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Photograph-based diagnosis of burns in patients with dark-skin types: The importance of case and assessor characteristics

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ABSTRACT

Aim: This study assessed whether photographs of burns on patients with dark-skin types could be used for accurate diagnosing and if the accuracy was affected by physicians' clinical background or case characteristics.

Method: 21 South-African cases (Fitzpatrick grades 4–6) of varying complexity were photographed using a camera phone and uploaded on a web-survey. Respondents were asked to assess wound depth (3 categories) and size (in percentage). A sample of 24 burn surgeons and emergency physicians was recruited in South-Africa, USA and Sweden. Measurements of accuracy (using percentage agreement with bedside diagnosis), inter- (n = 24), and intra-rater (n = 6) reliability (using percentage agreement and kappa) were computed for all cases aggregated and by case characteristic.

Results: Overall diagnostic accuracy was 67.5% and 66.0% for burn size and depth, respectively. It was comparable between burn surgeons and emergency physicians and between countries of practice. However, the standard deviations were smaller, showing higher similarities in diagnoses for burn surgeons and South-African clinicians compared to emergency physicians and clinicians from other countries. Case characteristics (child/adult, simple/complex wound, partial/full thickness) affected the results for burn size but not for depth. Inter- and intra-rater reliability for burn depth was 55% and 77%.

Conclusion: Size and depth of burns on patients with dark-skin types could be assessed at least as well using photographs as at bedside with 67.5% and 66.0% average accuracy rates. Case characteristics significantly affected the accuracy for burn size, but medical specialty and country of practice seldom did in a statistically significant manner.

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1. Introduction

As is the case for several injury types, burns are disproportionately distributed between and within countries. Burn mortality is up to 10 times higher in low- and middle- income countries than in high income ones and, in a country like South Africa, poor people are at much greater risk [1,2]. As specialized burn units are typically very few and hard to access in many parts of the world, burn patients may end up in smaller, overcrowded departments with no dedicated facilities to provide care; this is associated with delayed and poor diagnosis which in turn is a threat to successful outcomes [3–5]. Acute burn diagnosis is complex and studies showed that general clinicians are less accurate than burn experts when assessing both burn size [6–9] and depth [10,11]. This has been observed in both low- and high-income countries [3,6–9,11–13].

The great improvements in burn prevention and care seen over the last twenty years have mainly benefited those living in high-income countries [1]. Yet advances in telemedicine could help facilitate access to timely and quality expertise with low-cost alternatives made available by mHealth solutions [12,14]. Studies indicate that image-based teleconsultation for injury emergency care in general, and burns in particular, is an effective and reliable tool for communication [15]. More specifically, a number of studies have looked at the feasibility of using photographic support for remote burn diagnosis [16–22], including photographs taken by camera phones [20,23]. The evidence accumulated suggests that relatively accurate diagnoses can be made on both burn size and depth, and that some patient (age) and assessor (specialisation, experience) characteristics affect the results reached, e.g. diagnostic accuracy, specificity, and reliability [16–23].

Yet available evidence has methodological shortcomings, including small numbers of local assessors and poor or lack of gold standards [16,18,19,21,23]. An additional drawback is that except for one recent study [20], evidence rests largely on observations from patients with light skin, whereas burns on patients with dark-skin types may pose particular diagnostic problems [24,25]. Furthermore, whereas the assessment of both burn depth and size has been regarded as accurate [16,18–21,23,26], a recent study using laser Doppler as a gold standard for burn depth has questioned these results [17].

Against this background, this study was embarked upon to address the following research questions:

- How accurately can clinicians diagnose burns in patients with dark-skin types using photographs taken by camera phones?
- Does clinical background and country of practice of the assessor affect the diagnostic accuracy and reliability?
- Do case characteristics affect the diagnostic accuracy and reliability?

2. Materials and methods

2.1. Case selection and data collection

The burn photographs were taken at four hospitals from the Western Cape Province, South Africa, representing different levels of care (10 cases from district and regional hospitals, and 11 cases from a tertiary burn centre). All photographs were taken using the same type and model of phone (Samsung Galaxy SIII mini (5 MP, 2592 × 1944 pixel, autofocus, LED flash)) and in a standardised procedure carefully explained by a research group member. There was one hospital staff member responsible for this task at each facility.

