2002), socio-economic status (Muranjan et al., 2008), social deprivation (Colville et al., 2008), maternal education (Rennick et al., 2002), and child temperament (Connolly et al., 2004; Muranjan et al., 2008).

Injury and illness-related variables

Children's subjective ratings of disease severity and life threat predict PTSD (Rees et al., 2004). PICU patients rate their illness severity and risk of mortality higher than non-PICU patients (Rees et al., 2004). Objective measures of disease severity and life threat are inconsistent predictors of PTS in PICU (one of five studies; Bronner et al., 2008; Colville, 2008; Muranjan et al., 2008; Shears et al., 2005; Vermunt et al., 2008) as is length of PICU stay (one of six studies; Bronner et al., 2008; Colville et al., 2008; Muranjan et al., 2008; Rennick et al., 2002; Shears et al., 2005). The importance of subjective, rather than objective, ratings of disease severity is consistent with the wider paediatric injury literature (Brosbe, Hoefling, & Faust, 2011; Cox, Kenardy, & Hendrikz, 2008). PTS is not associated with PICU diagnosis (Bronner et al., 2008; Muranjan et al., 2008), or with traumatic brain injury or sepsis (Colville et al., 2008). Non-elective admission was predictive of PTS in one study (Colville et al., 2008).

Pain has not been explored as a risk factor in the PICU literature, although future attention is warranted, as pain, moderated by separation anxiety, is associated with PTSD in burn-injured children (Nixon, Nehmy, Ellis, Ball, Menne, & McKinnon, 2010; Saxe, Stoddard, Hall, & Chawla, 2005) and injured adults (Norman, Stein, Dimsdale, & Hoyt, 2008; Schreiber & Galai-Gat, 1993). Pain may exacerbate an existing stress response or, as has been suggested in adults, PTSD may increase pain sensitivity

Table 1 Summary of studies investigating post-traumatic stress (PTS) in children following paediatric intensive care unit (PICU) admission

Author, year of publication	*n*	Age	Sample characteristics	Timing of assessment post-discharge	Measure	Risk factors[a]	Main findings
(Bronner et al., 2008)	29 (3 months FU)	8–17	Inc: non-elective admission ≥ 7 days and/or ventilated for 24 hr	3 & 9 months	*CRTI*; child report	3 months: **mother's psychological distress & PTSD,** father's psychological distress & PTSD, LOS, length of ventilation, reason for admission, illness severity, gender, age	3 months: 35% subclinical PTSD; 14% likely PTSD
	28 (9 months FU)		Exc: admission for underlying illness, elective surgery, abuse, self-intoxication Comp: paediatric fire disaster survivors (retrospective)			9 months: as for 3 months, +**PTS at 3 months, father's psychological distress**	9 months: 36% subclinical PTSD; 18% likely PTSD No group differences in PTS
(Colville et al., 2008)	102 (96 PTSD Ax's)	7–17	Inc: all PICU survivors Exc: admission for self-harm; learning difficulties, long-term ventilation, readmission after contact, palliative care, address abroad	3 months	*CRIES-8*; child report	**Non-elective admission, illness severity, delusional memory,** LOS, factual memory, age, gender, ethnicity, social deprivation, opiates >48 hr, sepsis, TBI	28% likely PTSD
(Muranjan et al., 2008)	30 + 30 controls (24 hr) 17 + 22 controls (1 month FU)	5–12	Inc: admission ≥ 48 hr Exc: readmission before interview, neurological symptoms precluding interview Comp: admission to general care ward ≥ 48 hr, age & gender-matched, no prior PICU admission	<24 hr & 1 month	*IES*; child report	*Intensity of treatment*, age, SES, education, nature of illness, illness severity, LOS, premorbid temperament	PTSD prevalence not reported PICU pts had more intrusive thoughts versus control pts at 24 hr FU: 43% PICU versus 6.7% control No group diffs in PTS at 1 month
(Vermunt et al., 2008)		6–17	Inc: meningococcal septic shock (retrospective) Exc: non-Dutch speaking Comp: general population reference group	4–16 years	*Post-traumatic Stress Problems Scale, CBCL*; parent, teacher, & child report	**Age (parent report)**, age (child report), illness severity	18% clinical PTS self-report; 5% maternal report No group differences in PTS
(Shears, Nadel, Gledhill, Gordon, & Garralda, 2007)	40	3–16	As in (Shears et al., 2005)	9–12 months	*6 years +: K-SADS-IV-R*; clinician-administered interview <6 years: parent interview	*Only one child with PTSD*	2% PTSD

