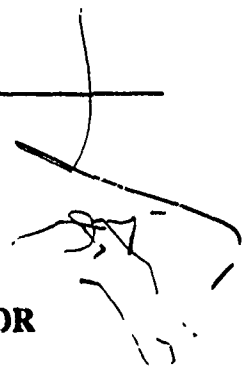


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IMAGING MULTISPECTRAL BURN DEPTH INDICATOR

ANNUAL REPORT

Martin A. Afromowitz
Department of Electrical Engineering
University of Washington

April 15, 1986

Supported by

U. S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
Fort Detrick, Frederick, Maryland 21701-5012

Contract No. DAMD-17-85-C-5106

University of Washington
Seattle, Washington 98195

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Summary

This research program is directed at developing a real-time video imaging system which can discriminate between areas of burn wounds expected to heal in three weeks or less from the day of injury, and those areas not expected to heal in that time period. The analysis can be performed on or about the third day post-burn on debrided burn wounds. The imaging system measures the reflectivity of the burn wound in the red, green, and near infrared wavelength bands, and uses an algorithm established in an earlier study to correlate this optical data with expected burn healing times. During the first year of this contract, the instrument was designed and fabricated. During the next year, we shall test the system in a clinical setting at the Burn Center at Harborview Medical Center, Seattle, Washington.

Statement of the Problem

Even in the best of circumstances, the assessment of the healing potential of a fresh burn is very difficult. Although very shallow burns and very deep full thickness burns can generally be identified, burns that fall in the partial thickness to full thickness category cannot generally be characterized accurately during the first week or two post-burn. Modern burn wound management practice, which strives towards early excision of full thickness burns, would be markedly improved if burn surgeons had an accurate diagnostic method which could identify full thickness burns early on, preferably as soon as the burn wound stabilizes on or about the third day post-burn.

Our previous research showed that the reflectivity of burn wounds in the red, green, and near infrared bands correlated very well with burn healing time, when these reflectivity measurements were made on post-burn day three. The present research is directed at developing an automated, nearly real-time, clinically useful imaging system which can provide the burn staff with a false color picture of the burn wound, wherein each area of the wound is characterized as to its potential for healing.

Background

As early excision plays an ever increasing role in burn management, a knowledge of the time required for healing becomes crucial in the decision tree. If small to moderate sized burns that will not heal within three weeks are excised and grafted within the first five days post-burn, the patient could be discharged as soon as the donor sites heal. The entire hospitalization would rarely extend as long as three weeks. On the other hand, if the burn is sufficiently superficial as to heal in less than three weeks, the patient can be spared operation, donor sites, and blood transfusions. In general, such superficial burns heal without scarring, and the hospitalization is no more than three weeks. Mistakes are made on both sides. A wound estimated to be superficial enough to heal in three weeks, that eventually requires grafting or does not heal for four or more weeks, markedly prolongs the patient's hospital stay. On the other hand, wounds that are quite superficial are sometimes incorrectly classified and needlessly excised with the attendant risks of surgery and transfusion.

The need for early and accurate assessment of burn injuries in the military environment is even more urgent than that encountered in civilian situations. In addition, the standard "eyeball" techniques used by experienced burn specialists at present to assess burn depth, which, except on very shallow or very deep burns, are not very accurate to begin with, may be expected to contribute to poor burn management decisions on the battlefield because of the relative inexperience of field medical personnel in diagnosing burn injuries.

For all these reasons, an early estimate of "time-to-healing" of burns becomes a crucial factor in modern burn management. The instrument which we are developing is intended to fill the gap in burn diagnosis described above. The imaging multispectral burn depth indicator is based upon several years of experimental and theoretical research on the optical properties of burn wounds. The key results of this research are summarized below:

- Theoretical analysis of the optical properties of clean (debrided) burn wounds shows that the reflection of red, green, and near infrared light from the wound is a function of the eschar thickness, the volume fraction of blood in the tissue near the surface of the wound, and the oxygen saturation of the perfusing blood. These parameters correlate very strongly with burn depth and burn healing time.

