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Research article

Children with burns referred for child abuse evaluation: Burn characteristics and co-existent injuries

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ABSTRACT

Intentional burns represent a serious form of physical abuse that must be identified to protect children from further harm. This study is a retrospectively planned secondary analysis of the Examining Siblings To Recognize Abuse (ExSTRA) network data. Our objective was to describe the characteristics of burns injuries in children referred to Child Abuse Pediatricians (CAPs) in relation to the perceived likelihood of abuse. We furthermore compare the extent of diagnostic investigations undertaken in children referred to CAPs for burn injuries with those referred for other reasons. Within this dataset, 7% (215/2890) of children had burns. Children with burns were older than children with other injuries (median age 20 months vs. 10 months). Physical abuse was perceived as likely in 40.9% (88) and unlikely in 59.1% (127). Scalds accounted for 52.6% (113) and contact burns for 27.6% (60). Several characteristics of the history and burn injury were associated with a significantly higher perceived likelihood of abuse, including children with reported inflicted injury, absent or inadequate explanation, hot water as agent, immersion scald, a bilateral/symmetric burn pattern, total body surface area ≥10%, full thickness burns, and co-existent injuries. The rates of diagnostic testing were significantly lower in children with burns than other injuries, yet the yield of skeletal survey and hepatic transaminases testing were comparable between the two groups. This would imply that children referred to CAPs for burns warrant the same level of comprehensive investigations as those referred for other reasons.

1. Introduction

Approximately 70 percent of children who attend hospital with burns or scalds are less than five years of age (American Burn Association, 2014; Kemp, Jones, Lawson, & Maguire, 2014). They sustain unintentional burns when exploring their environment without the cognitive awareness or motor skills to avoid hot household items and liquids and require constant supervision in a safe environment to prevent such incidents (Kemp, Jones, et al., 2014; Shields, McDonald, Pfisterer, & Gielen, 2015; Zou et al., 2015). A proportion of children who have sustained a burn have been physically abused or neglected and

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an estimated 3–24% are referred to child protection services for suspected abuse (Chester, Jose, Aldlyami, King, & Moiemen, 2006; James-Ellison et al., 2009; Kemp, Maguire, Lumb, Harris, & Mann, 2014b; Wibbenmeyer et al., 2014). In addition, children younger than three years of age who sustain a burn from any cause are seven times more likely to suffer from future child abuse or neglect by the age of six years than a case matched control population (Hutchings, Barnes, Maddocks, Lyons, & James-Ellison, 2010; James-Ellison et al., 2009). Burns are therefore both sentinel and significant injuries of maltreatment.

There are few published studies that describe the characteristics of burns amongst children who have been referred to a child protection team especially those who sustain non-scald burns (Kemp, Maguire, et al., 2014; Maguire, Moynihan, Mann, Potokar, & Kemp, 2008).

Although a skeletal survey is indicated for all children under the age of two years with any suspicious injury including bruises and other skin marks in non-ambulatory infants (American College of Radiology (ACR) & Society for Pediatric Radiology (SPR), 2014; Christian & Committee On Child Abuse and Neglect, 2015), studies have shown that rates of skeletal survey completion are relatively low in children with burns (DeGraw, Hicks, Lindberg, & Using Liver Transaminases to Recognize Abuse Study Investigators, 2010), despite a significant prevalence of associated occult fractures (Fagen, Shalaby-Rana, & Jackson, 2014; Hicks & Stolfi, 2007).

This study aims to characterize burns and scalds in children referred to CAPs, determine the likelihood of abuse, the level of associated injuries and which variables are associated with likely abuse together with the rate and yield of diagnostic testing for associated injuries.

2. Methods

2.1. Study design

This is a retrospective secondary analysis of data collected within the ExSTRA research network, methods of which have been published previously (Lindberg et al., 2012). The ExSTRA research network was a prospective, observational, cross-sectional study of children less than 10 years of age referred to 20 US child protection teams for concerns for possible physical abuse between 15 Jan 2010 and 30 Apr 2011. Teams were selected because they chose to participate and endorsed a common screening protocol for the assessment of siblings and contact children. In each center the child protection teams (CPTs) were led by Child Abuse Pediatricians (CAPs). Each child abuse team obtained approval from their respective institutional review board to participate in the parent study with waiver of informed consent. This study of previously collected data stripped of all patient identifiers was determined not to constitute human participants research by the Colorado Multi-Institutional Review Board. CAPs documented the teams' ultimate perceived likelihood of physical abuse using a previously published 7-point scale of the level of concern for abuse (Lindberg, Lindsell, & Shapiro, 2008). Level of concern for abuse was dichotomized as in prior studies (Lindberg et al., 2012). For this analysis we considered levels 5–7 to represent a high likelihood of abuse, and levels 1–4 to represent a low likelihood of abuse to determine the burn characteristics associated with high vs. low concern for abuse. Our sample size did not permit analysis as an ordinal variable since ultimate likelihood of abuse ratings tend to cluster at the poles – e.g. there are relatively few children ultimately rated as indeterminate likelihood of abuse.

2.2. Data abstraction

During the parent study, data were entered prospectively into a secure, web-based data entry form (Quickbase; Intuit, Waltham, Massachusetts). The data collected included demographic features and findings from clinical evaluation and laboratory tests. Investigators were asked to describe the history and the characteristics of injuries in free-text fields. A single researcher (MCP) abstracted relevant data from data fields and the free-text information to determine several characteristics of the burn injury, the history of injury, and the clinical evaluation.

