The Efficacy of Hair and Urine Toxicology Screening on the Detection of Child Abuse by Burning

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Abuse by burning is estimated to occur in 1 to 25% of children admitted with burn injuries annually. Hair and urine toxicology for illicit drug exposure may provide additional confirmatory evidence for abuse. To determine the impact of hair and urine toxicology on the identification of child abuse, we performed a retrospective chart review of all pediatric patients admitted to our burn unit. The medical records of 263 children aged 0 to 16 years of age who were admitted to our burn unit from January 2002 to December 2007 were reviewed. Sixty-five children had suspected abuse. Of those with suspected abuse, 33 were confirmed by the Department of Health and Human Services and comprised the study group. Each of the 33 cases was randomly matched to three pediatric (0–16 years of age) control patients (99). The average annual incidence of abuse in pediatric burn patients was 13.7 ± 8.4% of total annual pediatric admissions (range, 0–25.6%). Age younger than 5 years, hot tap water cause, bilateral, and posterior location of injury were significantly associated with nonaccidental burn injury on multivariate analysis. Thirteen (39.4%) abused children had positive ancillary tests. These included four (16%) skeletal surveys positive for fractures and 10 (45%) hair samples positive for drugs of abuse (one patient had a fracture and a positive hair screen). In three (9.1%) patients who were not initially suspected of abuse but later confirmed, positive hair test for illicit drugs was the only indicator of abuse. Nonaccidental injury can be difficult to confirm. Although inconsistent injury history and burn injury pattern remain central to the diagnosis of abuse by burning, hair and urine toxicology offers a further means to facilitate confirmation of abuse. (J Burn Care Res 2009; 30:587–592)

Child abuse defined as neglect, physical abuse, sexual abuse, and psychological abuse is not uncommon and presents a universal problem.[1–3] In 2001, there were more than 903,000 reports of child abuse and neglect within the United States, including 1300 fatalities.[4] Children who are abused suffer both short- and long-term sequelae and are at risk of developing behavioral and functional difficulties.[2] Childhood abuse is associated with several adult health-risk behaviors such as alcoholism and drug abuse, as well as physical and mental health disorders in adulthood.[2] The physically abused child is also likely to perpetuate abuse as an adult.[5]

Abuse by burning is estimated to occur in 1 to 25% of children admitted with burn injuries annually.[6–8] Abuse by burning is often difficult to verify, suggesting that many cases remain undetected.[3,9] The burn physician and nurse therefore rely on inconsistencies within the history of the injury, the burn injury pattern, and the developmental ability of the patient to confirm suspicions of abuse. Inconsistencies in these areas raise the suspicion of abuse.[10,11] Laboratory and radiographic tests are then selectively obtained to confirm or deny the suspicion of abuse. The usual tests include radiographic skeletal surveys, CT scans, and ophthalmic examinations in young infants. Additionally, urine and hair samples of the child can be

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obtained to test for exposure to illicit drug use by caretakers because parental illicit drug use is a major risk factor in child abuse. These additional tests may increase the physician's ability to detect child abuse. Hair sampling has the ability to detect drug exposure over time before the burn-related admission. Although hair sampling is used in forensic medicine, workplace drug testing, and rehabilitation drug testing, there are limited studies that have looked at its efficacy in documenting child abuse.[12,13]

To determine the impact of hair and urine toxicology on the identification of child abuse, we performed a retrospective chart review of all pediatric patients admitted to our burn unit. Additionally, we sought to determine factors associated with nonaccidental pediatric burns for potential incorporation into a screening tool to maximize and standardize our detection of child abuse.

