

**Photographic Assessment of Burn Wounds:
A Simple Strategy in a Resource-Poor Setting**

By

Michelle Kiser

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[Signature]_____

Advisor_____

Sue Tolleson-Rinehart, PhD

Date_____

[Signature]_____

Second Reader_____

Anthony Charles, MD MPH

Date_____

ABSTRACT

Objective

To validate the use of photographic burn wound assessment in evaluation of burn size and wound characteristics.

Methods

Feasibility study of agreement between methods of measurement of burn size and characteristics, in patients admitted to the burn unit at Kamuzu Central Hospital (KCH), Malawi, over two months in 2011. Burn wounds were photographed and assessed clinically, concurrently, by an experienced clinician. Photographs reviewed by two blinded burn clinicians after 4-6 weeks. Correlation between clinical assessment and photographic evaluation was calculated using Kappa score and Pearson's Correlation Coefficient.

Results

Thirty-nine patients were included in evaluation of TBSA, and fifty wounds assessed for their characteristics. Pearson's correlation coefficient for agreement of TBSA between clinical exam and photograph review by expert #1, and #2, was 0.96, 0.93 ($p < 0.001$), respectively. Pearson's correlation coefficients comparing expert #1 and #2 to the gold standard were: proportion of full-thickness burn (0.88 and 0.81, $p < 0.001$), and epithelialized superficial burn (0.89 and 0.55, $p < 0.001$). Kappa scores were significant for wound evolution (exp#1 0.57, exp#2 0.64 $p < 0.001$), and prognosis (exp#1 0.80, exp#2 0.80 $p < 0.001$).

Conclusions

Burn assessment with digital photography is a valid and affordable alternative to direct clinical exam, alleviating access issues to burn care in developing countries.

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Preface:

The following master's paper presents a project that began one year ago, and has just recently been published in the journal *Burns*. I completed the IRB application both at UNC and in Malawi, in order to conduct the study, and was responsible for every aspect of the research, from design to data collection, analysis, and writing the manuscript. Oversight was provided throughout the entirety of the process by my advisor, Dr. Anthony Charles. Gustaf Beijer was a medical student who assisted with clinical work, largely in the form of photographing wounds, and collating the pictures into anonymous files. Stephano Mjuweni was expert#2, and was responsible for evaluating the photographs and answering clinical research questions. Drs. Cairns and Muyco were both responsible for review and critique of the manuscript. This research, although it involved many collaborators, was solely my project, from start to finish.

INTRODUCTION

Burn injuries make a significant contribution to the global burden of disease. In 2004 the World Health Organization (WHO) estimated that ten percent of worldwide deaths are due to injury, and burns ranked fourth amongst all injuries [1]. It is estimated that, annually, almost 11 million people have burns severe enough to require medical attention—more than the combined incidence of HIV and tuberculosis. The vast majority of serious burn injury, death, and disability-adjusted life years (DALYs) occur in low- and middle-income countries (LMIC) [2]. The etiology for the disproportionately distributed burden of burn injury globally is multi-factorial; including the use of open fires within often overcrowded living quarters and absence of safe cooking facilities [2-6]. Maternal education level and increased numbers of children in the home, which may be proxies for poverty, have also been associated with an increased incidence of pediatric burn injury and deaths [7, 8]. The highest incidence of hospitalized pediatric burn injuries occurs in Africa [6], and burn epidemiology in Malawi has been shown to be representative of the sub-Saharan region [9, 10].

One of the earliest recognized determinants of outcome in severely burned patients is the adequacy of intravenous fluid resuscitation during the first 48 hours immediately following burn injury [11,12]. Although the various fluid resuscitation formulas in current use differ in terms of solution composition and infusion rate, they all take into account the extent of burn injury, expressed as a percentage of the total body surface area (TBSA) of the patient [13-17]. Consequently, accurate estimation of burn size constitutes a central tenet in the assessment of any patient with thermal burns. Several studies have demonstrated a significant variability between estimations provided by specialized burn physicians and less experienced medical professionals [18,19,20,21]. Given the dearth of surgeons and health

care professionals in sub-Saharan Africa, TBSA estimation is often inaccurate and unreliable, as specialized burn training is typically limited or altogether non-existent [22,23,24]. This highlights the need for implementing simple strategies aimed at improving outcome of management of burn-injured patients [25].

The primary objective of this study is to evaluate the accuracy of TBSA estimation by a trained burn specialist's review of a digital photograph, as an alternative to bedside clinical examination, with a secondary objective of determining the accuracy in evaluating burn wound depth, location, evolution, and prognosis.

