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Research article

Comparison between the Lund-Browder chart and the BurnCase 3D® for consistency in estimating total body surface area burned

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Abstract

Objective: Measure time required to determine total body surface area (TBSA) burned (% TBSA) using the Lund-Browder chart and BurnCase 3D®, and calculate discrepancy between the two methods' % TBSA estimates.

Methods: We asked 3 burn experts with 7 to 9 years of experience to participate in our experiment by estimating TBSA burned (% TBSA) for 26 subjects with a total of 262 photos, based on the Lund-Browder chart and the BurnCase 3D. We also measured time required for each estimation.

Results: Estimations via the Lund-Browder chart and the BurnCase 3D showed statistically significant differences for Observers 1 and 2 ($p < 0.05$), but not for Observer 3 ($p = 0.11$). Inter-observer variability was insignificant among the observers ($p = 0.31$). When using the BurnCase 3D, burn estimation was consistent across the 3 participants ($p = 0.31$), yet the time spent for each method was significantly different ($p < 0.05$) from using the Lund-Browder chart and the time spent for estimation did not statistically vary ($p = 0.20$). Time spent on burn estimation varied when using either the Lund-Browder chart or the BurnCase 3D for all participants ($p < 0.05$).

Conclusion: Using the BurnCase 3D over the Lund-Browder chart produced slightly different estimations for TBSA burned but estimation results stayed stable across inspectors. Due to the small sample size however, further investigation is necessary.

Keywords: [Up to 6 additional, relevant terms that don't appear in the title or abstract]

Introduction

Total body surface area burned (% TBSA) is the primary factor used in predicting burn patient mortality and it is the primary parameter for calculating total volume of fluid resuscitation.[1] A variety of fluid resuscitation techniques are practiced for burn patients and they all rely on the patient's body weight and % TBSA.[2] This approach has the disadvantage that the calculation result depends on the clinical practitioner's subjective measurement. Harish reported that estimation for % TBSA significantly varies among referring hospitals and burn units when identical patients were taken in.[3] Giretzlehner et al. observed that in extreme cases estimation for % TBSA for the same patient could deviate up to 16.5% in relation to the mean value among burn specialists.[4] which in turn either increase or decrease the volume of resuscitation fluid in the same proportion, or up to 5,280mL. Excessive or insufficient infusion amount has negative effects on treatment. Therefore, efforts have been made to address such subjective deviations.[5][6][7][8] Among many tools we noted that the BurnCase 3D®[5] is easy to adopt for most environments because it costs less than other alternatives and requires only commodity hardware to use, just a regular PC and any smartphone with a camera.

In this paper, we compare the difference of the estimation for % TBSA produced with the BurnCase 3D and the conventional Lund-Browder chart, as a preliminary study, this paper investigates pros and cons of adoption.

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Material and methods

For this study, 3 burn specialists with 7, 9, and 9 years, respectively, of experience in burn treatment made a review on a total of 262 pictures for 26 burn patients, who had been admitted to the Hanil General Hospital of South Korea between 2013 and 2017. In the data provided to the reviewers, we included age, sex, body weight, height, type of burn, and initial burn pictures. Those who suffered electrocution or inhalation injury without any external wound were ruled out. Additionally, cases with photos of poor quality were discarded. After consulting a statistician, the number of observers was determined to 3 in order to reduce inter-observer variation. Each of the 3 participating burn specialists produced an estimated % TBSA based on the Lund-Browder chart as well as the BurnCase 3D in sequence. Time spent on each estimation was recorded.

Statistical analysis was performed using the SAS® version 9.4 for Windows. To compare the results based on Lund-Browder chart and the BurnCase 3D, we performed a paired t-test. In consideration of inter-observer variability, we used repeated ANOVA measure, in which we opted for the default setting. To verify differences among the three groups, we used one-way model, in which we chose average and nested-effects for unit and effect, respectively.

