SMART BANDAGES: THE FUTURE OF INFECTION DETECTION

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WOUND MANAGEMENT AS AN UNDERRECOGNIZED MEDICAL PROBLEM

Medical technologies have undoubtedly come a long way in the past century. From the Human Genome Project to targeted cancer therapies, health disciplines such as cancer treatment and disease management have been the focus of scientists. While these are vital the improving the quality of human life, one specific discipline that has only had a handful of technical advances is in wound management. Most innovation in this field has come in the form of the range of dressings available, with a lack of focus on addressing the complexity of the wound healing process or making the process more efficient and less costly. Therefore, the practice and management of wound care and infection detection is a current engineering problem that researchers and engineers alike have started to direct their time and attention towards.

EARLY DETECTION OF CHRONIC WOUND INFECTIONS: A MAJOR ENGINEERING PROBLEM

As a child running around on the playgrounds and wandering through forests, small cuts and scratches seemed to attach to my body like a magnet. With every new adventure came a fresh scab on my knee from tripping and falling or a new scrape on my arm from a tree branch. Thankfully, all of these scrapes were minor and healed on their own in a matter of days because my body was able to quickly regenerate tissue. However, this regenerative process could be stalled with the threat of infection, a leading cause of the development of chronic wounds. Chronic wounds are a silent epidemic that affect a large portion of the population, especially diabetic patients who are prone to ulcerations which can persist for months, often causing complications that can manifest into life threatening impediments [1]. In the United States alone, chronic wounds are estimated to affect 1-2% of the population, causing a morbidity of 6.5 million patients at a cost of $25 billion per year [2]. If chronic wounds cannot be treated before it’s too late, this concerning trend will not only affect the future of health provision but also the national economy.

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Early detection of chronic wound infections and management of these wounds presents a major problem for the healthcare community and for biomedical engineers. It is common for individuals to seek treatment for wounds only once obvious, visible symptoms appear such as red inflammation, by which time the bacteria in the wound will have colonized to the point where invasive intervention is required. At this point, the current practice is to swab the wound site and test the swab in a microbiology lab for bacterial growth. This procedure is not only time consuming, but the swabs often detect only superficial pathogens and sometimes yield false positives of infection-causing bacteria [2]. Therefore, to reduce hospitalization time and the healthcare costs of performing these tests, there is a need for infection detection methods that provide timely, non-invasive, and accurate insight on wound status.

This issue is significant to society as a whole because open wounds can easily be looked over as non-dangerous or non-life-threatening, and therefore the tendency to refrain from seeking help is common. Getting treatment after serious symptoms have developed would mean that a series of invasive and lengthy tests to determine the nature and gravity of the wound would have to take place, only delaying treatment, meaning that the wound would have ample time to worsen and leading to more health care costs. Bioengineers alike should be interested in infection detection mechanisms because presently, this area utilizes underdeveloped and time consuming technologies which are slow to match the demand of early treatment from the increasing number of diabetic patients with ulcers. Had I known the threat of infection as a child running around not giving a second thought to my scrapes, I would never have been so carless with my wounds.

THE SOLUTION: A BIOSENSING DRESSING WITH WIRELESS CONNECTIVITY

In response to this issue, biomedical engineers and researchers have been developing a bandage system with wireless connectivity for uric acid biosensing as an indicator of wound status. This is a flexible, wearable, and human-interactive device with biosensors to detect uric acid (UA) concentration. According to a study done on mice, uric acid levels are elevated after cell death, promoting an inflammatory
response [3]. This means that UA concentration in wounds is highly correlated with the wound severity, making it a highly specific indicator of infection in wounds. To detect changes in urate levels, a biosensor fabricated through screen-printing enables sensitive and specific detection or UA at a very low working potential, meaning the most minuscule of levels will be recognized without interference so the early stages of infection threat can be addressed. The bandage in turn connects to a potentiostat, created specifically for wearable biosensors, which has integral wireless capability. The potentiostat measures output from the biosensor and the data is wirelessly transferred by radio frequency to a computer for data analysis [4].