Factors analyzed include the burn type (e.g. scald, contact burn), causative agent (e.g. hot water, iron), recorded mechanism (e.g. spill, touch, immersion), pattern (e.g. circumferential, symmetric), size (i.e. total body surface area [TBSA] affected), depth, and anatomical location. Characteristics of the history included whether there was any reported witnessed or admitted inflicted injury or preceding events (e.g.: child had soiled itself prior to injury, a sibling blamed for the burn, previous burn injury, history of assault, history of fall, sexual abuse), additional injuries, and whether the burn was the primary presenting complaint or identified during clinical evaluation. For characteristics abstracted from free-text fields a second researcher (DN) independently coded a random sample of 10% of the cases, and agreement was measured using Cohen's kappa test.

2.3. Statistical analysis

Descriptive statistics were used to describe prevalence of demographic features as well as history and burn injury characteristics. The distribution of age within the group of children who sustained a burn was compared with the remaining children in the ExSTRA database using Mood's median test. For categorical frequency data, comparisons between groups were made using contingency tables and Chi-squared testing. Associations are expressed by odds ratios with 95% confidence intervals and p-values. Values of $p < .05$ were considered statistically significant. Statistical analyses were performed with IBM SPSS Statistics v20 and the online tool Vassar Stats (vassarstats.net).

Table 1
Demographics and characteristics of all ExSTRA participants ($N = 2890$).

	Burn group participants $n = 215$, 7.4%		Comparison group participants $n = 2675$, 92.6%		OR [burn group vs. comparison group]	95% CI
Age [months]						
0–6	**30**	14.0%	**950**	35.5%	**0.30******	**0.20–0.44**
6–12	**28**	13.0%	**493**	18.4%	**0.66***	**0.44–1.00**
12–24	**66**	30.7%	**408**	15.3%	**2.46******	**1.81–3.35**
24–36	**43**	20.0%	**276**	10.3%	**2.17******	**1.52–3.10**
36–60	**28**	13.0%	**287**	10.7%	1.25	0.82–1.89
60–120	**20**	9.3%	**261**	9.8%	0.95	0.59–1.53
Gender						
Male	**120**	55.8%	**1567**	58.6%	0.89	0.68–1.18
Female	**95**	44.2%	**1108**	41.4%	1.12	0.85–1.48
Insurance type						
Public	**177**	82.3%	**2021**	75.6%	**1.51***	**1.05–2.16**
Private	**28**	13.0%	**481**	18.0%	0.68	0.45–1.03
None/Self-pay	**10**	4.7%	**173**	6.5%	0.71	0.37–1.36
Race/Ethnicity						
White, non-Hispanic	**75**	34.9%	**1169**	43.7%	**0.69***	**0.52–0.92**
Non-White or Hispanic	**135**	62.8%	**1454**	56.3%	**1.42***	**1.06–1.89**
Unknown	**5**	2.3%	**52**	0.2%	1.20	0.47–3.04
Level of concern						
Low (abuse unlikely)	**127**	59.1%	**1414**	52.9%	1.29	0.97–1.71
High (abuse likely)	**88**	40.9%	**1261**	47.1%	0.78	0.59–1.03

Significant odds ratios and their confidence intervals are given in bold; OR, odds ratio; CI, confidence interval.
* $p < .05$.
** $p < .01$.
*** $p < .001$.
**** $p < .0001$.

3. Results

Amongst the 2890 children in ExSTRA research network dataset, 7.6% (221) were coded as having a burn. Six of these cases were excluded from this analysis; two cases lacked clinical details and in four children the final diagnosis was a burn-like lesion (2), eczema (1), or diaper rash (1). The remaining 7.4% (215) participants with confirmed burn injuries form the main group for this analysis. Inter-rater reliability of free-text coding was at least ‘very good’ with kappa scores of 0.81 to 1.00 for all characteristics (Landis & Koch, 1977).

3.1. General characteristics

For 86.5% (186/215) of participants the burn injury was the primary presenting complaint. The 13.5% (29) of children in whom burns were identified as a secondary finding presented with general malaise (7); skin marks, abscesses, or bruises (6); musculoskeletal complaints (pain, swelling/cellulitis or decreased movement of an extremity; 6); seizures (1); injuries after fall (7) or being struck by adult (2). These two groups were combined for further analysis as we did not identify statistically significant differences in the majority of characteristics of the burn injury or history, nor the rates of diagnostic testing (Supplementary Tables 1 and 2). There were two exceptions, i.e. children with secondary burns had (i) a significantly higher proportion of small ($\leq$1%) contact burns in the shape of an implement (e.g. cigarette burns) and (ii) significantly higher levels of recorded additional history and injuries due to their nature as secondary injury (Supplementary Table 1).

Details on demographics and characteristics of all ExSTRA participants are shown in Table 1: Children with burns were older than those in the comparison group (median age of 20 months vs. 10 months, $p < .05$). There was no correlation between burn type, agent, mechanism, location, size or depth, or the number of additional injuries sustained and the child’s age. Burn group participants were more likely to have public insurance and be of non-White race or Hispanic ethnicity than comparison group participants. There was no significant difference between children in the burn group and comparison group regarding gender or the level of the perceived likelihood of abuse.