MATERIALS AND METHODS

The study was conducted at Kamuzu Central Hospital (KCH), a 625-bed tertiary care center situated in Lilongwe, Malawi. The hospital serves roughly 5 million people living in the central region of the country, for which KCH constitutes the principal tertiary referral center. A burn unit was established in January of 2011, with an average of 30-40 admissions per month. All patients admitted to the burn unit at Kamuzu Central Hospital between August 1st and September 30th 2011 with a diagnosis of burn injury, and a documented TBSA estimation performed by a medical intern or clinical officer (non-physician clinician) intern at the time of presentation to the hospital's Casualty Department were included in this study. Patients for whom no intern TBSA estimation was provided, who absconded prior to review in the unit, or who died before their first dressing change were excluded. There were two cell phone cameras used for photographing wounds: a 3-Megapixel still camera with autofocus (iPhone 3GS, Model no: A1303), and a 5-Megapixel ditto (iPhone 4, Model no: A1332). The third device used was a Nikon 14 megapixel Coolpix.

The burn wounds of study patients admitted to the KCH burn unit were

photographed during routine changes of wound dressings, by available personnel of differing knowledge levels, from medical student to burn trained clinician. Concurrently, in the same cohort, an experienced burn physician (expert #1) estimated the TBSA and assessed four major burn wound characteristics (**Table 1**) by way of bedside clinical examination. These estimates were documented and considered the Gold Standard. The photographs of individual patients were de-identified and presented to a blinded burn-experienced clinician (expert #2), and the same clinician who established the initial estimations (expert #1), whereupon they independently estimated the TBSA and assessed the same four wound parameters, by examination of the pictures. For comparison, the TBSA estimations performed by inexperienced surgical interns upon the patients' arrival to the Casualty Department were also documented (**Figure 1**). Sample pictures are included to illustrate picture characterization. (**Figure 2**)

Data was analyzed in STATA version 11. Univariate statistics included means, percentages, and distributions of data. Agreement between continuous variables assessed in person (gold standard) and those based on images (or by the inexperienced intern) was measured using Pearson's product-moment correlation coefficient, and represented graphically using Bland-Altman plots. Agreement between categorical variables was measured using the Kappa statistic, with standard error.

The IRB was registered with the US Office for Human Research Protections (OHRP) as an International IRB (number 11-0373). The Malawian National Health Research Council also approved the study (number 890).

RESULTS

The study cohort included 39 patients who underwent evaluation for % TBSA comparison, and of those, 23 patients (50 pictures) underwent evaluation of their wound characteristics (**Table 2**). We saw a slight preponderance of females in our study population, which is similar to our total source population in the burn unit. The median age was 4 years, with 80% of patients under 10 years of age. The majority of patients presented within 24 hours of injury (61.7%), and there was a slight preponderance of flame burns (52.8%). The average %TBSA was 16.7%, as determined by the bedside clinical exam in the burn unit (gold standard).

This study demonstrates a statistically significant correlation between the intern and the burn trained clinician's bedside estimation of %TBSA (0.84, $p < 0.001$), but an even higher degree of correlation between both burn trained clinicians' review of the patient photographs and the clinician's bedside exam (0.96, $p < 0.001$ and 0.93, $p < 0.001$ respectively). When stratified by age, correlation is generally less in the 0-5 year age range, than in the 6-18 year, or >18 year age ranges, with the exception of the intern, who has poorer correlation to the gold standard in the 6-18 year age range (0.65, $p = 0.04$) (**Table 3**). When stratified by burn mechanism, the estimations of flame burn size tend to have better correlation to the gold standard (0.87-0.97, $p < 0.001$) than the estimations of scald burns (0.80-0.92, $p < 0.001$), regardless of who is estimating (**Table 3**).

Using Bland-Altman plots, trends across the spectrum of burn size can be visualized (**Figure 3**). Expert#1 has greater agreement than expert#2, especially in those burns with large TBSA. However, both have better agreement to the gold standard than the intern estimation, regardless of TBSA. The best agreement is seen with the average estimation of

TBSA of expert#1 and expert#2 combined. When the difference between the intern estimation and the burn clinician estimation was quantified, there were 17 out of 39 patients (43.6%) who had differing treatments than otherwise indicated, based on the burn clinician's estimation of size. In 5 patients, the overestimation of burn size in casualty resulted in a treatment algorithm necessitating intravenous fluid resuscitation, foley catheter, and baseline laboratory studies, when ultimately their calculated size would not have required these measures. In fact, in 3 of those patients, admission would not have been necessary, based purely upon the criteria of burn size. In 2 patients, the underestimation in burn size placed the patients in a treatment algorithm not requiring the above resuscitation measures, but once evaluated by the burn clinicians, those measures would have been necessary. Ten patients had an estimation of %TBSA that was off by five or greater percent, leading to estimations of IV fluid resuscitation that were significantly different to what it should have been. The decisions made regarding patient care are multi-factorial, so assumptions regarding treatment based purely on burn size is not completely fair and is only provided as an illustration of how mis-calculation can affect treatment.

