



Mini Review

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Wearable Sensors and Telemedicine Strategies for Cystic Fibrosis Patients

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Abstract

Telemedicine is an emerging medical strategy to monitor patients at home, without hospitalization risks, ensuring continuous care. Cystic Fibrosis (CF) is one of chronic disease that could be monitored for some aspects at home. The advances in Artificial Intelligence (AI) and telemedicine have the potential to increase the accuracy, reduce the costs and extend the reach of screening for pathologies like glaucoma, diabetes, etc. Wearable sensors and other telemedicine strategies were tested for CF patients during the COVID-19 pandemic. The fields of application of Artificial Intelligence (IA) regards multiple aspects of patient's life, from mental status to physical activity. In this mini review, we focused on the most recent telemedicine strategies to improve life quality and care of CF patients.

Keywords: Cystic Fibrosis, Telemedicine, Sensors, Physical Activity, Artificial Intelligence, COVID-19 Pandemic, Healthcare, Electromyography, Hospitalization, Cellular Membrane, Malnutrition

Abbreviations: AI: Artificial Intelligence; CF: Cystic Fibrosis; CFTR: Conductance Regulator; EMG: Electromyography; GPS: Global Positioning System

Introduction

Telemedicine is an emerging tool that enables clinicians to provide direct patient care at a distance by leveraging telecommunication information technology [1]. The recent worldwide spread of the COVID-19 pandemic has highlighted the necessity to develop reliable monitoring devices capable of analyzing physio pathological parameters directly at home. This necessity is not only related to patients with COVID-19 disease, but also to all those patients with chronic diseases that show difficulties to be followed up and treated in hospital, due to risk of infections during hospitalization and difficulties to reach the appropriate care centers. To this end, wearable sensors used as medical devices that can continuously collect data from the human body are becoming more and more widespread. Their high flexibility, together with the

non-invasive measures and simple way of utilization for patients leads to possible applications as physical activity monitoring and personalized healthcare [2]. Cystic Fibrosis (CF) is a congenital disease which manifestations appears since intrauterine life and generally at the birth. It is inherited as an autosomal recessive manner. CF is characterized by chronic and progressive symptoms with a multiorgan localization [3].

Cystic Fibrosis Conductance Regulator (CFTR) is the disease-gene of CF, located on Chromosome 7, encoding a protein largely expressed in epithelial cells, which has the role of regulating the chloride efflux across the cellular membrane. About 2103 mutations are described in CFTR gene leading to protein degradation, protein misfunctions or protein mis localization [4]. Protein defects or



insufficient CFTR transcript amounts are the cause of an alteration of the flow of sodium and chloride ions through cellular membrane, resulting in dense secretions accumulation obstructing epithelial ducts. A progressive respiratory system impairment with chronic inflammation and specific bacterial colonization is the main cause of death about CF patients [5]. Psychological and social impairments as well as depression and anxiety symptoms are described in adults and adolescents with CF [6] and reflects the severity and the complexity of disease management.

In the last decades, a multidisciplinary approach for therapies have significantly improved both the life quality and life expectancy in CF patients. Frequent disease exacerbations are strictly associated with a diffuse sedentary lifestyle among CF patients, partly determined by impaired muscle function and malnutrition and the lung disease that led to a reduced exercise tolerance [7]. Due to the complexity of each patient's health status, exercise interventions could be continuously monitored, but also associated to mucus clearance techniques. Regular exercise is highly recommended in the care guidelines for CF patients, for the capacity of reduce mucus stagnation enhancing pulmonary functions, but also because it can produce an overall health state reducing anxiety and depression episodes and increasing sleep quality [8].

Last Advances in Telemedicine for Cystic Fibrosis

Recently, the COVID-19 pandemic has determined an increase of telemedicine and tele-health interventions for CF patients. Wearable activity monitors have been increasingly adopted to record data related to physical activity, such as heart rate, step count, distance traveled, elevation climbed and estimated energy expenditure, but also to monitor the variations of the quantity of electrolytes in sweat. Due to easily accessible collection and electrolytes composition, human sweat can reflect individual's physiological state, and thus represents an attractive target for wearable sweat sensors [9,10]. Tomlinson and colleagues have observed successful interventions in monitoring via Skype calls exercise training of nine CF patients [11]. Wrist-worn activity monitors, using optical sensing technology to detect variation of blood volume in microvascular tissue, had controversial accuracy in literature if compared with golden standard technique for detection of heart rate during high intensity exercise [12,13]. Other studies had observed accuracy and low cost of technology for chest straps heart rate monitors worn during physical activity in healthy population [14] and CF population [15].

Another example of telemedicine is provided by the increasing number of programs based on imaging with digital fundus cameras and remote interpretation, which has made screening for retinopathy large populations associated with diabetes possible [16]. The advances in Artificial Intelligence (AI) and telemedicine

have the potential to increase the accuracy, reduce the costs and extend the reach of screening, in the same way of glaucoma screening, using optic disc photographs and/or optical coherence tomography. This could indeed represent a cost-effective way to face glaucoma in populated nations like China and India, where most glaucoma cases still to remain undiagnosed [17]. Since physical activity plays an important role for the improving the quality of life for several chronic diseases, the development of Machine Learning methods capable of classifying human physical activity through data measured by on-body sensors such as accelerometers [18], heart rate monitors [19], a mix of accelerometers, cameras, GPS location and other sensors [20], becomes important in the determination of the appropriate physical activity needed to reduce the risks associated with chronic illness.

As far as CF is concerned, semi-automated devices which use audio and Electromyography (EMG) signals for cough detection were developed by [21]. Moreover, approaches based on AI techniques offer the possibility to correlate health state indicators and the type of physiotherapy exercise to be followed [22]. Artificial intelligence represents therefore a useful tool in determining the most appropriate physiotherapy. Not only, Zucker et al. Have recently shown that deep convolutional neural networks also facilitate Brasfield scoring of chest radiographies in patients with CF and thus the use of AI could also lead to important diagnostic improvements [23].

Conclusion

In conclusion, the use of AI can provide insights not only in the development of guidelines for choosing the best physical activity for CF patients, but it could also open new fields in diagnostics, enabling recognition of CF symptoms.

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