Results

We collected 262 pictures for 26 subjects (Table 1) consisting of 18 males and 7 females. The number of pictures for patients varied from 1 to 30. The patients were 54.2±15.8 years in age, and their body mass index was 24.6±3.4kg/m^2. World Health Organization (WHO) defines 25kg/m^2 and 30kg/m^2 in BMI as overweight and obesity each in general. However, Korean Society for the Study of Obesity (KOSSO) and Asia-Pacific section of WHO have agreed to use lower indices of 23kg/m^2 and 25kg/m^2 for overweight and obesity because the prevalence of diabetes and cardiovascular diseases doubles above the 25kg/m^2.[9][10][11] With the regular WHO standard, 13 patients, or 50% of the 26, were

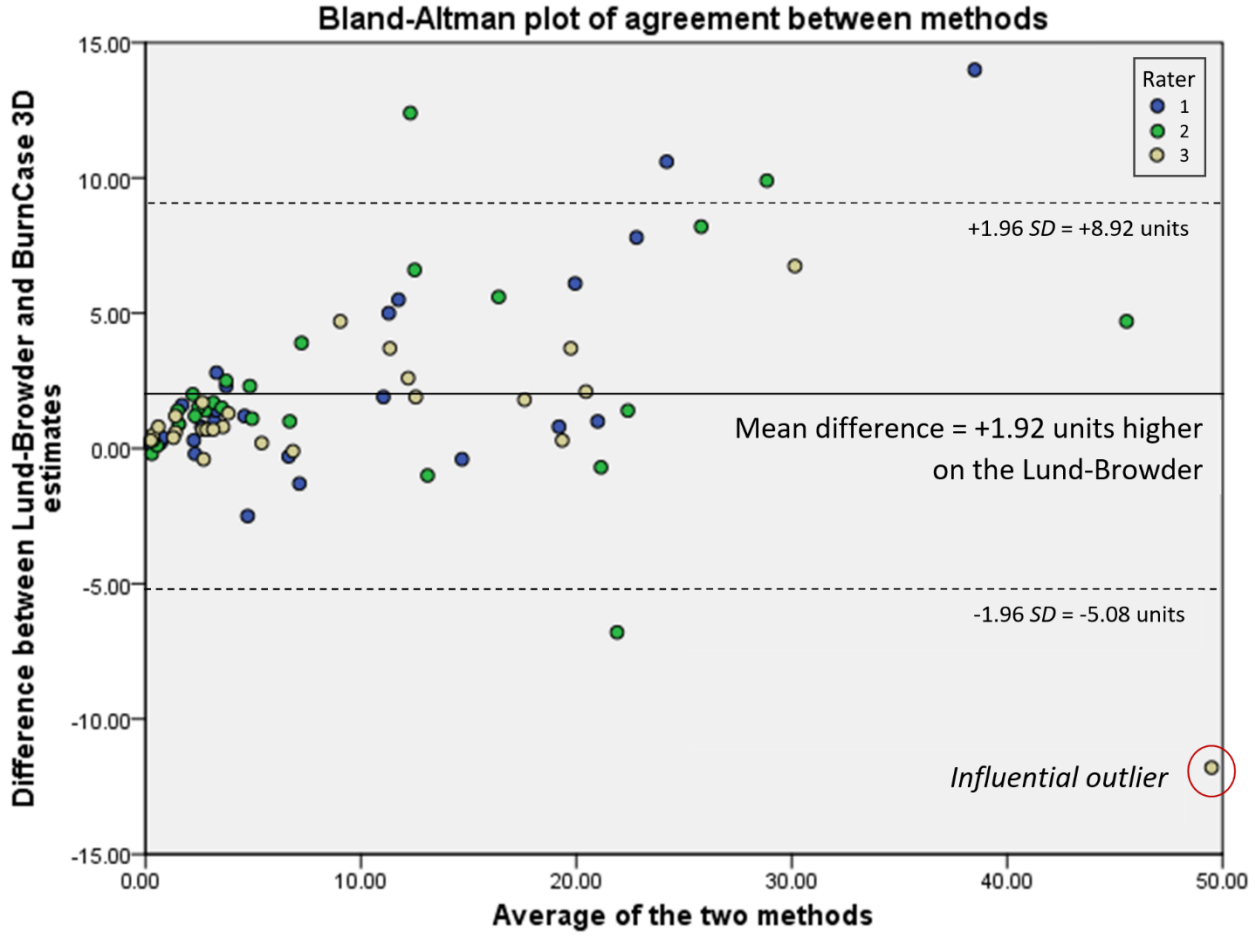

Figure 1 | Bland-altman plot of 3 clinicians' ratings of burn size, using two different methods

Table 1 | Basic characteristic about subjects

Case	Age	Sex	Height (Cm)	Body Weight (kg)	BMIa (kg/m2)	Type of Burn	No. of Pictures
1	42	M	168	77.9	27.6	Scalding	5
2	47	M	175	86	28.1	Flame	30
3	67	F	156	59.8	24.6	Scalding	9
4	66	M	168	76	26.9	Flame	25
5	62	M	165	75.5	27.7	Electric	12
6	42	M	175	80	26.1	Flame	18
7	58	M	170	69.5	24	Electric	17
8	71	F	159	70.4	27.8	Scalding	12
9	82	F	152	49	21.2	Scalding	6
10	49	F	148	53.6	24.5	Scalding	5
11	42	M	175	75	24.5	Electric	18
12	59	M	173	51.6	17.2	Contact	3
13	55	M	169	83.5	29.2	Electric	11
14	77	M	171	74.3	25.4	Chemical	4
15	45	M	183	86	25.7	Electric	9
16	53	M	175	72	23.5	Chemical	15
17	54	F	160	72	28.1	Scalding	3
18	53	M	160	64.8	25.3	Scalding	6