- Measurements of the optical reflection of burn wounds on the third day post-burn in the red, green, and near infrared bands are strongly correlated with time-to-healing. The overall statistical accuracy of our optical burn wound characterization analysis of 569 burn sites is 77% correct identification of excisable areas. Obvious superficial and obvious full thickness burns were excluded from the study. These results compare with a leading burn surgeon's 50% correct identification rate on the same group of patients on day three post-burn.

- The optical analysis technique is independent of patient age, sex, race, size of burn, burn etiology, or burn location.

- Denoting the red, green, and near infrared reflectivity of a burn by R, G, and IR, respectively, we found that the probability of healing within three weeks of the day of injury for any burn site was greater than 50% if

$$0.78 \text{ IR} + 0.55 \text{ G} - \text{R} < 0,$$

and that the probability of healing within three weeks of the day of injury for any burn site was less than 50% if

$$0.78 \text{ IR} + 0.55 \text{ G} - \text{R} > 0.$$

Approach to the Problem

Our approach to the problem of characterizing burn wound healing time, or equivalently, burn depth, on or about the third day post-burn, is to develop a real-time video system that can measure the red, green, and near infrared reflectivity of an entire burn area, point by point, and calculate on a point by point basis the probability of burn healing in three weeks. An image of the burn area is then presented on a color video monitor, showing by false color which areas are expected to heal within three weeks, and which areas are not expected to heal within three weeks. The burn surgeon can then use this information along with other clinical signs to help plan the management of the burn wound.

Documentation of the burn and the instrument's analysis is made easy by permitting the surgeon to freeze either a full color picture of the burn or the false color reflectivity analysis on the video terminal, and take an instant 8" x 10" color picture of either image for study or inclusion in the patient's file. Patient information or other data can be placed in a title window which appears on the bottom of the video screen, so that each hard copy picture can be readily identified.

Activities During the First Year

During the first year of the contract, the video system for the imaging multispectral burn depth indicator was designed and built. Figure 1 shows a block diagram of the instrument. It is operated in the following manner:

A solid-state video camera is focused on the burn wound. The camera sees the object through a color filter wheel, which rotates in front of the lens at 300 rpm. The wheel contains four different filters which transmit narrow-band red, green, blue, and near infrared light. Acquisition of a frame of video information takes 1/30 second. In one mode of operation, video frames are acquired sequentially through the red, green, and blue filters, once each revolution of the filter wheel. These frames are displayed as a full color image of the selected burn site. This mode is used for camera set-up, focusing, etc. At a keyboard command, the full color image can be frozen on the video display terminal. A second keyboard command places the system in the second mode of operation, and causes three successive video frames to be acquired sequentially through the red, green, and near infrared filters. The micro computer analyzes the information in these three frames, pixel by pixel, and displays a false color image of the burn wound in which the colors indicate various probabilities of burn healing. The meanings of the colors used in the false color image can be controlled by a simple set-up procedure. Hard copy pictures of the color monitor screen can be obtained simply by loading a film plate into the hard copy unit, exposing the film, and processing the plate in the attached instant film processor. Patient information can be typed onto the video terminal and displayed on the color images as well.

The entire system is built around the micro computer, which was programmed to accept keyboard commands and control the operation of the video mixer and video display terminal. The design, fabrication, and programming of this system occupied us for the entire first year of the contract.

Results and Conclusions

The imaging system seems to be working as planned. A few minor modifications of the system software still need to be made, and the system must be packaged in a closed, movable console. We have not yet been able to verify the accuracy of the analysis of burn healing predictions, as this will require clinical testing.

Plans for the Second Year

During the second year of the contract, we plan to move the imaging burn depth indicator system to the Burn Center at Harborview Medical Center, and, with the help of a research nurse, test the system on burn patients. The detailed description of the system will be documented as part of the Master's thesis of Mr. Larry DeSoto, who has been employed as a research assistant since the beginning of the project. Burn healing predicted by the burn depth indicator for a large variety of burns will be compared with actual patient outcomes. These data will give us a clear indication of the clinical value of the imaging system for characterizing the healing potential of burns during the first few days after injury.