3.2. Abuse likelihood according to characteristics of explanation and cause of injury

Physical abuse was deemed likely in 40.9% (88) of children with a burn injury (Table 1). The following features of the explanation were associated with a significantly higher perceived likelihood of abuse: A reported inflicted injury, an absent or inadequate explanation (i.e. an explanation that did not fit with injury seen or multiple explanations given), or additional history recorded, i.e. child had soiled itself prior to the injury (10), sibling was blamed for causing the injury (8), previous burn injury (2), history of assault (9) or fall (10), or sexual abuse (1) (Table 2).

Table 2
Abuse likelihood according to the characteristics of history and explanation, and the cause of the burn injury.

Characteristic	Abuse unlikely $n = 127$, 59.1%		Abuse likely $n = 88$, 40.9%		OR [abuse likely vs. abuse unlikely]	95% CI
History and explanation[a,b]						
Reported inflicted injury (22.3%, 48/215)	**9**	18.9%	**39**	81.3%	**10.43******	**4.70–23.17**
Additional history[c] (18.6%, 40/215)	**15**	37.5%	**25**	62.5%	**2.96*****	**1.46–6.03**
Adequate explanation (67.9%, 146/215)	**104**	71.2%	**42**	28.8%	**0.20******	**0.11–0.37**
Inadequate explanation[d] (14.0%, 30/215)	**11**	36.6%	**19**	63.3%	**2.90*****	**1.31–6.46**
Absent explanation (9.3%, 20/215)	**6**	30.0%	**14**	70.0%	**3.82*****	**1.40–10.36**
Burn type						
Scald (52.6%, 113/215)	**66**	58.4%	**47**	41.6%	1.06	0.62–1.82
Contact (27.9%, 60/215)	**44**	73.3%	**16**	26.6%	**0.42*****	**0.22–0.81**
Other (5.6%, 12/215)	**9**	75.0%	**3**	25.0%	0.46	0.12–1.76
Unknown[e] (14.0%, 30/215)	**8**	26.6%	**22**	73.3%	**4.96******	**2.09–11.76**
Agent[a]						
Hot water (39.5%, 85/215)	**43**	50.6%	**42**	49.4%	**1.78***	**1.02–3.11**
Hot food/beverage (11.2%, 24/215)	**21**	87.5%	**3**	12.5%	**0.28*****	**0.10–0.82**
Iron/Hair straightener (9.3%, 20/215)	**14**	70.0%	**6**	30.0%	0.59	0.22–1.60
Radiator (6.0%, 15/215)	**13**	86.7%	**2**	13.3%	**0.20***	**0.05–0.93**
Cigarette (4.7%, 10/215)	**5**	50.0%	**5**	50.0%	1.47	0.41–5.23
Other (12.6%, 27/215)	**19**	70.4%	**8**	29.6%	0.57	0.24–1.36
Unknown[e] (16.3%, 35/215)	**12**	34.3%	**23**	65.7%	**3.39*****	**1.58–7.26**
Mechanism[a]						
Touch (22.3%, 48/215)	**35**	72.9%	**13**	27.1%	**0.46***	**0.22–0.92**
Immersion (20.0%, 43/215)	**15**	34.9%	**28**	65.1%	**3.48****	**1.73–7.03**
Running water (11.2%, 24/215)	**16**	66.7%	**8**	33.3%	0.69	0.28–1.70
Spill/Splash/Pull down (14.0%, 30/215)	**24**	80.0%	**6**	20.0%	**0.31***	**0.12–0.80**
Run/Fall/Climb/Step on (8.8%, 19/215)	**14**	73.7%	**5**	2638%	0.49	0.17–1.40
Other (7.4%, 16/215)	**10**	62.5%	**6**	37.5%	0.86	0.30–2.45
Unknown[e] (18.1%, 39/215)	**15**	3850%	**24**	61.5%	**2.80*****	**1.37–5.72**

Significant odds ratios and their confidence intervals are given in bold; OR, odds ratio; CI, confidence interval; Unknown, due to caregiver not knowing or not informing the clinician.
* $p < .05$.
** $p < .01$.
*** $p < .001$.
**** $p < .0001$.
[a] Numbers do not add up to number of cases ($n = 215$) as more than one subcategory could be selected.
[b] Numbers do not add up to number of cases since only some subcategories are presented in the table.
[c] Additional history includes: child had soiled itself prior to injury, sibling blamed for causing injury, previous burn injury, history of assault, history of fall, sexual abuse.
[d] Inadequate explanation includes: explanation that did not fit with injury seen and/or multiple versions of the course of events.
[e] A total of 39 cases had 'unknown' items: In all cases where the burn type was 'unknown', agent and mechanism were also unknown. In the remaining five cases with an unknown agent, the mechanism was also unknown; in four cases only the mechanism was unknown. In the majority of cases this was due to the caregiver giving no history or an inadequate explanation for the burn injury, because the injury occurred in the care of somebody else, or was unwitnessed by the caregiver.

The predominant burn types were scalds in 52.6% (113) and contact burns in 27.6% (60/215); chemical (4), friction (3), flame (4), or sunburn (1) accounted for 5.6% (12) of burns. The most common causative burn agent was hot water in 39.5% (85/215). The main burn mechanisms were touch in 22.3% (48), and immersion in 20.0% (43). Hot water, immersion burns, and unknown burn type, agent or mechanism were associated with a significantly higher perceived likelihood of abuse (Table 2). Hot food/beverage or a radiator as burn agent, touch or spill/splash/pull down as mechanism, and contact burns were associated with a significantly lower perceived likelihood of abuse (Table 2).

