Surface pH and acute burn wound healing

ABSTRACT

Context: There is a lacuna in our knowledge to objectively assess the progression of healing in an acute burn wound.

Aim: This study aims to validate if a trend in changes of wound surface pH can be used as a reliable indicator to prognosticate wound healing in acute thermal burns.

Materials and Methods: Hospital-based longitudinal observational study was conducted in the department of burns of a tertiary care center. One hundred and twenty-three patients with acute thermal burns in the age group of 15–60 years with total burn surface area between 30%–60% were included in the study. Surface pH of wound from a specific area of dimension 10×10 cm was measured on day 1, 3, 5, 7, 9, 11, 13, and 15 using HANNA HI 99181 pH meter and the trend of wound surface pH level changes over time was observed. Wound healing was clinically assessed by wound grading chart on day 7 and 15.

Results: The trend of reducing pH values had a negative correlation coefficient of -0.95 with improved wound healing, and the trend of increasing pH values had a positive correlation coefficient of 0.74 with deteriorating wound. This is statistically highly significant with \( P < 0.0001 \).

Conclusion: The analysis showed that the trend of change in pH value over time has high statistical significance with wound healing in burns patients with reducing trend, i.e., toward slightly acidic pH being associated with better wound healing and increasing trend, i.e., toward alkalinity suggesting worsening of wounds. Hence, wound surface pH can be used as a reliable indicator to prognosticate wound healing in acute thermal burns.

Keywords: pH meter, surface pH, thermal burns, wound healing

INTRODUCTION

Since time immemorial, the most important tools to assess the status of the wound are the keen eyes of a trained clinician making it a highly subjective entity. From time-to-time, researchers have attempted to deskill this subjectivity and to develop a wound healing measurement device that would provide objectivity and uniformity in the assessment of wound status.

Since pH of the wound can affect many factors including tissue oxygen release, angiogenesis, enzymatic protease activity, and altering bacterial toxicity,\(^1\) variation of pH during the process of wound healing was studied on chronic wounds such as venous, diabetic, and pressure ulcers. As there is limited literature correlating surface pH changes with burn wound healing, this topic provided a significant opportunity for research.

MATERIALS AND METHODS

The hospital-based longitudinal observational study was conducted in the department of burns of a tertiary care center. The study group consisted of 123 patients with acute thermal burns in the age group of 15–60 years with total burn surface area (TBSA) between 30%–60%. Only patients who presented to the burns casualty within 24 hour of burn injury were included in the study. Pregnant women and patients with any comorbidities such as diabetes, immune-compromised state were excluded.

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Divakar T, Srivastava RK. Surface pH and acute burn wound healing. Indian J Burns 2019;27:57-62.
Patients were managed according to the conventional line of burn treatment in the hospital. All patients received resuscitation measures and nutrition according to body requirements. Regular dressings were done with silver sulfadiazine to standardize treatment regime. Patients received their usual regimen of drugs, and appropriate antibiotic therapy was initiated according to culture and sensitivity reports which were done once weekly.

A measurement site on the patient with dimensions of 10 cm × 10 cm was identified. Mean pH of the wound taken from five areas within the measurement site was considered for study [Figure 1]. Time since the burn injury was indicated as postburn day (PBD) with the day of burn being defined as day 1. The evaluation of wound surface pH was done on PBD 1, 3, 5, 7, 9, 11, 13, and 15.

Surface pH of wound from the measurement site was obtained using HANNA HI 99181 pH meter [Figure 2]. HANNA HI 99181 pH meter, HANNA instruments (Woonsocket, Rhode Island, USA) is a battery-operated, portable device with a flat probe to measure skin and surface pH with accuracy of ± 0.02 pH.

The following procedure was used to measure the pH—the probe was first calibrated in pH 4.01 and 7.01 buffers. The probe is then placed flat against the wound, and the result is displayed on the meter. pH reading up to two decimal points were noted down. Readings are taken immediately when the dressing has been removed as overexposure of the wound to the atmosphere could invalidate the result due to the influence of heat or cold or drying effect of the wound surface [Figure 3]. It is important to state that results obtained are of surface pH and not tissue pH. After pH measurement wounds were rinsed with saline and dressing reapplied.

The clinical observation of improvement in wound healing was assessed by the wound grading chart [Table 1] on PBD 7 and 15.

**RESULTS**

Categorical variables were presented in number and percentage, and continuous variables were presented as mean ± standard deviation and median. The normality of data was tested by the Kolmogorov–Smirnov test. If the normality was rejected, then nonparametric test was used.