19	57	M	174	85.3	28.2	Scalding	10
20	51	M	164	56	20.8	Electric	16
21	26	M	180	78	24.1	Electric	2
22	75	F	145	32.6	15.5	Flame	11
23	25	M	180	73.5	22.7	Electric	7
24	76	F	150	46	20.4	Flame	6
25	22	M	165	74.9	27.5	Flame	10

overweight and none were in the category of obesity. With the WHO standard for Asians, then, 6 patients (23.1%) were overweight and 13 patients (50%) obese. Among them, 8 cases were caused by scalding, 7 by flame, 2 by chemical, 1 by contact, and 8 by electric burn. Out of the 26 subjects, the wounds appeared on different body parts as following: 8 cases in the head; 8 cases in the neck; 16 cases in the trunk (Ant. & Post.); 2 cases in the right buttock; 3 cases in left buttock; 4 cases in the genitalia; 10 cases in the right arm (except hand); 11 cases in the left arm (except hand); 2 cases in the right hand; 3 cases in the left hand; 8 cases in the right leg; 7 cases in the left leg; 4 cases in the right foot; 3 cases in the left foot. Only 3 cases had wounds near the anus or the perineum (Table 2). The average estimation for burn size against size of TBSA burned based on the Lund-Browder chart by each observer was: 10.5±11.2% (Observer 1), 11.5±12% (Observer 2), and 9.9±10.9% (Observer 3) (Table 3). The average of all of the observers with the Lund-Browder chart was 10.6±11.3%. On the other hand, the average % TBSA based on BurnCase 3D was: 8.2±8.3% (Observer 1), 9.1±10.9% (Observer 2), and 8.9±12% (Observer 3). The average of all of the observers with the BurnCase 3D was 8.7±10.4%.