3.3. *Abuse likelihood according to characteristics of burn injury sustained*

The majority of participants had only one site affected, although up to five sites per child were recorded (Table 3). Among the 113 participants with scalds, the most common locations were legs (35.4%, 40), buttocks/perineum/genital region (29.2%, 33), and trunk (26.6%, 30). Among the 60 participants with contact burns, the most common locations were legs (33.3%, 20), arms (23.3%, 14), and hands (21.7%, 13). No specific location of a burn site was associated with a significantly higher perceived likelihood of abuse. A bilateral/symmetric burn pattern was associated with a significantly higher perceived likelihood of abuse (Table 3). The majority of burns (85.6%, 184) involved less than 10% TBSA (Table 3). As expected, the burn mechanism significantly influenced the burn size; 66.7% (32/48) of touch burns affected ≤1% TBSA and 87.0% (20/23) of running water scalds affected 2–9% TBSA, whereas 31.8% (14/44) of immersion burns affected a TBSA ≥10%. The depth of burn injury was recorded as superficial or partial thickness in the majority of burn cases (83.7%, 180). The burn injury affecting a TBSA ≥10%, or being of full thickness depth was associated with a significantly higher perceived likelihood of abuse (Table 3).

Table 3
Abuse likelihood according to the characteristics of the burn injury sustained.

Characteristic	Abuse unlikely $n = 127$, 59.1%		Abuse likely $n = 88$, 40.9%		OR [abuse likely vs. abuse unlikely]	95% CI
Different sites affected ($N = 317$ sites)						
One site (60.0%, 129/215)	**78**	60.5%	**51**	39.5%	0.87	0.50–1.51
Two to five sites (37.7%, 81/215)	**48**	59.3%	**33**	40.7%	0.99	0.56–1.73
Not recorded (2.3%, 5/215)	1	20.0%	4	80.0%	6.0	0.66–54.6
Location of sites[a]						
Legs (31.6%, 68/215)	**44**	64.7%	**24**	35.3%	0.71	0.39–1.28
Face/head/neck/shoulder (21.4%, 46/215)	**27**	58.7%	**19**	41.3%	1.02	0.53–1.98
Trunk (21.9%, 47/215)	**30**	63.8%	**17**	36.2%	0.77	0.40–1.51
Hands (20.9%, 45/215)	**26**	57.8%	**19**	42.2%	1.07	0.55–2.08
Buttocks/perineum/genital (20.0%, 43/215)	**23**	53.5%	**20**	46.5%	1.33	0.68–2.61
Feet (17.7%, 38/215)	**20**	52.6%	**18**	47.4%	1.38	0.68–2.78
Arms (16.3%, 35/215)	**22**	62.9%	**13**	37.1%	0.83	0.39–1.75
Pattern[a]						
Bilateral/symmetric (17.2%, 37/215)	**16**	43.2%	**21**	56.8%	**2.17**[*]	**1.06–4.46**
Circumferential or genital/perineal immersion (5.6%, 12/215)	**4**	33.3%	**8**	66.7%	3.08	0.90–10.55
Shape of implement/cigarette (6.0%, 13/215)	**7**	53.8%	**6**	46.2%	1.25	0.41–3.87
Other (27.0%, 58/215)	**40**	69.0%	**18**	31.0%	0.56	0.30–1.06
Not recorded[b] (50.2%, 108/215)	67	62.0%	41	38.0%	0.78	0.45–1.35
TBSA						
≤1% (40.5%, 87/215)	**54**	62.1%	**33**	37.9%	0.81	0.46–1.42
2–9% (45.1%, 97/215)	**61**	62.9%	**36**	37.1%	0.75	0.43–1.30
≥10% (14.4%, 31/215)	**12**	38.7%	**19**	61.3%	**2.64**[*]	**1.21–5.77**
Burn depth						
Superficial (4.2%, 9/215)	**9**	100.0%	**0**	0%	0	n/d
Partial thickness (79.5%, 171/215)	**104**	60.8%	**67**	39.2%	0.71	0.36–1.37
Full thickness (11.2%, 24/215)	**9**	37.5%	**15**	62.5%	**2.69**[*]	**1.12–6.47**
Not recorded (5.1%, 11/215)	5	45.5%	6	54.5%	1.79	0.53–6.04
Additional injury						
None (68.8%, 148/215)	**109**	73.6%	**39**	26.4%	**0.13**[****]	**0.07–0.25**
One (22.8%, 49/215)	**17**	34.7%	**32**	65.3%	**3.70**[****]	**1.89–7.23**
Two to five (8.4%, 18/215)	**0**	0%	**18**	100%	n/d	n/d
Type of additional injury[a] ($N = 101$ injuries)						
Cutaneous (25.6%, 55/215)	**13**	23.6%	**42**	76.3%	**8.01**[****]	**3.93–16.2**
Fracture (7.9%, 17/215)	**2**	11.7%	**15**	88.2%	**12.84**[****]	**2.86–57.75**
Oropharyngeal/frenum tear (4.6%, 10/215)	**1**	10.0%	**9**	90.0%	**14.35**[**]	**1.78–115.49**
Traumatic brain injury (3.3%, 7/215)	**0**	0%	**7**	100.0%	n/d	n/d
Retinal hemorrhage (1.4%, 3/215)	**0**	0%	**3**	100.0%	n/d	n/d
Abdominal/thoracic (0.9%, 2/215)	**0**	0%	**2**	100.0%	n/d	n/d
Other[c] (0.9%, 2/215)	**1**	50.0%	**1**	50.0%	1.45	0.09–23.45

Significant odds ratios and their confidence intervals are given in bold; OR, odds ratio; CI, confidence interval; n/d, not defined; Not recorded, feature not recorded in the notes.