Doctors and health care workers would then be able to not only get feedback on the severity of the wound, but they could better understand the progression of the wound and direct patient care based on the results. Rather than analyzing swab results, which can take a matter of hours or days to receive, this method of infection detection provides nearly instantaneous results through non-invasive measures. I believe that keeping the comfort of the patient should be a main priority for health professionals, and the smart bandage is an intelligent and effective way to manage the wound without having to go through multiple dressing changes, ensuring patient wellbeing. This technology is significant to engineers because it is engineers themselves who are being funded in order to help create these dressings for doctors to use. On the University of Texas at Arlington team working on their own smart bandage, Weidong Zhou, a professor of electrical engineering, for instance, “brings imaging and nanomaterial expertise to the team” working on the device while Liping Tang, a bioengineering professor, “handles in vivo testing of the device” [5]. Engineers from varying disciplines are needed to collaborate in order continue research on the smart bandage so that it can one day become a commonplace tool used in the medical field.

The performance of the biosensor on the smart dressing was evaluated based on sensitivity, selectivity, operational stability and robustness through a series of in vitro experiments in order to determine its analytical performance. The UA sensor showed a small sensitivity coefficient of -2.4 nA, exhibiting strong linearity, rendering it highly sensitive. When the urate was exposed to interferents, there was no significant effect on the UA current, meaning that the sensor does a good job of detecting only relevant species, in this case the UA. Even in response to a 400 µM UA standard repeatedly every 15 min over 8 hours, the UA current was still strong with no decrease in the sensitivity coefficient. Finally, with significant stress applied to the dressing to mimic the movement and curvature of the human body, the UA biosensor showed the same level of electrochemical response [4]. These figures are promising in terms of the effectiveness of the smart bandages for defining the status of a wound. Furthermore, the screening process to manufacture the dressing is low-cost and viable compared to the current swab method of analysis, meaning faster, easier, and cheaper results for doctors to diagnose the patient. Khosrow Bebahani, dean at the UTA College of Engineering, recognizes that the smart bandage “could lead to devising wearable health-monitoring devices that are less costly and more accurate than current systems” because of the numerous applications of such a device [5].

With this dressing, individuals affected with ulcers in outpatient or homecare environments would be informed of the status of their wound without the need of dressing removal because the data from the biosensor would be wirelessly transferred to to a healthcare provider, who can then take appropriate action based on the results. Society is also benefited by this technology because it reduces unnecessary dressing removals to evaluate the progress of a chronic wound, saving money on the costs of the dressings and reducing the discomfort of the patient. While I personally have not had experience with ulcers, older relatives of mine have had to live with them for years. There is a serious economic burden on them through medical visits in order to keep updates on the infection in the wound. I truly feel that they would benefit from the smart bandage because it would reduce the number of medical visits they have to endure. Engineers and health professionals are collaborating to expand the different detection systems on a smart bandage as it is gaining popularity in the medical community. For instance, Toby Jenkins, a professor of biophysical chemistry at the University of Bath, worked with clinical researches and bioengineers to unveil a prototype of a color-changing bandage that contain capsules that release nontoxic fluorescent dye in response to contact with infection-causing bacteria [6]. Using similar technology as the uric biosensing wireless bandage, Jenkins is just one of many professionals to be focusing on innovating this device, recognizing this could change the face of healthcare diagnosis in the near future. Even Keith Harding, head of the wound health research unit at the Cardiff University School of Medicine, who was not involved in Jenkins’s research, recognizes that these smart dressings are “undoubtedly a step forward’ from today’s medical microbiology techniques” [6]. The human-interactive infection detecting device is a breakthrough in medicinal technology that will not only aid patients in easing their pain through ulcer monitoring, but it will also benefit doctors to acquire accurate and rapid data results from the wound itself.

THE FUTURE OF WOUND CARE: SMART BANDAGES HELP PATIENTS, DOCTORS, AND THE ECONOMY

Wound infection is a common yet potentially dangerous occurrence in humans, especially those diabetic patients afflicted with chronic ulcers. Current practices for detecting any infection in these wounds includes swabbing and running the sample through a microbiology lab to detect bacteria levels. This time consuming process causes discomfort in the patients because of the frequent dressing changes, which in turns costs a lot of money for both the patient and for the national
In order to resolve this issue, smart bandages have been developed with biosensors that detect uric acid levels, a biomarker for infection level, in the wound and wirelessly send the data to computers for doctors to analyze. This provides health professionals with a better idea of the quality of the wound so they can take appropriate action in aiding the lesion. The future of these smart bandages is still being explored as it is a fairly new innovation, but many engineers and scientists agree that these dressings are the future of wound care. These smart bandages could set the direction for future devices utilizing similar technology but for different medical disciplines.

**SOURCES**


**ADDITIONAL SOURCES**


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