Article — Artikel

A method for determining the extent of thermal burns in elephants

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ABSTRACT

A practical method was developed to assess the extent of burns suffered by elephants caught in bush fires. In developing this method, the surface areas of the different body parts of juvenile, subadult and adult elephants were first determined using standard equations, and then expressed as a percentage of the total body surface area. When viewed from a distance, the burnt proportion of all body segments is estimated, converted to percentages of total body surface area, and then summed to determine the extent of burns suffered.

Key words: burn extent, elephants, thermal burns.

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INTRODUCTION

Bush fires are common in southern Africa in the dry months just prior to the rainy season, and the risk to wildlife increases substantially in fenced areas. Wildlife managers often face the difficult decision of whether or not to humanely cull in order to prevent undue and or extended pain and suffering, but this often relies on very subjective assessments of the extent of burns. We therefore developed a method that can reliably predict the prognosis and outcome of fire-sustained lesions in elephants in order to allow managers to arrive at an informed decision.

The understanding of the severity of a burn includes extent, depth and location of the burn wound(s). However, the extent of body surface area burned expressed as a percentage of the total body surface area (%TBSA) is often used in humans for burn management (*e.g.* fluid therapy, nutritional support) and predicting outcome (*e.g.* morbidity, mortality)[6].

In dogs, partial-thickness burns (extending into the dermis) of 20 % of the body surface area results in a loss of up to 28 % of plasma volume at 6 hours post-burn, whereas burns covering 40 % can result in 50 % of total plasma volume loss within 2–3 hours[1]. The burned areas transmit water vapour greater than 4 times as rapidly as normal skin, with values of up to 150 mℓ/m^2 burned area per hour in dogs, with each litre requiring 550 kcal for evaporation[1]. The potential for dehydration, hypoproteinaemia and large metabolic demands therefore increases greatly as % TBSA involvement rises and must be considered when treating burn cases. In addition, immune suppression apparently becomes significant at 20 % TBSA, and includes depressed neutrophil chemostasis, suppressed macrophage function, T-cell suppression, IgG loss through leakage and malfunctioning of the complement pathway[1]. Control of septic foci is therefore crucial.

In humans, the extent of a burn injury can be determined by at least 3 methods. A commonly used, convenient and rapid method is known as the 'Rule of Nines'[6]. The surface area of the body is divided into areas representing 9 % or multiples of 9 % of TBSA. When all body areas of 9 % are added, 1 % remains, which is assigned to the genitalia and perineum. The accuracy of this method diminishes when applied to human patients younger than 15 years.

A 2nd, more accurate but cumbersome method makes use of Lund and Browder charts that subdivide the body into segments and assigns a proportionate percentage of body surface to each area based on age[2,6].

A 3rd method is based on the size of a hand, assuming that the surface area of the palm plus the digits is roughly 0.8% of TBSA in males and 0.7% in females[4]. The percentage of TBSA burned can be estimated by summation of the number of patient's hand areas required to cover the burned areas. This is especially useful if the burn areas are scattered. The palm itself, i.e. the hand minus the digits, more accurately represents 0.5 % of TBSA in males and 0.4 % in females .

In humans, a newborn baby's head is proportionately much larger than any other area of the body and, as the child grows, the head becomes relatively smaller and assumes less of the TBSA[2,3]. Likewise, with growth, the lower extremities gradually assume a larger proportion of TBSA. This has a major effect on the accuracy of % TBSA in juveniles.

Using the above as guidelines, we set about developing a method for determining the extent of burn wounds in elephants. Such a method must be practical and easy to use in the field. It must also be accurate enough so that consensus is readily reached.

MATERIALS AND METHODS

As burn injuries can affect different body segments to varying degrees it is necessary to first determine what proportion each segment of the body contributes to TBSA.

Determining the proportion of each body segment as a percentage of TBSA.

Photographs of 2 juvenile elephants, 3 subadults (8–10 years old), a cow (>20 years old) and an adult bull were used as models. The length of the lateral side of the sole of the front foot was used as a *standard unit* of measurement. Each elephant's body was subdivided into segments, each segment being constituted in such a way that it could be modelled either as a circular flat area, a cylinder, a cone or part or combinations of these, as illustrated Fig. 1. The lengths of the sides, heights and diameters of the various shapes were then converted to multiples and/or fractions of the standard unit. The surface areas of the different shapes were calculated using standard equations and expressed in *square standard units*. These values were then summed, the total being an estimate of total body surface area (TBSA). Each segment's surface area was then expressed as a percentage of TBSA.