For the purpose of this survey we aimed to cover acute burn wounds of different complexity levels (based on burn degree, type of burn, and burn size), from different body regions, and on both adult and paediatric patients. Photographs were taken on 15 burn patients: 14 with a Fitzpatrick skin type [27] 5 or 6 and one with skin type 4 (most were admitted between 3 h and 3 days post-burn). Informed consent was obtained from all patients, or from legal guardians in the case of children. In order to present photographs with only one burn depth and one body part, up to three ''cases'' per patient were generated for the survey ($n = 21$).

In addition to burn size and depth, we also distinguished the cases considering the patient age group (adult/child), the wound complexity (simple/complex); and perceived image quality (good/less than good).

For each patient a burn surgeon determined the burn size and depth at bedside, which was then used as the gold standard for validity assessments.

A web-based survey (using SurveyMonkey) was designed and all 21 cases were entered, represented by 1, 2 or 3 photographs, depending on the burn's size and complexity as well as minimal case information (age, gender, comorbidities or burn causal agent) (see Fig. 1). Survey respondents were asked to diagnose the burn depth and size and rate the quality of the images provided (5 closed alternatives from clearly diagnostic to non-interpretable). For the burn depth, 3 categories were proposed (superficial thickness, partial thickness, and full thickness) and for the burn size an open ended question to fill in with percentage TBSA was asked. At the end of the survey additional questions were asked to better measure the participant's background, experience and appreciation of the questionnaire.

The survey was entered on two matching laptop computers (Dell Vostro i3 2.4 GHz with 3 GB RAM Windows 7) with a 15.4″ screen, both set to a screen resolution of 1366 × 768 dots per inch. All respondents filled in the survey individually and on a voluntary basis. No time limit was given to fill in the survey.

2.2. Survey respondents

We aimed for diversity of clinical background and settings in the recruitment of survey respondents. In the Western Cape Province (South Africa) itself we recruited both burns specialists ($n = 3$) and referring clinicians from emergency care ($n = 5$). A number of opportunities allowed us to complement our sample with additional groups of practitioners: (1) burn surgeons from burn centres ($n = 7$) and emergency medicine specialists ($n = 2$) from Sweden, mainly familiar with the treatment of burns on light skins (as is the case in earlier studies); (2) a convenience sample of American emergency physicians directly involved in the assessment, stabilisation and treatment of burns victims ($n = 7$). A total of

Fig. 1 – Examples of cases presented in the web-survey.

24 respondents completed the questionnaire between November 2013 and July 2014 (see Table 1).

For intra-rater assessments six of the South African participants – an equal mix of burn surgeons and emergency physicians – repeated the survey after at least 2 months.

Table 1 – Distribution of the participants' characteristics (in numbers) regarding their age, clinical expertise and experience categorised by their country of practice.

	Participants' country of practice		
	South Africa	United States	Sweden
Age			
<40	4	4	1
41–50	2	2	3
51–60	–	1	4
61–70	1	–	1
>70	1	–	–
Professional qualification			
Burn surgeon	3	–	7
EM Specialist	5	7	2
Number of patients managed in the last six months			
<10	3	2	2
10–19	2	1	–
20–49	–	4	2
≥50	3	–	5

2.3. *Statistical analyses*

The analyses were conducted in several steps. We first compiled overall measures for all burn cases aggregated and then split the respondents into two groups based on whether they were burn surgeons or not. We considered in turn burn size and burn depth. For burn size the percentage of accurate answers and under- and over-estimated answers were tabulated for each participant. The mean percentage for each category was then calculated and presented. For burn depth the percentage agreement with the gold standard was first calculated and mean and standard deviation were used to present overall results.

We then took into account a variety of case characteristics (adult/child, partial/full thickness, simple/complex and good/less than good perceived image quality) and divided the respondents based on their country of practice. These sub-analyses were done using similar methods as described above. Results for cases' pairs of characteristics were tested for statistical significance using the Mann–Whitney *U* test.

Inter-rater reliability was tested using both percentage agreement and Cohen's linear weighted kappa for pairs of assessors. Results were then pooled for each sub-analysis using the mean of the obtained values. Fleiss kappa was also performed in order to have the agreement of assessors' answers as a group. Intra-rater analysis was tested using percentage agreement between the results obtained for both surveys by the same assessor, and the six obtained values were pooled using mean and standard deviation.

