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Pattern of injury in child fatalities resulting from child abuse

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ABSTRACT

According to the US Department of Health and Human Services, in 2005, an estimated 1460 children died of maltreatment. The purpose of this study is to further examine the pattern of bony injuries in child maltreatment fatalities, with an emphasis on the prevalence of antemortem fractures and the presence of associated perimortem fractures. The sample was 162 male and female children. The majority of the data were collected from the case files of the NC Child Fatality Prevention Team at the Office of the Chief Medical Examiner in Chapel Hill, North Carolina (n = 152) spanning from 2000 to 2005. An additional 10 cases from 2001 to 2006 were included from the Charleston County Coroner's Office, Charleston, SC. Six age categories were used in this study: 0–3 months, 4–6 months, 7–9 months, 10–16 months, 17 months to 2 years, and 2–6 years. Lesions were documented and categorized into four general body loci: craniofacial, thoraco/abdominal, appendicular, and multiple. The peak age categories of death were 0–3 months (25%) and 2–6 years (19%), with 50% of deaths occurring in infants 9 months old or younger. The body locus most frequently affected was craniofacial.

Either intentional or unintentional (accidental) trauma may lead to an injured child. When the child presents at a medical facility, alive or dead, many steps are involved in the evaluation of traumatic injuries in order to accurately determine the etiology of the trauma. When evaluating injuries in young children, physicians should consider nonaccidental trauma as an etiology of trauma. According to the US Department of Health and Human Services, the Administration for Children and Families, in 2005, there were an estimated 1460 fatalities due to child maltreatment. Of these, 42.2% were as a result of neglect only, 24.1% were caused by physical abuse only, and 27.3% by a combination of types. The remainder of deaths included sexual abuse, psychological abuse, medical neglect, other, and unknown causes. Children younger than 4 years old accounted for 76.6% of all maltreatment fatalities, with 41.9% of these deaths occurring in infants [1]. Child fatality rates per 100,000 children in the United States for years 2000–2005 are presented in Table 1. The data show a slight rising trend between 2000 and 2004.

Skeletal trauma is usually limited to cases where there is clinical evidence of physical abuse by history of living examination. The extremities, skull, and ribs are the most common sites of fractures in physical abuse cases [2]. The study by Merten et al. [3] performed in living children concluded that skeletal surveys have a significant but limited role in identification and documentation of child abuse. The study by Collins and Nichols [4] of homicides of children under 5 years of age, attempted to develop a common profile of a pediatric homicide. They found that 45% of homicides were due to head trauma, followed by asphyxia, including drowning at 25%, and lastly other trauma and poisoning (primarily by carbon monoxide).

Head injury is recognized as the leading cause of death of abused children younger than 2 years old [5,6]. The study by Rubin et al. [5] examined high-risk criteria, which included rib fractures, multiple fractures, facial injury, or age less than 6 months, and if such criteria were found in children with normal neurological exam. Screening for occult head injury was undertaken using head CT or MRI. Rubin et al. found that 37.3% (19/51) patients had an occult head injury, including scalp swelling, skull fracture, and intracranial injury. Skeletal survey alone missed 26% (5/19) of the cases. It has been estimated that the failure to diagnose child abuse on initial presentation may result in a 30–50% chance of repeated abuse and a 5–10% chance of death [2].

The purpose of the present study is to further examine the pattern of bony injuries in child maltreatment fatalities, and to attempt to determine the prevalence of antemortem (healed or healing) fractures and the presence of associated perimortem (acute) fractures. It also serves as a descriptive study of a population of child homicides.

1. Methods

The sample was 162 male and female children, ages 0–6 years of age. The majority of the data were collected from the homicide autopsy case files, which

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Table 1
Child fatalities rates per 100,000 children, USA, 2000–2005.

Reporting year	Number of child fatalities	Rate per 100,000 children	Estimated child fatalities
2000	1306	1.84	1330
2001	1373	1.96	1420
2002	1397	1.99	1450
2003	1317	1.92	1400
2004	1386	2.03	1490
2005	1371	1.96	1460

Adapted from child maltreatment (2004, 2005) [1].

include associated reports (e.g. police, radiological, etc.) of the NC Child Fatality Prevention Team at the Office of the Chief Medical Examiner in Chapel Hill, North Carolina ($n = 152$). An additional 10 cases were included from the Charleston County Coroner's Office in Charleston, South Carolina. The data recorded consists of manner of death (which were all known homicide cases), age, sex, race, county, and trauma (both perimortem and antemortem injuries). The cause and mechanism of death were known and included abusive head trauma, blunt force trauma, gunshot wounds, shotgun wounds, alcohol poisoning, asphyxia, suffocation, drowning, hyper- and hypothermia, carbon monoxide poisoning, strangulation, and thermal injuries. Recognizing the larger number of infants in the study, 6 age categories were assigned as: 1 (0–3 months), 2 (4–6 months), 3 (7–9 months), 4 (10–16 months), 5 (17 months to 2 years), and 6 (2–6 years). These categories are also loosely based on developmental stages. Each individual's lesions were documented and categorized into one of four general body loci: craniofacial, thoraco/abdominal, appendicular, and multiple (any combination of the previous). The prevalence of trauma and distribution of injury patterns for biological and demographic categories (e.g. age, sex, race, geographic regions, and month of death) were tested for independence and significance with simple frequencies and chi-square tests. In addition, the data from this study will be compared to the NC Vital Statistics data. The analyses were conducted using the software SSPS 16 for Windows [7].