The second objective of the study was to determine the accuracy of photographic evaluation of burn wound characteristics as a valid alternative to direct bedside exam (**Table 1**). With regards to burn depth, photographic evaluation proved to be in agreement with a bedside clinical examination, regardless of which burn expert reviews the photo (0.95 and 0.81, $p < 0.001$) (**Table 4**). In evaluating burn evolution, expert #1 has a higher Pearson's Correlation coefficient (0.88 vs 0.55) for estimation of the percentage of superficial wound that is healed, however they were both significantly in agreement with the gold standard ($p < 0.001$ and 0.007, respectively)(**Table 4**). Expert #1 had higher correlation than expert #2 in

all parameters except for evolution of full thickness wounds, with only “moderate” agreement (**Table 5**) with the gold standard (0.57 and 0.64, $p < 0.001$). With determination of location and prognosis, both had an “almost perfect” level of agreement, with kappa scores ranging between 0.8-1.0. The exception was with expert #2, whose agreement of location was “substantial”, (kappa 0.76 SE 0.09, $p < 0.001$)

When viewed graphically across the spectrum of percentages, correlation is better at the extremes of the spectrum, seen with small or large percentages of either full or partial thickness wounds, as well as with small or large percentages of healed wounds (Figure 7, A-D). Agreement is not as good when wounds are a mixture of depth or evolution. Most of the wound evaluated on our cohort had dichotomous characteristics with the majority being either mostly partial thickness or full thickness, or mostly healed or not healed. Fewer wounds had mixed characteristics regarding depth or evolution. Therefore the lower level of agreement in the evaluation of mixed burns may be a reflection of smaller sample size (**Figure 4**).

DISCUSSION

Malawi is officially considered one of the world's least developed countries (LDC), as determined by per capita gross national income (GNI), Human Assets Index and Economic Vulnerability Index employed by the UN Committee for Development Policy [27]. Resources, especially human resources, are limited, with only 0.2 physicians and 2.8 nurses per 10,000 people, and an annual per capita healthcare spending of \$50 per person [28]. Therefore, an innovative approach to burn size estimation in this resource-poor environment is to strategically utilize modern cell phone technology, which is increasingly available throughout the developing world [29], to overcome the lack of trained health care providers in the vast rural areas.

Cell phones have now become ubiquitous throughout sub-Saharan Africa. If burn-experienced clinicians at a tertiary health care center could feasibly assess the extent and severity of burn wounds from photographs sent to them by less experienced medical staff in remote regions, they could make clinical decisions regarding patient triage and treatment. This would translate into a more efficient allocation of existing resources, without the need for extensive educational programs. The concept of telemedicine and its potential utility for a large number of medical specialties has received much attention in recent years, with the ever-increasing possibilities offered by continuing technological progress [30]. Several investigators have endorsed a more extensive implementation of telemedicine, for treatment, and follow-up of burn patients [31, 32, 33]. However, the specific role of digital imaging for burn wound assessment and subsequent decision-making has been inadequately evaluated, [34,35,36]. We believe that it has its utility in alleviating clinical challenges inherent in an environment of health care workforce shortages as is seen in sub-Saharan Africa. Even in our hospital, many patients are managed in

casualty by a medical intern, just out of medical school, and are never seen by someone with more experience. As we have highlighted, intern estimations of %TBSA differed from burn clinician estimations in ways that ultimately changed the management of patients. We found that four patients (10%) were admitted based on a burn size which, once evaluated by the burn clinicians, would not have met criteria for admission. These errors are not insignificant in a country that has continuous shortages of resources, and per capita health care spending of \$50 per year. It is unknown how many more patients were treated and sent home, who should have benefitted from inpatient management.

Limitations to this study include the potential for bias on the part of the burn-trained expert who also made the gold standard examination. This is seen in the results, by the closer agreement of expert #1 to the gold standard than expert #2 for most variables. However, to only have expert #2 evaluate the pictures, when expert #1 did the bedside evaluation, brings forth the very real potential for inter-user variability that obscures whether the variability comes from using a different evaluator or from the different method of evaluation. Having both the same evaluator and a different evaluator from that which determined the gold standard controls for both inter-user variability and recall bias. Having the inexperienced intern as the proxy for comparison for all non-burned trained clinicians is making a generalization, so future research will focus on further elucidating the actual burn knowledge base of the clinicians in the rural referral districts. Also, using digital cameras and phone cameras to capture the photographs may not yet be feasible with regards to widespread implementation of camera cell phones out in smaller district hospitals. Photo quality and environmental conditions were not controlled in this setting. Pictures were taken during dressing changes, to reduce the effect it had on the patient care. They were not at a

standardized angle or distance from the lens. However, we decided a priori that we would not control for picture quality, as Jones et al. had concluded from their study that digital picture size in megabytes did not influence their assessment of burn wounds [34], and we believed that structuring a stringent protocol would actually decrease the generalizability of the study. There may also be a bias inherent in the quality of the photo, relative to the burn knowledge of the photographer. This was minimized in our study by having numerous people, with varying levels of burn experience, contribute to the photography efforts. Also, the expectation for this technology would be that it is used in situations where the distant observer would be more knowledgeable about burns than the photographer. Therefore the distant observer should be able to reliably interpret the picture, regardless of the bias when the picture is taken. We were able to demonstrate this by having expert#2, who had not participated in the photography (and could serve as a “distant observer”) reliably interpret pictures.