Statistical analyses were conducted using SPSS v.22 and Microsoft Excel 2010 computer statistical software.

The study was approved by the Human Ethics Research Committee at the Stellenbosch University.

3. Results

3.1. Respondents' satisfaction with the survey

Table 2 presents the views expressed by the respondents regarding the use of photographs for diagnosing burn wounds (confidence, comfort, easiness, and helpfulness). All considered photographs to be helpful for diagnostic purposes but many pointed out that additional case information was needed. Most were satisfied with the survey.

3.2. Overall diagnostic accuracy

Table 3 presents the accuracy of burn size and burn depth assessments by all respondents aggregated and by clinical expertise. Overall, participants were correct over two thirds of the times, with results which were comparable between burn surgeons and emergency medicine (EM) specialists. However, the standard deviation presenting the range of accuracy rates was much larger in the EM group (16.7% and 22.5% vs. 8.2% and 18.6% for burn surgeons), meaning that the burn surgeons tend to have more similar rates than EM specialists. In addition, the inter-rater reliability values of burn surgeons were higher than those of EM specialists. For burn size, burn surgeons had 77.5% concordance and EM specialists 67.6% and for burn depth the corresponding values were 63.8% and 53.5%, respectively. This means that about half of the time two EM specialists had different diagnoses for burn depth.

Table 2 – Participants' evaluation of the use of photographs for teleconsultation and of the quality of those presented in the questionnaire by current country of practice.

	Participants' country of practice		
	South Africa	United States	Sweden
Confidence			
Completely confident	–	–	–
Mostly confident	4	4	3
Confidence varied depending on image	4	3	6
Poorly confident	–	–	–
Not confident	–	–	–
Comfortability			
Completely comfortable	3	3	3
Somewhat comfortable	5	4	6
Somewhat uncomfortable	–	–	–
Completely uncomfortable	–	–	–
Easiness			
Very easy	5	5	4
Somewhat easy	3	2	5
Somewhat difficult	–	–	
Very difficult	–	–	–
Helpfulness			
Helpful	8	7	9
Images make no difference	–	–	–
Counter productive	–	–	–
Quality of images			
Mean number of cases with quality lower than borderline	5.1	4.6	5.8

3.3. Burn size

Overall, 67.5% of burn size diagnoses were accurate with the highest percentages for participants from South Africa and the United States (69%). Across all cases there was a similar amount of under- and over-estimations, however, for full thickness cases there was a higher overestimation of burn size. Full thickness burns were the ones which were the least accurately diagnosed, with only slightly more than one in three accurate answers. This differed significantly from the accuracy obtained for cases with partial thickness. Furthermore, child cases, those considered simple and those perceived as having good image quality were significantly better diagnosed than those of adult, complex, and with less than good perceived image quality, respectively (Table 4). Finally, there were no significant differences in results between participants of the three different countries.

3.4. Burn depth

The accuracy of burn depth assessment was slightly lower than that of burn size with 66.0% of the diagnoses being accurate (Table 5), and was highest (74.2%) for South African clinicians. Burn depth scores were quite similar between types of cases with approximately 65% accurate answers. Only full thickness cases were less often accurately diagnosed (60.0%). There were however large discrepancies between survey respondents as revealed by the size of the standard deviations. The sensitivity of partial thickness and full thickness cases were, respectively, 67.5% and 35.8%. Specificities for superficial, partial and full thickness were 84.2%, 64.2% and 85.7%, respectively, indicating that participants tended to underestimate the depth of the burn.

Table 6 presents the inter-rater reliability. Overall, it was low with only 55.1% agreement between assessors but the South African participants assigned the same depth to a wound as their colleague in two of three instances. A Fleiss kappa of 0.164 confirmed that the inter-rater reliability was low.

4. Discussion

The results showed that both the size and the depth of a burn on patients with dark-skin types (Fitzpatrick skin types 4–6) could be accurately assessed using photographs taken with a camera phone over two thirds of the times. While the overall inter-rater reliability was relatively low it was higher among burn surgeons and for all South African respondents. In fact, across all case characteristics and for both burn size and depth, the South African assessors had higher scores than those from other countries. The intra-rater reliability among the South African clinicians was also high.

