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## Shedding light on the brain with near-infrared spectroscopy

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In 1977 it was first shown that light in the near-infrared region of the spectrum penetrates biological materials sufficiently to measure changes in cerebral oxygenation, a completely non-invasive technique.[1] Since then, near-infrared spectroscopy (NIRS) has been used to monitor oxyhaemoglobin, deoxyhaemoglobin, blood volume and cytochrome oxidase for a variety of clinical and research applications.

### Imaging with near-infrared light

Oxyhaemoglobin and deoxyhaemoglobin absorb light in the 650 - 1 000 nm wavelength range, and attenuate measurements of light transmitted through tissue. In a non-scattering medium, the concentration of an absorbing compound is proportional to the ratio of light attenuation through the medium, and the distance between the source and the detector. In the case of two absorbing compounds, the concentrations of each can be calculated from measurements of light attenuation at two different wavelengths using the Beer Lambert law – the same principle used in pulse oximetry.

However, because biological tissue is highly scattering, an unknown amount of light attenuation results from scatter rather than absorption. Because of this, continuous wave NIRS – the simplest and most commonly used technique – is able to provide quantified concentration *changes* relative to an arbitrary baseline, but not absolute haemoglobin concentrations.

Clinically and in neuroscience research, NIRS measurements from a single source and detector are commonly used. An emerging imaging technique, which is an area of current research in physics and engineering, is diffuse optical tomography (DOT), which requires surface measurements from multiple overlapping source-detector pairs. Three-dimensional tomographic images of the interior of a small area can then be reconstructed using mathematical models of light propagation through tissue.

### Applications of NIRS

The principal clinical application of NIRS is for monitoring brain oxygenation in neonatal intensive care.[2] Attempts have also been made to monitor fetal cerebral oxygenation, both transabdominally and during delivery.[3] Other pregnancy-related applications include transabdominal measurement of placental oxygenation[4] and assessment of embryo viability for *in vitro* fertilisation.[5] NIRS and DOT are also used, often in conjunction with mammography or ultrasound, to detect changes in haemodynamics related to tumours in the breast.[2]

Perhaps the fastest-growing application area is in the study of brain function, where, as an alternative to functional magnetic resonance imaging (fMRI), NIRS is used to measure changes in cerebral oxygenation in response to a stimulus. A localised increase in metabolic demand in a cortical region results in an increase in oxyhaemoglobin and a decrease in deoxyhaemoglobin which can be measured by detectors placed on the scalp, as shown in Fig. 1.

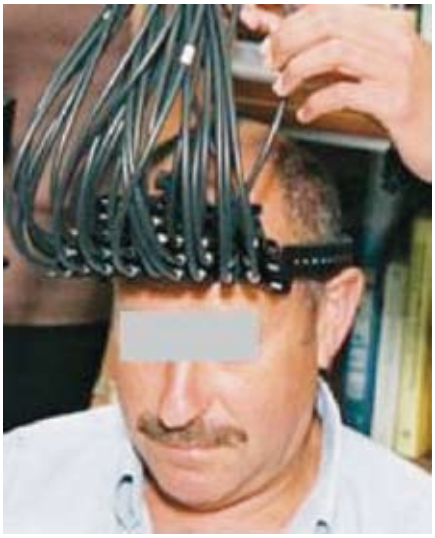

*Fig. 1. Set-up of sources and detectors over the prefrontal cortex area.*

In sports science research, NIRS can be used to measure oxygenation in the brain and muscles simultaneously, for example to investigate the relationship between the two and perceived exertion during an exhaustive cycling test.[6]

NIRS has several advantages which makes it useful in clinical and research settings. It is portable, allows for long-term monitoring, and is relatively inexpensive.[7] Although NIRS has lower spatial sensitivity than fMRI and positron emission tomography (PET), and is limited to detecting cortical activation[8]

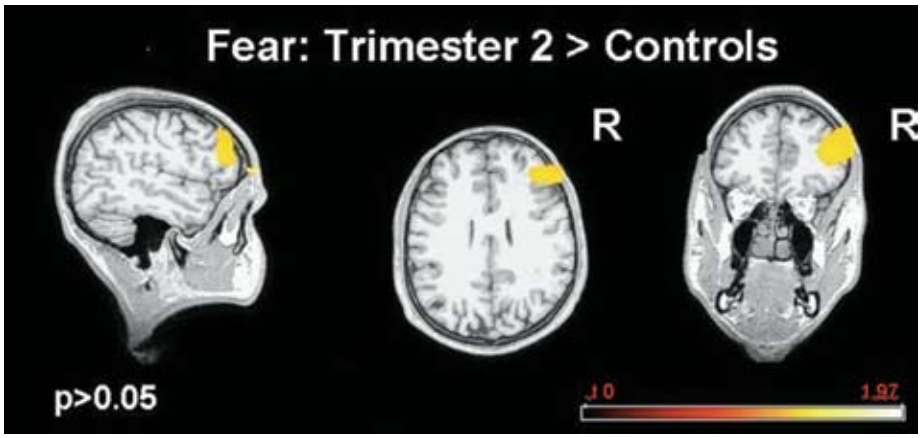


*Fig. 2. Increased activation in the right PFC in response to fearful faces in pregnant women at trimester 2 compared with non-pregnant controls.*

it does not expose subjects to harmful radiation,[9] which makes it safe for use in studies of infants and pregnant women.