In conclusion, our results validate the accuracy of digital photography in the evaluation of burn wound size, depth, prognosis, location, and to a lesser degree, evolution. These findings have downstream effects on resource utilization, cost effectiveness, and, importantly, patient outcome, which will be further explored by the investigators in the future. Issues regarding the ethical implications of telemedicine should be explored, especially pertinent in regions where the population is more vulnerable due to poverty. To do that issue justice is beyond the scope of this research, and has been discussed by others (37-40). But the issues must be addressed in order to expand this technology outside of the realm of research. To utilize it throughout our healthcare system there will need to be established criteria for burn “expertise”, a system of liability, consent and security measures in place to protect patients’ privacy and autonomy, and an agreement

addressing compensation. We foresee this as best done through the referral system within Malawi's Ministry of Health, as collaborators and colleagues. By forming collaboration and transfer agreements between burn trained clinicians at tertiary care facilities and clinicians who reside in the larger underserved rural areas, we can improve burn care to patients, and simultaneously improve the health system by supporting and empowering the few healthcare providers on the frontline of burn care with existing mobile digital photo-technology.

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Table 1: Measured Wound Characteristics

Depth	Location	Evolution	Prognosis
-Percent partial thickness	1-extremity crossing joint	Partial thickness: -percent healed	1-will require skin graft or heal with disabling scar
-Percent full thickness	2-extremity not crossing joint	Full Thickness: 1-eschar adhered	2-heal without disabling scar
	3-trunk	2-eschar lifting	
	4-head/neck	3-granulated	
	5-multiple		

Table 2: Patient Demographics

Demographics (N=39)	
Median Age, years	4 (range 0.75-38)
Gender	
-Percent female	51%
Time between Injury and Presentation	
-Percent less than 12 hours	32.3%
-Percent within 12-24 hours	29.4%
-Percent greater than 24 hours	38.2%
Mechanism	
- Percent scald	47.2%
- Percent flame	52.8%
Average %TBSA (gold standard)	16.7 (range 3-53)

Table 3: Inter-user agreement between bedside clinical examination and photographic evaluation of TBSA measurement.

Categories:	Number	Pearson's Correlation (p value)			
		Intern v GS	#1 v GS	#2 v GS	Avg v GS
Total	39	0.84 (<0.001)	0.96 (<0.001)	0.93 (<0.001)	0.96 (<0.001)
Age:					
0-5 years	24	0.71 (<0.001)	0.85 (<0.001)	0.82 (<0.001)	0.87 (<0.001)
6-18 years	10	0.65 (0.04)	0.99 (<0.001)	0.98 (<0.001)	0.99 (<0.001)
>18 years	5	0.94 (0.02)	0.998 (<0.001)	0.94 (0.02)	0.99 (0.002)
Mechanism:					
Scald	17	0.84 (<0.001)	0.92 (<0.001)	0.80 (<0.001)	0.89 (<0.001)
Flame	19	0.87 (<0.001)	0.97 (<0.001)	0.96 (<0.001)	0.97 (<0.001)

Table 4: Inter-user agreement between clinical exam and photographic evaluation of wound characteristics.

Wound Characteristics (N=50)	Pearson's Correlation Coefficient or Kappa statistic (SE)			
	Expert#1	P value	Expert#2	P value
Percent Full Thickness	0.88	<0.001	0.81	<0.001
Percent Healed Partial Thickness	0.88	<0.001	0.55	0.007
Evolution of Full thickness	0.57 (0.09)	<0.001	0.64 (0.14)	<0.001
Location	0.83 (0.13)	<0.001	0.76 (0.09)	<0.001
Prognosis	0.80 (0.15)	<0.001	0.80 (0.15)	<0.001

Table 5: Interpretation of Kappa Score, as described by Landis and Koch, 1977 [26]

Kappa Score	Interpretation
0.0 or less	Poor
0.01 – 0.20	Slight
0.21 – 0.40	Fair
0.41 – 0.60	Moderate
0.61 – 0.80	Substantial
0.81 – 1.00	Almost Perfect

