

# Can a Single Cup of Hot Liquid Cause a Life-Threatening Injury? A Retrospective Analysis of 544 Beverage Scaldings

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## Abstract

Over 75% of childhood thermal injuries are scald injuries in a child. Most of these scalds are small and therefore not life-threatening for the child. However, national campaign aiming to reduce beverage scalding to young children, point out that even one cup of hot liquid can cause a life-threatening scalding of up to 30% of the total body surface area (TBSA) of an infant. We hypothesize that this is a theoretical value rather than an everyday average. This retrospective study reviews the extent of scalding injuries obtained by children from a single hot beverage over a ten-year period, and then uses a theoretical approach to obtain the maximum mathematically possible TBSA.

**Material and Methods:** This is a retrospective study of the 2012-2022 period, including all inpatients and outpatients (m/f) between the ages of 0 and 17 years with a history of an explicitly documented accident mechanism caused by a cup of hot liquid. A statistical evaluation is performed using SPSS and Spearman's Rho correlation analysis, and the theoretically possible extent of scalding by the liquid contents of a cup is estimated.

**Results:** The dataset consisted of 544 scald burns, each caused by one cup of hot beverage. The mean TBSA was 4.34% (min: 0.5%; SD 8.95). 62.5% of all scalds had a TBSA <5%. The maximum TBSA caused by a single cup was 21%. A life-threatening injury (TBSA > 10%) was present in 3.75% of all patients (n=9), who were on average 1.2 years old. Commonly, multiple locations were affected: The most frequent injury location was the thorax (n=305), followed by the upper extremities (n=290), the head (n=147), lower limbs (n=147) and abdomen (n=130). There was no significant relationship between age ( $r=0.067$ ,  $p=0.143$ ) or gender ( $r=0.073$ ,  $p=0.127$ ) and the investigated accident mechanism (beverage scalding vs another scalding accident). The calculated maximum possible area that can be covered by the liquid contained in a single cup depends on the child's body surface area, and thus on their age, as well as on the volume of the cup. The amount of hot liquid in an average-sized cup (175 ml) can theoretically scald 47.3% of the TBSA of an infant, 33% of the TBSA of a toddler, or 23.6% TBSA of a preschooler.

**Conclusion:** In our 10-year review we observed a small TBSA (< 10%) in 96,5% of all children following a hot beverage burn. Even though the theoretical approach demonstrated, that the maximum possible TBSA can be 30%, in our patient collective 7 patients exceeded 10 %TBSA with the maximal TBSA being 21%.

**Keywords:** scalding; pediatric burns; TBSA; cup of hot liquid.

## Introduction

Over 75% of childhood thermal injuries are due to scalding injuries in infancy. [1,2,3] Approximately 90% of those scalds are related to cooking, drinking or serving hot liquids. [4] Between 30 and 75% of such accidents are related to cups, mugs or tableware containing hot liquids, which are most commonly pulled down (48%) or spilled over (32%). [5,6,7] Even though many of those scalding injuries affect only a relatively small total body surface area (TBSA) and are not life-threatening, they are painful and can cause lifelong hypertrophic scarring, too. Managing scalding injuries therefore leads to considerable health care costs. [8] Despite any prevention campaigns over the last 10 years, which have addressed pediatric scalds in general and especially focused on beverage scalds, the overall number of those accidents remains high in Germany. However, national campaign aiming to reduce beverage scalding to young children, point out that even one cup of hot liquid can cause a life-threatening scalding of up to 30% of the total body surface area (TBSA) of an infant. [9] We hypothesize that this is a theoretical value rather than an everyday average. The aim of this retrospective study is to review the possible extent of a scalding injury from a single hot beverage and the burn distribution based on patients files gathered over a ten-year period. Additionally, we compared our findings with a theoretical approach, in which we estimated the maximum possible TBSA by mathematical calculation.

## Materials and Method

### Mathematical calculation of the maximum possible extent of scalding

We describe the theoretically possible extent of scalding from the liquid contents of a cup in relation to different age groups based on a cup volume  $V$ , a distribution of the liquid over an area  $a^2$  (in  $\text{cm}^2$ ), and a liquid height of  $b = 0.1$  cm.