Table 2 | Wound areas (burn) of the 26 subjects

Burn area	Case count
Head	8
Neck	2
Ant. & Post. Trunk	16
Rt. buttock	2
Lt. buttock	3
Proximity near anus	3
Genitalia	4
Rt. arm (except hand)	10
Lt. arm (except hand)	11
Rt. hand	2
Lt. hand	3
Rt. leg (including thigh)	8
Lt. leg (including thigh)	7
Rt. foot	4
Lt. foot	3

The % TBSA difference between the two methods was calculated with a paired t-test. The BurnCase 3D produced significantly smaller estimates, t (77) = 4.74, p<.0005, 95% *CI*: 1.11 to 3.58. Agreement ranking the size of the burns was high across methods, r = .95, p<.0005. In subgroup analysis for each rater separately, Observers 1 and 2 showed statistical significance (p < 0.05) whereas Observer 3 did not (p= 0.11) (Table 4).

The intraclass correlation for raters on the Lund-Browder chart was .97 using an absolute agreement, random effects model, ICC(A,1) in McGraw & Wong's parlance. For BurnCase 3D, the ICC(A,1) was .92. Both are considered "excellent" reliability according to multiple rubrics.[12][13] (Table 3).

A Bland-Altman plot examined the reproducibility of burn size estimates across methods, looking at the size of the discrepancy between the Lund-Browder minus BurnCase 3D estimates as a function of the average of

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Table 3 | TBSA results of the observers (%)

	Observer 1		Observer 2		Observer 3			
Case	**Lund[a]**	**BurnCase[b]**	**Lund[a]**	**BurnCase[b]**	**Lund[a]**	**BurnCase[b]**	**CV[c]**	**CV[d]**
1	3.7	2.7	3.5	2.1	3.2	2.5	0.1	0.1
2	45.5	31.5	47.9	43.2	43.6	55.4	0	0.3
3	2.2	2.4	3.2	1.7	2.5	2.9	0.2	0.3
4	29.5	18.9	29.9	21.7	33.5	26.8	0.1	0.2
5	0.3	0.2	0.2	0.4	0.6	0.1	0.6	0.7
6	12	10.1	12.6	13.6	13.5	11.6	0.1	0.1
7	13.8	8.8	19.2	13.6	13.5	10.9	0.2	0.2
8	14.5	9	15.8	9.2	11.4	6.7	0.2	0.2
9	4	2.6	6	3.7	4	3.2	0.2	0.2
10	6.5	7.8	7.2	6.2	5.5	5.3	0.1	0.2
11	23	16.9	20.8	21.5	21.5	19.4	0.1	0.1
12	0.8	0.6	0.6	0.5	1	0.2	0.3	0.5
13	4.9	2.6	2.9	1.7	3.5	1.8	0.3	0.2
14	2	1.1	2	1.1	2	0.8	0	0.2
15	1	0.6	0.5	0.2	0.4	0.1	0.5	0.9
16	26.7	18.9	33.8	23.9	19.5	19.2	0.3	0.1
17	4.7	1.9	5.5	4.4	4.5	3.2	0.1	0.4
18	3	2.2	4	2.3	3	2.3	0.2	0
19	6.5	6.8	9.2	5.3	6.8	6.9	0.2	0.1
20	21.5	20.5	23.1	21.7	21.6	17.9	0	0.1
21	2.4	2.1	3.2	1.2	1.7	1.1	0.3	0.4
22	14.5	14.9	18.5	6.1	13.2	9.5	0.2	0.4
23	3.5	6	4.3	2.8	3.2	2.5	0.2	0.5
24	5.2	4	5	2.5	3.5	2.8	0.2	0.3
25	19.6	18.8	18.5	25.3	18.5	16.7	0	0.2
26	2.5	0.9	2.2	0.8	1.5	1.1	0.2	0.2
Inter-observer significance of each method (p)							0.06	0.46

[a]TBSA results using the Lund-Browder chart

[b]TBSA results using the BurnCase 3D

[c]Coefficient of variance among observers in the Lund-Browder chart

[d]Coefficient of variance among observers in the BurnCase 3D

the two estimates. The plot showed that the Lund-Browder tended to produce larger estimates of burn size, and that the difference increased with the size of the burns. There was a potentially influential outlier based on regression analyses, and dropping this outlier made the tendency of the Lund-Browder method to yield larger burn sizes even more pronounced.