(Shears et al., 2005)	60 (26 PTSD Ax's)	3–16 (>8 for PTSD Ax's)	Inc: meningococcal disease Exc: insufficient parental English	3 months	*IES*; child report	**Parent PTS, child pre-admission psychological status,** LOS	15% PTSD
(Connolly et al., 2004)	43	5–12	Inc: cardiac surgery Exc: insufficient English or cognitive functioning *Note: not all PICU admissions*	1–3 days pre & 4–8 weeks post	*DISC*; computerised interview, child report	*LOS>48 hr*, cognitive ability, temperament, family support	No PTSD preop 12% PTSD post-op; PTS increased in 23% pre to post-op
(Rees et al., 2004)	35 (19 valid CAPS-C) + 33 matched controls (27 valid CAPS-C)	5–18 (6–12 controls)	Inc: retrospective PICU admissions Exc: meningococcal disease, terminal illness, neurological disorder, intentional overdose, pre-admission learning difficulties, insufficient English Comp: admission to general care ward, age, gender, assessment time & diagnosis matched	6–12 months	*CAPS-C*; clinician-administered interview *IES*; child report	**Child- & parent-perceived severity of illness & life threat, parental PTS**	21% PTSD since discharge; 5.3% PTSD current on CAPS-C 17% likely PTSD on IES More PTSD in PICU pts than control pts (non-PICU = 0% on CAPS-C; 9.5% on IES)
(Judge, Nadel, Vergnaud, & Garralda, 2002)	29	2–15	Inc: meningococcal disease	3 & 12 months	*IES*; child or parent report	-	62% PTS; 10% likely PTSD
(Rennick et al., 2002)	60 + 60 non-PICU controls	6–17	Inc: admission ≥ 24 hr, all diagnoses Exc: insufficient English or French Comp: admission to general care ward ≥24 hr, age & illness matched, no prior PICU admissions	6 weeks & 6 months	*CIES*; child self-report	6 weeks: **invasive procedures**, age, illness severity, LOS, maternal education 6 months: **family visiting,** age, gender, LOS, maternal education, illness severity, invasive procedures	No group differences in PTS at 6 weeks or 6 months 25% elevated PTS at 6 weeks & 6 months; elevated PTS at 6 weeks did not resolve by 6 months

[a]Risk factors in bold typeface represent statistically significant predictors.

FU, follow-up; PTSD, post-traumatic stress disorder ; Ax's, assessments; Inc, inclusion criteria; Exc, exclusion criteria; Comp, comparison group; LOS, length of stay; TBI, traumatic brain injury; SES, socio-economic status; CRTI, Children's Responses to Trauma Inventory; CRIES-8, Children's Revised Impact of Event Scale; CIES, Children's Impact of Event Scale; IES, Impact of Event Scale; K-SADS-IV-R, Schedule for Affective Disorders and Schizophrenia for School Aged Children; CBCL, Child Behaviour Checklist; DISC, Diagnostic Interview Schedule for Children; CAPS-C, Clinician-Administered PTSD Scale for Children.

via arousal of shared neurobiological pathways (Kenardy & Dunne, 2011).

Treatment-related variables

Exposure to invasive procedures and treatment intensity predicted PTS in two studies (Muranjan et al., 2008; Rennick et al., 2002). The mechanism of this association is unclear, although duration of ventilation is not predictive of PTS (Bronner et al., 2008). At present, it is not known whether therapeutic medications (cumulative amounts or particular agents) are predictive of PTS in children, either directly or moderated by hallucinations or altered recall of the PICU event. Receiving opiates for more than 2 days is not associated with PTSD (Colville et al., 2008). Benzodiazepine use increases PTSD vulnerability in adult ICU patients (Davydow et al., 2008).

