Original article

Validation and inter-rater reliability of inexpensive, mini, no-touch infrared surface thermometry devices as an assessment tool for prediction of wound-related deep and surrounding infection

ABSTRACT

Industrial infrared thermometry devices are large and, despite being less expensive than the current gold standard Exergen Dermatemp medical infrared thermometer, are still not affordable enough to ensure unrestricted and consistent use of this assessment modality in regular wound-related day-to-day practice. An increased skin surface temperature differentiation of 3°F associated with a wound has a positive predictive ability to detect deep or surrounding wound infection. This study hypothesised that inexpensive, pen- or pocket-sized, no-touch surface infrared thermometry devices will be equal in ability to detect a 3°F increased skin temperature compared to the Exergen Dermatemp infrared device and be reliable in the hands of any wound assessor. The odds of the control and other thermometers to detect a 3°F temperature difference, irrespective of the raters, were achieved in all five of the mini thermometers tested, with a correct temperature difference prediction that occurred in 90.933% of the times (odds determined 9/10). As a result of this study mini, no-touch infrared thermometry, to detect a 3°F temperature difference in wound assessment to determine tendency, could be implemented into primary health care clinics, rural clinics, day-to-day hospital practice and standard outpatients departments at a small financial cost, regardless of which thermometer is put to use.

For referencing Smart H et al. Validation and inter-rater reliability of inexpensive, mini, no-touch infrared surface thermometry devices as an assessment tool for prediction of wound-related deep and surrounding infection. WCET® Journal 2019; 39(1):18-22

DOI https://doi.org/10.33235/wcet.39.1.18-22

Hiske Smart*
RN, MA(Nur), PG Dip WHTR (UK), IIWCC(Can)
Clinical Nurse Specialist, Wound Care and Hyperbaric Oxygen Therapy Unit, King Hamad University Hospital, Kingdom of Bahrain
Email hiske.smart@khuh.org.bh

Eman Al Jahmi
RN, MSc(Nur), IIWCC (South Africa)
Wound Care Practitioner, Wound Care and Hyperbaric Oxygen Therapy Unit, King Hamad University Hospital, Kingdom of Bahrain

Ebrahim Buhiji
MD, MB (Egypt), MSc Wound Management (UK), IIWCC(UAE) Wound Care and Hyperbaric Oxygen Therapy Unit, King Hamad University Hospital, Kingdom of Bahrain

Sally-Anne Smart
BSc Hons (Actuarial Science), BSc (Actuarial & Financial Mathematics), TASSA, University of Pretoria, South Africa (MSc Candidate Actuarial Science)

** Corresponding author*

INTRODUCTION

The use of no-touch infrared surface thermometry is validated in the assessment of wounds to determine the status of bacterial burden and a subsequent provoked host response, by determining an increased 3 degree Fahrenheit (3°F) surface difference when measured against an opposing limb or body area, as determined by Fierheller[1]. Medical-grade infrared surface thermometry devices are large and expensive, putting routine use of this assessment modality into advanced wound care units only and out of reach for clinicians in everyday practice. A recent study by Mufti, Coutts and Sibbald[2] has validated the use of industrial hand-held surface infra-red thermometers against the current gold standard Exergen Dermatemp device. Industrial devices are large and, despite being less expensive than this medical infrared thermometer, are still not affordable enough to ensure unrestricted and consistent use of this assessment modality in regular wound-related day-to-day practice. In validating inexpensive, pen- or pocket-sized, no-touch infrared devices, this modality can be made accessible to any clinician (interprofessional) dealing

with wounds on a regular basis, without compromising on infection control measures.

BACKGROUND

The challenge to clinicians in a subgroup of patients with an impaired inflammatory response is that clinical markers of localised infection (redness, swelling, exudate, lack of movement, pain, heat), present only when the infection is already overwhelming the patient's host response[3,4]. In the validation study to determine superficial and deep tissue infection markers for the chronic wound[5], the highest significance to detect deep tissue infection, was achieved by identifying an increased skin surface temperature differentiation of 3°F. This marker achieved an eight times more likely predictive ability to detect deep tissue infection than any other marker in the STONEES© criteria set (size increased, temperature difference, Os probing to bone, new breakdown and necrotic tissue, erythema flare, exudate or smell)[5].

The temperature differentiation is done by obtaining the highest skin surface temperature reading, 1cm away from the skin in a perpendicular position, measured on the wound edge. That reading is then compared to a reading taken in the same manner on a similar area of an opposing limb or skin area[1]. This method establishes a temperature difference tendency. The increased surface temperature obtained, with two additional other criteria added from the STONEES© set is validated to be predictive of deep or surrounding wound infection[5] opposed to critical colonisation[6].