The means of elapsed time with the Lund-Browder chart were 172±174 seconds (Observer 1), 97±93 sec.(Observer 2), and 188±153 sec. (Observer 3) (Table 5), with the net mean of 152±148 sec. The means of elapsed time with the BurnCase 3D were 461±334 sec. (Observer 1), 500±563 sec. (Observer 2), and and 757±989 sec. (Observer 3), with the net average of 573±688 sec. The elapsed time difference between the two methods was also tested, and all of the Observers showed statistical difference ($p < 0.05$) (Table 6). This signifies that no difference exists between the observers ($p = 0.20$). Inter-individual variation had statistical significance for each method ($p < 0.05$) (Table 6).

Discussion

Accurate estimation for % TBSA is essential in burn treatment. This value is used for patient mortality (Baux score) estimation as well as calculating the required amount of resuscitating fluid.[1][2] Three methods have been established and widely used for % TBSA estimation,[14][15][16][17] yet all of them have relied on practi-

Table 4 | Wound areas (burn) of the 26 subjects

Observer	Assessing Method	Average of diference	Intra-observer significance (p)	Inter-observer significance (p)
1	Lund-Browder / BurnCase 3D	2.3 ± 3.8	< 0.05	0.31
2	Lund-Browder / BurnCase 3D	2.4 ± 3.8	<0.05	
3	Lund-Browder / BurnCase 3D	0.9 ± 3.1	0.11	

Table 5 | Elapsed time of the observers for assessment (in seconds)

	Observer 1		Observer 2		Observer 3			
Case	**Lund[a]**	**BurnCase[b]**	**Lund[a]**	**BurnCase[b]**	**Lund[a]**	**BurnCase[b]**	**CV[c]**	**CV[d]**
1	73	371	47	329	120	387	0.5	0.1
2	820	1247	431	2631	611	4543	0.3	0.6
3	84	32	50	279	87	452	0.3	0.3
4	405	1153	222	1275	517	2918	0.4	0.6
5	25	46	23	135	82	306	0.8	0.8
6	120	431	171	1053	250	1510	0.4	0.5
7	280	789	221	1085	440	1200	0.4	0.2
8	264	800	147	734	237	629	0.3	0.1
9	110	321	46	190	58	56	0.5	0.7
10	104	372	57	331	116	187	0.3	0.3
11	190	803	136	1033	261	916	0.3	0.1
12	78	210	20	166	44	100	0.6	0.3
13	185	681	77	260	190	525	0.4	0.4
14	37	36	16	88	30	78	0.4	0.4
15	141	140	39	118	69	140	0.6	0.1
16	482	837	168	633	319	929	0.5	0.2
17	48	107	29	128	89	216	0.6	0.4
18	45	193	21	191	93	270	0.7	0.2
19	107	290	56	263	154	507	0.5	0.4
20	221	554	154	800	343	1147	0.4	0.4
21	71	142	52	100	39	178	0.3	0.3
22	211	690	113	367	226	1086	0.3	0.5
23	68	585	43	206	93	520	0.4	0.5
24	81	275	38	168	154	208	0.6	0.2
25	178	515	110	372	216	588	0.3	0.2
26	40	90	31	71	46	76	0.2	0.1
Inter-observer significance of the each method (p)							< 0.05	< 0.05