### NIRS in cognitive-affective neuroscience of pregnancy

Recently, NIRS has been used to investigate the regulation of emotion in pregnancy.[10] This is important as there is a high prevalence of mood and anxiety disorders in pregnancy, but it is not clear why pregnant women are at increased risk for developing these disorders. Pregnant women underwent an imaging session with NIRS to investigate prefrontal cortex (PFC) activation in response to emotional facial stimuli including fear, and completed self-report questionnaires on distress and anxiety at each trimester. Non-pregnant controls completed these assessments at a once-off session. There was significant PFC activation in response to fearful faces in both pregnant women and controls, compared with a resting phase. However, women in the second trimester of pregnancy showed greater right PFC activation than controls in response to fearful faces (Fig. 2). In pregnant women, this increased PFC activation was significantly associated with increased distress and anxiety at all trimesters. This suggests that PFC processing of threat stimuli is altered in pregnancy, which may help explain why pregnant women have an increased vulnerability for developing mood and anxiety problems.

### Conclusion

Because of its biochemical specificity and non-invasiveness NIRS has a wide variety of applications. Although it lacks the spatial resolution of fMRI and cannot detect activation in subcortical structures, in neuroscience research NIRS and DOT can be used in situations where for ethical or practical reasons fMRI can not. NIRS therefore holds particular promise for investigating cortical brain activity in pregnant women and infants, as well as in ambulatory tasks which cannot be performed inside an MRI scanner. Advances in imaging and analysis methods and fusion with other imaging modalities will increase the accuracy of spatial localisation and provide further information about the metabolic dynamics of the brain, as well as of other organs.

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**References available at www.cmej.org.za**

## Computer-aided diagnosis in chest radiography

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Despite the popularity of three-dimensional imaging techniques such as computed tomography (CT) and magnetic resonance imaging (MRI) and a strong likelihood that these modalities will soon replace many current diagnostic and screening techniques, the chest radiograph remains the most common radiological procedure, accounting for at least one-third of all radiological examinations.[1] It is simple and inexpensive, and has tremendous clinical value.[2] However, chest radiographs are extremely difficult to interpret.[1] Poor contrast and complex backgrounds comprising superimposed anatomical structures (such as large blood vessels and ribs) overlapping with regions of interest make the detection of abnormalities difficult, even for experienced radiologists.[3] The development of computerised systems to aid radiologists in reading images and to harness the clinical value of chest radiographs would ease these difficulties. It is therefore not surprising that computer-aided diagnosis (CAD) of lung diseases in chest radiographs has become a popular area of research in medical imaging and diagnostic radiology.[4]

Arguably the primary objective of developing the digital computer was to create a system that could aid or replace humans in performing tasks that traditionally relied entirely on human intelligence. Soon after the development of the first digital computer in the 1940s, research began on the topic of computerised analysis of radiographic images.[1] Early studies investigating the computerised detection of lung abnormalities in chest radiographs, published in the 1970s, generally assumed that computers would ultimately replace radiologists in the diagnostic procedure.[4]

A distinction should be made between fully automated computer diagnosis (FACD) and CAD. Although FACD and CAD, in the context of radiography, are both based on the development of computer algorithms for the quantitative analysis of digital images, the difference lies in the utilisation of the output of the algorithms. An FACD system involves no external input; rather, the digital radiograph is independently examined by the algorithm and the computer's output is the final diagnosis. The accuracy of the system is based entirely on the performance and accuracy of the algorithm. The output of the algorithm used in a CAD system, on the other hand, is merely a tool to assist the radiologist. It is used as a second opinion and the radiologist makes the final diagnosis. The performance of the system is measured by evaluating the accuracy of the radiologist's diagnosis when using the computer output as an aid. The accuracy of the algorithm therefore does not have to be as high as it does in an FACD system.[4]

As with the early enthusiasm surrounding the capabilities of artificial intelligence, the expectations of computerised detection schemes for lung diseases have diminished.[1] The primary focus of current research is directed at developing CAD systems to aid radiologists in making improved diagnoses of chest abnormalities. The purpose of these systems is to improve the diagnostic accuracy and image reading time of radiologists.[3] The literature reveals that the most widely researched CAD applications for chest abnormalities are:[3] detection of nodules, detection of interstitial diseases, differential diagnosis, evaluation of interval changes, and detection of asymmetrical opacities.