Environment-related variables

Fewer family visits predict PTS 3 to 6 months following PICU discharge (Rennick et al., 2002; Saxe et al., 2005). This may be reflective of a variety of factors such as poor family functioning, fewer family resources, parental mental health difficulties, family structure, or separation anxiety. Associations have been reported between separation anxiety and PTS in burn-injured children (Saxe et al., 2005). Parental psychopathology and PTS also increases children's vulnerability (Bronner et al., 2008; Rees et al., 2004; Shears et al., 2005). Noise and sleep disruption have not been explored as risk factors in the PICU literature, although we suggest that distress may arise from increased discomfort, activation of stress response pathways or by altering children's processing, and recall of their PICU experience (see following section). Future attention is warranted.

The Role of Memory in Children's PTS

At any age, critical care admission is potentially traumatic, but children may be at particular risk of PTS because they are undergoing rapid psychological and emotional development and may have limited ability to accurately understand and appraise the PICU admission, its consequences, or treatment events. A number of cognitive theories suggest that the way individuals process, recall, and interpret traumatic events is integral to the development of PTSD (see Dalgleish, 2004 for a review). Two prominent cognitive theories of PTSD, Brewin et al.'s (1996) *dual representation theory* and Ehlers and Clark's (2000) *cognitive model of PTSD*, propose different underlying psychological processes, but they also feature commonalities: individuals who develop PTSD engage in sensory-based processing during a traumatic event rather than contextual processing; such processing of the trauma results in a sense of current threat and excessively negative appraisal of the event and/or its sequelae; disruption to consciousness during the event contributes to poorer contextual processing; poor contextual and autobiographical integration lead to difficulty in intentional recall (disorganised, fragmented memories); sensory-based processing leads to stimulus-cued, vivid, intrusive re-experiencing symptoms (e.g., nightmares, flashbacks); behaviours such as avoidance inhibit cognitive change; cognitive change is required to restore a current sense of safety.

There is some evidence that cognitive factors are associated with PTS in children, consistent with the earlier-mentioned theories. PTS in traumatised children has been associated with greater subjective appraisal of threat at the time of the trauma, greater self-reported negative views of the future, cognitive avoidance, and use of other cognitive coping strategies (e.g., distraction, thought suppression, rumination; see Dalgleish, Meiser-Stedman, & Smith, 2005). Of particular relevance are three studies; Meiser-Stedman, Dalgleish, Glucksman, Yule, and Smith (2009) reported that maladaptive appraisals about the trauma and its consequences predicted PTS 6 months post-trauma. Other cognitive variables such as sensory-based memories, ruminative style, and subjective assessment of threat had an effect only in the acute phase. Ehlers, Mayou, and Bryant (2003) reported that sensory-based processing during a traumatic accident, negative appraisals of trauma consequences, and cognitive strategies such as rumination, suppression, and persistent dissociation were associated with PTS in children up to 6 months post-trauma, and McKinnon, Nixon, and Brewer (2008) reported that perceptions of memory quality mediated the relationship between sensory-based processing and intrusive reactions.

The role of memory, appraisal, and cognition may be particularly relevant to children following PICU admission as a variety of factors may interrupt children's processing and recall of the PICU event, and they are required to try to make sense of often unexpected and unfamiliar events.

Factors Affecting Memory in ICU

Unfortunately, admission to ICU presents challenges to effective processing and recall of the experience. Delirium secondary to a medical condition is not uncommon within the critical care environment, although the prevalence and consequences of delirium remain unclear in children. Delirium occurs through imbalances in the synthesis, release, and activation of neurotransmitters

arising from conditions such as infections, drug intoxication, or withdrawal (particularly sedatives), sepsis, autoimmune disease, head trauma, and organ failure (Turkel & Tavare, 2003). Changes in sleep architecture also contribute to the incidence of delirium in critical care. At least 5% of children in PICU experience delirium, although this is likely an underestimate as delirium can be difficult to assess in children (Schieveld et al. 2007). Delirium affects episodic memory and may result in dense amnesia for the period of confusion, although islands of memory can remain while the patient's ability to attend to external stimuli fluctuates (Smith, Fuchs, Pandharipande, Barr, & Ely, 2009). Vivid hallucinations and delusions can also occur. Delirium in adult ICU patients is associated with significantly less factual (autobiographical) recall relative to patients with no delirium (Roberts, Rickard, Rajbhandari, & Reynolds, 2007).