Figure 1: Study Algorithm

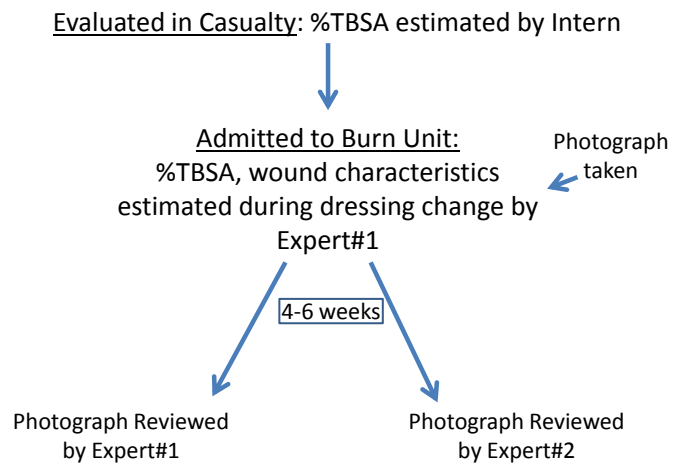


Figure 2: Sample pictures of patients who were evaluated. A) 3 year old female with flame burn. Gold standard estimations for this patient included a 5% TBSA, full thickness burn to the abdomen, with eschar lifting, and will require skin graft. B) This patient was deemed to have a 2%TBSA, partial thickness burn that was 100% open (non-epithelialized), but would not need a graft C)This patient was deemed to have a 10%TBSA, partial