Determining the extent of burn injury as a percentage of TBSA

The burned portion of each body segment was estimated. Each value was then

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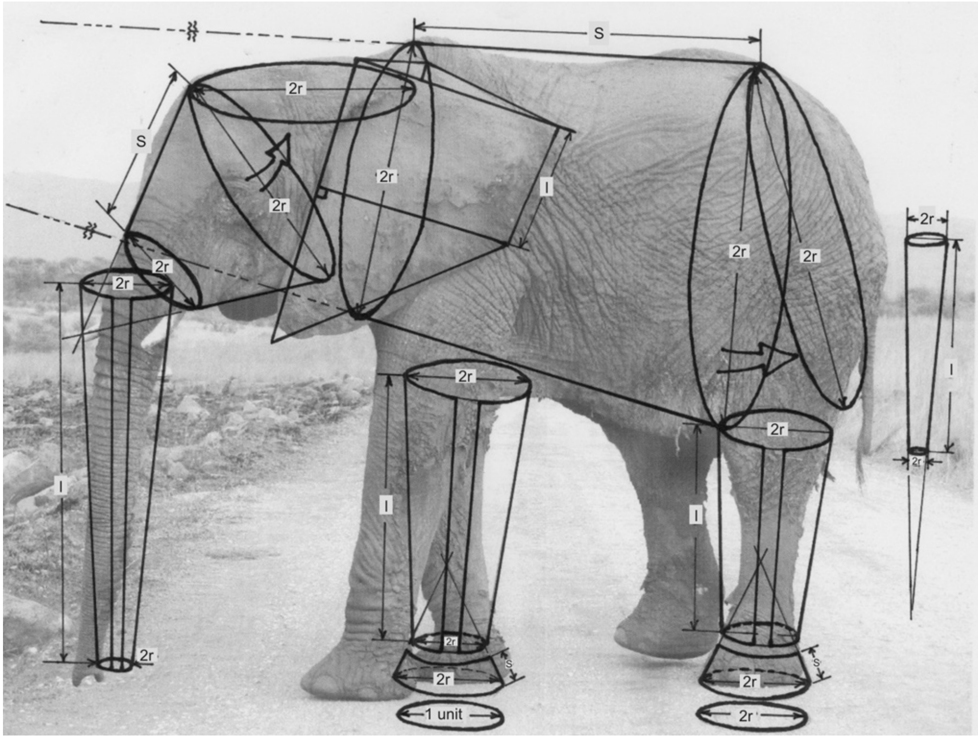

Fig. 1: **An illustration of the method used to determine the total body surface area** (TBSA) **of an elephant by summation of the various shapes representing the different body segments (r = radius, l = length, s = slope length).**

multiplied by the percentage value of TBSA allocated to that particular segment. The results were then summed to give % TBSA.

When forced to move through a raging bush fire, the underbody of an elephant (i.e. the thorax and abdomen) is most likely to be burned over an area that is closest and parallel to the ground. However, the underbody resembles the lower section of a cone (Fig. 1) that is tilted upwards towards the head. The lower caudal abdominal area, owing to its proximity to the ground and relatively larger surface area, will bear the brunt of a fire and will sustain the worst and most extensive damage. The narrower chest region, which is elevated relative to the abdomen, will consequently sustain relatively less damage. The inguinal area will therefore, in most cases, sustain greater damage than the axilla. A fire, even though it burns to a given height above the ground, will therefore not cause symmetrical damage to the cone-shaped body. An elephant's body constitutes a large proportion of TBSA, hence slight errors in estimating the damage will be magnified when calculating the total extent of burn lesions. Care should therefore be taken when estimating the extent of damage to the body.