MATERIALS AND METHODS

We performed a retrospective review of the medical records of 263 children aged 0 to 16 years who were admitted to our burn unit from January 2002 to December 2007. Records were reviewed for demographics, family characteristics, injury history including time of medical assistance, burn cause and distribution, presence of caretakers at the time of the injury, hospitalization course, and child abuse workup. Suspected abuse in 65 children was established by review of our hospitals abuse registry and/or medical record review for external identification codes (E-Codes 967.0–967.9). Of those with suspected abuse, 30 were not confirmed by the Department of Health and Human Services (DHS) and two were unknown (reported by external hospitals and therefore by law we could not determine if their abuse was confirmed). The final 33 with confirmed child abuse by DHS comprised the study group. Each of the 33 cases was randomly matched to three pediatric control patients (99). The controls were randomly selected from 3 years by choosing every other patient admitted from January to December of each year.

By law, all burn children suspected of abuse are reported to DHS in Iowa. Petitions of abuse may be filed by any member of the team, however, social work services usually completes the report. Our University's childhood abuse workup includes additional ancillary tests when indicated. These tests include skeletal survey, CT scanning, retinal examination, urine drug screening, and hair analysis. Urine and hair analysis have been obtained in pediatric burn cases since August 2004. However, they were not consistently obtained until March 2007 when our childhood abuse workup policy was reviewed. Blood alcohol levels were not routinely obtained during this study; only one patient had a blood alcohol level obtained. A general pediatrician with specialty training in child abuse and neglect is a member of our child abuse team (R.O.). She is consulted on most of the children with suspicion of abuse.

Hair samples were sent to the United States Drug Testing Laboratories, Inc. (Des Plaines, IL). Analysis required a 1.5 in lock of hair (20 mg). Initial analysis was performed with enzyme-linked immunoassay and confirmed with either gas or liquid chromatography and mass spectrometry.[14] The test detected 1 to 14 drugs of abuse. For our child abuse workup, we ordered a child guard analysis that obtains nine drug levels (amphetamines [including methamphetamine and ecstasy], cocaine [including benzoylecgonine], opiates [including hydrocodone and oxycodone], phencyclidine, tetrahydrocannabinol [THC, including carboxy-THC and native-THC], barbiturates, benzodiazepines, propoxyphene, and methadone). Urine samples were analyzed at our hospital by fluorescent immunoassay (Biosite, San Diego, CA). Urines were tested for amphetamines (including methamphetamine), benzodiazepines, cocaine, opiate, phencyclidine, THC, and tricyclic antidepressants. The records of all children with urine samples positive for opiates and benzodiazepines were reviewed for administration of these substances at the referring hospital.

Children were identified as abused if their abuse was confirmed by an independent investigation of the injury by the DHS. To test for seasonal variation of abuse, the burn injuries were coded as occurring in the winter (October–March) or summer (April–September). To analyze the significance of burn patterns of injury, burns were classified by anatomic location: face, torso (anterior chest and abdomen), upper extremities, hands, and lower extremities (back, perineum, genitalia, lower extremities, and feet). Burn injuries were further classified as being anterior or posterior in reference to the anatomical position. Finally, the scald injuries were classified as secondary to hot tap water (bathing injuries) or another agent (kitchen or spill injury secondary to food substance).

All statistical analyses were performed using SAS version 9.1 (SAS Institute Inc., Cary, NC). Cases and controls were compared using logistic regression analysis. Both backward and forward selections were used to enter all variables found to be significant on univariate analysis into a multiple logistic regression equation. Annual trends in child abuse and performance of ancillary testing were determined by the

Cochran-Armitage test. Data were presented as means ± standard deviation with the range given in parenthesis when appropriate. Significance was determined at $P < .05$. The study was approved by our institutional review board.

RESULTS

Study Group Characteristics

During the study period, a mean of 38 children per year were admitted annually to the burn unit (18.2% of total annual admissions). Nearly two thirds of the 99 randomly selected control patients and the 33 abused patients were younger than 5 years (66.5 ± 63.2 months; Table 1). The mean burn size of the 132-patient study group was 9.3 ± 11.4%. A majority of patients had two parents living in the home and ≥2 siblings. These patients were injured during the day, and their biologic parent was present greater than 80% of the time. The injuries were more likely to be unilateral on the anterior surface of their body and asymmetric. Almost one third underwent operative intervention and the mean length of stay was 5.9 ± 7.3 days.