thickness burn that was 100% open (non-epithelialized), but would not need a graft.

A



B



C



Figure 3: Bland-Altman plot describing agreement between the percent total body surface area (%TBSA) estimated by A) the intern level trainee; B) expert#1's review of a photograph; C) expert#2's review of a photograph; D) an average of the two burn-trained clinicians' review of a photograph and that of the gold standard.

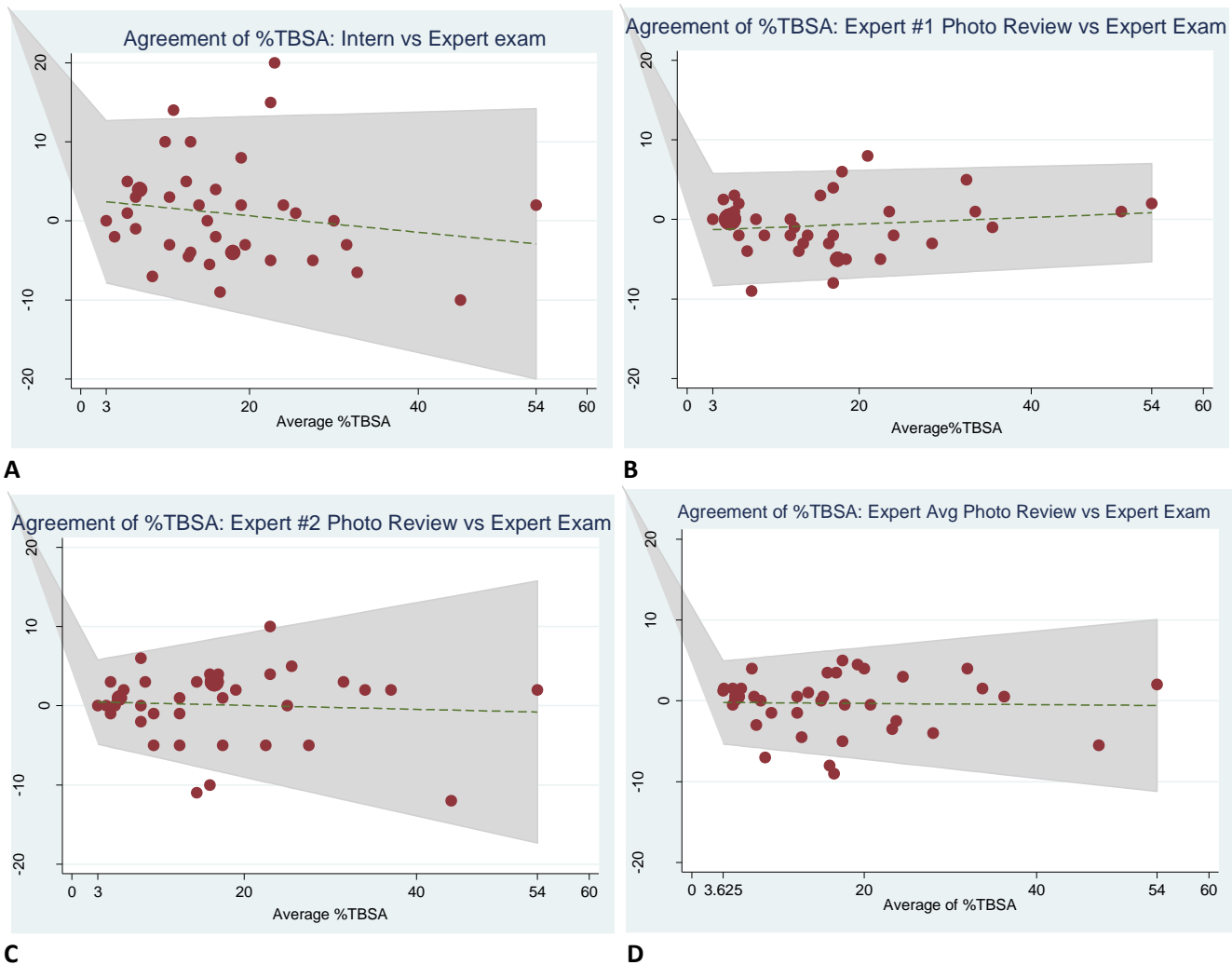
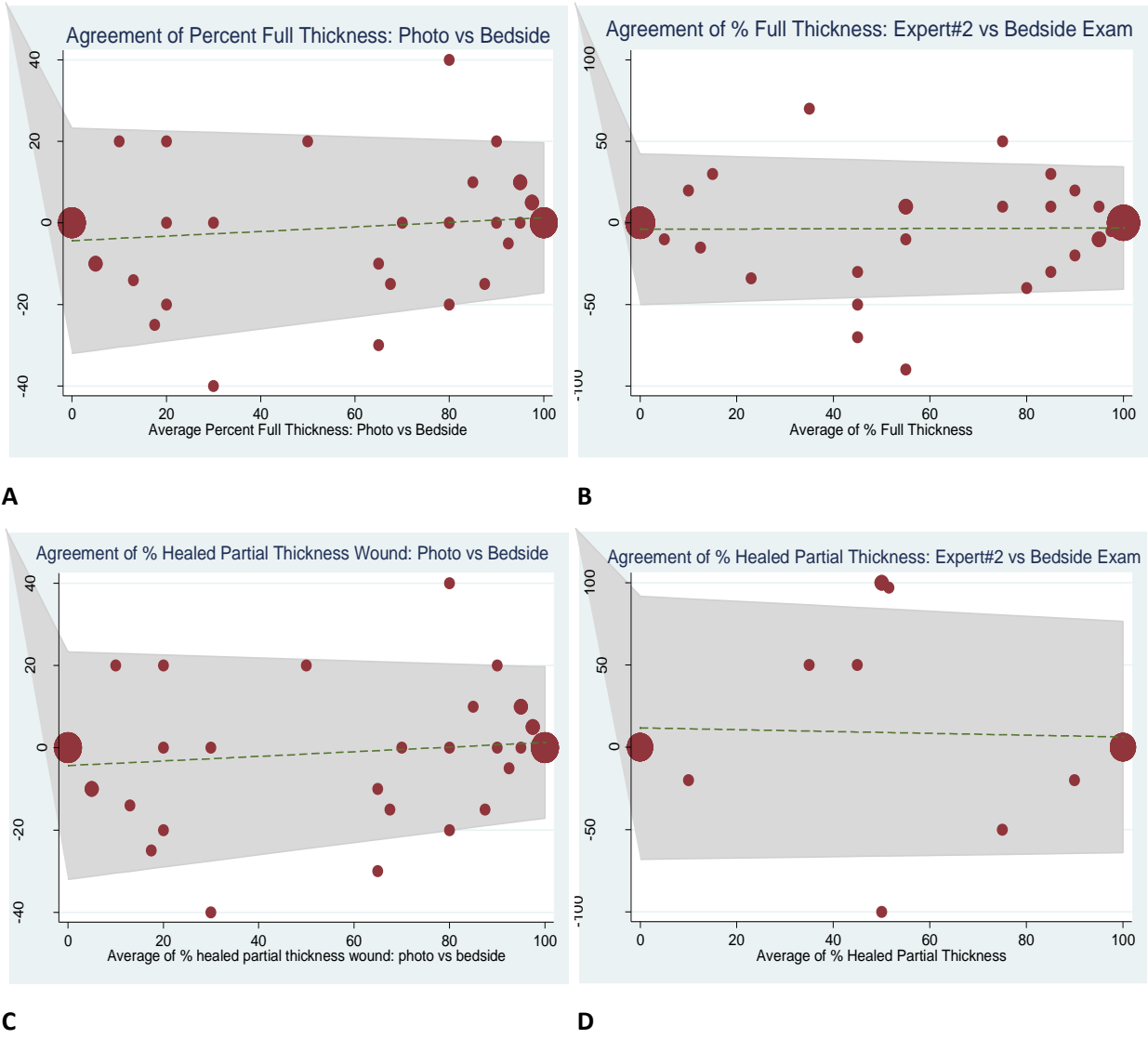


