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Wearable Itch Monitoring System to Study Scratching Behavior

Nora V Bergasa[1*] and David Cowan[2]

[1]Department of Medicine, Health + Hospitals/Metropolitan, Physicians Affiliate Group of New York, New York, Medical College, Valhalla, New York

[2]inch-inc. Brooklyn, New York

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Corresponding author:
Nora V Bergasa,
Department of Medicine, Health + Hospitals/Metropolitan, New York,
Email: Nora.bergasa@icloud.com

ABSTRACT

Pruritus is a perception that cannot be quantitated. To study pruritus and its behavioral manifestation, scratching activity, instruments that record it independent from gross body movement have been developed. A new version of a portable device to monitor scratching activity in patients with pruritus is described. The main feature of the device is the use of a piezo film attached to a fingernail. Vibrations of the fingernail in the act of scratching induce electrical impulses in the piezo-element that can be filtered according to their frequency, and recorded. The use of behavioral methodology in studies of patients with pruritus can provide insight into the pathogenesis of this complex and well preserved reflex, scratching, a manifestation of systemic and dermatological conditions.

INTRODUCTION

Cholestasis is defined as impaired secretion of bile [1]. It is a complication of liver disease. Pruritus, mediated, at least in part, by the endogenous opioid system, is one of the symptoms secondary to cholestasis [2]; a central component has been proposed [3]. The pruritus can be devastating and has a major negative impact on the quality of life of patients who suffer from liver disease [2]. Accordingly, the study of pruritus is a research priority.

One of the barriers in the scientific study of pruritus concerns methods of quantitation: pruritus is a sensation, and, as it is a sensation, it cannot be directly quantified; scratching activity, the behavior that results from the sensation of pruritus can be quantitated by the use of methodology that allows for the recording of scratching activity independent from gross body movements.

The barrier to apply behavioral methodology was removed by the development of a scratching activity monitoring system that employed a piezo film sensor attached to the middle fingernail of a subject's dominant hand and supporting electronics that amplified, transmitted, and processed signals generated by the fingernail in the act of scratching, and independent from gross body movements, and picked up by the piezo film, which is, in essence, a contact microphone [4]. A key aspect of the scratching activity monitoring system is the signal processor, which is a frequency counter incorporating a threshold detector and a band filter to prevent that counts derived from movements not related to scratching be counted, proven by hours of testing the scratching behavior of normal volunteers. The upper and lower cutoff frequencies of

the analog band pass filter were selected by Fourier analysis of the raw signal from the piezoelectric film obtained during scratching. This analysis revealed that the frequencies from scratching behavior specifically fall within 30 to 1,000 kHz [4]. It is implicit in the design of the instrument that maneuvers used by individuals to relief itch different from scratching are not captured. Prolonged periods of observation of people scratching revealed that most scratch with their dominant hand, thus, the sensor was placed on that hand of the study subjects.

The scratching activity monitoring system was used in several clinical trials to study the effect of opioid antagonists on the treatment of patients with liver disease and pruritus, and which revealed that this type of drugs decreases the sensation of pruritus and its behavioral manifestation, scratching activity [5-8]. One limitation of the first scratching activity monitoring system was the required proximity to the computer that stored that information, making it necessary for the study subjects to be admitted to a clinical research center for recording of scratching behavior [4].

The system evolved to a portable instrument comprised of a piezoelectric bimorph element fitted in a steel tube, worn by the subject, and a flexible wire. The vibrations produced by the fingernail in the act of scratching are picked up by the piezoelectric film from which they are filtered and recorded [9]. The portable scratching activity monitoring system was used in the evaluation of ondansetron, a serotonin type 3 receptor antagonist, for the treatment of patients with pruritus from liver disease. The results of this study did not support a major role of serotoninergic neurotransmission in the mediation of the pruritus of cholestasis [10]. Although portable, it was necessary to upgrade the product to make it minimally intrusive. In this paper, we describe the updated product.

