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Original Article

Evaluation of near infrared spectroscopy as screening tool for detecting intracranial hematomas in patients with traumatic brain injury

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ABSTRACT

Background: Traumatic Brain Injury (TBI) is one of the most common surgical emergencies in service hospitals of India. Computed tomography (CT) has been a consistent and reliable technique for detecting intracranial hemorrhages but is limited by its non-availability in most service hospitals. Therefore the need for a cheaper, portable and easily available option required to be explored. The aim of this study was to determine the sensitivity, specificity, Positive Predictive Value (PPV) and Negative Predictive Value (NPV) of Near Infra Red Spectroscopy (NIRS) against the gold standard of NCCT head.

Methods: An observational, prospective study was conducted in 100 patients of closed head injury, attending the emergency department or surgical OPD of a service zonal hospital with NIRS. All these patients were subsequently subjected to NCCT head. Sensitivity, specificity, and positive and negative predictive values of NIRS were calculated. The study was conducted from Oct 2010 to Jul 2012.

Results: All the 100 patients were evaluated with NIRS and subsequently subjected to NCCT head. The results were compiled and statistical analysis of the same was conducted. The data revealed a sensitivity of 58.46%, a specificity of 42.86%, a positive predictive value of 65.52% and a negative predictive value of 35.71%.

Conclusion: Near Infra Red Spectroscopy (NIRS) is a good screening tool for prediction of intra cerebral haemorrhage in the field and even intensive care units. This was the first study of its kind in the Indian subcontinent and the results suggest that NIRS is a good device to predict intracranial subdural and epidural haematomas. It is however not superior to computer tomography and magnetic resonance imaging.

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Introduction

Traumatic Brain Injury (TBI) is one of the most common neurosurgical emergency in both civil and military parlance. Patients with TBI may develop Intracranial Haemorrhage (ICH), brain parenchymal injuries in the form of contusion, oedema or diffuse axonal injury (DAI). It is of utmost importance to diagnose these lesions early, initiate prompt treatment to prevent secondary brain injuries resulting from hypoxia, hypothermia and other metabolic abnormalities.¹ Amongst the various available imaging modalities computed tomography (CT) is the most consistent and reliable technique for detecting ICH.²⁻⁴ However some of its limitations are non-availability in field locations, exposure to ionizing radiation, and difficulty in shifting a haemodynamically unstable patient.

Taking this into consideration, there is certainly a requirement of an imaging technique which is simple to use, is non-invasive, less expensive, portable and which can be used in the field by both doctors and paramedical staff. Near Infra Red Spectroscopy (NIRS) is one such device fulfilling the above criteria.⁵ In this study the sensitivity, specificity, positive predictive value of NIRS was measured.

Material and methods

An observational, prospective study was conducted from October 2010 to July 2012 on 100 patients of closed head injury. All these 100 patients were evaluated with NIRS first and subsequently subjected to NCCT head.

Inclusion criteria

All patients brought to the hospital with history suggestive of head injury.

Exclusion criteria

1. Patients having scalp laceration or any active bleeding
2. Large local scalp haematoma (extra cranial haematoma)

Diagnostic study

A prospective observational study was conducted from October 2010 to July 2012. The patients were evaluated initially with NIRS and then followed by NCCT head. The radiologist and the surgeon were mutually excluded from their respective observations.

Principle of Near Infra Red Spectroscopy (NIRS)

Near Infra Red Spectroscopy (NIRS) is a portable bedside, non-invasive and battery powered device for detecting ICH. It is a handy device to diagnose ICH in field locations, intensive care units (ICU) and emergency rooms for quick triage. Near infra-red light is capable of penetrating scalp, the bony skull, dura and the brain parenchyma. The principle used to identify ICH

Fig. 1 – Crain scan.

Fig. 2 – Sites of NIRS probe placement.

with NIRS is that the extra vascular blood absorbs NIR light more than the intra-vascular blood. Acute intracerebral bleed therefore has a attenuated signal in comparison to normal brain on the contralateral side. Thus, ICH can be detected by difference in optical density (ΔOD).

The NIRS device used for the study (Crain Scan) is shown in Fig. 1. The device has a laser source and photo receiver, which are applied over the scalp of the patient. The reflected activity of near Infra Red light (IR) gets reduced in the presence of haemorrhage. Usually a 4 cm distance between the source and the detector suffices to measure a tissue volume of 2×2.5 cm. The NIRS probe is placed successively on frontal, temporoparietal and occipital region on either side of the scalp Fig. 2. The device measures the difference in absorption of near IR light (at 785 nm wavelength) between the normal and the affected site i.e. ΔOD .^{6,7,3} As per the instrument specification, the difference in $\Delta OD > 0.45$ was considered clinically significant.⁸

Fig. 3 – Age distribution of the patients.

Aim of study

The aim of this study was to determine the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of NIRS against the gold standard of NCCT head.