Figure 4: Bland Altman plots describing agreement between A) estimation of percent of a burn that is full thickness as determined by expert#1’s review of a photograph; B) estimation of percent of a burn that is full thickness as determined by expert#2’s review of a photograph; C) percent of a partial thickness burn wound that is healed (epithelialized) by expert#1’s review of a photograph and; D) percent of a partial thickness burn wound that is healed (epithelialized) by expert#2’s review of a photograph, and the gold standard.



Appendix 1: Methodology

The study was conducted at Kamuzu Central Hospital (KCH), a 625-bed tertiary care center situated in Lilongwe, Malawi. The hospital serves roughly 5 million people living in the central region of the country, for which KCH constitutes the principal tertiary referral center. A burn unit was established in January of 2011, with an average of 30-40 admissions per month.

Patients were first evaluated by the general medical intern or clinical officer intern who was completing through their 3 month or 6 week (respectively) surgery rotation. This encounter occurred in the casualty department (equivalent to the surgical emergency department). The interns were supervised directly in the casualty department by a surgical clinical officer or upper level surgical resident who was present somewhere in the hospital, if not in casualty. A consultant level surgeon was available of needed. All patients who were admitted to the burn unit at Kamuzu Central Hospital between August 1st and September 30th 2011 with a diagnosis of burn injury, were considered for this study. Admission criteria included the following:

Age:

- All Neonates
- Babies <1 year with %Total Body Surface Area (TBSA)>5%
- Children with TBSA >8%
- Adults with TBSA>15%

Site:

- Head, neck
- Hands/feet
- Groin, Axilla
- Perineum
- Any circumferential burn

Depth:

- Electrical burns
- Chemical burns

Other:

- inhalation injury
- question of abuse

Therefore, patients are largely admitted, based upon the size estimation of their burn, and should all have that measurement completed by the intern in casualty. However, patients for whom no intern TBSA estimation was provided, or who absconded or died prior to review in the unit were excluded from the study. Once patients were admitted, they received every other day dressing changes. The burn wounds of study patients admitted to the KCH burn unit were photographed during these routine changes of wound dressings, by available personnel of differing knowledge levels, from medical student to burn trained clinician.

Concurrently, in the same cohort, an experienced burn physician (expert #1) estimated the TBSA and assessed the following four major burn wound characteristics by way of bedside clinical examination. These estimates were documented and considered the Gold Standard.

1 Depth

- Percent partial thickness
- Percent full thickness

2 Location

- extremity crossing joint
- extremity not crossing joint
- trunk
- head/neck
- multiple

3 Evolution

If Partial thickness:

- percent healed

If Full Thickness:

- eschar adhered
- eschar lifting
- granulated

4 Prognosis

- will require skin graft or heal with disabling scar
- heal without disabling scar

There were two cell phone cameras used for photographing wounds: a 3-Megapixel still camera with autofocus (iPhone 3GS, Model no: A1303), and a 5-Megapixel ditto (iPhone 4, Model no: A1332). The third device used was a Nikon 14 megapixel Coolpix. There were no patterns or criteria for which camera was used to photograph the wounds, other than availability. Distance from the camera, background, whether flash was used or not, and lighting were not controlled during the study. This was the decision made a priori, based upon the background literature and the clinical setting in which the study took place.

The photographs of individual patients were de-identified and stored on a password protected computer. They were presented to a blinded burn-experienced clinician (expert #2), and the same clinician who established the initial estimations (expert #1), after 4-6 weeks, whereupon they independently estimated the

TBSA and assessed the same four wound parameters, by examination of the pictures. For comparison, the TBSA estimations performed by inexperienced surgical interns upon the patients' arrival to the Casualty Department were also documented. The study algorithm is included in Figure 1.

Data Analysis:

Data were analyzed in STATA version 11. Univariate statistics included means, percentages, and distributions of data. General characteristics of the population, including mean burn size, mechanism, patient age, gender, and time to presentation to the hospital were aggregated and are included in Table 2. We compared the estimations of TBSA by both burn experts' review of the photograph to the gold standard clinical exam, and agreement was measured using Pearson's product-moment correlation coefficient, and represented graphically using Bland-Altman plots. The same comparisons were made between intern estimations of TBSA and the gold standard. Agreement between categorical variables (wound characteristics) was measured using the Kappa statistic, with standard error.

The IRB was registered with the US Office for Human Research Protections (OHRP) as an International IRB (number 11-0373). The Malawian National Health Research Council also approved the study (number 890).

Appendix 2: Nano-Systematic Review

I searched PubMed using a combination of MeSH and keyword searching. The final search, though broad, produced the most appropriate results. It consisted of the following MeSH terms: (("Telemedicine" [MeSH] AND "Burns"[Mesh]) AND (English[lang])). Several MeSH searches were completed prior to the final search, with inadequate results. These began as a more narrowed approach, and focused on photographic documentation and burn injury, as well as included "underserved" and "resource-poor headings". However, due to the paucity of data in this field, as it relates to global health, the resulting articles were not representative of the topic. The final search outlined above produced the most relevant articles to the topic of telemedicine in the realm of evaluation of wounds. This search initially produced 84 results. Publications were then evaluated for appropriateness, and excluded if not directly related to telemedicine, or burn or wound inspection, or if they were specifically related to video-conferencing rather than inclusive of photographic documentation. During review of the abstracts, all case reports and letters to the editor were excluded. The final review was completed with 16 articles involving the use of telemedicine for evaluation of wounds (mostly burn wounds, but if directly applicable to the subject, inspection of other wounds was accepted). Preliminary reviews were initially conducted on May 27, 2012, and the final systematic review was completed on June 1, 2012. Results are included in **Table A1**.