Therapeutic drugs including sedatives and analgesics also disrupt memory processes. Propofol (an anaesthetic) causes total amnesia for the duration of administration in children and has also been associated with retrograde amnesia for events prior to administration (Miner et al., 2005; Quraishi, Girdharry, Xu, & Orkin, 2007; Sung, Tillette, Freniere, & Powell, 1990). The mechanism underlying propofol-induced amnesia is not well understood, but it appears that information may be acquired but forgotten over time (Veselis, 2006). Benzodiazepines are well known to have an amnesic effect (Kain et al., 2000; Twersky, Hartung, Berger, McClain, & Beaton, 1993), and again, long-term storage of information appears to be affected, rather than acquisition or formation of associations (Reder et al., 2006). There is also some evidence to suggest that, consistent with adults, implicit learning takes place even though children's explicit recall is severely impaired (Pringle, Dahlquist, & Eskenazi, 2003; Stewart, Buffett-Jerrott, Finley, Wright, & Valois Gomez, 2006). This has particular implications for the likelihood of sensory-based processing to take place while children are sedated, while conceptual or autobiographical processing and recall may be poor.

Alterations to sleep in PICU may also impact recall. It is generally well accepted that sleep enhances memory consolidation in adults, and it appears that children's declarative memory is also enhanced by sleep, particularly for emotional information (Prehn-Kristensen et al., 2009; Wilhelm, Diekelmann, & Born, 2008). It is suggested that during slow-wave sleep, reactivation of stored memories in the hippocampus stimulates transfer of the information to other neocortical brain regions where it is consolidated and integrated into a network of other related memories (Gais & Born, 2004; Paller & Voss, 2004). Thus, the suppression of slow-wave sleep in children in PICU may contribute to a lack of integration of PICU memories with other autobiographical memories. There is also suggestion in the adult literature that REM sleep contributes to the processing and neocortical integration of emotional memories that are associated with amygdala-dependent processing (Diekelmann, Wilhelm, & Born, 2009). However, it is unclear whether REM sleep is of benefit in children's memory consolidation (Prehn-Kristensen et al., 2009).

Stress also appears to affect the quality and quantity of information retained. Although a physical stress response to an emotionally traumatic event is not unique to ICU, critical illness and associated features also stimulate the HPA axis, including cold, fever, infection, trauma, burns, inflammatory agents, pain, hypotension, haemorrhage, and other challenges to homeostasis (Marik & Zaloga, 2002). In adults, stress at the time of encoding appears to narrow attention such that only select cues are attended to, and there is a failure to integrate contextual cues while learning (Schwabe, Böhringer, & Wolf, 2009). Furthermore, it appears that memory consolidation and integration during sleep are inhibited if cortisol levels are high (Gais & Born, 2004). There are mixed results to date on arousal and memory in children. Some studies suggest that greater subjective distress is associated with poorer memory, but physiological stress responses (as measured by cortisol levels) are not associated with recall in children (Chen, Zelter, Craske, & Katz, 2000; Merrit, Ornstein, & Spicker, 1994). Another showed an association between greater cortisol reactivity and enhanced memory (Quas, Yim, Edelstein, Cahill, & Rush, 2011); however, the association between arousal and contextual recall has not been investigated in children.

Dissociative symptoms can occur in response to extreme psychological stress (as in Acute Stress Disorder; American Psychiatric Association, 2000). Dissociation during or after the event may interfere with the formation of an organised memory of the event and impede the elaboration and integration of the trauma memory with other autobiographical memories (Ehlers & Clark, 2000).. Associations between dissociation and autobiographical memory disturbance has been reported in adults (see Schonfeld, Ehlers, Bollinghaus, & Rief, 2007), but there is less evidence in children. In fact, there is mixed support for the role of dissociation in PTS in children, with some studies reporting weak associations (Kassam-Adams & Winston, 2004; Kenardy et al., 2007) and another reporting a stronger association (Ehlers et al., 2003).

Memory of PICU and PTS

In general, children display accurate recall for medical events, even over multiple interviews and across time

(Baker-Ward, Gordon, Ornstein, Larus et al., 1993; Chen et al., 2000; Merrit et al., 1994). Older children's recall is superior to that of younger children, and younger children are more susceptible to memory distortion and misleading suggestions (Baker-Ward et al., 1993; Salmon, Yao, Berntsen, & Pipe, 2007).