The section of the cone representing the body of an elephant when viewed from the side resembles the shape of the lower section of an equilateral triangle. The base of this triangle will be seen as a vertical line, which represents the circular abdominal profile of the body, and therefore a small shift from either end of the vertical line will represent a relatively large section of the circumference of the circle (Fig. 2a). The radius of a circle splits the circumference into 6 equal parts. Thus a 7 % shift from either end of the vertical

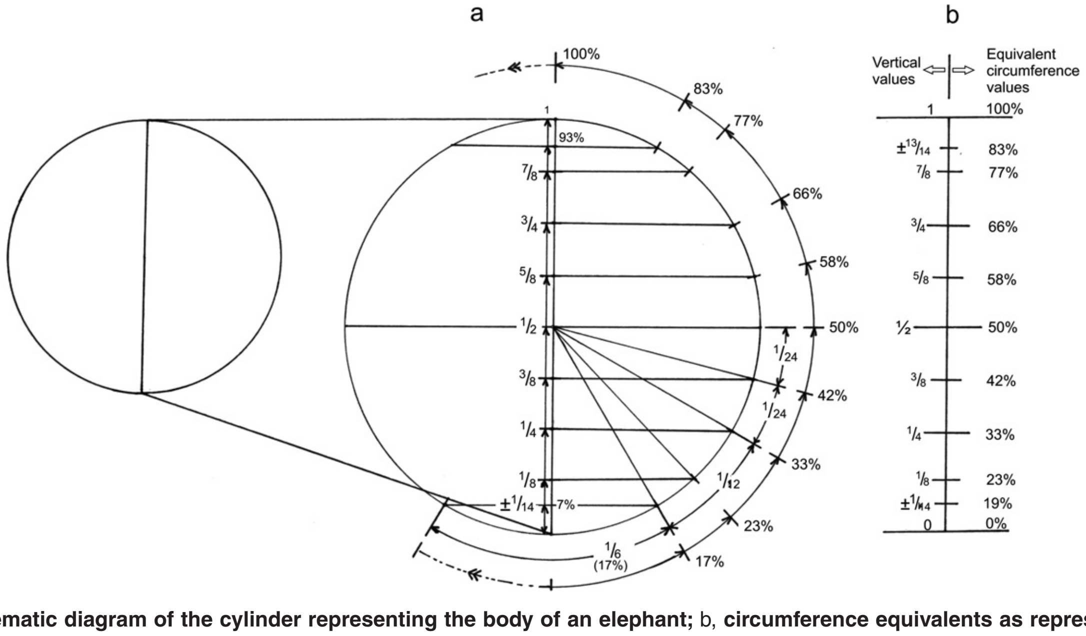

Fig. 2: a, **Schematic diagram of the cylinder representing the body of an elephant;** b, **circumference equivalents as represented by the vertical line**.

Table 1: **Body segment percentages of TBSA of juveniles and subadult/adult elephants.**

Body segment	Juveniles (still suckling; *n* = 2) Area (square units)	Juveniles % TBSA	Subadults (*c.* 8–10 years; *n* = 3) plus and adult cow and bull Area (square units)	Subadults plus adult % TBSA	Average (%)
Front legs	15.88	14.5	15.9	15	15
Sole (front leg)	0.78	0.72	0.79	0.76	0.74
Front legs minus soles	14.32	13	14.32	13.5	13.5
Back legs	13.92	13	13.97	13.5	13
Sole (back leg)	0.94	0.87	0.96	0.92	0.89
Back leg minus soles	12.98	12	12.05	11.5	11.5
Body	50.21	46.5	46.62	44.5	46
Head	12.02	11	11.78	11.5	11
Ears	11.9	11	11.78	11.5	11
Trunks	2.92	2.5	2.64	2.5	2.5
Tail	1.58	1.5	1.61	1.5	1.5

line represents 17 % of the circumference; a 25 % shift from either end represents 33 % of the circumference, and the closer to the mid-point the more the two values equate. As the midpoint of the vertical line is passed so the circumference represented alters for the same reason as discussed. However, the abdominal/thoracic profile of an elephant when viewed from behind forms more of an oval shape than a circle which will further exaggerate the circumferential values represented by the vertical line, especially at either end of the vertical line. The vertical line is split into equal divisions for ease of use, and the equivalent percentage circumference involved from the most ventral point is illustrated in Fig. 2b. These figures are a rough guide as there will be significant variation in the abdominal profile of elephants.