Table 3 – Validity of burn size and burn depth, inter- and intra-reliability all assessors aggregated and by clinical expertise.

	Validity		Inter-rater reliability		Intra-rater reliability	
	Number of assessors	Mean (S.D.)	Number of assessors	Mean (S.D.)	Number of assessors	Mean (S.D.)
Burn size						
All assessors	24	67.5 (13.8)	24	65.9 (16.5)	6	69.1 (29.0)
Burn surgeons	10	64.3 (8.2)	10	77.5 (8.6)	3	79.4 (23.5)
EM specialists	14	69.7 (16.7)	14	67.6 (16.3)	3	58.7 (35.1)
Burn depth						
All assessors	24	66.0 (20.7)	24	55.1 (19.6)	6	77.0 (11.1)
Burn surgeons	10	69.3 (18.6)	10	63.8 (17.4)	3	74.7 (13.8)
EM specialists	14	63.7 (22.5)	14	53.5 (20.5)	3	79.4 (9.9)

No significance was found for validity results between clinical expertise categories using Mann–Whitney *U* test.

It was also of note that there was more variability in the diagnoses of the size than the depth of the burns. For size, child cases were more accurately diagnosed than adult ones, and those with partial thickness more than full thickness ones.

In the literature at hand, image-based diagnosis was compared to the bedside diagnosis made by the same assessor [16,19–21,23]. In the current study the diagnosis was determined at bedside by a burn surgeon in service when the patient was treated. Thus all respondents were blind to the diagnosis which strengthens the results obtained.

It has already been documented that burn size can be assessed using photographs on patients with light-skin types [17,23] and there were indications that this applied even to those with dark-skin types [20]. We confirmed that burn size can be appropriately diagnosed on dark-skin types and even more so by specialised physicians familiar with cases of that type.

To date more studies have been performed regarding burn depth than burn size; however, each of these used different measures to define burn depth. When looking at two depth category endpoints [16,20,23] image-based diagnosis has proven to be accurate. Other studies using three categories of depth, including a recent study that used laser Doppler as a gold standard, have only found poor to good agreement [17–19]. The accuracy rate for burn depth diagnosis in our study using three categories of thickness was relatively high and supports the use of image-based diagnosis.

This being said, the inter-rater reliability for burn depth was fairly low when all cases and all physicians were aggregated. However, it was higher for burn surgeons and for South African assessors from the cases' catchment area. Only one previous study looked at inter-rater reliability for burn depth and found poor agreement between assessors (although higher for burn surgeons than for referring physicians) even though they were all working in the same

Table 4 – Burn size's rating accuracy as mean percentages by type of case and assessors' country of practice.

Cases	All assessors (n = 24)			Assessors' country of practice					
				South Africa (n = 8)		United States (n = 7)		Sweden (n = 9)	
	Accurate answers	P value	(Under-overestimation)	Accurate answers	P value	Accurate answers	P value	Accurate answers	P value
All cases (n = 21)	67.5	n.a.	(17.1–15.5)	69.0	n.a.	69.4	n.a.	64.5	n.a.
Age groups									
Children (n = 9)	77.8	0.001	(7.4–14.8)	76.4	n.s.	76.2	n.s.	80.3	0.001
Adults (n = 12)	59.7		(24.3–16.0)	63.5		64.3		52.8	
Wound depth									
Partial (n = 17)	74.8	0.001	(16.2–9.1)	75.0	0.001	80.7	0.002	69.9	0.002
Full (n = 4)	36.5		(20.8–42.7)	43.8		21.4		41.7	
Wound complexity									
Simple (n = 8)	79.2	0.001	(11.5–9.4)	76.6	n.s.	85.7	n.s.	76.4	0.001
Complex (n = 13)	60.2		(20.5–19.2)	64.4		59.3		57.2	
Perceived image quality									
Good (n = 6)	81.9	0.001	(8.3–9.7)	81.3	n.s.	83.3	n.s.	81.5	0.001
Less than good (n = 15)	61.7		(20.6–17.8)	64.2		63.8		57.8	

P value calculated using Mann–Whitney *U* test; n.a.: non applicable; n.s.: non significant ($P > 0.05$).