Statistical tests were applied as follows: quantitative variables were compared using ANOVA/Kruskal–Wallis test (when the data sets were not normally distributed) between the three groups - improved, deteriorated and deceased. Qualitative variables were correlated using Chi-square test/Fisher’s exact test. Kaplan–Meier survival analysis curve was used to find out the overall survival rate. The Pearson correlation coefficient was used to find out trend of pH with respect to time of each patient. $P < 0.05$ was considered statistically significant. The
data were entered into MS Excel spreadsheet and analysis was done using Statistical Package for Social Sciences (SPSS) version 21.0 (SPSS Inc., Chicago, US).

The age distribution of the study group is shown in Figure 4. Seventy-five percent of the patients were in the age group of 21–40 years.

About 54.86% of patients in the study were females while 45.14% were males [Figure 5].

Of the 123 patients included in the study, 37 patients died, 81 patients showed improved wound healing, and 5 patients showed deterioration of the wound which is shown in Figure 6.

By PBD 7, 71% of patients had Grade 3 wounds, i.e., partially granulating, 9% wounds were Grade 2 showing full granulation tissue. By PBD 15 5% wounds were Grade 1, 58% wounds were Grade 2, 25% Grade 3, and 11% were Grade 4, i.e., nonhealing [Figure 7].

When a graph was plotted with the mean wound surface pH of improved, deteriorated, and deceased patients with time along the X-axis and pH along the Y-axis, 3 linear graphs were obtained. The graph for the improved set of patients showed a downward slope suggesting a steady reduction in the pH while that for the deteriorated and deceased group showed an upward slope suggesting a steady increase in pH over time.

Figure 8 shows the trend of mean pH in the patients whose wounds showed improvement, patients whose wounds deteriorated, and patients who died. We can infer that there is a correlation between the pH values and wound healing process in improved and deteriorated set of patients. This is also confirmed by the statistical analysis which is provided in Table 2.

Correlation coefficient of the trend of pH with time is shown in Figure 9. There was a negative correlation coefficient (−0.95) of pH with time for patients with improved wound healing.
i.e., surface pH of healing wounds decreased to slightly acidic range during the study. This is significantly different for patients whose wounds deteriorated and patients who died. There was a positive correlation coefficient of 0.74 and 0.80 in the deteriorated and the deceased group, respectively, i.e., the wound surface pH steadily increased toward alkalinity during the study. This means pH is increasing in the patients whose wounds deteriorated and in patients who died. Furthermore, this is statistically highly significant with $P < 0.0001$.

There is a significant difference in the slope of the pH graph and correlation coefficient among the improved set of patients and deteriorated set of patients which clearly indicates that pH can be used as an indicator for assessing burns wound healing.

**DISCUSSION**

Numerous intrinsic and extrinsic factors affect burns wound healing making it a complex multi-faceted process. Until now, the most common way of identifying an improving or deteriorating burns wound was by inspection of the wound by an experienced physician in corroboration with the general condition of the patient. An effort toward deskillling the assessment of wound healing through a combination of validated outcome measures to determine the treatment efficacy at time points earlier than complete wound closure will be of high value to the clinical management of burns wound.

Wound swabs, although reliable, have a waiting time to obtain the results. This test is not very specific. It is difficult to recognize the differences among bacterial contamination...
or critical colonization. Histological tissue bacterial count is invasive and time-consuming.\(^1\) Usually, these tests assist to modify burn patient management by suggesting an antibiotic change, while the wound is already infected.

The availability of a convenient and reliable method to predict the beginning of local infection or early detection of local wound infection would be valuable to clinical studies.\(^1\) An ideal test should be quick to perform, require minimal training, should be noninvasive, reproducible, inexpensive, and easily available, and must cause minimal discomfort or harm to the patient.

