

A critical evaluation of the Lund and Browder chart

Measurement of wound size and, more specifically, surface area is an important aspect of assessing any wound. With regards to burn wounds this measurement, expressed as percentage of the total body surface area, is the cornerstone of management. The Lund and Browder chart is regarded by most authors as the most accurate in measuring this percentage and is widely used in everyday clinical practice. In this article, important clinimetric properties that are applicable to the Lund and Browder chart, such as its reliability, concurrent and construct validity, acceptability and readability will be evaluated and weaknesses will be identified.

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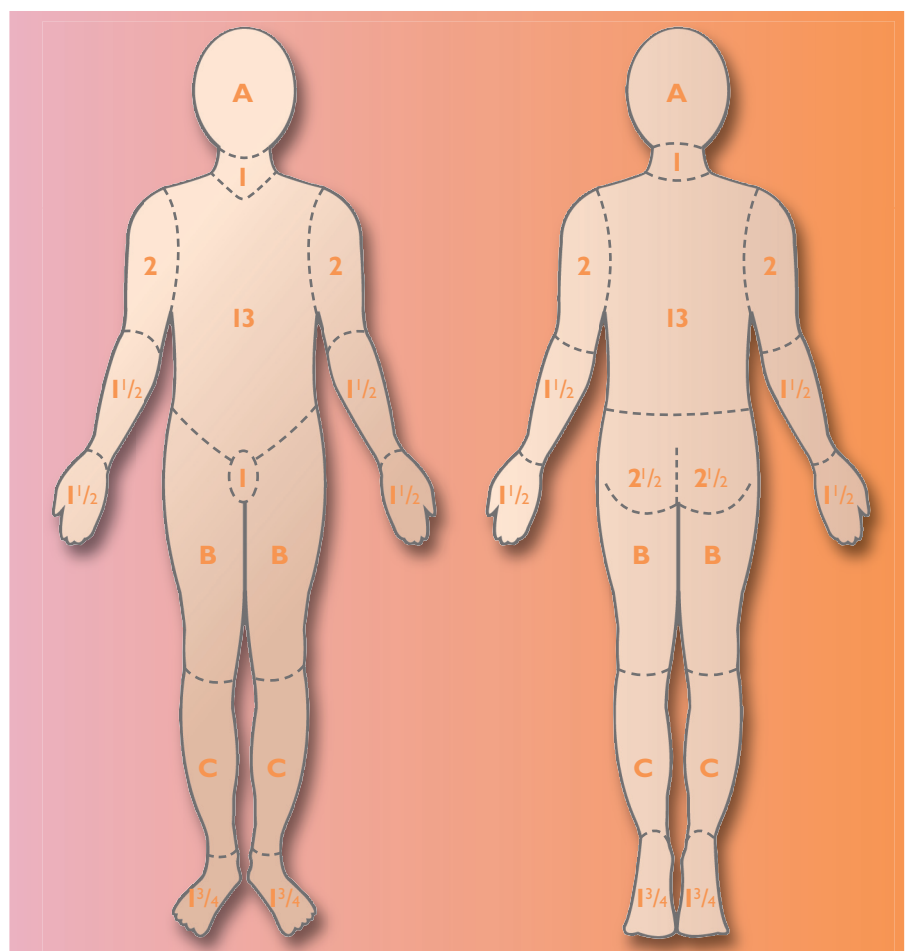
KEY WORDS

Lund and Browder chart
 Critical evaluation
 Psychometric properties
 Clinimetric properties
 Burns surface area

In his article *Psychometric Experiments* Francis Galton defined psychometry as the 'art of imposing measurement and number upon operations of the mind' (Galton, 1879). Psychometrics became the discipline of measuring psychological phenomena. Based on psychometrics, 'clinimetrics' is a term introduced by Feinstein in the mid-1980s as 'a methodologic discipline focusing on measurements issues in clinical medicine' (de Vet et al, 2003). Despite the debate whether it should exist as a separate discipline from psychometrics (Streiner, 2003; Fava and Belaise, 2005), clinimetrics is important in both the development and the evaluation of measurement instruments (de Vet et al, 2003).