Table 2 summarises studies describing children's recall of PICU. Consistent with adult ICU survivors, most children (around 60–80%) recall aspects of their PICU admission (only Carnevale, (1997) reported near or total amnesia). Playfor, Thomas, and Choonara (2000) found that two-thirds of children recalled PICU, and most memories were neutral or positive. Negative recollections were related to aspects of medical care (nasogastric and endotracheal tubes), environmental factors (noise levels and not knowing the time), and many recalled feelings of pain and fear. Another study reported very similar responses in a larger sample (Kurande, Kelkar, & Kulkarni, 2005). However, studies suggest that children show some difficulty recalling complete and accurate factual details of their admission. Barnes (1975) found that children had detailed but distorted recall of their environment and events occurring to themselves and others, with children misunderstanding and misinterpreting PICU events. Morse, Castillo, Venecia, Milstein, and Tyler (1986) reported that most children who survived critical illness recalled "near-death" experiences (e.g., out-of-body sensations, entering darkness, being in a tunnel), but their narratives were fragmented. Age may play a role in recall and understanding, as Corbo (1985) reported that adolescents displayed good recall of having an endotrachael tube (e.g., feelings, procedures), with a minority reporting confusion. School-aged children, however, appeared to show more confusion and negative feelings towards having an endotrachael tube (Corbo & Abu-Saad, 1984).

Few studies have investigated the association between memories of PICU and psychological distress in children, although associations have been reported in adult ICU literature. It is well documented that ICU survivors experience difficulties recalling memories of real events (factual memories), while often recalling memories of unreal experiences (also known as "delusional" memories) such as confusion, dreams, nightmares, hallucinations, and delusions. Such delusional memories have been associated with PTS in ICU survivors (Granja et al., 2008; Jones, Griffiths, Humphris, & Skirrow, 2001; see Kiekkas, Theodorakopoulou, Spyratos, & Baltopoulos, 2010 for a recent review). Delusional memories are associated with younger age, longer length of stay, fever, renal failure, surgery, ventilator support, and therapeutic drugs (propofol, benzodiazepines, opioids; Ringdal, Johansson, Lundberg, & Bergbom, 2006). To our knowledge, only two studies have investigated the relationship between PICU recall and distress in children. Board (2005) found that children with little recollection about the PICU had higher levels of anxiety than those with greater recall. In a more specific investigation of the quality of memories in PICU and PTS, Colville et al. (2008) reported that 63% of children had at least one factual memory of their stay in the PICU. Some 32% of children reported experiencing at least one delusional memory, and PTSD was related to delusional, but not factual, recall.

At odds with cognitive models, factual recall in children and adult ICU patients does not appear to have a protective effect. This may be methodological, as the measure most commonly used to assess recall (ICU Memory Tool; Jones, Humphris, & Griffiths, 2000), requires endorsement of isolated memories but does not provide a clear indication of *how much* is recalled of the total stay or whether factual recall is fragmented, disorganised, and lacking in contextual quality. Alternatively, while factual recall may help patients reject delusional memories, recall of frightening events might directly contribute to PTS. Associations between delusional memories and PTS have been attributed to the vividness, high emotional content, and long duration compared with factual recall (Kiekkas et al., 2010). In view of cognitive theories, delusional states may be related to poor information processing, as disorientation in time and place and the quality of delusional recall may impede contextual processing of real events and promote encoding of delusional events. Fear or distress experienced during delusional states may narrow attention and impede recall of contextual features. Finally, misinterpretation of actual events (e.g., perceiving an injection as a violent physical attack) may lead to difficulties integrating such events into the autobiographical knowledge base. It is unclear, however, whether delusional memories directly influence PTS responses or whether other factors such as delirium, sleep disruption, sedation, and analgesia are responsible for both delusions and PTS.

Memory Based Interventions

To the best of our knowledge, no memory-based intervention strategies have been implemented with PICU patients. However, strategies have been implemented to reduce procedural distress following medical events. Chen, Zeltzer, Craske, and Katz (1999) reported that enhancing children's beliefs about the efficacy of their coping strategies, encouraging realistic appraisals of their prior responses, and increasing their subjective memory accuracy for a prior lumbar puncture reduced anticipatory anxiety and procedural distress for a subsequent

Table 2 Summary of studies investigating children's recall of paediatric intensive care unit (PICU)

