Near-Infrared Spectroscopy (NIRS) for Non-Invasive Diagnosis

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Artificial Intelligence (AI), has gained a great significance in developing computer-aided diagnostics solutions for the diagnosis of various diseases. Near-infrared (NIR) spectroscopy, is one of the emerging tools for non-invasive diagnosis in pathological conditions. However, its full potential as a diagnostic tool is yet to be discovered. NIRS has already earned an eminence in the quality control of natural products by assessing them qualitatively and quantitatively through non-invasive devices.

Currently, amongst its applications, the most popular is the monitoring of food quality. NIRS handheld device, using its chromophore infrared light absorption provides multi-constitutional results in less than 10 seconds through cloud computing data processing software for on-site detection. It provides a fast qualitative and accurate quantitative analysis of different parameters, real-time monitoring with high sample throughput. It is a cost-effective, non-destructive, and user-friendly processing tool, compared to traditional, lengthy, arduous, time consuming, chemical analysis methods. Besides quantitative analysis, NIR spectroscopy is also used for identification of materials used in the manufacturing processes: raw material, its intermediate, and the final product.

The popularity of NIRS is due to its characteristic attributes of convenience and ease of use. Basically NIR spectroscopy belongs to the field of molecule vibration, in which the interaction with electromagnetic radiation probes the vibrational (i.e. internal) degree of freedom (DOFs) of molecules. The system includes mainly a NIR device, detector, and processing unit. The NIR device is used for reading the sample and requires simple cell phone for detection with the installed application. The data from the cloud is retrieved and can be processed on the computer. The near-infrared emitter, NIR device emits wavelengths illuminating the tissue at an isosbestic point, a constant equilibrium point, at which the total absorbance of the sample is not altered during a physical change or even chemical reaction. A photodiode sensor detects NIR light exiting from the tissue. This is quantified within seconds through various processes, mostly by the cloud computing data processing software.[1]

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Regarding NIR use for bio-applications, several researchers have attempted to utilise this technology for medical use. Solihin *et al.* used NIR spectroscopy to predict blood glucose levels. Using a handheld micro NIR device, they developed a non-invasive predictive model. They tested the calibrations using Interval Partial Least Squares (IPLS) regression methods. A linear relationship was established by them between NIR spectral data and the blood glucose concentration retrieved from the fingertip, proving the handheld spectrometer as a potential tool for non-invasive blood glucose testing.[2]

In forensic medicine, NIR has a huge potential because currently major preference in forensics is towards adoption of the portable devices. Pereira *et al*. used a handheld NIR sensor for *in situ* confirmatory identification of dry blood stains on different substrates, considering its non-invasive and non-destructive quality.[3] They used human and animal blood stain samples.

Once non-invasive deep tissue sampling of NIRS is established, it can become a powerful tool for evaluating breast cancer.[4] However, a number of studies have employed NIR spectroscopy for cancer tissue evaluation such as that of colorectal carcinoma tissues, brain, and many others were done post-biopsy.[5,6] Researchers concluded that NIR spectroscopy can be used for not only prognosis, cancer therapy, and its management, but it can also be applied on a larger group of patients with multiple clinical applications.[7] The advantage of employing NIHS was that they discovered a number of other important chemical characteristics of the cell-tissues, through their absorption spectra which can be one of the biomarker's attributes.

In Pakistan and other developing countries, diagnosis of diseases through computer-aided diagnostics solutions enabled by Artificial Intelligence (AI) will carry huge benefits for the population. This innovative technological tool can be evolved into a diagnostic tool by the combined efforts of the clinician, the researcher, and IT experts.

Due to the increase in the incidence of dermatologic pathologies, lack of awareness and understanding among masses along with inadequate availability of services and medical and clinical experts, there is an urgent requirement for AI systems to assist clinicians in this field. Researchers around the world have developed datasets, particularly deep learning algorithms through AI solutions for large number of skin pathologies which are publically available. These different image modalities show distinct differences between benign lesion and malignant skin. Despite all these big claims, AI is still at a very nascent stage for accurate diagnosis of various skin problems and not properly equipped to aid clinicians.

Once established, benefits of NIRS can be anticipated as enormous. It can play the role of a handy scanner, which can scan and construct the image of the injured area to evaluate the depth of injury and to combat any emergency situations even in remote areas. This will be connected to the experts for monitoring, shortening the time from diagnosis to treatment, especially in critical conditions.

Among the potential benefits of NRS, there are fast diagnostics results which are immediately available without waiting for laboratory analysis; reduced need for biopsies as non-invasive measurements can be used to determine whether a biopsy may be called for, and if so, choose the optimum location on the skin. It also allows to take multiple measurements and the data can be acquired periodically over time, for example, to assess the healing process or the effects of medication. It is not location-bound; hence, measurements can be taken at the patient's location and can be conveniently used in remote areas where medical accessibility is limited. With this technology, there can be significant cost reduction since the use of advanced handheld sensing technology enabled through cloud-AI reduces the need for trained and skilled experts to operate laboratory equipments.

The NIRS devices used at present exhibit low sensitivity, offering detection limits on the order of 0.1% (w/w). The instrument, currently available, is expensive and to further develop, optimize, train the device, and implement the method requires huge expenditure, though it might pay for itself later through rapid utility. Secondly, the NIR devices require continuous maintenance and highly trained personnel for developing calibration models.

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