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Figure 1. The essential elements of a Lund and Browder chart.

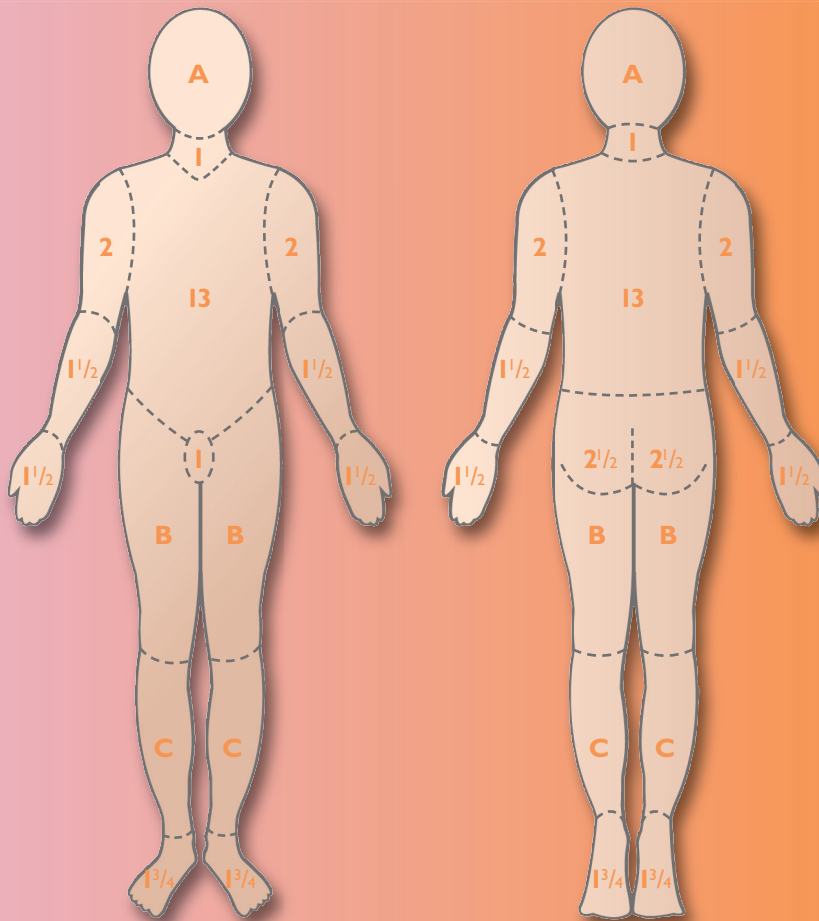


Relative percentage of areas affected by growth

Age in years	0	1	5	10	15	Adult
A – 1/2 of head	9 1/2	8 1/2	6 1/2	5 1/2	4 1/2	3 1/2
B – 1/2 of one thigh	2 3/4	3 1/4	4	4 1/4	4 1/2	4 3/4
C – 1/2 of one leg	2 1/2	2 1/2	2 3/4	3	3 1/4	3 1/2

Chart for estimating severity of burn wound

Lund and Browder charts



Relative percentage of body surface area affected by growth

Area	Age 0	1	5	10	15	Adult
A – 1/2 of head	9 1/2	8 1/2	6 1/2	5 1/2	4 1/2	3 1/2
B – 1/2 of one thigh	2 3/4	3 1/4	4	4 1/4	4 1/2	4 3/4
C – 1/2 of one leg	2 1/2	2 1/2	2 3/4	3	3 1/4	3 1/2

Name _____

Ward _____

Number _____

Date _____

Age _____

Admission weight _____

Ignore simple erythema

Partial-thickness loss (PTL)

Full-thickness loss (FTL)

Region	%	
	PTL	FTL
Head		
Neck		
Ant. trunk		
Post. trunk		
Right arm		
Left arm		
Buttocks		
Genitalia		
Right leg		
Left leg		
Total burn		

Figure 2. A commonly used Lund and Browder chart.