The following values were assumed for cup volumes of  $V_1 = 150$  ml,  $V_2 = 175$  ml,  $V_3 = 200$  ml and  $V_4 = 250$  ml.

$$a^2 = V/b \quad (1)$$

The following age values ( $n$  in months) with their corresponding body surfaces (50th percentile) were selected by way of example:  $n_1 = 6$ ,  $n_2 = 12$ ,  $n_3 = 18$ ,  $n_4 = 24$ ,  $n_5 = 36$ ,  $n_6 = 48$ ,  $n_7 = 60$ ,

### Patients

This retrospective study examined the patient files of infants, toddlers and children below 17 years of age with a scald injury treated at our pediatric hospital between 1 January 2012 and 31 August 2022. In accordance with the above-mentioned criteria, only patients with a history of being scalded by the contents of a cup were included. Cases with other types of accidents or unreliably documented accident mechanisms were excluded.

### Statistics

SPSS database version 25 (SPSS Inc., Chicago, IL, USA) was utilized for the current research. Both Spearman's rho correlation analysis, regression analyses and chi-square test were used to compare categorical data between the study and the control groups, with

two-sided p values < 0.05 considered as statistically significant.

## Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of Medical University Hospital Hannover (Reference No.:10514\_BO\_K\_2022)

## Results

### Mathematical Theoretical Approach

Following the above-stated formula, the area that can be covered with the liquid contents of a cup is between 0.15 m<sup>2</sup> for a 150 ml cup volume and 0.25 m<sup>2</sup> for a 250 ml cup volume calculated for a liquid height of 0.1 cm. The relationship between the average body surface area according to age and the potential surface area that can be covered by a spilled beverage shows that, theoretically, a volume of 250 ml could cover up to 67.57% of the body surface area of a 6-month-old child (Table 1). Assuming an average hot beverage volume of 175 ml, the extent of the scalding can still reach 47.3% TBSA for an infant, 33% TBSA for a toddler and 23.6% TBSA for a preschooler. The area scalded by the smallest volume (V<sub>1</sub>=150 ml) can potentially range from 20.27% TBSA in a 5-year-old to 40.54% TBSA in a 6-month-old.

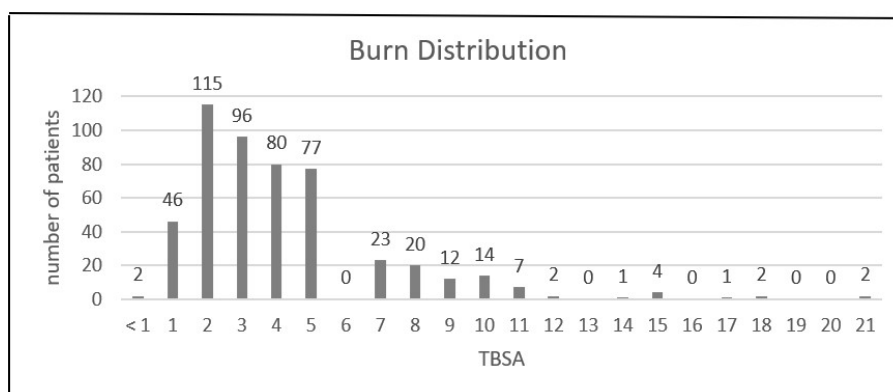
Table 1: Maximum possible TBSA depending on age, body surface area, and cup volume (V) (if considered liquid height is 0,1)

Age in months	Body surface area (P50) in m <sup>2</sup>	maximal TBSA V1 = 150 ml in %	maximal TBSA V2 = 175 ml in %	Maximal TBSA V3 = 200 ml in %	maximal TBSA V4 = 250 ml in %
6	0,37	40,54	47,3	54,05	67,57
12	0,43	34,88	40,7	46,51	58,14
18	0,5	30,0	35	40	50
24	0,53	28,30	33,02	37,74	47,17
36	0,6	25	28,72	33,33	41,66
48	0,68	22,06	25,74	29,41	44,05
60	0,74	20,27	23,06	27,03	33,78

### Patients results

Beverage scalding was explicitly mentioned for 27,15 % of all burn patients at our pediatric hospital during the period under study (544 in a total of 2004 patients). Slightly more than half (54.2%) were female, and they ranged in age from 0 months to 17 years, with 90.8% of the total patients being under 5 years of age. Spearman's rho correlation analysis showed no significant relationship between age ( $r=0.067$ ,  $p=0.143$ ) or gender ( $r=0.073$ ,  $p=0.127$ ) and the investigated accident mechanism (beverage scalding vs another scalding accident).