Table 1. Demographic and burn-related variables by case-control status

Variable	Cases, N = 33 (%)*	Controls, N = 99 (%)*
Age (<5 yr)	29 (87.9)	54 (54.5)
Sex (male)	18 (54.6)	74 (74.7)
Race (non-white)	6 (18.2)	16 (16.2)
Marital status (single)	19 (57.6)	25 (25.2)
Nonbiologic parent present at time of injury	6 (18.2)	25 (25.2)
≥2 siblings	21 (63.6)	61 (64.2)
Season of burn (winter)	20 (62.5)	37 (37.4)
Time of burn injury (2400–1400)	13 (40.6)	26 (29.6)
Body surface area ≥10%	11 (33.3)	26 (26.3)
Operative intervention	12 (36.4)	27 (27.3)
Symmetry of the burn	19 (57.6)	31 (31.3)
Posterior location of burn	18 (54.6)	16 (16.2)
Bilateral burns	18 (54.6)	11 (11.1)
Lower extremity burns	16 (58.5)	22 (22.2)
Burn etiology		
Scald	23 (50.0)	43 (43.4)
Contact	3 (11.4)	11 (11.1)
Others	7 (21.2)	45 (45.4)
Specific scalding agent		
Hot tap water†	15 (57.7)	14 (32.6)
Others	11 (42.3)	29 (67.4)
Positive ancillary test‡	11 (33.3)	2 (4.9)

* Frequency (percentage); missing values were dropped from the analysis.
† The percentage of hot tap water scald burns is obtained by dividing hot tap water burns by the number of scald burns less the number of contact burns in each group.
‡ Ancillary tests include hair and urine toxicology, radiologic workup, and ophthalmologic screening.

Variables Associated With Abuse

The average annual incidence of abuse in pediatric burn patients was 13.7 ± 8.4% of total annual pediatric admissions (range, 0–25.6%). There was no significant variation in the annual incidence of abuse throughout the study period. There were eight variables associated with abuse on univariate analysis (Table 2). These included four demographic variables (age, male sex, hot tap water cause, and winter season) and four injury-related variables (symmetric injury, lower extremity burn, posterior body surface burn, and bilateral burn injury). Of these variables, only hot tap water cause, age younger than 5 years, bilateral and posterior location of injury remained significant on multivariate analysis (Table 3).

Ancillary Testing for Abuse Confirmation

Positive ancillary testing was not significantly associated with confirmed abuse on either univariate or multivariate analysis. Although ancillary testing was performed more frequently in the latter years of the study, the increase in testing was not significant ($P = .13$).

Table 2. Univariate analysis of factors related to child abuse by burning

Variable	Estimate (OR)	95% CI	*P*
Age (<5 yr)	6.4	1.11–6.82	.000
Male gender	2.5	1.09–5.61	.031
Race (non-white)	1.3	0.46–4.77	.607
Marital status (single)	1.0	0.87–6.14	.891
Nonbiologic parent present at time of injury	1.3	0.44–3.66	.667
Two or more siblings	1.0	0.45–3.34	.256
Season of burn (winter)	2.8	1.23–6.36	.015
Time of burn (2400–1400)	0.6	0.26–1.42	.254
Burn surface area ≥10%	1.4	0.60–3.29	.434
Symmetry of burn	3.0	1.32–6.70	.008
Posterior location of burn	4.2	2.61–11.85	.000
Bilateral burns	5.6	3.79–12.30	.007
Lower extremity burns	3.3	1.44–7.56	.005
Scald etiology	3.0	1.18–7.49	.021
Hot tap water agent of scald burn	5.4	3.60–10.99	.000
Positive Ancillary test*	0.7	0.55–13.42	.913

OR, odds ratio; *CI*, confidence ratio.
* Ancillary tests include hair and urine toxicology, radiologic workup, and ophthalmologic screening.