Measurement of wound size and more specifically surface area is an important part of a wound assessment. With regards to burn wounds, this measurement is expressed as a percentage (body surface area percentage — BSAP) of the total body surface area (TBSA), and it is the cornerstone of the management of patients with burns. It is used to establish the need for fluid resuscitation, the calculation of fluid requirements, evaluation of prognosis and monitoring the progress of

healing (Scott-Conner et al, 1986; Muir et al, 1987).

BSAP is assessed by three methods (Johnson and Richard, 2003): the rule of nines chart (Polaski and Tenisson, cited in Knaysi et al 1968); the area measured in units based on the patient's hand surface area (Perry et al, 1996; Rossiter et al, 1996; Amirshaybani et al, 2001); and the Lund and Browder (LB) chart (Lund and Browder, 1944), with or without modifications of the original (Sakson,

1959; Mercer et al, 1988). The LB chart is regarded by most authors as the most accurate and is widely used in everyday clinical practice (Muir et al, 1987).

The LB chart

The LB chart consists of two drawings of the human body — one of the anterior and the other of the posterior aspect of the human body (Figures 1 and 2). The BSAP of the various parts of the body appears on either the corresponding part of the drawing

and/or a separate table that goes alongside the drawings. The latter gives the BSAP according to age for the parts of the body that are affected by growth.

The assessor draws on the illustrations the actual burn, ignoring simple erythematous areas on the patient, and then compares the various parts of their drawing with the BSAP for that part of the body on the chart and assigns a value of the BSAP of the actual burn of that particular part of the body, which is then recorded in a further table on the LB chart. By summing up the estimated BSAP of the burn for the various parts of the body, the total BSAP that is affected by burns is calculated. An advantage of the method is that a graphical record of the burn is produced. Also, the LB chart considers the different proportions of children.

Unlike scales that measure quality of life for patients with burns (Blalock et al, 1994; Sanz et al, 1998), their psychometric properties and errors associated with them, BSAP is a physical measure. As an instrument that assesses a physical measure, the LB chart is vulnerable to a number of errors, due to the subject, the instrument (e.g. inaccurate percentages assigned to various parts of the body), error by the assessor or due to interpretation (Mason and Pruitt, 1988). They may be pre-analytic, analytic (e.g. the assessor wrongly estimates the BSAP) or post-analytic (e.g. the summation of the percentages is incorrect). This article will examine the evidence about the reliability of the LB chart.

Reliability

For physical measures, the term precision is used (Plassmann and Peters, 2001), and refers to the ability to give the same BSAP values on repeated measurements of the same patient with a burn wound (Streiner and Norman, 1995).

Test-retest reliability

This refers to the ability of the chart to produce identical or very close BSAP values when assessing the same patient under the same conditions

but on separate occasions (Streiner and Norman, 1995). If the results correlate, then the test-retest reliability is high (Greehalgh, 1997). It may be inappropriate for assessing the LB chart if the tester remembers the BSAP estimated on the first assessment, as they may be subconsciously inclined to record the same percentage during the subsequent assessment in order not to appear inconsistent. Also, if the interval between assessments is longer than a few days, the wound may be partially healed, and the second BSAP estimate will not be a true expression of variability.

Another interesting finding was that there was less variability between assessors on a version of an LB chart where the anterior/posterior orientation of the figure on the chart was reversed, indicating that psychometric properties of the chart can improve with minor modifications.