Author, year of publication	*n*	Age	Sample characteristics	Time of assessment post-PICU discharge	Method of data collection	Main findings
(Colville et al., 2008)	102	7–17	See Table 1	3 months	Structured interview (ICU Memory Tool)	63% recalled factual details (people, equipment, environment), 32% recalled at least one delusional memory, 33% recalled confusion, 28% recalled fear, 17% recalled pain, 17% recalled discomfort, 10% recalled panic Delusional, but not factual, recall was associated with PTSD
(Board, 2005)	21	7–12	Inc: any PICU admission Exc: prior hospitalisation	<24 hr	Structured interview	67% recalled PICU events, mostly medical procedures (29%) or feelings (24%) Negative recall = feelings; positive recall = people Greater recall was associated with higher anxiety
(Kurande et al., 2005)	50	5–12	Inc: admission ≥ 24 hr, Exc: intellectual impairment, surgical emergencies, prior PICU admission	1–5 days	Semi-structured interview	74% had neutral recollections, 18% negative, 16% positive, positive recall = clean environment (52%), doctors (36%); negative recall = injections (50%), fear (64%), pain (74%), hunger (16%), disturbed sleep (18%)
(Playfor et al., 2000)	38	4–16	Inc: (A) 24 children admitted prospectively + (B) 14 children (retrospective) Exc: severe learning difficulties	(A) 1–12 days (B) 4–28 weeks	Semi-structured interview; drawings	66% remembered PICU, recollections were mainly neutral (equipment, feelings, environment; 60%), some positive (staff, environment; 25%), some negative (environment, confusion, procedures; 16%), 55% recalled staff, 29% recalled pain, 21% recalled fear, 16% recalled sleep difficulties, 5% recalled unusual dreams
(Carnevale, 1997)	17	2 weeks–17 years	Inc: selected for diversity of demographics	3 months–5 years	Field observations, interviews with parents, nurses, and children	Total or near total amnesia for PICU
(Morse et al., 1986)	11 + 29 (control)	3–16	Inc: critical illness with unconsciousness, full neuropsychiatric recovery Comp: Age matched, seriously but not critically ill	>2 months	Interview: semi-structured narrative followed by structured scale; drawings	64% recalled "near-death experiences" (being out of the physical body; seeing body from above; darkness; travelling in a tunnel; returning to body). Fragmented narratives. 0% of comparison group recalled near-death experiences.
(Corbo, 1985)	14	12–16	Inc: intubation ≥ 5 hr	1–10 days	Semi-structured interview	86% accurate recall of intubation (feelings, procedures, purpose, location); 14% were confused.
(Corbo & Abu-Saad, 1984)	8	7–13	Inc: cardiac surgery, intubation ≥ 5 hr	1–3 days	Semi-structured interview	88% recalled intubation, 86% were confused, 63% had negative feelings towards intubation, 25% identified something positive about intubation.
(Barnes, 1975)	13	6–13	Inc: cardiac surgery	3–4 days	PICU observations, child drawings, & semi-structured interview	Negative recollections (e.g., fear, pain, anger, boredom, confusion), detailed recall of events happening to themselves and others, recall of dreams, misperceptions of suctioning and location of tube

Inc, inclusion criteria; Exc, exclusion criteria; Comp, comparison group; ICU, intensive care unit; PTSD, post-traumatic stress disorder.

lumbar puncture. Salmon, McGuigan, and Pereira (2006) also found that children provided with comprehensive information about an invasive medical procedure plus distraction (a cartoon video) recalled more information, appraised the procedure as less painful, and were less distressed relative to standard care. Distraction alone was ineffectual in reducing distress. These studies suggest that memory and appraisal-based strategies may be promising in the prevention of children's distress following medical care.

Discussion

While the past decade has seen significant progress in our understanding of children's psychological responses following PICU admission, the scientific standing of the epidemiology, aetiology, and course of PTS is still in its infancy. Nonetheless, some tentative conclusions can be drawn from the literature reviewed: (1) PICU admission presents a variety of disease-related, treatment-related, and environment-related stressors for children; (2) a significant minority of children are at risk of adverse post-traumatic outcomes up to 12 months following critical care admission; (3) acute symptoms may persist over several months without intervention; (4) it is unclear whether PICU admission increases vulnerability to PTS relative to general care ward admission and other trauma; (5) pre-admission psychopathology, subjective disease severity and threat to life, non-elective admission, aggressive treatment, reduced family contact and parental PTS and psychopathology appear to increase vulnerability to PTSD; (6) age, gender, objective disease severity, and length of PICU are not consistent risk factors; (7) factors related to processing, understanding, appraisal, and recall of traumatic event may be relevant to children's PTS; (8) the PICU presents a number of unique factors that may interfere with children's processing and recall of events; and (9) as in adults, delusional recall appears to predict PTS following PICU admission.