In validating the least costly and most readily available skin surface thermometry devices against the Exergen Dermatemp in a similar design to Mufti *et al.*[2], the quick assessment ability of wound-related deep tissue infection can be made available to all clinicians, regardless of resource restrictions that may apply to certain clinical environments.

It is important to note that infrared skin surface measurement is different from physiological infrared measurement used to detect fever, which in adults[7] is less reliable than in the paediatric population[8]. Infrared surface thermometry is done without a physiological conversion factor built into the modality; it is utilised in engineering, electromechanical environments and the building industry and has been well-researched since the early 1960s. Currently industrial research is focussed on nuclear reactor safety[9], operational machine surface temperatures and critical deviations as part of safety measures.

The clinical grade Exergen Dermatemp infrared surface thermometer is sold at a price that ranges from US$700 to US$900 (BD 265–340) per piece. The industrial thermometers tested by Mufti *et al.*[2] ranged from US$80to US$100 (BD 30–37) per piece. The devices used in this study cost no more than US$20 (BD 7.5), with three devices priced at US$10 or less (BD 3.6). Due to the cost of one Exergen Dermatemp, clinicians have overlooked their ability to ensure fast and efficient wound assessment for identification of wound surface bacterial burden reaction. By having access to a more affordable modality, timely intervention can be quicker to prevent wound deterioration due to a deep wound infection being identified too late.

METHOD, DESIGN AND SAMPLING

Hypothesis

Inexpensive, mini (pen- or pocket-sized), no-touch surface infrared thermometry devices are equal in ability to detect a 3°F increased skin temperature compared to the gold standard Exergen Dermatemp infrared device.

Objectives of the study

- To compare five inexpensive no-touch surface infrared thermometers (Mastercraft 0574568-4, Infrared 68199, Infrared EM512, Infrared DT8220 and Infrared H10140 with a distance to spot ratio of 1:1 or more) against the Exergen Dermatemp clinical infrared surface thermometer (distance to spot ratio 1:1).
- To determine the precision of measurement of the inexpensive, pen- or pocket-sized, no-touch surface infrared thermometry devices compared to the skin temperature obtained by the Exergen Dermatemp device. (This would predict if the inexpensive devices are similar to the Exergen Dermatemp in measurement).
- To determine the accuracy of inexpensive, pen- or pocket-sized, no-touch surface infrared thermometry devices in detecting a 3°F increased skin temperature compared to the Exergen Dermatemp device. (This would predict if the difference detected by the Exergen Dermatemp can be detected by the inexpensive devices as well).
- To determine the inter-rater reliability of professionals using this modality by measuring consistency of temperature difference obtained by three investigators. (This would predict the chance/odds of any clinician to obtain a correct assessment compared to the control).

The study took place in the hyperbaric and wound care unit of King Hamad University Hospital, in the Kingdom of Bahrain, where the use of no-touch infrared skin surface thermometry is a standard assessment modality with every dressing change procedure. This was a prospective cross-sectional study that included all consecutive consenting patients with either a new wound or an existing wound treated as part of the patient load of this unit for a period of one month. Three clinicians were doing six measurements (one control and five test devices) per patient at the same time. They followed one after the other, after the hot spot and contra-lateral spot was identified by rater 1, who is the clinical specialist of the unit. The two other raters were a doctor and a registered nurse, both working in the wound care unit.

Study sample inclusion and exclusion criteria

Inclusion: All patients with a wound who attend for a regular dressing change at the unit were eligible for a once-only inclusion into this study.

Figure 1: The thermometers tested in this study

Exclusion: Patients who were unable due to their condition or unwilling due to time constraints to give signed informed consent for five added measurements being done apart from the standard Exergen Dermatemp infrared reading that is mandatory for every visit. Patients who were already assessed with the five devices compared to the Exergen Dermatemp and already included in the study.

Design and sample size

The sample size reached 100 patients with 300 thermometer readings obtained for each device and 1800 thermometer measurements done in total.

DATA COLLECTION METHODS, INSTRUMENTS USED AND MEASUREMENTS

Patients who have given signed and informed consent had all previous dressing materials removed and all exudate wiped clean from the wound bed with all standard wound care procedural preparations in place as per standard dressing change protocol.