[*] $p < .05$.
[**] $p < .01$.
[***] $p < .001$.
[****] $p < .0001$.
[a] Numbers do not add up to the number of cases ($n = 215$) as more than one subcategory could be selected.
[b] Pattern 'not recorded' may not have been applicable (no specific burn pattern apparent), rather than undocumented.
[c] Other injuries were: soft tissue swelling and periosteal reaction.

The burn was the only injury identified in 68.8% (148) of participants; 31.1% (67) had up to five additional injuries (Table 3). Thereby, additional injuries were found in 24.2% (45/186) of children with a primary burn and 75.9% [22/29] of children with a secondary burn (with the remaining seven attending for general malaise or seizures). The most frequent additional injuries were other cutaneous injuries (i.e. bruises, lacerations, abrasions, and/or bites) in 25.6% (55), and fractures in 7.9% (17). The perceived likelihood of abuse was significantly higher for participants with any type of additional injury in comparison to those with an isolated burn (Table 3).

3.4. Investigations to identify occult injury

Skeletal surveys (SS) were obtained in significantly fewer participants in the burn group than the comparison group (Table 4). Whereas there was no difference in the proportion of children younger than 6 months or older than 24 months of age who had a SS, significantly fewer children in the burn group between 6 and 24 months old had a SS than in the

Table 4
Diagnostic testing using skeletal survey and neuroimaging, and injury identification, in children who presented to CAPs, grouped by burn and comparison group cases and subdivided by age group.

Diagnostic test	Burn group participants			Comparison group participants			OR [burn group vs. comparison group]	95% CI
	n	*N*	%	*n*	*N*	%		
Skeletal survey								
Obtained	**119**	**215**	**55.3**	**1930**	**2675**	**72.1**	**0.48******	**0.36–0.63**
Age 0–6 months	26	30	86.7	883	950	92.9	0.49	0.17–1.45
Age 6–12 months	20	28	71.4	447	493	90.7	**0.26****	**0.11–0.62**
Age 12–24 months	35	66	53.0	339	408	83.1	**0.23******	**0.13–0.40**
Age 24–36 months	30	43	69.8	177	276	64.1	1.29	0.64–2.59
Age 36–60 months	8	28	28.6	71	287	24.7	1.22	0.51–2.88
Age 60–120 months	0	20	0	13	261	5.0	n/d	n/d
Identified new injury	**19**	**119**	**16.0**	**449**	**1930**	**23.3**	0.63	0.38–1.04
Age 0–6 months	6	26	23.1	245	883	27.7	0.78	0.31–1.97
Age 6–12 months	3	20	15.0	102	447	22.8	0.60	0.17–2.10
Age 12–24 months	3	35	8.6	55	339	16.2	0.48	0.14–1.64
Age 24–36 months	5	30	16.7	29	177	16.4	1.02	0.36–2.89
Age 36–60 months	2	8	25.0	14	71	19.7	1.36	0.25–7.46
Age 60–120 months	0	0	0	4	13	30.8	n/d	n/d
Neuroimaging								
Obtained	**55**	**215**	**25.6**	**1637**	**2675**	**61.2**	**0.22******	**0.16–0.30**
Age 0–6 months	17	30	56.7	840	950	88.4	**0.17******	**0.08–0.36**
Age 6–12 months	12	28	42.9	390	493	79.1	**0.19******	**0.10–0.43**
Age 12–24 months	10	66	15.2	205	408	50.2	**0.18******	**0.09–0.36**
Age 24–36 months	12	43	27.9	103	276	37.3	0.65	0.32–1.32
Age 36–60 months	4	28	14.3	78	287	27.2	0.45	0.15–1.33
Age 60–120 months	0	20	0	21	261	8.0	n/d	n/d
Identified new injury	**8**	**55**	**14.5**	**719**	**1637**	**43.9**	**0.22******	**0.10–0.46**
Age 0–6 months	2	17	11.8	366	840	43.6	**0.17*****	**0.04–0.76**
Age 6–12 months	2	12	16.7	179	390	45.9	0.24	0.05–1.09
Age 12–24 months	1	10	10.0	90	205	43.9	0.14	0.02–1.14
Age 24–36 months	2	12	16.7	42	103	40.8	0.29	0.06–1.39
Age 36–60 months	1	4	25.0	29	78	37.1	0.56	0.06–5.67
Age 60–120 months	0	0	0	13	21	61.9	n/d	n/d

Significant odds ratios and their confidence intervals are given in bold; OR, odds ratio; CI, confidence interval; n/d, not defined.
* $p < .05$.
** $p < .01$.
*** $p < .001$.
**** $p < .0001$.

comparison group (Table 4). Among the children that underwent SS, there was no significant difference in the proportion of surveys that identified new skeletal injury between the burn group and comparison group (Table 4). Of the burn group participants with identified new skeletal injury, 89.4% (17/19) had fractures, whereby five had one fracture, and 12 had multiple fractures (range 3–10). Fractures affected ribs (8), long bones (8), skull (3), and hands/feet (3), and other sites (5), or were classic metaphyseal lesions (4). In nine of the 17 children with newly identified fractures, the burn injury had been the primary presenting complaint; whereas in the remainder burns were identified after the child presented for musculoskeletal problems (pain, swelling/cellulitis, or decreased movement of an extremity; 5), injury after a fall (2) or being struck by an adult (1).