2. Results

Fig. 1 shows that 50% of deaths occurred in infants 9 months old or younger. The peak age categories were 0–3 months (25%) and 2–6 years (19%). Fig. 2 shows that most of the deaths occurred in the Piedmont and Inner Coastal Plain regions of North Carolina, corresponding to state demographic population data. African Americans account for 47.5% of deaths, while children of European descent account for 38.3% and Hispanics for 14.2%. In this study, it was found that many more boys (68%) than girls (32%) died from maltreatment. Death rates were highest in the months of July (13.6%), August (11.7%) and December (13.6%). Consistent with previous studies, the craniofacial area (47%) was the most frequent fatally injured body region, with the thoraco/abdominal region (8%) being an unusual area for isolated fatal injury (Fig. 3).

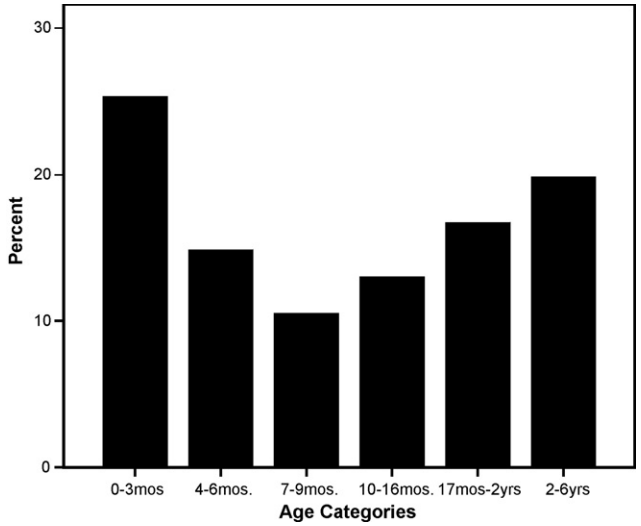

Fig. 1. Age category by percent frequency.

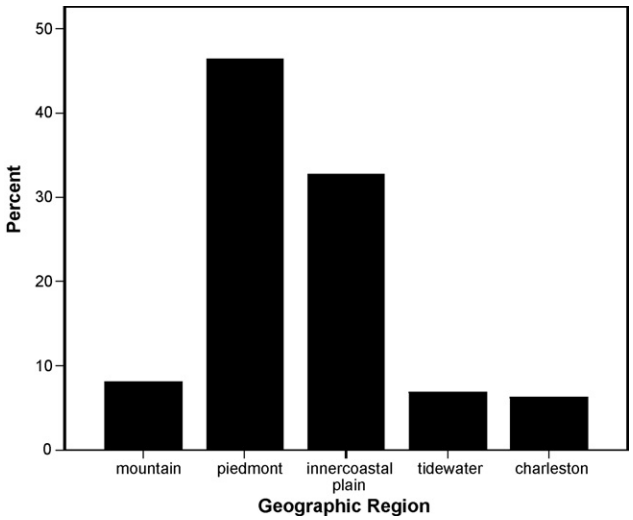

Fig. 2. Region by percent frequency.

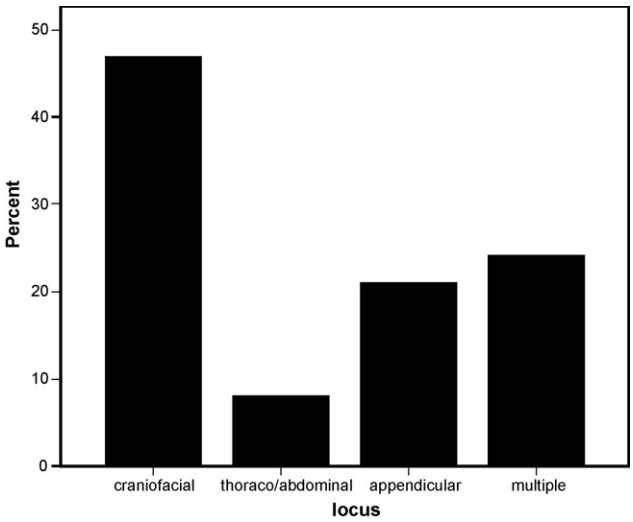

Fig. 3. Trauma locus by percent frequency.

Surprisingly, 76% of the cases did not show any antemortem fractures and 64% did not show any perimortem fractures. A chi-square test for independence, however, revealed a significant association ($p < .05$) between antemortem and perimortem fracture frequencies. For those children *without* antemortem fractures, only 34/123 = 28% had perimortem trauma. For those children *with* antemortem fractures, 24/39 = 62% had concomitant perimortem fractures (Table 2). When comparing the data from this study to total statewide deaths from the North Carolina State Center for Health Statistics [8], it was found that proportionately more minority children than white children are dying from intentionally violent deaths (Table 3).