Data collection procedure

- The Dermatemp measurement was done on the wound edge in Fahrenheit before any cleansing of the wound bed occurs to prevent cooling down of the wound edges due to the cleansing fluid. The highest reading obtained by the first rater at the wound edge on intact skin served as the test reading and was recorded on the data collection sheet. The warmest spot was marked on the skin with a small dot from an operating room pen.
- The reading on the exact mirror image side of the limb or body part was taken as reading two, recorded as reading opposing limb and was marked with a small dot to determine the temperature differentiation.
- All five of the small devices marked 1–5 were set to measure surface temperature in Fahrenheit and were then respectively used in the order 1–5, with the first measurement on dot 1 and second reading on dot 2 for each thermometer. Each temperature reading recorded in the same manner as for the Exergen Dermatemp on the data collection sheet until readings from all six devices were collected for one patient (see Figure 1).
- In order to determine inter-rater reliability and inter-professional variations, this procedure was then to be repeated two times more times to include three testers (two RNs, one MD) who stayed consistent for the duration of the study.
- Added data on the collection sheet was patient gender, age, diagnosis and any important adverse factors affecting healing for later analysis.

RESULTS

The help of a statistician was acquired for data analysis as more than one statistical method was needed to determine the fine variations of both the devices and the inter-rater reliability testing.

Comparison of infrared thermometers

When the raw temperature measurement variation observed by each thermometer was compared to each other using a paired T-test (test to determine whether mean values are significantly different from one another) the p-values observed showed some deviation (depicted in Table 1).

With each of these five T-tests, the null hypothesis (that the measurement of the control is not significantly different from any other thermometer) is rejected in thermometers 2, 4 and 5 at a 95% significance level. Thus, we can conclude that in absolute precision there was deviation and significant variation in the exact performance of these thermometers.

As the assessment of elevated skin temperature to determine deep and surrounding infection forms part of a bundle (NERDS© and STONEES©)[5], the aim of infrared thermometry is

Table 1: Thermometers compared to the Exergen Dermatemp as control

Thermometer comparison on precise raw measurement			P value
Control	Thermometer 1	Infrared 68199 orange	0.0358 (CI .95%)
Control	Thermometer 2	Mastercraft 0574567-4	<0.0001(CI .95%)
Control	Thermometer 3	Blue infrared EM512	0.0043(CI .95%)
Control	Thermometer 4	Grey pen/orange H10140	<0.0001(CI .95%)
Control	Thermometer 5	Red pen DT8220	<0.0001(CI .95%)

Table 2: The ability to correctly predict a 3°F difference

	Rater 1	Rater 2	Rater 3	Average
Control vs T1	0.91	0.9	0.89	0.9
Control vs T2	0.93	0.89	0.87	0.896667
Control vs T3	0.92	0.93	0.92	0.923333
Control vs T4	0.95	0.92	0.89	0.92
Control vs T5	0.92	0.9	0.9	0.906667
Average	0.926	0.908	0.894	0.90933

to determine a greater than 3°F difference to have a positive test result. Therefore, the thermometers tested do not have to reproduce the exact raw temperature value compared to the control, but should definitely be able detect a temperature difference of 3°F to make it a viable measurement modality in a clinical practice setting. That was the next test done on this dataset.

The odds of the control and other thermometers to detect a 3°F temperature difference (either both >=3 or both<3) for each of the respective raters is depicted in Table 2. The finding was that, irrespective of the raters, all five of the mini thermometers were able to make the correct call to detect a 3°F temperature difference in 90.933% of the times, giving it a success odd of 9/10.

Interpretability of thermometers

Paired T-tests were performed to determine whether there were statistically significant differences in the averages achieved by the three raters (test to determine whether mean values are significantly different from one another) as depicted in Table 3. The p-values were recorded in the table and had to be more than 0.05 to show consistency and similarity.

In the control measurement and each of the measurements of thermometers 1 and 3, there were no statistically significant differences detected in the mean observed by the three raters. There were statistically significant differences in the measurements from thermometer 2 (rater 1 and 2), thermometer 4 (rater 1 and 3) and thermometer 5 (rater 1 and 2; rater 1 and 3).

The best performing thermometers, in relation to the Exergen Dermatemp, were thermometers 1 and 3 with performance that was consistent irrespective of the user. Variations based on the user were, however, observed for thermometers 2, 4 and 5 shown in p-values lower than 0.05.

DISCUSSION

The high odds of the mini infrared thermometer devices to detect a 3°F temperature difference and the level of inter-rater reliability achieved to determine that difference in this study opens more clinical options to incorporate this modality into standard wound care practice for comprehensive wound assessment. With minimal teaching given to the raters, apart from reading the brochure of the device, our raters could achieve a clinically correct thermometry assessment compared to the gold standard device 9 out of 10 times.

Of the mini devices tested (Table 4) there were two that were more consistent between users and compared very favourably to the control thermometer value, both on raw temperature measurement precision and 3°F prediction ability. Thermometer 1 had a distance to spot range of 8:1 (best as well for infection control maintenance) that could have added in the precision of measurement and a very comfortable hand grip that had added to stability. Thermometer 3, despite having a distance to spot ratio of 1:1, had performed consistently as well. Despite being small and compact, it fitted the hand of the clinician snugly that added to device stability when aiming to obtain the measurement.