Table 3. Multivariate regression analysis of factors related to child abuse by burning

Variable	Estimate (OR)	95% CI	*P*
Hot tap water agent of burn	4.0	1.43–6.18	.014
Age (<5 yr)	3.4	1.29–6.36	.004
Bilateral burns	3.0	1.70–7.26	.000
Posterior location of burn	2.6	1.30–4.16	.000

OR, odds ratio; *CI*, confidence ratio.

The increase in hair sample analysis and urine testing were largely responsible for this trend. Ancillary testing was performed in 32 (97.0%) of the abused population and 41 (44.0%) of the matched controls. Among the cases, 25 (75.8%) had skeletal surveys, 23 (69.7%) had urine testing, 20 (60.6%) had hair testing, and 11 (33.3%) had ophthalmologic examinations. Only 13 (39.4%) abused patients had positive ancillary tests. These included four (16%) skeletal surveys positive for fractures and 10 (45%) hair samples positive for drugs of abuse (one patient had a fracture and a positive hair screen). In three patients (9.1%) who were not initially suspected of abuse but later confirmed, positive hair test for illicit drugs was the only indicator of abuse. In the abuse cases, the drugs identified included cocaine in six children, benzoylecgonine in five children, cannabinoids in three children, and methamphetamine in one child. Four children tested positive for more than one drug. In the matched control group, there were two urine tests positive for illicit drugs; one for ethanol in a 16-year old patient and one for THC in a 16-year old patient. There were no positive hair tests in the control group and no positive eye examinations in either group.

DISCUSSION

Although child abuse was documented in the 1940s, it was not until the landmark article by Kempe et al in 1962[15] describing "The battered child syndrome" brought widespread attention to the problem of child abuse. This heightened recognition of child abuse led to the passage of legislation in all 50 states mandating the reporting of child abuse and neglected by the late 1960s.[16] Detecting abuse is integral in stopping the cycle and getting needed help for children and families. Many inflicted injuries, however, go undetected.[3,9] Detection of abuse depends first on the recognition of suspicious injuries and second on the acquisition of ancillary tests.[2] We undertook this study to better characterize children admitted to our burn unit with abusive burn injuries and to determine the added efficacy of hair and drug toxicology on the reporting of abuse.

Inflicted burns share common etiologic causes and burn patterns. Because the passage of the legislation mandating the setting of new hot water heaters at 125° Fahrenheit, hot tap water burns have become uncommon.[17,18] Inflicted burns, however, are more likely than accidental burns to be the result of tap water.[10,11,19] In our study, children presenting with hot tap water scald burns were 2.8 times more likely to be the result of abuse. In addition to the cause, the pattern of burn injury is often suggestive of abuse. Inflicted injuries are usually present with an immersion pattern,[7,11,20] involving buttocks, perineum, lower extremities, or combination of the above.[21] Similar patterns have also been reported and cited in many publications.[10,22–24] In our study, inflicted burns were 3.0 times more likely to be bilateral and 2.6 times more likely to involve the posterior body surfaces. Lower extremity burns and symmetric burns were also related to abuse, although not independently.

However, the cause and pattern of injury distribution alone may not be sufficient to diagnose abuse. In a small study, Titus et al[25] reported on three consecutive children with lower extremity hot tap water burns that were ruled as accidental injuries. Other burn characteristics such as symmetry, uniform depth, and absence of splash marks are important variables that have been associated with abusive burn injuries.[6,11,20,26] Their presence should be documented in the physical examination. Secondary to the retrospective nature of this study, only symmetry of the burn wound could be accurately retrieved from the medical records. Symmetry of the burn wound was 3.0 times more likely to occur in our burn children on univariate analysis alone.

Several demographic risk factors have also been linked to abuse. One of these risk factors is age of the child. In this study, age was independently related to abuse with children less than 5 years being 3.4 times more likely to suffer an inflicted injury compared with older children. Bennett and Gamelli[27] previously reported that children who were 3 years or younger were at higher risk for abuse. Other reports site ages between 2 and 5 years as being the susceptible age for abuse.[9,10,28] A second demographic risk factor that has been reported is sex, with boys being more likely to present with inflicted injuries than girls.[5,6,28] In our study, boys were 2.5 times more likely to be abused than girls, however, sex was not independently associated with abuse on multivariate analysis. Only the study by Hammond et al[29] found more inflicted injuries in girls with a ratio of 1.6:1.