In their quest to find a suitable wound assessment device, wound characteristics were intensively studied by researchers. It was realized that the surface pH of the intact skin was in the slightly acidic range of 4.2–5.6 due to the acidic sebum keratin secreted by the eccrine sweat glands.\(^1\) Breach in the continuity of skin increases the surface pH toward alkalinity which later returns to its original level when the wound is healed with complete epithelialization. Monitoring wound surface pH may provide a method of measuring the condition of the wound bed and also aid in understanding the wound response to treatment. This knowledge was used to study the variation of pH on chronic wounds such as venous ulcers and diabetic ulcers. Jones et al. emphasized that pH of a wound gradually decreases as the wound progresses through the various stages of healing.\(^3\)

Tsukada, in his study to understand the variation of pH on pressure sores, suggests that the change in pH of the wound surface from alkaline to weak acidic may be a reasonable indicator of epidermalization of the wound.\(^4\)

Shorrock in her study – “The exploration of tissue pH and its relationship to bacterial contamination” has concluded that the measurement of pH of the wounds is not just noninvasive and efficient but also provides an objective assessment of the health of the tissue.\(^3\)

Ono et al. studied if wound exudate pH in second degree burns could be used as an indicator to predict the onset of local infection in burn wounds. They observed that a rise in tissue pH in burns wounds preceded the onset of local infection while the pH declined in the absence of infection, and the wounds progressed to healing.\(^1\)

Since pH of the wound can affect many factors including tissue oxygen release, angiogenesis, enzymatic protease activity, and altering bacterial toxicity,\(^1\) variation of pH during the process of wound healing was studied. However, most literature talks about the influence of wound pH on chronic wounds such as venous leg ulcers, diabetic foot ulcers, and pressure ulcers. Very few studies have targeted “the influence of pH on Burns wound management” as area of interest. This provides an opportunity for research in evaluating whether the surface pH of the burns wound has any significance with the wound healing.

pH is not generally used as a factor to support clinical decision-making in wound healing as the measurement of wound pH is still tedious and not highly evolved. The devices commonly available are used to measure pH of fluids or meat, which requires immersing the bulb of pH meter or piercing the pH probe into the substance, respectively. Such instruments cannot be used to measure wound pH without causing considerable discomfort to the patient while they themselves cause more trauma and cell death thereby altering the wound pH. Only litmus paper and pH meters with flat probes can measure the surface pH of the wound. Color coding of litmus papers makes it a quantitative parameter, but it is not useful when subtle pH changes are to be studied. pH meters with flat probes to measure surface pH are infrequently available and are expensive. The difficulty in pH measurement thus limits the use of pH as a reliable factor in clinical decisions for wound management.

Our study showed that there is a significant difference among the improved set of patients and deteriorated set of patients with reference to slope of pH trend graph and correlation coefficient. The analysis pointed out that the trend of pH value changes over time had a high statistical significance with wounds healing process in burns patients. The wounds that progressed toward healing showed a reducing pH trend, i.e., trend toward slightly acidic pH being associated with better wound healing and increasing pH trend, i.e., toward alkalinity suggested worsening of wounds. Hence, consecutive measurement of wound surface pH can be used as a reliable indicator to prognosticate wound healing in acute thermal burns.

The limitation of our study was that a small population of burns patients was studied. A study on larger population would be required to generalize the results. The specific measurement site was chosen on the patient for repetitive pH measurement. This measurement site need not be a representative of the total burns surface area. In addition, the biological mechanism of wound healing and its interplay with pH was not studied. Hence, further research would be warranted in this direction.

**CONCLUSION**

“Trend of pH change” can be used as an indirect indicator to predict epithelialization. It can be a valuable tool in targeted
therapeutic approach toward burns wound healing. Most of the available options only provide for localized wound pH measurements. Arriving at techniques that can measure the pH of the whole wound is still an area of research. In addition, there is a potential to combine independent parameters such as wound surface pH, wound depth, and TBSA to develop a unique “burn wound healing measurement device.”

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

REFERENCES
1. Ono S, Imai R, Ida Y, Shibata D, Komiya T, Matsumura H, et al. Increased wound pH as an indicator of local wound infection in second degree burns. Burns 2015;41:820-4.
2. Rashaan ZM, Krijnen P, Klamer RR, Schipper IB, Dekkers OM, Breederveld RS. Nonsilver treatment vs. Silver sulfadiazine in treatment of partial-thickness burn wounds in children: A systematic review and meta-analysis. Wound Repair Regen 2014;22:473-82.
3. Jones EM, Cochrane CA, Percival SL. The effect of pH on the extracellular matrix and biofilms. Adv Wound Care (New Rochelle) 2015;4:431-9.
4. Tsukada K. The pH changes of pressure ulcers related to the healing process of wounds. Wounds Compend Clin Res Pract 1992;16-20.
5. Shorrock SM. The Exploration of Tissue pH in Wounds and its Relationship to Bacterial Contamination. Vol 1. A Thesis Submitted to the Faculty of the Worcester Polytechnic Institute; 2000. p. 1-2.