Owing to the tilting-cone effect, and since the burn line is probably at a given height parallel to the ground, a further correction is needed. If the burn extends partially along the abdominal floor, the lesion resembles a slightly curved triangle when viewed from below. Calculating this surface area will therefore be half the base multiplied by the height, which in this case will be:

Area burnt = ½(% circumference) × fraction of lesion length.

If the lesion extends up the thoracic wall, the lesion resembles a section of a cylinder, in which case the surface area will be:

Area burnt = ½(sum of % circumference of both ends) × fraction of lesion length (which equals 1 in this case).

A similar situation involving tilted cones applies to the head; however, the animal can lift this segment out of the way of danger, and will therefore be less prone to damage. An error involving this body segment will not have a large impact on the final % TBSA value since the contribution of the head surface area to TBSA is less than a quarter of that due to the body segment (see Table 1).

The ears, especially the inner surface (rostral planum) can be readily evaluated. However, unless directly visualised, the outer surface (caudal planum) burn area should be reduced to approximately a third of the damage to the inner surface. *Post mortem* examination of four elephants confirmed this observation and is probably due to the outer surfaces being protected from the fire when held close to the neck at the time of the insult.

The soles of the elephants' feet examined at *post mortem* appeared to be relatively free of damage macroscopically, so when determining the extent of burn lesions, the leg segments minus soles should be used.

Ideally, when determining the extent of the burn, it would be preferable to map all sides of the elephants. However, this may not be practical or possible, in which case it is probably safe to assume that both sides were damaged to the same extent.

To illustrate the above method a burned subadult (Fig. 3) and a juvenile (Fig. 4) elephant are evaluated below.

Fig. 3: **A subadult elephant** (Sehlare) **with *c.* 38 % burn lesions.**

Fig. 4: **Juvenile elephant** (Abeni) **with *c.* 70 % burn lesions.**

Table 2: **Percentages burn injury in a subadult and a juvenile elephant.**

	Subadult (*c.* 8 years)			Juvenile		
	% of segment involved	% TBSA	% Burnt	% of segment involved	% TBSA	% Burnt
1. Forelegs (minus soles)	90	13.5	12	100	13.5	13.5
2. Backlegs (minus soles)	100	11.5	11.5	100	11.5	11.5
3. Body	(40 +10)/2 = 25 %	46	11.5	(50 + 35)/2 = 42.5 %	46	19.5
4. Head	10	11	1	100	11	11
5. Ears	10	11	1	100	11	11
6. Trunk	10	2.5	0.25	100	2.5	2.6
7. Tail	20	1.5	0.33	100	1.5	1.5
Burn extent			*c.* 38			70.50

Practical use of the above method

Fifteen burned elephants were evaluated for burn extent using the method described above.

RESULTS

Table 1 gives the body segment areas in square standard units taking the lateral length of the front sole of each elephant as *one standard unit*. As these measurements were taken from photographs and not from actual subjects, the values obtained are not accurate and vary considerably because the subjects were rarely ideally positioned. The values obtained are averages of a number of measurements taken by one person on a number of occasions. The borders of the different body segments could not be consistently replicated, as the stance of the subject was seldom ideal. To give a range of values is to imply a degree of accuracy whereas the purpose this method is to provide rough guidelines, similar to the 'Rule of Nines'.

The body segment percentage of TBSA was also determined. The juvenile values were determined separately to detect potential differences between body segments that may occur with age. As the values were found to be similar (see Table 1), the average percentage for each segment is also given.

Table 2 gives the percentage involvement of each segment; the percentage TBSA of each segment and the final percentage burn of the subadult and juvenile elephant. The subadult elephant had a burn extent of 38 %, while the juvenile had a burn extent of 70 %.

Table 3 shows the % TBSA of 15 of 17 elephants that were translocated to bomas for intensive treatment and care. The values were determined from photographs taken 2–4 weeks after the incident, with a few of the longer surviving animals having repeat estimates done from more recent photographs. The burn extent did not change in any of the cases that had repeat evaluations. Although most of the elephants analysed had burn wounds that extended to a line roughly parallel to the ground, 3 animals exhibited additional burns well above this burn line, involving almost their entire hindquarters, which will underestimate the extent of the total burn in these cases.