Inter-rater reliability

This refers to the ability of the LB chart to produce similar values of BSAP for the same patient when assessed by different people. If these values correlate for a number of patients, then the inter-rater reliability is high (Streiner and Norman, 1995). Wachtel et al's (2000) study is the only one identified which aims to assess inter-rater reliability of the LB chart. This illustrates the absence of validation studies of this long-standing and widely used instrument. The authors employed 24 assessors to estimate the BSAP using drawings of 10 burns using different versions of the LB chart and the rule of nines charts. They showed different variability of estimates obtained by two different groups of professions (burn nurses and other estimators exhibited a significantly greater variability than burn surgeons, physicians' assistants and residents). Less variability (higher reliability, agreement or precision) was dependent on the greater number of

drawings the practitioner had made previously, rather than the length of experience in burns care. There was greater variability between assessors when assessing irregularly shaped burns rather than regularly shaped burns; increasing variability with burn size initially, which then levelled in large burns and then decreased slightly in extensive burns. Another interesting finding was that there was less variability between assessors on a version of an LB chart where the anterior/posterior orientation of the figure on the chart was reversed, indicating that psychometric properties of the chart can improve with minor modifications. In the same study, the rule of nines charts were shown to have greater variability between assessors.

There are two main weaknesses of the study. First, they assessed only part of the construct by ignoring an important aspect of the method of assessment, namely, to copy an actual burn of a tri-dimensional patient in the charts, as they were looking at hypothetical, drawn burns and recording their findings on LB charts (Wilson et al, 1987). Second, they did not produce an analysis of variance (ANOVA) table for drawings and raters for the LB chart specifically, from which a reliability coefficient could be calculated and a more meaningful conclusion be drawn (Streiner and Norman, 1995).

Validity

Validity refers to the ability of the LB chart to measure what it is supposed to measure, i.e. the BSAP of a burn wound. Even if it is reliable and its values reproducible, the LB chart may be measuring something different and may not be accurate (Streiner and Norman, 1995). Its importance is highlighted in two studies: a retrospective study by Collis et al (1999) criticised by McGugan et al (2000) which showed inaccuracies in burn size estimation in A&E departments before referral, and subsequent inappropriate fluid resuscitation and transfer of patients. A similar study of inaccuracies before transfer by Hammond and Ward

(1987) showed that large burns are underestimated, perhaps because assessors tend to calculate the percentage of the intact rather than the burnt skin areas.

Validity can be tested in a number of ways and the most important and applicable will be examined in turn.

Concurrent validity

Concurrent validity refers to the ability to use the LB chart to produce BSAP values that correlate with those produced by another instrument. It relies on the existence of another tool (ideally a gold standard) that measures BSAP (Streiner and Norman, 1995). At the time when the chart was introduced there was no such standard.

Ways to measure BSAP that are perhaps most accurate but are not widely used in everyday clinical practice, involve computerised planimetry or stereogrammetry (Siegel et al, 1986). Goldman and Salcido (2002) point out the drawbacks of higher cost and the need to have a trained operator. Comparison of the LB chart with these methods is important, as they both measure the construct directly and they are as close as possible to the gold standard in terms of both accuracy and precision (Plassmann and Peters, 2001).

In a study by Wachtel et al (2000), the LB chart and the rule of nines chart were both compared with the gold standard of planimetry. Even though the study aimed at assessing reliability, the authors pointed out the less accurate estimation of BSAP by the rule of nines chart than by the LB chart compared with planimetry estimates. They did not assess concurrent validity statistically.

In a useful study by Nichter et al (1985), computerised calculations of BSAP from physicians' sketches in LB charts of a projected photographic image of a simulated patient with burns were very close to the computerised calculation of BSAP from the projected image (using a scaling conversion based on the patient's

height and weight). This indicates that fairly accurate diagrams of the burn were made by physicians. This was also found to be independent of the level of experience of the practitioner. However, physicians' estimates of BSAP which were based on the rule of nines were found to be inaccurate. Main weaknesses of the study are that it involved only one burn percentage and that it does not take into account the three-dimensional nature of the patient (Nichter et al, 1985). The study could have examined various simulated burn sizes for which the results might have been different.