The texture of a region in an image is a statistical description of the intensity variation in the region, and may provide information on the health anatomy represented in the image. Although much research has been conducted into the use of computer-aided textural analysis for the detection of interstitial lung diseases in chest radiographs, research into its application for the detection of pulmonary tuberculosis (TB) is limited. Perhaps the most comprehensive work on the computer-aided detection of TB has been presented by van Ginneken *et al.*[5] In this work, the lung fields were subdivided into regions of interest, which were classified as normal or abnormal based on the analysis of textural features.

The chest radiograph is often the main diagnostic tool for childhood TB in endemic settings.[6] We have used the methods of van Ginneken *et al.*[5] to classify lung regions in paediatric chest X-ray images and produce a probability map indicating the likelihood of abnormality in any region towards CAD of childhood TB.[7] Fig. 1 shows examples of the successful classification of abnormal regions in images obtained using a linear-slot-scanning digital X-ray machine (Lodox Statscan).

Preliminary work on CAD for TB detection shows promise, and motivates further development of computerised TB detection schemes.

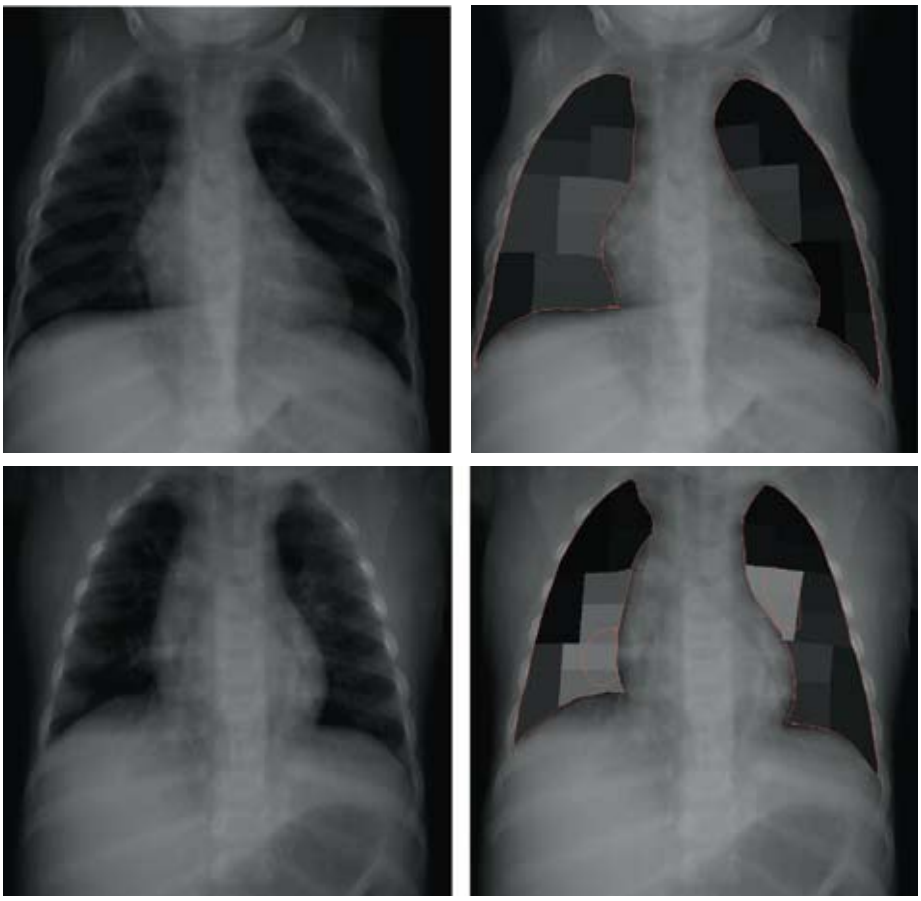

*Fig. 1. Original images (left) and probability maps (right). The first pair shows a healthy chest scan and the second pair shows a chest scan with small regions of abnormality. In each case the probability map indicates the abnormality in the appropriate region (brighter intensities = more abnormal), and accurately depicts the rest of the lung fields as normal (darker intensities). Outlines of abnormal regions, made by a radiologist, and lung borders are shown.*

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**References available at www.cmej.org.za**

# SINGLE SUTURE

## *Stay of execution*

Delays in the execution of death-row inmates are likely to lengthen now that the USA's sole manufacturer of a lethal injection drug has announced that it is abandoning production.

Hospira had already stopped making the anaesthetic, sodium thiopental, in the USA late last year because of difficulties in obtaining the raw materials. It intended to resume production in Italy, but recently bowed to pressure from Italian authorities who do not want a drug exported from their country to be used in capital punishment.

Hospira said that it would not take the risk that it might be held liable if its Italian-made sodium thiopental was used as a tool for execution. It claims that it has never condoned this use of the drug.

Last year's halt in US production has already delayed executions in California and Oklahoma. Some states managed to acquire the drug from the UK, but last November the British government banned its export for use in capital punishment.

*New Scientist,* 29 January 2011, p. 5.