Table 2
Crosstabulation of antemortem and perimortem fracture frequencies for the study sample.

	Perimortem fracture		Total
	No	Yes	
Antemortem fracture			
No	89	34	123
Yes	15	24	39
Total	104	58	162

Table 3
Racial distribution and frequency of children born in North Carolina in 2000–2005, statewide deaths of children 0–4 years in 2000–2005, and NC Child Fatality Prevention Team children 0–6 years in 2000–2005.

	NC statewide total births, 2000–2005	NC statewide total deaths, 0–4 years, 2000–2005	NC child fatality prevention team 0–6 years, 2000–2005
White	519,606	3714	62
Minority	197,165	3213	100

3. Discussion

The results of this study showed several interesting trends. The peak age-at-death categories were 0–3 months (25%) and 2–6 years (19%), which could reflect newborn stress and coincide developmentally with independent stages, respectively. Toddlers are particularly vulnerable to evoking hostile care from their parents during this developmental phase when they show defiance and self-assertiveness in their attempts to seek autonomy [9]. Our result showing that boys are more likely to die of physical abuse than girls coincides with conclusions by Sobsey et al. [10] who found that more boys were physically abused than girls. A racial bias is also seen in the results. Chi-square tests for independence show that not only are significantly more ($p < .0001$) minority children dying in North Carolina compared to white children but also significantly more ($p < .0001$) minority children are dying as a result of specifically abusive causes.

In child maltreatment cases, fractures are the second most common presentation of physical abuse after soft tissue lesions [2,11,12]. The most commonly inflicted fractures in infants are the ribs followed by long bone metaphyses [12,13]. Radiologic skeletal surveys have been the most common form of diagnostic procedure used to evaluate traumata in both clinical and postmortem maltreatment cases [14–16]. Krishnan and co-workers found that more than 70% of abused infants (<1 year) had multiple fractures in different stages of healing and fractures were present 50% of all abused children [17,18]. A single fracture may be seen in an estimated 50–65% of cases, two or three fractures in 33% of cases and multiple (>3) fractures in 17% of all cases of child physical maltreatment [19,20]. Belfer and Klein [14], in their clinical sample ($n = 96$), per contra, found skeletal trauma in only 26% of the cases of suspected abuse. Significantly, skeletal trauma was not detected by the pediatrician prior to the skeletal surveys and out of 25 cases of skeletal trauma, 20 were infants. Kleinman et al. [16], in their postmortem study of 31 infants, documented 165 fractures. Fifty-eight percent of the fractures were identified by skeletal survey and 98% were diagnosed with specimen radiography. They also noted that rib head fractures were difficult to assess. However, in the present study there was not a strong association of abuse deaths with antemortem or perimortem fractures. Notably, in only 24% of our sample were there any antemortem fractures suggesting that radiographic skeletal surveys alone are not an effective method for identifying or predicting abuse.

Fractures in infants and young children, the population at highest risk for maltreatment, are most often subtle and difficult to detect [21]. A contributing factor to the missed diagnosis is related to the child's age. Because of the increased vascularity and osteogenic activity of children's bones, they heal more quickly than adult bones [22]. Furthermore, the rate of bone healing is directly related to the child's age with more rapid healing occurring in the youngest [22]. For example, in a newborn, femoral diaphyseal fractures heal in 3–4 weeks, while in an adolescent it would take 12–16 weeks to heal [22,23]. In addition, bone turnover is even faster in the metaphyses [21]. Thus, "symptomatic" inflicted metaphyseal injuries (or classic metaphyseal lesion) may be difficult to locate if the injury is not surveyed within the healing window. When compared to adult bone, the diaphysis of a child is thinner and more porous, which helps to prevent complete fractures and accounts for the higher frequency of greenstick fractures and plastic bending injuries in children [22,23]. Swischuk and Hernandez [21] stress the importance and value of using comparative views to detect commonly missed fractures in children such as plastic bending fractures, hairline fractures, impaction fractures, subtle epiphyseal–metaphyseal Salter–Harris fractures and subtle angle buckle fractures. This accelerated healing could be a factor influencing the results of our study. It is likely that these children did in fact receive multiple insults, but the fractures were no longer detectable. Another contributing factor could be the inability to detect antemortem or perimortem fractures using conventional diagnostic procedures. Dedouit et al. [24] found that multislice computed tomography (MSCT) was a more effective screening method for evaluating skeletal injuries than conventional X-rays. In a swine model study comparing autopsy, radiological, and tomographic diagnostic procedures, Cattaneo et al. [25] reported that traditional radiology detected only 47% of fractures, while CT scans detected 34% and autopsy 65%. Furthermore, they found that CT scans over detected fractures. The results of our study further underscore the need for additional, more aggressive and combined screening techniques, such as repeat radiology and bone scans, MSCT, MRI scans, autopsy and full skeletal surveys, and serum or cerebrospinal markers in order to detect injuries in cases of suspected abuse.

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