Table 5 – Accuracy of burn depth ratings, by type of case and assessors' country of practice, presented as means of individual percentages and (standard deviations).

Cases	All assessors (n = 24)	Assessors' country of practice		
		South Africa (n = 8)	United States (n = 7)	Sweden (n = 9)
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)
All cases (n = 21)	66.0 (20.7)	74.2 (9.7)	60.0 (21.3)	63.5 (26.5)
Age groups				
Children (n = 9)	67.1 (24.0)	75.0 (17.6)	54.0 (26.8)	70.4 (24.9)
Adults (n = 12)	65.3 (24.2)	73.8 (16.1)	64.7 (23.8)	58.3 (30.1)
Wound depth				
Partial (n = 17)	67.4 (24.6)	77.8 (16.3)	58.1 (25.5)	65.4 (28.9)
Full (n = 4)	60.4 (27.5)	59.4 (37.7)	67.9 (12.2)	55.6 (27.3)
Wound complexity				
Simple (n = 8)	65.1 (28.3)	75.0 (20.0)	60.7 (17.6)	59.7 (31.1)
Complex (n = 13)	66.7 (19.3)	73.7 (9.6)	59.8 (17.6)	65.8 (25.8)
Perceived image quality				
Good (n = 6)	63.2 (25.5)	66.7 (21.8)	57.1 (31.7)	64.8 (25.6)
Less than good (n = 15)	68.1 (23.2)	77.2 (11.0)	64.2 (21.5)	63.0 (31.1)

No significant differences were found between case characteristics all assessors aggregated or by country of practice, using the Mann–Whitney U test.

hospitals as where the patients were admitted [17]. The low inter-rater reliability seen in our study was most likely a result of the large number of respondents and the variety of their clinical background. To our knowledge, this was the first study to look at intra-rater reliability for the image-based assessment of burn wounds and results were promising as physicians diagnosed the cases similarly in the second repeat survey.

An additional finding of importance was that there was more variability in the diagnoses for burn size than for burn depth when attention was paid to the case characteristics and to country of practice. As few previous studies have considered aspects of the like, these results are difficult to compare. However, a previous study on burn size showed that adult cases were more accurately assessed than paediatric ones, contrary to our findings [20]. This difference might find an explanation in other case characteristics or in differences in physicians' expertise levels.

This study was performed with a camera phone as previously suggested by Shokrollahi and colleagues [23]. Since that study was performed both phones and the quality of pictures taken have increased dramatically. Our study confirmed that the camera phone was a good enough camera to take photographs for burn diagnosis. Indeed, this type of camera is easy to use and can be easily accessible in lower-income countries. In addition, smartphones provide the opportunity to send the photographs through an App which could permit a secure server and discussion between the referring physician and the expert.

Hop and colleagues suggested the use of laser Doppler rather than bedside diagnosis as the gold standard for burn depth [17]. In our study bedside diagnosis was used as the gold standard because the laser Doppler technique was not currently in use in South Africa. In addition, the fact that no superficial thickness burns were presented in the survey made it impossible to do sensitivity analysis for this burn depth.

Table 6 – Mean inter-rater agreement and (kappa scores) for pairs of assessors by type of case and assessors' country of practice.

Cases	All assessors (n = 24)	Assessors' country of practice		
		South Africa (n = 8)	United States (n = 7)	Sweden (n = 9)
	Agreement (kappa)	Agreement (kappa)	Agreement (kappa)	Agreement (kappa)
All cases (n = 21)	55.1 (0.24)	66.7 (0.27)	55.7 (0.30)	51.2 (0.24)
Age groups				
Children (n = 9)	56.2 (0.19)	72.2 (0.29)	52.4 (0.26)	55.3 (0.13)
Adults (n = 12)	54.1 (0.28)	62.4 (0.29)	57.2 (0.34)	48.2 (0.29)
Wound depth				
Partial (n = 17)	54.7 (0.14)	70.0 (0.21)	51.7 (0.22)	51.3 (0.07)
Full (n = 4)	56.0 (0.18)	50.9 (0.11)	72.6 (0.44)	50.7 (0.21)
Wound complexity				
Simple (n = 8)	52.7 (0.16)	67.9 (0.22)	49.4 (0.20)	45.5 (0.09)
Complex (n = 13)	56.7 (0.27)	66.5 (0.28)	59.9 (0.34)	54.1 (0.29)
Perceived image quality				
Good (n = 6)	51.3 (0.20)	60.7 (0.25)	49.2 (0.24)	49.5 (0.16)
Less than good (n = 15)	56.9 (0.28)	69.1 (0.31)	58.4 (0.33)	51.9 (0.29)

Overall this resulted in more underestimation of burn depth than overestimation, contradictory to previous findings [16,17].