The recent direction in research towards memory and cognitive factors is consistent with our understanding of risk factors that appear to reflect children's subjective experience of PICU and their underlying ability to appraise and cope with the admission. It appears that the accuracy of children's PICU recall is less important in influencing subsequent PTS than their interpretation of what has happened to them. Recall of confusing and unreal events (delusional recall) in particular may be associated with PTS, although it is unclear whether these memories directly influence PTS responses or whether other factors such as delirium, sleep disruption, sedation, and analgesia are responsible for both delusions and PTS. Still, there are several methodological and conceptual limitations within the extant literature, so the conclusions of this review should be considered preliminary.

Limitations of Existing Research

There are several limitations within the existing studies that require consideration. Most studies have relied solely on questionnaires, rather than diagnostic interviews, to assess PTS in children. Checklists do not enable explanation or clarification and thus may affect children's understanding and accurate endorsement of symptoms. Furthermore, these questionnaires have not been validated in paediatric critical illness survivors. Many studies used the Impact of Event Scale, which was developed for use in adults and has problematic psychometric properties in this cohort (Rennick et al., 2002).

In addition, most existing studies have employed small sample sizes, are cross-sectional, and/or retrospective in design, reflecting difficulties in researching this sensitive cohort. The time frames for assessment vary enormously both within and across studies, and the samples vary in terms of children's age, reason for admission (diagnosis and elective status), and prior PICU admissions. No studies examined the effect of prior trauma, prior PICU admissions, or prior medical status as potential risk factors. Some included non-PICU children in their samples, and some sample children from specific diagnostic groups. These weaknesses limit our ability to draw conclusions regarding the prevalence and course of PTS and associated risk and protective factors. The detection of important differences between PICU and comparisons groups is also limited, which affects the focus of future studies attempting to delineate particular stressors for children in the medical trauma literature.

Directions for Future Research

Significant gaps remain in our understanding of PTS in PICU patients. In particular, there is a need to better understand the prevalence, onset, and course of PTS and the impact on functioning and developmental trajectories. Exploration of the presentation of PTS in PICU survivors is warranted as PICU presents unique and often prolonged stressors. Longitudinal studies are of particular importance to assess long-term psychological and physical outcomes and identify early predictors of later distress. Increased use of developmentally sensitive diagnostic interviews and larger samples would be a welcome addition to the literature, as would validation of existing screening and distress measures in PICU patients.

There is also a need to delineate the contributions of pre-admission, disease-related, treatment-related, and environment-related factors to vulnerability, particularly

those amenable to intervention. Studies should seek to include: prior trauma exposure (especially medical), parental and child premorbid psychological status, admission status, subjective and objective ratings of disease severity, pain, delirium, sedation, invasive procedures, sleep, exposure to distressing events, and parental PTS (which may be related to the PICU admission or events leading to the admission). This will ultimately lead to the development of screening measures to target those most at risk at PICU discharge. The association between parental factors and PTS in children also warrants further attention. As one of the most consistent risk factors for PTS in traumatised children, delineation of important factors may lead to better screening and intervention strategies (e.g., inclusion of parents in screening and treatment).

The recent focus on memory and cognitive factors also appears promising in identifying children at risk of distress. Associations between recall, appraisal, and distress should be further investigated. In particular, longitudinal studies investigating memory stability over time and reciprocal influences of PTS and recall, and PTS and appraisals, are warranted. Identification of aspects of PICU treatment and environment that impact on children's processing of events would also further our understanding of the impact of recall and appraisal on children's PTS following PICU admission.

With a greater understanding of these issues, development and implementation of prevention and early intervention strategies will be a focus for the future. Of particular interest may be interventions aimed at increasing accurate contextual understanding and recall of PICU, although the focus at present should remain on identification of vulnerability factors and screening for those at risk. Although there are many challenges in working with this population, there is the potential to improve the psychological and emotional outcomes of PICU survivors and potentially prevent a failure to make appropriate gains in development.

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