[a]Elapsed time using the Lund-Browder chart

[b]Elapsed time using the BurnCase 3D

[c]Coefficient of variance among observers in the Lund-Browder chart

[d]Coefficient of variance among observers in the BurnCase 3D

tioner's subjective estimation. It has even been suggested that estimated % TBSA could vary depending on the physician's burn-related experience grows.[18] Collis et al. have reported that smaller burns tend to be overestimated while larger burns underestimated.[19] A recent study suggested that estimation discrepancy worsens as time progresses.[3] Such a gap is found among burn professionals and the discrepancy of burn size estimation could be as large as 16.5% ,[4] which could vary fluid used during resuscitation by as much as 5,000mL. Inadequate infusion in burn treatment may be a cause for both over-resuscitation and under-resuscitation. Over-estimation leads to excessive infusion, which may promote pulmonary complications, compartment syndrome, and increase in likelihood of escharotomy.[20] On the other hand, under-estimation may cause acute kidney injury and/or circulatory collapse. Such negative results, however, may be caused by diverse factors including pre-morbidities, burn type, preceded dehydration.[21] Even so, inaccuracy in % TBSA estimation due to subjective observation only hinders treatment and research for burn.

Table 6 | Wound areas (burn) of the 26 subjects

Observer	Assessing Method	Average of diference	Intra-observer significance (p)	Inter-observer significance (p)
1	Lund-Browder / BurnCase 3D	2.3 ± 3.8	< 0.05	0.31
2	Lund-Browder / BurnCase 3D	2.4 ± 3.8	<0.05	
3	Lund-Browder / BurnCase 3D	0.9 ± 3.1	0.11	

We chose the BurnCase 3D to test if burn area estimation can be made less prone to subjective discrepancy. The basis for our choice is ease of adoption for most clinical environments: it does not require purchasing special hardware for data capturing or processing. It only requires a commodity smartphone with a camera and a PC to run the software. For comparison, we used the Lund-Browder chart, which produces improved accuracy over the rule of palm and the rule of nines, but it has been reported that the result may be inaccurate for obese patients.[17] Despite this shortcoming, the Lund-Browder chart offers more practical benefits in photographic assessment.

In our study, 3clinicians with 7 to 9 years of burn treatment experience participated for burn area estimation with the Lund-Browder chart and the BurnCase 3D. We identified inter-observer difference in the BurnCase 3D-based estimations. In % TBSA assessment, we found meaningful statistical differences with the two methods between two observers while difference was insignificant for one observer. This implies variance in burn expertise among the observers. All 3 of the observers had substantial experience of 7 to 9 years as burn surgeons. Before starting with burn estimation, all 3 were given detailed instruction on how to use the software and went through a tutorial with 5 burn images, which were excluded from burn estimation for this study. Observer 3 is an author of this study and had some experience of using the software, which may explain the insignificant statistical difference. There is a possibility that in the case of Observer 3, such previous experiences could have improve the burn size estimation. In other words, the experience of using BurnCase 3D and checking the output may have enabled Observer 3 to 'calibrate' the result for when not using BurnCase 3D. This suggests that results obtained using BurnCase 3D are more positive and closer to being objective when compared with classical methods as part of the training and calibration process.[5][22][23] This implies that the discrepancy of burn-size estimation could be reduced among burn specialist, medical students, and research associates if BurnCase 3D is widely used.[22] However, we believe research on this calibration effect and the learning curve for BurnCase 3D merits additional research.

Repeated measures ANOVA and the Bland-Altman plot both indicate a small but significant tendency for the Lund-Browder method to produce larger estimates of burn size than the BurnCase 3D. This was true for 2 of 3 clinicians in subgroup analysis, and significant overall with an average difference of ~2% for burn size. The Bland-Altman plot indicates that the discrepancies tend to increase as the burn size increases. These results differ from findings in Giretzlehner et al.[4] BurnCase3D produces lower levels of % TBSA in comparison with the Lund-Browder Chart and one possible explanation is that BurnCase3D estimates burn area more accurately, free from clinicians' subjective bias. In our experiment, however, in large burn areas, % TBSA estimation unexpectedly tended to be larger and the differences with the Lund-Browder Chart results were larger. To identify the cause of the seemingly anomalous differences, we investigated our data if pictures with large burn areas were taken in such a way that burn area estimation would be difficult but only in vain. We also looked in the literature to see if such differences are a characteristic of burn estimation that is based solely on the Lund-Browder Chart but did not find any work on the topic. Therefore, research investigating the % TBSA estimation differences with different methods, e.g., Rule of 9's, Palm method, the Lund-Browder Chart, looks necessary in the future.