It is important to note that studies show that burn size can be incorrectly diagnosed up to two thirds of the time [10,28]. Burn depth is also correctly diagnosed only 64% to 76% of the times [11,29,30], even when experienced burn surgeons are included. In addition, respondents had to give a diagnosis for both burn depth and burn size based on only one to three photographs. In a clinical setting the expert would probably have more information regarding the patient and might also have written or oral contact with the referring physician. Indeed, answers to the satisfaction survey showed that all the participants found the use of photographs helpful in making burn diagnosis and found the system at least somewhat comfortable to use. In addition, most of the participants suggested the need for additional information regarding the patient and the wound. While Hop and colleagues suggested the use of live videoconferencing [17] as was previously demonstrated [31], we believe that in low-income settings photographs would be sufficient for diagnosis if they are paired with some information regarding both the burn and the wound, such as capillary refill.

This study demonstrates that just as in high-income countries like the United States [31] and the United Kingdom [32], there is a potential for lower resourced settings to use teleconsultation in acute burn care diagnosis and management as a tool towards more equitable access to high-quality health care. The manner in which the photographs are taken might need to be standardised and a number of ethical principles will need to be dealt with in order to maximise benefit and minimize harm [33–36].

5. Conclusion

Burn size and depth of dark-skin types can be assessed at least as well using photographs as at bedside. Medical specialty (burn surgeon vs. emergency physician) and country of practice (South Africa vs. other) seldom affected the results in a statistically significant manner whereas case characteristics did for burn size.

Although inter-rater reliability was relatively low and not as good as bedside assessments documented on cases with lighter skin type, accuracy levels and intra-rater reliability were satisfactory.

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REFERENCES

[1] Mock C, Peck MD, Peden M, Krug E. A WHO plan for burn prevention and care. Geneva: World Health Organisation; 2008.

[2] Van Niekerk A, Laubscher R, Laflamme L. Demographic and circumstantial accounts of burn mortality in Cape Town, South Africa, 2001–2004: an observational register based study. BMC Public Health 2009;9:374.

[3] Scheven D, Barker P, Govindasamy J. Burns in rural Kwa-Zulu Natal: epidemiology and the need for community health education. Burns 2012;38:1224–30.

[4] Allorto NL, Oosthuizen GV, Clarke DL, Muckart DJ. The spectrum and outcome of burns at a regional hospital in South Africa. Burns 2009;35:1004–8.

[5] Rode H, Berg AM, Rogers A. Burn care in South Africa. Ann Burns Fire Disasters 2011;24:7–8.

[6] Berkebile BL, Goldfarb IW, Slater H. Comparison of burn size estimates between prehospital reports and burn center evaluations. J Burn Care Rehabil 1986;7:411–2.

[7] Berry C, Wachtel T, Frank HA. Differences in burn size estimates between community hospitals and a burn center. J Burn Care Rehabil 1982;3:176–8.

[8] Hammond JS, Ward CG. Transfers from emergency room to burn center—errors in burn size estimate. J Trauma—Inj Infect Crit Care 1987;27:1161–5.

[9] Wachtel TL, Berry CC, Wachtel EE, Frank HA. The inter-rater reliability of estimating the size of burns from various burn area chart drawings. Burns 2000;26:156–70.

[10] Hlava P, Moserova J, Konigova R. Validity of clinical assessment of the depth of a thermal injury. Acta Chir Plast 1983;25:202–8.

[11] Jaskille AD, Shupp JW, Jordan MH, Jeng JC. Critical review of burn depth assessment techniques: Part I. Historical review. J Burn Care Res 2009;30:937–47.

[12] Saffle JR, Edelman L, Morris SE. Regional air transport of burn patients: a case for telemedicine? J Trauma—Inj Infect Crit Care 2004;57:57–64.