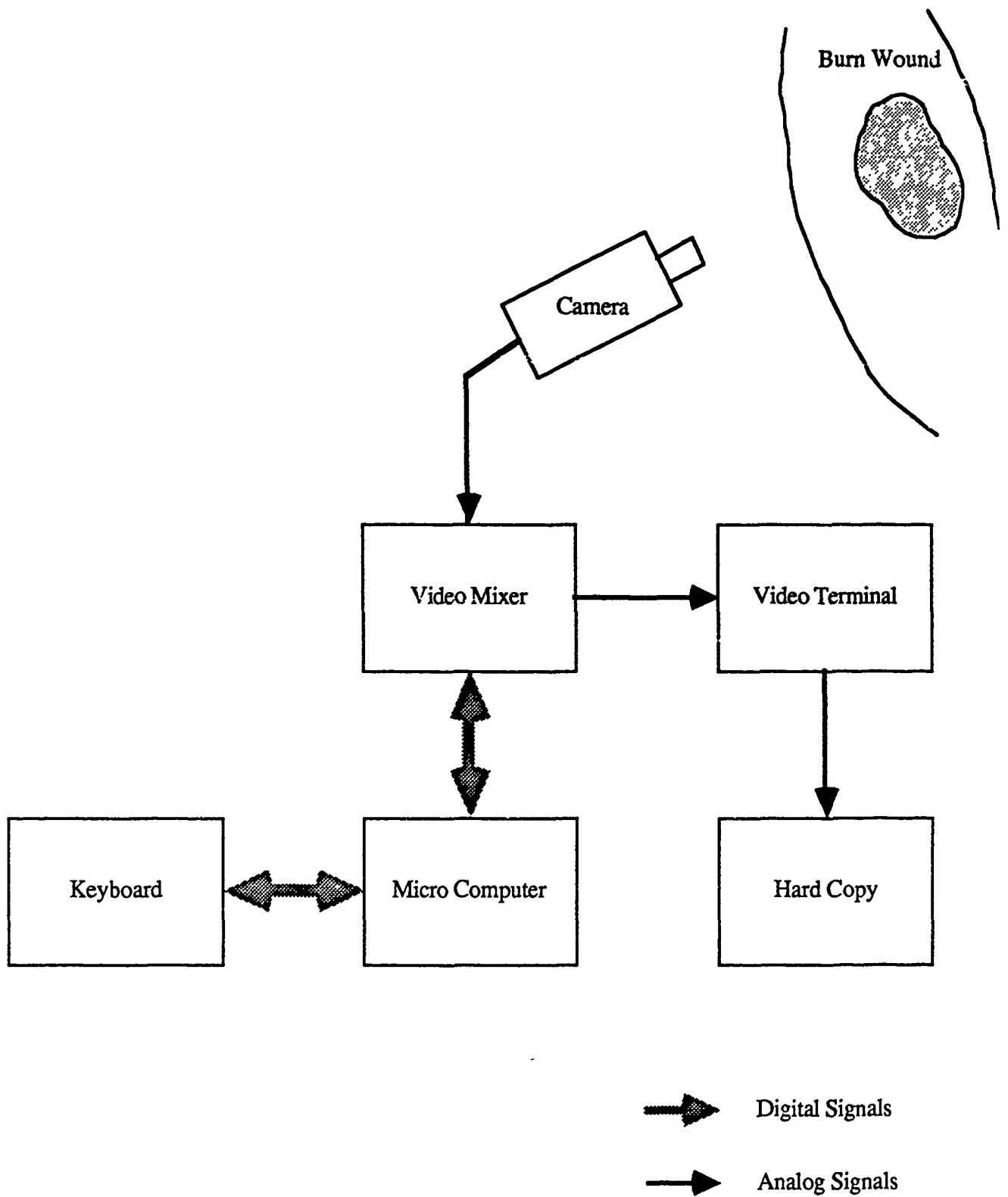


Figure 1
Block Diagram of Burn Depth Indicator