Neuroimaging (computed tomography or magnetic resonance imaging) was performed in significantly fewer participants in the burn group than comparison group; particularly for children less than 24 months old (Table 4). Of the children who underwent neuroimaging, a significantly lower proportion of the burn group than comparison group participants had new cranial injuries identified (Table 4). Newly identified cranial injuries were identified in eight children in the burn group. Injuries included subdural hematoma (5), subarachnoid hemorrhage (2), skull fracture (3), and diffuse cerebral atrophy (1). In 37.5% (3/8) of participants with a new injury identified on neuroimaging, a scald injury had been the primary presenting complaint whereas in the remainder, burns were identified after the child presented. Their history included decreased movement of an arm; 1, injury after a fall (3) or being struck by adult (1). Four children with burns had an impaired level of consciousness and there were nine other injuries recorded that included fractures (4), further cutaneous injuries (6), retinal hemorrhages (3), oropharangeal (2) and intra abdominal injuries (2).

Diagnostic testing for abdominal injuries is shown in Fig. 1. The hepatic transaminases aspartate transaminase (AST) and/or alanine transaminase (ALT) were obtained less frequently for participants with burns (Fig. 1). Yet, abdominal injuries were no less frequent in comparison group than burn group participants in those participants with hepatic transaminases obtained (2.6% [2/76] vs. 4.9% [72/1462]; OR 0.52, 95% CI 0.13–2.17) and in all children regardless of testing (0.9% [2/215]

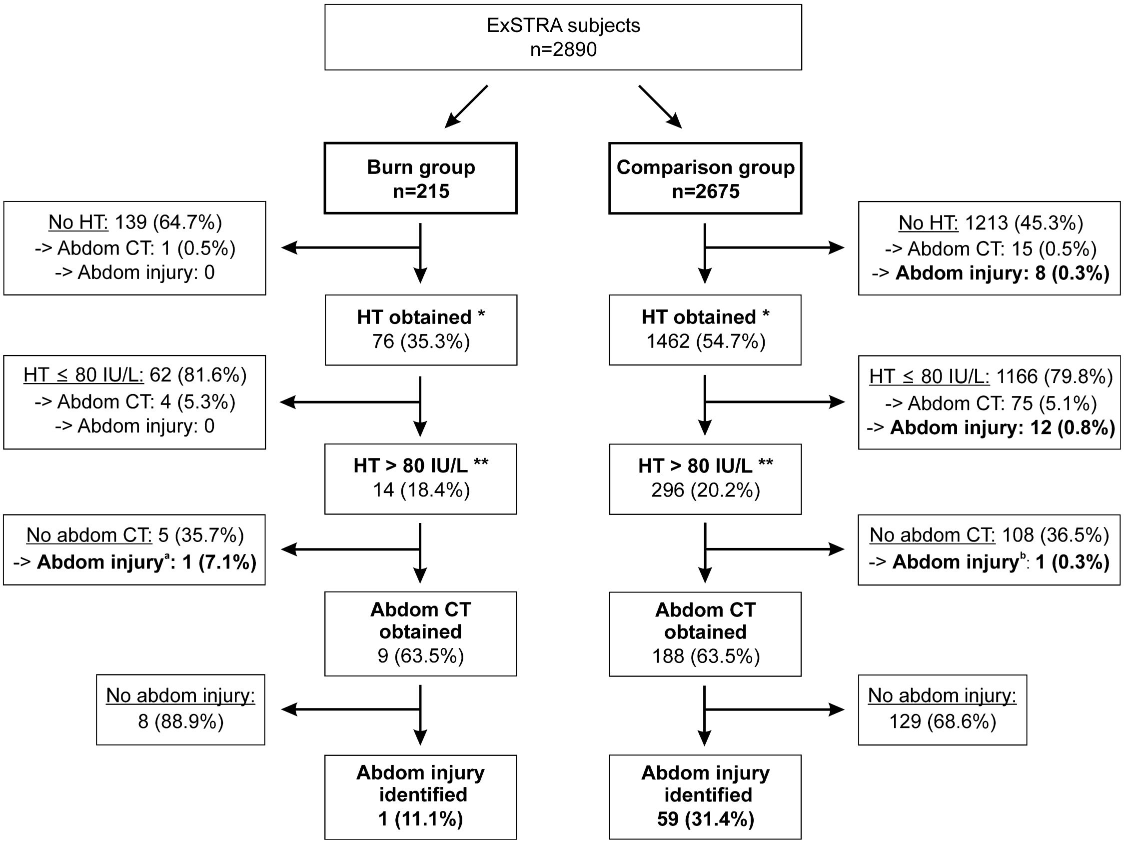

Fig. 1. Patient flow of the diagnostic testing for intra-abdominal injury using hepatic transaminase testing and abdominal Computed Tomography. HT, hepatic transaminases; Abdom CT, abdominal computed tomography; Abdom injury, intra-abdominal injury identified. [a] Identified at post mortem.[b] Identified by kidney, ureter, and bladder X-ray.* HT obtained [burn vs. comparison group]: OR 0.45, 95% CI 0.34–0.61. ** HT > 80 IU/L [burn vs. comparison group]: OR 0.89, 95% CI 0.49–1.61.

vs. 2.9% [80/2675]; OR 0.31, 95% CI 0.07–1.25). In 64.3% (9/14) of burn group participants with AST/ALT >80 IU/L (Lindberg et al., 2009) the burn injury was the primary presenting complaint; whereas in the two cases of identified intra-abdominal injury among burn group participants the burn was a secondary finding after presenting for decreased movement of arm (1) and injuries after a fall (1).