Table 3: Paired T-test p-values to determine differences between raters with each thermometer. (Values lower than 0.05 showing statistically significant differences)*

		Rater 1 vs Rater 2	Rater 1 vs Rater 3	Rater 2 vs Rater 3
Control	Exergen Dermatemp	0.4821	0.1137	0.2632
Thermometer 1	Infrared 68199 orange	0.6759	0.4683	0.6098
Thermometer 2	Mastercraft 0574567-4	0.0119*	0.0614	0.7037
Thermometer 3	Blue infrared EM512	0.218	0.0648	0.2689
Thermometer 4	Grey pen/orange H10140	0.2459	0.0205*	0.1597
Thermometer 5	Red pen DT8220	0.0011*	0.0357*	0.341

Table 4: The distinguishing factors of each thermometer

	Manufacturer	Convenience factors (size and form factor)	Price range	Distance to spot ratio
Control	Exergen Dermatemp	Gold standard	US$700	1:01
Thermometer 1	Infrared 68199 orange	Hand size pocket	US$17	8:01
Thermometer 2	Mastercraft 0574567-4	Hand size pocket	US$20	1:01
Thermometer 3	Blue infrared EM512	Hand size pocket	US$7	1:01
Thermometer 4	Grey pen/orange H10140	Pen size	US$10	1:01
Thermometer 5	Red pen DT8220	Pen size	US$10	1:01

Both of these devices also had legible numerical displays for easy reading of a value from a distance.

The pen-type thermometers all had a distance to spot ratio of 1:1, had the largest deviations between raters and highest error factor on precision. These devices have very small display screens that made it difficult to read accurately from a distance. Most of the mini devices used button batteries that added to cost over the longer term as the life time of the batteries was limited and depleted by the end of the study.

When it came down to accuracy in the ability to detect a 3°F temperature difference, all of the thermometers as well as all of the raters could achieve that 90.9% of the time (odds 9/10). These cost-conscious, mini infrared devices could be used to start to bridge a gap in practice and empower the clinician in resource-restrained environments to also be able to utilise non-invasive surface thermometry in assessment for the presence of deep and surrounding wound infection. This would substitute the subjective assessment of clinicians who are using the back of their hand as a touch indicator on patient skin to detect temperature differences[10], by providing a quantifiable and comparable alternative.

CONCLUSION

Mini, no-touch infrared thermometers could be used to detect a 3°F temperature difference to add in comprehensive wound assessment, regardless of which device is chosen. There is a high reliability that the clinician will detect that difference with 90.9% accuracy each time, regardless of which mini infrared device is used.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

FUNDING

The authors received no funding for this study.

REFERENCES

1. Fierheller M. A clinical investigation into the relationship between increased peri-wound skin temperature and local wound infection in patients with chronic leg ulcers. Adv Skin Wound care 2010 Aug; 23(8):369–79.
2. Mufti A, Coutts P & Sibbald RG. Validation of commercially available infrared thermometers for measuring skin surface temperature associated with deep and surrounding wound infection. Adv Skin Wound Care 2015 Jan; 28(1):11–16.
3. Sibbald RG, Goodman L, Woo KY *et al.* Special considerations in wound bed preparation 2011: an update©. Adv Skin Wound Care 2011 Sep; 24(9):415–36.
4. Gardner SE, Frantz RA & Doebbeling BN. The validity of the clinical signs and symptoms used to identify localized chronic wound infection. Wound Repair Regen 2001; 9:178–86.
5. Woo K & Sibbald RG. A cross-sectional validation study of using NERDS and STONEES to assess bacterial burden. Ostomy Wound Manage 2009; 55(8):40–8.
6. Hurlow J & Bowler PG. Clinical experience with wound biofilm and management: a case series. Ostomy Wound Manage 2009; 55(4):38–49.
7. Vernon GI. Non-contact infrared thermometers. Br J Gen Pract 2014 Dec; 64(629):615.
8. Teran C, Torrez-Llanos J, Teran-Miranda T, Balderrama C, Shah N & Villarroel P. Clinical accuracy of a non-contact infrared skin thermometer in pediatric practice. Child Care Health Dev 2012; 38:471–6.
9. Habera J, Kashida MN, Borhanib N *et al.* Infrared imaging of temperature profiles in microreactors for fast and exothermic reactions. Chem Eng J 2013; 214:97–105.
10. Murff RT, Armstrong DG, Lanctot D, Lavery LA & Athanasiou KA. How effective is manual palpation in detecting subtle temperature differences? Clin Podiatr Med Surg 1998; 15:151–4.