Results

A total of 100 patients of traumatic brain injury were taken into this study. All patients ($n = 100$) underwent NIRS followed by NCCT head. The study included 69 male and 31 female patients. The age wise distribution of patients is depicted in Fig. 3 and their distribution as per the Glasgow coma scale (GCS) in Fig. 4. There were 10 patients of severe head injury (GCS < 8), 29 patients with moderate head injury (GCS 9–12) and 61 patients with mild head injury (GCS 13–15). On doing NIRS, 58 patients showed presence of ICH ($\Delta OD > 0.45$), while the remaining 42 patients showed no evidence of ICH. Out of

Fig. 4 – Patient data as per the Glasgow Coma Score.

these 42 patients, 7 showed presence of ICH on CT head. A total of 65 patients showed presence of ICH and the remaining 35 were negative for ICH on CT head. In our study, the true positive (TP) was 38%, true negative (TN) 15%, false positive (FP) 20% and false negative (FN) 27%. The sensitivity and specificity of the NIRS was 58.46% and 42.86% respectively. The positive predictive value (PPV) and negative predictive value (NPV) was 65.52% and 35.71% respectively (Tables 1 and 2).

Discussion

Head injury refers to trauma to the head and at times includes injury to the underlying brain.⁹ The terms TBI and head injury have been used sine qua non in medical literature.¹⁰ Epidemiological studies show that road traffic accidents (RTA) contribute to 60% of TBI's. It is estimated that nearly 2.5 million new TBI cases occur every year resulting in death of 250,000 people. As per WHO RTA's will be the fifth leading cause of death in India by 2030. Head injuries are also common in children accounting for 10% of all paediatric hospital admission.¹¹ The injury to the underlying brain can be at the site of impact or on the contralateral side (countercoup effect). A plain CT head is mandatory for all moderate to severe head injury patients. MRI brain is the investigation of choice when there is a clinical suspicion of more extensive injury where the CT head is normal as in cases of DAI. MRI brain is safe in pregnant ladies including first trimester with no untoward effects of radiation as per the literature search.^{12,13} The first mention of NIRS as a tool to assess intracranial bleed finds mention in 1977. NIRS is a light weight, portable, painless equipment which is placed gently on the scalp. It can record readings in all the scalp locations within 3–5 min under ideal conditions. However in infants and children, it can take up to

Table 1 – Comparing NIRS with NCCT head.

NIRS	NCCT		Total
	+ve	–ve	
+ve	38	20	58
–ve	TP	FP	42
	27	15	
	FN	TN	
	65	35	100

Table 2 – Result of sensitivity/specificity/PPV/NPV with 95% CI.

	True +	True –
Test +	38	20
Test –	27	15
Measure of association and 95% confidence interval		
Sensitivity	58.5%	45.6–70.3
Specificity	42.9%	26.8–60.5
Positive predictive value (PPV)	65.5%	51.8–77.2
Negative predictive value (NPV)	35.7%	22.0–52.0

10–15 min. It can be used directly in the Emergency room or in ICU setting if the patient is too critical to be shifted to CT scan. NIRS was extensively studied on 148 patients at RasoolAkram General Hospital in Tehran, Iran in 2007. It gave a sensitivity of 88.9% and specificity of 77.7%.¹⁴ In another study conducted on 305 head-injury patients at Baylor College of Medicine in 1992, the ΔOD was significantly elevated in 98% of the patients having intra cranial haematoma ($p > 0.05$). The use of NIRS was further validated in a study by Robertson et al. whereby they concluded that it could detect early intracranial haematoma.¹⁵ In our study there were 7 cases of false negative. Four out of these cases were elderly and had Chronic subdural haemorrhage. The two other cases were children of Battered Baby Syndrome while the remaining one case had subgalealedema. The high percentage of false positive could be because of patient being agitated, children being uncooperative or some other confounding factor. The possible reason for low sensitivity and specificity in our study in comparison to other studies could be because of ethnic variations, thick skull-bone and presence of coarse/thick hair in contrast to Western population. NIRS has its limitations in sub-acute to chronic cases where the haemoglobin is undergoing degradation and also in presence of subgaleal haematoma. The finding of cerebral vasospasm in a retrospective study¹⁶ on US soldiers in the ongoing Iraq conflict has forced neurosurgeons, military think tank and others to develop an additional battlefield tool for effective triage. The use of NIRS is being extensively studied by US researchers for this purpose.

Conclusion

Near Infra Red Spectroscopy is a good screening tool for prediction of intra cerebral haemorrhage in the field, emergency rooms and intensive care units. It is not reliable in bilateral lesions, sub-acute to chronic haemorrhage and in cases of diffuse axonal injury without intra cerebral haemorrhage. This was the first study of its kind in the Indian subcontinent and the results suggest that NIRS is a good device to predict intracranial subdural and epidural haematomas. It is however not superior to computer tomography and magnetic resonance imaging.

Conflicts of interest

The authors have none to declare.

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