4. Discussion

Burns are an important subset of the injuries referred to CAPs; 7.4% of children who were evaluated by CAPs for physical abuse had at least one burn identified. The perceived likelihood of abuse was similar in children with a burn and all other children referred to CAPs. Children with burns received fewer investigations than children with other presenting features. However, the yield of occult fractures from skeletal survey and elevated AST/ALT levels from hepatic transaminase testing were comparable to that of children referred to CAPs for reasons other than burns. The yield of cranial injury from neuroimaging was lower in children with burns than all other children referred to CAPs with 1:7 cases vs. 1:2 positive cases, respectively. It is possible that the actual number of occult injuries was underestimated in children who had a burn, as fewer children were tested and they may have had occult injuries. The rate of positive testing will also be influenced by the clinical decision as to who should be tested since children assessed as high risk are more likely to receive the test.

Intentional burns have been described in 7–22% of all physically abused children (Caniano, Beaver, & Boles, 1986; DeGraw et al., 2010; Fagen et al., 2014; Toon et al., 2011). Figures from this study are consistent with these previous publications. The higher reported prevalence figures are drawn from studies of hospital admissions, rather than for children presenting to CAPs for evaluation. Consistent with previous publications (DeGraw et al., 2010; Hicks & Stolfi, 2007), this study confirmed that children referred to CAPs with burns were older than children referred for other injuries.

Typical characteristics of the history and explanation that were associated with a higher perceived likelihood of abuse have been reported in other studies and included an absent or inadequate explanation (Daria et al., 2004; Hobbs, 1986, 1989), a sibling being blamed (Hobbs, 1986, 1989; Yeoh, Nixon, Dickson, Kemp, & Sibert, 1994), or a trigger event such as the child soiling itself prior to sustaining the injury (Daria et al., 2004; Maguire et al., 2008). Those children with the severest burns and those with the greatest extent of additional injuries were associated with a higher perceived likelihood of abuse.

Scalds were the predominant burn type sustained by children referred to CAPs in this study. Scalds are also the most common burn type amongst all young children presenting with burns (Fagen et al., 2014; Kemp, Jones, et al., 2014). Whereas, concordant with Chester et al. (2006), scalds in themselves were no more prevalent in the abuse likely group than when abuse was unlikely. However the scald agent and mechanism of injury differed between the two groups. Hot water immersion scalds were associated with a significantly higher perceived likelihood of abuse than other scalds. This finding would coincide with studies that confirm that unintentional scalds are predominantly related to hot food or beverages rather than hot water (Maguire et al., 2008), and studies that confirm that hot water immersion scalds (Bajanowski, Verhoff, Wingenfeld, & Püschel, 2007; Daria et al., 2004; Purdue, Hunt, & Prescott, 1988; Wibbenmeyer et al., 2014), and a symmetrical pattern (Daria et al., 2004; Yeoh et al., 1994) are associated with scalds from physical abuse.

The age distribution in this dataset of children with a burn injury referred to CAPs was very different from that seen in unintentional burns. The children referred to CAPs were older than children who typically present with unintentional burns, where the peak age is one year old, likely related to new toddler exploration (Kemp, Jones, et al., 2014). Whereas within this dataset burn distribution did not appear to be associated with a change in the perceived likelihood of abuse, the distribution of burns in this study of children referred to CAPs was very different to that seen in children with unintentional burns. The most common mechanism of unintentional scalds is a 'pull over' scald, typically involving a hot drink or food (Kemp, Jones, et al., 2014; Lowell, Quinlan, & Gottlieb, 2008), and the sites usually affected involve the upper limb, face, neck and anterior trunk (Kemp, Jones, et al., 2014) and rarely the buttocks, genitalia or lower limbs as seen in this dataset. The typical mechanism for an unintentional contact burn is touching or grabbing a hot object, such as domestic iron (Hobbs, 1986), hair straighteners (Poiner, Kerr, Wallis, & Kimble, 2009), oven door or the top of the stove (Kemp, Jones, et al., 2014). Thus the most common site for unintentional contact burns in children is the hand, recorded in up to 70% of childhood contact burns (Kemp, Jones, et al., 2014). However in the population referred to CAPs the contact burns were more widely distributed to the leg, followed by arms and hands. This difference between the distribution of burns and scalds in this dataset and that of unintentional burns or scalds is likely to reflect the level of concern about children who have burns in unusual burn locations. Of note, a total of 10 children referred with cigarette burns were allocated equally to the abuse unlikely and abuse likely group.