[13] Samuel JC, Campbell ELP, Mjuweni S, Muyco AP, Cairns BA, Charles AG. The epidemiology, management, outcomes and areas for improvement of burn care in Central Malawi: an observational study. J Int Med Res 2011;39:873–9.

[14] Saffle JR. Telemedicine for acute burn treatment: the time has come. J Telemed Telecare 2006;12:1–3.

[15] Hasselberg M, Beer N, Blom L, Wallis LA, Laflamme L. Image-based medical expert teleconsultation in acute care of injuries. A systematic review of effects on information accuracy, diagnostic validity, clinical outcome, and user satisfaction. PLoS One 2014;9:1–22.

[16] Boccara D, Chaouat M, Uzan C, Lachere A, Mimoun M. Retrospective analysis of photographic evaluation of burn depth. Burns 2011;37:69–73.

[17] Hop MJ, Moues CM, Bogomolova K, Nieuwenhuis MK, Oen IMMH, Middelkoop E, et al. Photographic assessment of burn size and depth: reliability and validity. J Wound Care 2014;23:144–52.

[18] Jones O. Measurements of the clinical competence of doctors and nurses to process telemedicine referrals for burns patients. J Telemed Telecare 2005;11:89–90.

[19] Jones OC, Wilson DI, Andrews S. The reliability of digital images when used to assess burn wounds. J Telemed Telecare 2003;9:S22–4.

[20] Kiser M, Beijer G, Mjuweni S, Muyco A, Cairns B, Charles A. Photographic assessment of burn wounds: a simple strategy in a resource-poor setting. Burns 2013;39:155–61.

[21] Roa L, Gomez-Cia T, Acha B, Serrano C. Digital imaging in remote diagnosis of burns. Burns 1999;25:617–23.

[22] Wallace DL, Jones SM, Milroy C, Pickford MA. Telemedicine for acute plastic surgical trauma and burns. J Plast Reconstr Aesthet Surg 2008;61:31–6.

[23] Shokrollahi K, Sayed M, Dickson W, Potokar T. Mobile phones for the assessment of burns: we have the technology. Emerg Med J 2007;24:753–5.

[24] Laruche G, Cesarini JP. Histology and physiology of Black skin. Ann Dermatol Venereol 1992;119:567–74.
[25] Hettiaratchy S, Papini R. ABC of burns—initial management of a major burn: II—Assessment and resuscitation. Br Med J 2004;329:101–3.
[26] Shokrollahi K. Photography and the mobile phone camera: a good method for burn depth analysis with implications for remote assessment. Burns 2012;38:459.
[27] Fitzpatrick TB. The validity and practicality of sun-reactive skin types I through VI. Arch Dermatol 1988;124:869–71.
[28] Atiyeh BS, Gunn SW, Hayek SN. State of the art in burn treatment. World J Surg 2005;29:131–48.
[29] Heimbach DM, Afromowitz MA, Engrav LH, Marvin JA, Perry B. Burn depth estimation—man or machine. J Trauma-Inj Infect Crit Care 1984;24:373–8.
[30] Devgan L, Bhat S, Aylward S, Spence RJ. Modalities for the assessment of burn wound depth. J Burns Wounds 2006;5:7–15.
[31] Saffle JR, Edelman L, Theurer L, Morris SE, Cochran A. Telemedicine evaluation of acute burns is accurate and cost-effective. J Trauma—Inj Infect Crit Care 2009;67:358–65.
[32] Wallace DL, Hussain A, Khan N, Wilson YT. A systematic review of the evidence for telemedicine in burn care: with a UK perspective. Burns 2012;38:465–80.
[33] Gardiner S, Hartzell TL. Telemedicine and plastic surgery: a review of its applications, limitations and legal pitfalls. J Plast Reconstr Aesthet Surg 2012;65:E47–53.
[34] Benger J. A review of minor injuries telemedicine. J Telemed Telecare 1999;5(Suppl. 3):S5–13.
[35] Hersh W, Helfand M, Wallace J, Kraemer D, Patterson P, Shapiro S, et al. A systematic review of the efficacy of telemedicine for making diagnostic and management decisions. J Telemed Telecare 2002;8:197–209.
[36] Kim YS. Telemedicine in the USA with focus on clinical applications and issues. Yonsei Med J 2004;45:761–75.