Table 3: **Analysis for burn extent of fifteen affected elephants.**

Name	% Burn extent of TBSA	Outcome
Baby	76	Died (25 Sept 2005)
Shikumba	95	Euthanased (12 Oct 2005)
Abeni	70	Died (13 Oct 2005)
Mashadu	66	Euthanased (23 Oct 2005)
Chisa	89	Died (26 Oct 2005)
Toothpick	61	Euthanazed (31 Oct 2005)
Dinare	67	Died (03 Nov 2005)
Mansa	61	Euthanased (17 Nov 2005)
Mabuko	50	Euthanased (*c.* 18 Nov 2005)
Shakura	65	Euthanased (*c.* 20 Nov 2005)
Amari	58	Euthanased (*c.* 20 Nov 2005)
Tabanzi	69	Euthanased (23 Nov 2005)
Hlanye	40	Euthanased (01 Dec 2005)
Sehlare	38	Released
Gambo	12	Released

From these figures it appears that only elephants with a percentage burn extent of less than 40 % TBSA will survive.

DISCUSSION

Humans can sustain burn injuries to any part of the body and the area involved can be quickly assessed thanks to the relative ease of 'hands-on' evaluation. With wild elephants this is not as easy and initial determination of the extent of the burn injuries will be done from a distance and probably with the animals on the move. Therefore a method to estimate the extent of burns must be quick and easy to use.

The first step in determining the total extent of burns is to estimate the percentage contribution of each body segment to TBSA. There will be variation in profile, shape and length of appendages among elephants in a group and even more so between subpopulations living in diverse habitats, and this will affect the percentage contribution of body segments relative to TBSA. Nevertheless, as with the 'Rule of Nines' and the 'palm size' methods used in humans, the values arrived at using our method are simply a guide for the quick determination of the extent of burns.

The differences between body segment surface areas between juveniles and older elephants, unlike humans, were small, and allowed for the use of a single set of average values, which simplified matters considerably.

Tail and trunk lesions can vary extensively between individuals, probably as some animals may lift these body parts out of the way of the flames. The same applies to the head and ears. Since these body segments make up small percentages of TBSA, inaccurate estimates of these burn lesions will have a relatively minor impact on the final % TBSA value.

Animals that had badly burned ears and trunks were observed to rarely move these appendages, which in the case of the ears may eventually have an effect on the cooling mechanism of the elephant.

A few elephants had severe burns to their hindquarters, even though the lateral body wall burn extent was much less. It seems likely that these animals attempted to protect themselves by backing into the oncoming fire.

In humans, the inner surface of the hand is between 0.7 % and 0.8 % of TBSA depending on gender, which is almost identical to the front sole surface area in elephants of 0.74 % of TBSA. There could even be sexual variation in elephants, but since there appears to be a propensity for the younger elephants to be caught in bush fires and that differentiation of the sexes at these ages is not easy, especially from a distance, the average value presented above should be used in the interim.

The surface area of the soles were not included in calculating burn extent as these exhibited very little damage, either macroscopically at necropsy or when 'knocked down' during treatment. Exposure of the thickened sole surface to the fire could be brief as the fire would be smothered quickly when trampled.

Dogs and cats with either partial or full-thickness burn lesions covering more than 50 % of their total body surface area carry a grave prognosis and a recommendation for humane euthanasia[1]. The same applies to horses[5]. However, in domestic animals, intensive care in the form of intravascular fluids and regular and sustained treatment, which is impossible in wild elephants, will raise the % TBSA value for survivability in domestic animals relative to that in elephants. All elephants that died and were analysed for burn extent using our method had burn lesions greater than 40 % TBSA.

CONCLUSIONS

A method that can reliably predict the prognosis and outcome of fire-sustained lesions in elephants will help to limit the debate about whether or when to humanely cull in order to prevent undue and or extended pain and suffering. The proposed method first determines the surface area of the different body segments as a percentage of total body surface area, followed by simple calculations to estimate the extent of burn lesions, expressed as a percentage of total body surface area (% TBSA). The % TBSA values are not exact but are nevertheless a relatively reliable means of gauging burn wound extent.

Despite the limited number of elephants involved in this study, it is the opinion of the authors that those with over 50 % burn wounds, as in the case of domestic animals, should be humanely culled. However, when adequate support and treatment are not available, this figure should be reduced to 40 %.

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