Another useful study assessing accuracy (validity) by Scott-Conner et al (1988) employed computerised planimetry. It showed a statistically significant correlation between values recorded in 148 hand-drawn LB charts and computer calculated percentages. Even though the (computerised) planimetry was applied to chart drawings and not three-dimensional patients, their result complements findings of Nichter et al's (1985) study. Potential assessor bias exists, as the assessor was not blinded, and sample bias may also exist, e.g. the exclusion criterion of vaguely drawn admission burn charts. This may be inappropriate as these burns may represent ill-defined, irregular burns whose BSAP would have been inaccurately estimated by a human assessor, but perhaps correctly estimated by the computerised planimetry if the latter was directly applied to the patients. A specific PC software (Tripodi et al, 2004) and a similar computer-aided design (CAD) mapping method (Kanthraj, 2005) were evaluated as tools to determine the BSAP of atopic dermatitis and cutaneous lesions in general. Although these tools were not used to assess burns in particular, and the studies do not evaluate the LB chart, they project the significance of computers as part of methods that estimate BSAP and approximate the gold standard of assessment techniques, against which the LB chart's concurrent validity could be compared.

Sensitivity and specificity

Sensitivity (true positive), specificity (true negative), positive and negative predictive values are all indicators of validity that apply to dichotomous variables. The LB chart measures BSAP, a variable that is at a ratio level of measurement (on a continuous numerical scale with equal intervals between points and with an absolute zero) (Streiner and Norman, 1995). Therefore, sensitivity and specificity, which are important indicators of validity for dichotomous variables, cannot be applied to the LB chart.

Construct validity

If we presume that there is not a gold standard against which concurrent validity of the LB chart can be assessed, construct validity is the form of validity that needs to be employed, and is more concerned with the underlying attributes (Streiner and Norman, 1995) which, in this case, are the BSA burnt and the TBSA, the latter being an anthropometric measure (Reading and Freeman, 2005). As the BSAP measured by the LB chart is not measured directly (neither the surface area of the burn nor the TBSA is measured directly), but, instead, relies on earlier documentation on the chart, the construct validity of the test can only be evaluated by examining the percentages assigned to the various body parts and presented in the chart. These were introduced by Lund and Browder (1944) based on earlier work by Funke in 1858 (Knaysi et al, 1968) who calculated TBSA by counting adhesive paper squares covering a cadaver's skin; Du Bois and Du Bois in 1915 (Lund and Browder, 1944) produced a formula for TBSA based on weight and height; in 1924 Berkow (Lund and Browder, 1944) who introduced the idea of assessing the body by segments; and Boyd's 1935 monogram (Lund and Browder, 1944) which provided useful data about the surface area for different body parts and for various ages. Klippel (1979) expressed a number of valid concerns surrounding this earlier work. These concerns, alongside the facts that the chart has not

been developed or validated by an expert panel using stringent scientific principles and defined protocols, and that the anthropometric data on which it is based are more than 60 years old, suggest that the tool needs to be validated using psychometric methods and modern data.

Acceptability

Acceptability refers to the degree that the LB chart is suitable for the target population (Streiner and Norman, 1995). The chart is used on everyone, irrespective of age; size of burns; whether the patient may be particularly ill and require rapid assessment or have associated conditions such as amputated body parts, obesity, breast hyperplasia and pregnancy that may affect body proportions.

With regards to different age groups, this is the exact reason that the chart was introduced. Lund and Browder identified inaccuracies in the percentages assigned to various body parts when applied to children, and they accounted for the different relative proportions of these body parts in their chart based on Boyd's work (1935). In addition, Wilson et al (1987) showed that by introducing separate charts for different age groups, the recording of the BSAP improved significantly.