Seasonal variation of abuse has not been previously reported in inflicted burn injuries. In our study, abuse was 2.8 times more likely to occur in the winter

months than during the summer months on univariate analysis alone. We speculate that this was secondary to the confinement of the family at home. We were unable to show a relationship of time of the day to abuse. Thomas et al[28] reported an association of decreased incidence of child abuse on Sundays and during the National Child Abuse Prevention month.

To our knowledge, the efficacy of uniform hair and urine toxicology in detecting child abuse has not been examined in burn children. There are case reports of the selective use of hair toxicology in pediatric abuse or custody cases.[13,30] As parental drug use has been associated with child abuse, it seems imperative that the child with suspected abuse is tested for drug exposure. The detection of exposure to illicit drugs in either the hair or the urine of children is sufficient for abuse confirmation in Iowa. In our study three children with no initial suspicion of abuse, either from the injury pattern or from the injury history given by the caregiver, had positive hair toxicology. DHS then subsequently confirmed abuse. We were unable to show an association between positive ancillary testing and confirmed child abuse, including hair and urine toxicology, in our study. We suspect this is secondary to the absence of this testing in greater than one third of the population leading to inadequate sample size.

Unlike urine, hair testing has the advantage of detection of remote drug exposure. Hair toxicology, however, has several short comings that should be mentioned.[31] It is currently not possible to determine if a positive hair sample is secondary to environmental exposure or ingestion. However, when used for determining the presence of child abuse, this distinction is not important because protecting children from both environmental exposure and actual ingestion is the parents' responsibility. Positive hair toxicology proves significant environmental exposure, placing the child in a dangerous situation. Race also affects the threshold of drug detection in the hair. Darker hair has greater absorption than lighter hair potentially leading to more false negatives in patients with lighter hair. Moreover, hair toxicology requires a 1.5 in lock of hair that is not always possible in children. Furthermore, test results are not immediately available and often come back after discharge, potentially exposing the child to further harm. Finally, the test is expensive (hospital charge is $450.00). The expense may prohibit uniform testing. However, as child abuse tends to be repeated, missed injuries may result in life-threatening injuries more in future.[32,33] The future cost to society to treat potential physical, psychiatric, and substance abuse issues in survivors of child abuse, although unknown, is probably greater than the cost of a well-executed child abuse workup.

This study had several limitations. This was a single-center study with a limited number of cases. Further, because it was a retrospective study and relied on accurate documentation, we were unable to consistently determine the impact of an incompatible burn mechanism or fluctuating narrative of the burn injury on the diagnosis of abuse. Additionally, we were unable to assess the impact of parental stressors or socioeconomic status of the family on abuse. These variables remain central to the initial suspicion of child abuse but can only be accurately assessed prospectively. Furthermore, nearly one half of the suspected abused children were subsequently not confirmed by DHS. This is a vulnerable population that requires more study. Finally, a consistent protocol for child abuse was not followed until the latter part of the study. Therefore, it was difficult to determine the impact of ancillary testing on reporting child abuse.

In conclusion, this is the first study to our knowledge that has looked at the impact of drug toxicology testing on abuse confirmation in pediatric burn patients. We have shown that age younger than 5 years, hot tap water cause, and burns occurring bilaterally or involving the posterior body surfaces should raise the suspicion of child abuse. Although hair testing detected abuse in 9.0% of children in whom we did not initially suspect abuse, urine toxicology screening did not appear to be beneficial in burned children. Physicians are the initial caregivers and team leaders who evaluate all burn admissions, and therefore play a pivotal role in detecting and reporting abusive burn injury.[34] A prospective study is underway to further investigate these variables and evaluate the efficacy of hair toxicology testing to improve the detection rate of child abuse in the hope of protecting children and helping families.

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