All three observers work in the same hospital. Burn estimation based on BurnCase 3D showed no difference between the observers (inter-observer variation), which agrees with the study by Parvizi et al.,[6] which reported intraclass correlation of 0.98 with BurnCase 3D, similar to the ICC of .92 observed in the present study. These results imply that % TBSA estimation is consistent when the BurnCase 3D is used by different raters. With the few studies around the software, it merits further research to see if burn estimation variance can be reliably reduced with the BurnCase 3D.

BurnCase 3D has two methods of estimating % TBSA based on patient's photos: one that involves superimposing the photo on the 3D model; and the other that does not. In the non-superimposition method, the wound and the 3D model are merely displayed separately. Superimposing photos on the 3D model creates a more accurate wound representation at the cost of more estimation time by users. On the other hand, without superimposition, % TBSA estimation can be performed faster and the time difference is even more marked when the burn area is large. Observers spent around 2.5 minutes for burn estimation with the Lund-Browder chart and more than 9 minutes with the BurnCase 3D, and more than 10 minutes for cases when % TBSA was considered to be greater than 10%. The greater the number of burn images, the more time our observers took for estimation. For our experiment, all of the photos were superimposed, and this may have contributed to the increased estimation time for each observer. Had we provided only the non-superimposition method, their estimation time may have been reduced, however, this factor was not anticipated in the experiment designing phase. In future work, we will adopt both methods for % TBSA estimation.

One known shortcoming of BurnCase 3D is that estimation result can be inaccurate when the wound is located where different body parts overlap, e.g., perineum or medial side in the buttock. Only 3 out of the 26 patients had wounds near the buttock or the perineum in our sample, limiting the potential for evaluating whether the BurnCase 3D has a weakness in estimating burn areas in these regions.

Despite sufficiently wide spread of EMR (electronic medical record) systems in South Korea, little work has been published on computer-aided burn size estimation. In writing this paper as a preliminary study, we hoped to trigger future research activities.

Conclusion

This preliminary study found that both the Lund-Browder chart and BurnCase 3D showed excellent inter-rater reliability in % TBSA estimation. The BurnCase 3D scores were very highly correlated with the Lund-Browder scores, but showed a small yet significant tendency to make smaller estimates of burn size (by almost 2%). The BurnCase 3D also took significantly longer to complete and score. These considerations need to be balanced against the lower costs associated with hardware and use of the BurnCase 3D.

Study limitations include that were very few subjects with TBSA 20% or above and few with burns on perineum; the small number of relevant observations did not let us evaluate some factors that might affect accuracy of BurnCase 3D. The meaningful discrepancy in user proficiency for using BurnCase 3D among observers and weak diversity of burn areas were additional factors that could be improved in future work.

Future studies should include a larger number of observers with varied proficiency, more in-depth evaluation methods for BurnCase 3D, diverse burn areas, as well as perhaps oversampling specific body parts that might be more challenging for some imaging techniques. Because accuracy of % TBSA estimation is related to prognosis, correlation of % TBSA estimation versus mortality would meaningfully contribute to future work.

Additional information

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Disclosure

We were granted license for BurnCase 3D by Dr. Michael Giretzlehner of RISC Software GmbH, Austria, for academic research, and we did not request or receive any other form of financial or research assistance from him.

Conflict of interest

All authors declare that there is no conflict of interest.

Authors' contribution

KT Yoo has written most of the manuscript. GW Woo and TY Jang has contributed assessing data and data collection. JS Song performed the statistical analysis and its interpretation. All authors participated in the design of the study and approved the final version of the manuscript.

Ethics statement

This study was approved by the institutional review board in the Hanil General Hospital (HIRB-2017-009).

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