Of these articles, all but one was published after the year 2000. Fourteen of the articles contained some form of evidence, and two were systematic reviews of the literature. All of the papers provided description of some element of telemedicine with regard to wound care and patient management. Six (37.5%) of the articles contained data regarding still (digital) images, and 10 (62.5%) involved video conferencing as well as digital photos. None of the articles addressed the use of this technology in resource poor or undeveloped countries, though many focused on access to care in rural areas of the US or UK. Variables include study design, sample size (or number of articles for systematic review), a scale of quality of internal validity as well as generalizability (with regards to the applicability of the study findings to the undeveloped world), and then a highlight of the main contributions or findings. The internal validity had an overall scale of 37.5% "good", with very few "excellent" (12.5%), and half being "poor" (50%). The generalizability was overall excellent (43.8%), or good (50%), with only one study that was too cost-prohibitive to even be applicable to a resource-poor setting.

Table 1A: Nano-systematic review—critique of the literature on telemedicine and burn injury

Authors	Publication date	Study design/article type	Sample size/no. articles	Findings/Contributions	Internal Validity Poor, Limited, Good, Excellent	Generalizability to resource-poor region: poor, good, excellent
Gardiner S, Hartzell TL.	2012	Systematic literature review	29 articles	Telemedicine improves access to plastic surgery	-N/A	good
Holt B, Faraklas I, Theurer L, Cochran A, Saffle JR.	2012	Survey	50 responses (40% rate)	% use of telemedicine in USA, benefits and problems encountered	<i>Good</i> -Poor response rate	good
Wallace DL, Hussain A, Khan N, Wilson YT.	2011	Systematic literature review	24 studies	Telemedicine has potential for triage, management and outpatient care of burns	-Peer reviewed journals -1966-2010 -comprehensive	excellent
Engel H, Huang JJ, Tsao CK, Lin CY, Chou PY, Brey EM, Henry SL, Cheng MH.	2011	Case control	100 patients	Digital evaluation of flaps has good accuracy, and leads to shorter response times to compromised flaps	<i>Good</i> -potential for bias -not blinded -not randomized	good
Turk E, Karagulle E, Aydogan C, Oguz H, Tarim A, Karakayali H, Haberal M.	2010	Descriptive	1560 patients	Used telemedicine and digital photography to make clinical decisions regarding patients care	<i>Limited</i> No research question, no validation.	excellent
Saffle JR, Edelman L, Theurer L, Morris SE, Cochran A.	2009	Case control	70 used tele, and 28 were “pre-tele”	Telemedicine reduced air transport referrals, and increased local management of burns	<i>Good</i> - comparable groups, comprehensive outcomes	Concept: excellent Technology: poor

Wallace DL, Jones SM, Milroy C, Pickford MA.	2007	Case control	996 patients	Telemedicine changed triage decisions only with regard to outpatient day surgery scheduling	<i>Limited</i> - no comparison between tele group and no tele group	good
Wallace DL, Smith RW, Pickford MA	2007	Case control	996	Same as above, though with more clinical parameters for comparison	Same limitations, though more depth regarding patient groups	good
Sagraves SG, Phade SV, Spain T, Bard MR, Goettler CE, Schenarts PJ, Toschlog EA, Newell MA, Claims BA, Peck MD, Rotondo MF.	2007	Feasibility study/Case Series	311	Burn patients can be managed at a non-burn center with the assistance of telemedicine	<i>Good, for study design</i> —descriptive --comprehensive review	excellent
Jones O.	2005	Case-control	60	Outcome: correlation of burn depth from photo vs bedside Physicians and nurses had poor agreement between photo and clinical exam	<i>Poor</i> -little description of methods -didn't address inter-user variability	excellent
Johansen MA, Wootton R, Kimble R, Mill J, Smith A, Hockey A.	2004	Case series/ Feasibility	4 (32 emails)	Parents are able to email photos to MD, regarding pediatric patients, and successfully communicate about care.	<i>Good for descriptive study</i> -Comprehensive data collection	excellent
Nguyen LT, Massman NJ, Franzen BJ, Ahrenholz DH,	2004	Case series	294 (1000 follow up visits)	Follow up of burn care via telemedicine is cost-effective	<i>Poor/Limited</i> -descriptive study -little clinical information	Good -used video device rather than digital

Sorensen NW, Mohr WJ 3rd, Solem LD					-no controls	imaging -infrastructural costs
Saffle JR, Edelman L, Morris SE.	2004	Retrospective review	225	Inappropriate transfer of burn patients can be reduced by use of telemedicine	<i>Poor</i> -comparisons (chi2) made based upon assumptions from charts, w/o controls	good
Jones SM, Milroy C, Pickford MA	2004	Case-control	82	Digital photo evaluation of patient correlates to bedside exam	<i>Poor</i> -no account for recall bias, or who is participating in evaluation of photos	excellent
Jones OC, Wilson DI, Andrews S	2003	Case-control	60	No difference in correlation of wound characteristics based upon picture file size	<i>Limited</i> -didn't address recall bias → same observer for bedside and photo	excellent
Roa L, Gómez-Cía T, Acha B, Serrano C	2002	Case-control	22 (38 pictures)	Good agreement between photo and clinical exam, regardless of photo compression	<i>Excellent</i> -prospective -characteristics of patients well- documented -patients were own control	excellent