MATERIALS AND METHODS

An updated version of the scratching activity recording system named Wearable Itch Monitoring System (WIMSY) has now been developed by inch-inc [11]. The device is a small and lightweight system easily wearable that should not interfere with ordinary life activities, especially sleeping, and can be used in clinical trials. Limited by a small budget, a minimum viable product that is wearable, and that generates and measures useful data was created (Figures 1 and 2). The prototype takes advantage of a "Teensy" 3.2 CPU, which is powerful, lightweight, and, true to its name, quite small.

To assess the patient's scratching we used a Piezo bimorph element, identical in specification to a prior device [9]. It is a contact microphone with 70hz – 1.2khz bandpass. The complete device is small enough to be placed on the wrist of the subject and will last 8+ hours on a 350 mAh LIPO battery. The data are recorded on a 32Gb micro SD card on a shield. There is filtering hardware, and a filtering algorithm was created to interpret the data to determine the frequency and duration of the patient's scratching activity. This system can be further developed for production.

RESULTS

The product is depicted in Figures 1 and 2.

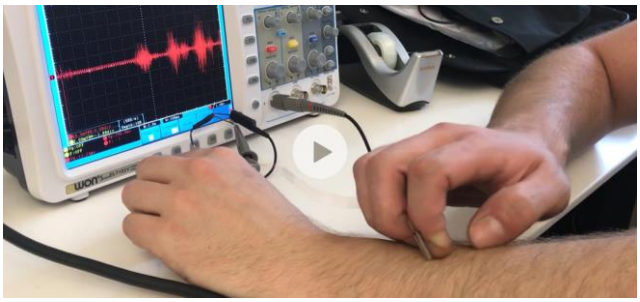

Figure 1: Scratching activity recording by the use of the Wearable Itch Monitoring System (WIMSY) worn by a

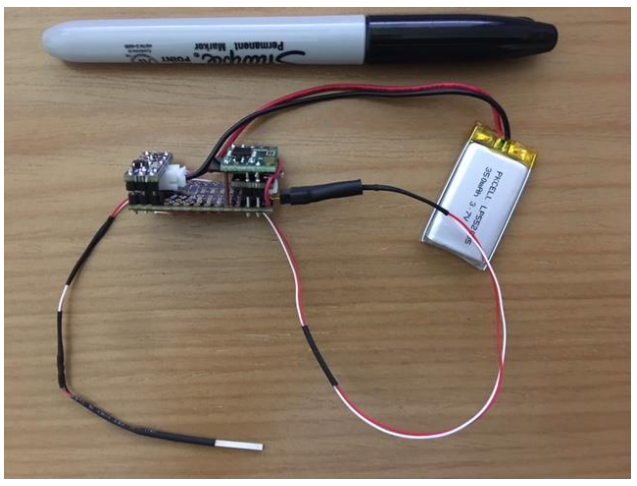

Figure 2: Anatomy of the Wearable Itch Monitoring System versus a marker to show size.

DISCUSSION

The stage to explore the behavioral manifestation of pruritus, scratching activity, is set. Investing in the development of the type of instrument described above, and created by inch-inc, will improve the study of a maddening complication of liver

disease: pruritus. The potential use of this instrument is wide, as pruritus is a complication of many other conditions including dermatological diseases such as psoriasis [12] and atopic dermatitis [13], cancer [14], and uremia [15].

A number of new medications have been recently studied for the treatment of the pruritus of cholestasis [16,17], and other forms of pruritus [13,15]; however, progress in understanding the pathogenesis, and the behavior of scratching is limited by the lack of incorporation of behavioral methodology in clinical trials. For example, it has been demonstrated that scratching behavior in some patients with cholestasis displays a 24 hour rhythm [5]; this information would not have been discovered in the absence of 96 hours of consecutive recording of scratching activity. This finding has further suggested that there may be a central regulator of pruritus and scratching, and that circadian biology may be involved.

The use of behavioral methodology in studies of pruritus may lead to the discovery of unique features of the scratching reflex, a well preserved reflex in evolution, and will improve the quality of clinical trials by providing objective data that, in conjunction with measures of quality of life, may lead to improvement in the development of effective treatments for patients with pruritus.

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