The majority of burns and scalds in this study affected a TBSA of less than 10%. Whereas this is a lower rate of severe burns than in previous studies (Bajanowski et al., 2007; Hicks & Stolfi, 2007), this may be explained by the fact that our data includes all burn injuries referred to CAPs, and not just those admitted to burn or other inpatient units.

The dataset did not address children with burns resulting from neglect, yet cases of neglect may outnumber those due to inflicted injury by 9:1 (Chester et al., 2006). It can be particularly difficult to distinguish burns due to neglect from unintentional burns, where there may have been a momentary lapse of supervision. In neglect there may be pervasively inadequate levels of supervision, serious caretaker impairments or intoxication and/or inappropriate response to ensure the resulting burn is appropriately treated (Caniano et al., 1986; Chester et al., 2006; Wibbenmeyer et al., 2014). It is important to evaluate the circumstances around the burn and assess associated risk factors for neglect such as previous involvement of social services, single parent, and substance misuse within the home to aid in identifying these cases (Chester et al., 2006; Hayek et al., 2009; Wibbenmeyer et al., 2014).

Occult or hidden injuries are an important manifestation of physical abuse, multiple fractures of different ages can highlight the severity and repetitive nature of the assaults and the chronicity of abuse. Our data confirm that a proportion of children with burns referred to CAPs have additional occult injuries. Yet despite international recommendations that all children less than two years of age with suspected abuse should undergo a skeletal survey for suspected abuse, this appears less likely to be undertaken amongst those presenting with burns (DeGraw et al., 2010), although some authors have noted an 84% rate of investigation in children with burns in this age group (Hicks & Stolfi, 2007). This study showed a low rate of SS. However, this seems difficult to justify, given that 16.0% of children in this dataset had an occult fracture, many of which were identified in children with a single burn and no additional overt injuries. This level of occult fractures is similar to previous studies which identified occult fractures in 14% of children with a burn undergoing a skeletal survey (Fagen et al., 2014; Hicks & Stolfi, 2007); or described fractures in 16% (24/147) of cases in a similar population, although not all of those children had a skeletal survey (DeGraw et al., 2010). The prevalence of fractures in this study did not differ significantly from all other children referred to CAPs who received a SS. Thus, there would seem to be ample justification for conducting a skeletal survey in children less than two years presenting with a burn as a possible indication of suspected abuse.

Previous studies have shown a low yield from neuroimaging amongst children with abusive burns (Caniano et al., 1986; Daria et al., 2004; Wibbenmeyer et al., 2014), which may explain the low rates of neuroimaging in this dataset. Although only 25.6% underwent screening for abusive head trauma, 14.5% of those were positive. The findings in this study indicate that neuroimaging should be considered in young children presenting with a burn in whom abuse is suspected.

A strength of this study is the large number of children involved, all of whom were assessed by sub-specialist CAP teams. Although participating centers endorsed a common standard of care for testing of siblings and contacts of abused children, there was no common protocol for testing or injury screening in the index children that are the participant of this analysis. Thus, the selection of tests made by clinicians varied across CAPs and centers. We are not able to determine the reasons that some CAPs chose to perform additional testing. We suspect that differences may depend on the clinical circumstances of each case, or the practice patterns of clinicians or centers. The relatively large numbers of centers and CAPs does not permit robust statistical analysis of these hypotheses with our relatively small cohort.

Although these results indicate that there was an important prevalence of occult injury, we do not know if those who underwent skeletal screening, neuroimaging, or hepatic transaminase testing were representative of the whole population. It is possible that CAPs used other, unmeasured or undocumented factors such as prior history of abuse, parental affect or subjective gestalt to identify children at higher risk for occult injury.

This is a retrospectively planned, secondary analysis and we did not mandate structured documentation for some of the characteristics that were analyzed. For example, it is possible that some CAPs chose not to record when children with burns were reported to have had toileting accidents just prior to the burn. If CAPs were less likely to report these characteristics in children with low perceived likelihood of abuse, the true significance of these characteristics would be less than our estimates.

Although we analyzed a large database of children referred to CAPs, our sample size for several individual types of injuries was not sufficient for meaningful statistical analysis. As an example, we had insufficient participants to determine whether some burn locations, like buttock/perineum/genital or lower extremity injuries, were associated with abuse in tap water immersion scalds.

Given that all children in this dataset were referred to CAP's with a consideration of maltreatment, they are not representative of all children who may attend an emergency department with a burn. As this study was conducted in a setting with mandatory reporting, it is unknown what impact this may have had on thresholds for referral to CAPs.

5. Conclusions

Burns and scalds are commonly seen among children being assessed for possible child maltreatment. Within this dataset, specific characteristics of the burns or the history were associated with a greater likelihood of abuse; among those inadequate explanation, agent hot water, immersion mechanism, bilateral pattern, TBSA $\geq$10%, and full thickness depth. Compared to studies investigating accidental/unintentional burns, the agent, mechanism, and distribution of burns amongst the children referred to CAPS in this dataset differ from those in children with injuries judged unintentional. Although within this dataset fewer of the children with burns were screened for occult injury compared to those referred to CAPS for other reasons, the yield of fractures and raised AST/ALT in those who were tested was not significantly different, and for four of the seven children with identified abusive head trauma the burn injury was the primary presenting complaint. Thus this study indicates that children presenting with a burn that is concerning for abuse warrant the same level of comprehensive investigations as those presenting with other possibly abusive injuries.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.chiabu.2016.03.006.