The burns covered a median body surface area of 4.34% (min: 0.5%; SD 8.95). (**Figure 1**). The maximum TBSA caused by a single cup was 21%. 62.5% of the patients had a TBSA <5%.



**Figure 1:** Burn distribution according to the total body surface (%)

The majority of burns involved the thorax (56,09%) and upper limbs (53,33 %), followed by the head and lower limbs (each 27,03 %). (**Table 2**) The abdomen was affected in 23%. The combination of head and thorax scalding injuries were found to be significantly ( $p < 0,005$ ; SE\_beta: 0,291). Additionally, a reciprocal relationship was seen in head and lower limb burns ( $p < 0,005$ ; SE\_beta: -,168).

**Table 2:** Burn Distribution

Burn Distribution	Number of Children	Percentage of Children
Head	147	27,03
Thorax	305	56,09
Abdomen	130	23,90
Upper limbs	290	53,33
Lower limbs	147	27,03

Nineteen patients suffered a potentially life-threatening scalding injury with a TBSA  $> 10\%$ . (Supplementary File **Table: A1**), of which 89.47% were younger than 33 months (median: 17; SD: 37,51). Their mean TBSA was 14% (median: 12, SD: 3,44). Regarding the scald distribution, 18 out of the 19 involved the thorax, followed by the upper limbs, the head and the abdomen ( $n = 15, 13, 13$  respectively). The lower limbs were only affected in 3 out of the 19 patients. Almost half of the patients ( $n = 8$ ) had four out of five body areas affected, 7 patients suffered a scalding injury in three areas, and 4 patients had only two affected locations.

## Discussion

Scalding accidents are the leading cause of pediatric burn injuries. A literature search revealed consistent findings regarding the median age of children with scalding injuries (17.5 months (range, 3 months to 11.5 years) [10].

In our study, we found that beverage-related burns contributed to 27% of all pediatric burn admissions at our center. Other studies support this finding with a proportion ranging from 18 to 60%, highlighting that this is one of the most common mechanisms of children's burns [11,12,13,14]. Kemp et al. revealed in their multicenter study that being scalded by a cup of hot beverage accounted for up to 55% (305 out of 554 patients) of all their scalding injuries, with the most common mechanism being a pull-down injury (48%, 66 out of 554 patients) [15].

The current study has identified the frequency of distribution of scalding injuries as follows: thorax (56%), upper limbs (53%), head and lower limbs (27%), and abdomen (23%). These findings are consistent with the scalding pattern sustained by a child with a pull-down scalding injury. Examining the literature, Delaware et al. made similar findings, whereby the thorax and upper extrem-

ities were the most commonly scalded areas[16].

Tea, followed by coffee and boiling water, is the most common cause of scalding injuries from hot beverages [17]. Coffee is often served at 79°C, making it high-risk for immediate severe scalds when spilled or pulled down by a child [18]. Considering that freshly brewed tea or coffee can remain above 65°C even after 10 mins of cooling time, the risk of scalding may last considerably longer than many parents realize [19].

Some studies have examined the cooling characteristics in relationship to cup design [20] while others addressed the link between the shape of the cup and the scalding risk [21]. However, the literature review revealed scarce information regarding the comparison between the theoretically possible TBSA and the median body surface area as seen in daily practice.

Following the theoretical approach and assuming the average cup volume ( $v = 175$  ml), the maximal potential TBSA of an infant can reach 47.3% TBSA. This clearly contrasts with our 10-year dataset, which shows a maximum TBSA of 21%. Other studies have found similar results, with a median body surface area of 4% and a TBSA ranging between 0.25 and 32%, i.e., significantly lower than the theoretical maximum [22].