With regards to the time required to complete the chart, Wachtel et al (2000) showed that time to assess was slightly greater with the LB charts compared with the rule of nines charts, but statistical analysis was not mentioned and the standard deviations of the average times were high enough to preclude any meaningful conclusions. By having separate charts for different age groups, and printing the percentages assigned to the different body parts on the drawing where they can be seen immediately, Wilson et al (1987) simplified the assessment process with their version of the LB chart.

Regarding patients with amputated parts or with conditions

that affect body part proportions, such as acromegaly, Lund and Browder admitted that the BSAP estimated with their chart could be inaccurate. In spite of this, the authors claimed that the chart is applicable to 95.5% of the population. The need still exists for corrections when faced with such patients, perhaps in an inset in the chart.

Large-breasted or pregnant women have the potential of affecting the relative body proportions and the BSAP estimates based on the LB chart. Hidvegi et al (2004) argued that the LB chart was based on only three women and eight men. In their study of 20 men, 20 small-breasted and 20 large-breasted women, no significant difference in torso surface area/TBSA ratio was found, but the proportion of anterior to posterior trunk size did depend on gender and breast size. Irrespective of weaknesses in their study, such as the fact that bra cup size is an unreliable proxy for breast surface area (Greenbaum and Dunn (2005), their criticism of the LB chart still has relevance (Evison and Berry, 2005).

Obese patients are another group of patients for which the LB chart may be less appropriate (Livingston and Lee, 2000). This becomes more significant if we consider that the prevalence of obesity in the western world is greater than ever (Greenbaum and Dunn, 2005). The need to validate the instrument's construct validity with current anthropometric data is once more highlighted.

Readability

Readability usually refers to the patient completing a questionnaire independently, but in the case of the LB chart, the psychometric property of readability becomes applicable to the assessor of the burn, who may be an experienced burns surgeon but more commonly is inexperienced and unfamiliar with the chart. It refers to the degree that the chart is easy to understand, uses appropriate language and avoids ambiguity either in the

instructions or in the items included (Streiner and Norman, 1995).

Lund and Browder identified ambiguities in the edges of the body regions on the chart, for instance where the thighs separate from the trunk and whether the buttocks are included in the posterior trunk or the lower limbs. They clarified and clearly defined these regions and introduced lines in the body drawing in their chart. Furthermore, Wilson et al (1987) showed that having the percentages on the corresponding parts of the drawing on the chart simplifies the recording of the burn, prevents inaccuracies and encourages people to use it. They attribute inaccuracies in great part to inclusion of simple erythema as part of the BSAP, which should not be included. This emphasises the importance of a

Key Points

- ▶▶ The application of clinimetric principles is required for the evaluation and revalidation of even long established wound assessment tools such as the Lund and Browder chart.
- ▶▶ Concurrent validity of the chart based on computerised planimetry standards appears high.
- ▶▶ Evaluation of the instrument's construct validity with current anthropometric data is required.
- ▶▶ The LB chart does not take into account obesity, breast size, pregnancy status, and amputated body parts, all of which may affect the calculated BSAP.
- ▶▶ Healthcare professionals using the LB chart should be formally trained and made aware of its weaknesses.

written instruction, which does appear in some versions of the chart.

However, simple erythema can sometimes be difficult to distinguish from partial-thickness burns in the first hours post-burn.

Conclusion

The psychometric properties of the LB chart are seldom addressed in the literature. Even though concurrent validity of the chart based on computerised planimetry standards appears high, the fragmented approach employed to evaluate this instrument's other clinimetric properties precludes any meaningful conclusions. Although its importance in various aspects of the management of patients with burns, established primarily through its age and its relative ease of use, cannot be underestimated, the age of the data upon which it is based and the flaws identified, especially in relation to its suitability for everyone, raise issues that can be resolved only with the application of scientific principles and defined protocols by a team of experts in a more formal approach. Educating assessors, especially staff unfamiliar with the chart or burn injuries, and increasing awareness of the chart's flaws is paramount. **WUK**

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