Of course, there are effects of direct immersion of hot fluid to exposed skin areas compared to the fluid distribution when clothing was worn. However, to our best of our knowledge, there have been no studies concerning this topic. Our retrospective study is not suitable to investigate this question, since the vast majority of children had already been stripped of their wet clothing preclinically. In fact, for thick clothing, there can be a significant temperature difference between the outer surface of the clothing and the surface of the skin in scalding accidents. Nevertheless, the only publication available on this specific topic showed that a single layer of cotton minimized the temperature difference across the clothing to less than 1° C.

In 3.5% of cases the scalded body surface area was greater than 10% and therefore potentially life-threatening. The systemic response to pediatric burn injuries are well documented with TBSA > 10% [23,24,25]. Seditious and vasoactive intercessors such as prostaglandins, cytokines and histamines are released causing a systemic capillary leak, intravascular fluid loss, and large fluid shifts, which can reach up to 30 of the circulating blood volume.[26] Our retrospective study over 10 years suggests that life-threatening beverage scalding occurs relatively rarely. There is no evidence in the literature describing the percentage of pediatric beverage scalds in the overall pediatric population suffering a scald injury. However, evidence can be found in the literature that only 3% of burn injuries in children under five years of age in England and Wales being greater than 10% TBSA.[27] Assuming that the majority of those burn injuries are typically scalds, the percentage is comparable to ours, although it's not only defined as beverage scalding. The difference between the theoretically calculated value and the actual burn surface can be explained above all by the fact that children have a dynamic three-dimensionality that cannot be adequately compared with a static surface area. This leads to the following findings: Firstly, in most cases, not all of the cup volume directly touches the child's skin because some of the hot liquid is absorbed by their clothing. Secondly, some of the hot beverage strikes where the liquid has already come into contact with the child's skin, creating a second skin contact and not affecting any additional area of healthy skin.

In our 10-year review we observed a small TBSA (< 10%) in 96,5% of all children following a hot beverage burn. Even though the theoretical approach demonstrated, that the maximum possible TBSA can be 30%, in our patient collective 7 patients exceeded 10 %TBSA with the maximal TBSA being 21%.

## Author Contributions

For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used “Conceptualization, M.S.; methodology, K.S. software, K.S.; validation, K.S.; formal analysis, M.R.; investigation, K.S.; M.S. writing—original draft preparation, K.S.; writing—review and editing, K.S.; visualization, K.S.; supervision, M.S.;

All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of Medizinische Hochschule Hannover (Reference No.:10514\_BO\_K\_2022)

Informed Consent Statement: Due to the study structure, in which participating patients (even by the patients themselves) cannot be identified, the patient’s consent was waived in consultation with the data protection officer.

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This research received no external funding.

## Data Availability Statement

All data are contained within the article.

## Conflicts of Interest

The authors declare no conflict of interest.

## Supplementary Materials

Table A1: Burn distribution of burns > 10 % TBSA

	TBSA	Age	Sex	Burn Distribution				
	in %	in months		head	thorax	abdomen	upper limb	lower limb
Patient 1	11	7	male	yes	yes	no	no	no
Patient 2	11	26	male	yes	yes	no	yes	no
Patient 3	11	33	female	yes	yes	no	yes	no
Patient 4	11	17	male	yes	yes	yes	yes	no
Patient 5	11	15	male	yes	yes	yes	yes	no
Patient 6	11	21	male	no	yes	yes	no	yes
Patient 7	11	24	male	no	yes	yes	no	yes
Patient 8	12	9	female	yes	yes	no	no	no
Patient 9	12	16	female	no	no	no	yes	yes
Patient 10	14	23	female	yes	yes	no	yes	no
Patient 11	15	8	male	no	yes	yes	yes	no
Patient 12	15	14	female	no	yes	yes	yes	no
Patient 13	15	168	male	no	yes	yes	yes	no
Patient 14	15	17	female	yes	yes	yes	yes	no
Patient 15	17	17	male	yes	yes	yes	yes	no
Patient 16	18	10	female	yes	yes	yes	yes	no
Patient 17	18	84	male	yes	yes	yes	yes	no
Patient 18	21	20	male	yes	yes	yes	yes	no
Patient 19	21	23	female	yes	yes	yes	yes	no

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