Journal of Clinical Neuroscience 40 (2017) 136–146

Contents lists available at ScienceDirect

Journal of Clinical Neuroscience

journal homepage: www.elsevier.com/locate/jocn

Case study

Portable near-infrared rapid detection of intracranial hemorrhage in Chinese population

Long Xu [a,1], Xiaogang Tao [a,1], Weiming Liu [a], Yanong Li [c], Jun Ma [c], Te Lu [a], Bo Han [a], Baiyun Liu [a], Yuanli Zhao [a], Jingsheng Li [a], Jizong Zhao [a,b,*]

[a] Department of Neurosurgery, Beijing Tiantan Hospital, Capital Medical University, 6 Tiantan Xili, Beijing 100050, China
[b] China National Clinical Research Center for Neurological Diseases (NCRC-ND), Beijing 100050, China
[c] Department of Neuroradiology, Beijing Tiantan Hospital, Capital Medical University, 6 Tiantan Xili, Beijing 100050, China

ARTICLE INFO

Article history:
Received 26 January 2017
Accepted 12 February 2017

Keywords:
Intracranial hemorrhage
Traumatic brain injury
Near infrared
TBI
NIR

ABSTRACT

Background: Secondary brain injury is the main cause of mortality from traumatic brain injury (TBI). One hallmark of TBI is intracranial hemorrhage, which occurs in 40–50% of severe TBI cases. Early identification of intracranial hematomas in TBI patients allows early surgical evacuation, and can reduce the case-fatality rate of TBI. Since pre-hospital care is the weakest part of Chinese emergency care, there is an urgent need for a capability to detect brain hematomas early. The purpose of this observational study was to evaluate the performance of a near infrared (NIR) based, device to screen for traumatic intracranial hematomas in Chinese population.
Methods: Data was collected using the NIR device at the time of a computed tomography (CT) or magnetic resonance imaging (MRI) scan was performed to evaluate a suspected TBI. 85 patients were included in the per protocol population. Of the 85 patients, 45 were determined by CT scan to have intracranial hemorrhage. The CT and MRI scans were read by an independent neuroradiologist who was blinded to the NIR measurements.
Results: The NIR device demonstrated sensitivity of 95.6% (95% confidence intervals [CI] 83.6–99.2%) and specificity of 92.5% (CI 78.5–98%) in detecting intracranial hematomas larger than 3.5 ml in volume, and that were less than 2.5 cm from the surface of the brain.
Conclusion: These results confirm in Chinese population the results of previous studies that demonstrated a NIR based device can reliably screen for intracranial hematomas that are likely to be of clinical importance.

1. Introduction

In China, trauma has become the fourth leading cause of death after heart disease, cancer, and cerebrovascular accidents, and it is the leading cause of death in adults under the age of 40. Among various traumas, traumatic brain injury (TBI) has the highest mortality and the most serious consequences and is the most difficult to treat. It has been reported that patients who die of TBI account for 87% of all trauma deaths. The proportion of severe TBI in China is much higher than that in other countries (20% vs. 10%) [1]. TBI is frequently referred to as the 'silent epidemic' because complications from TBI, such as cognitive, sensory or emotional impairments may not be readily apparent. The loss of human potential, long-term impairments and disabilities associated with TBI has a tremendous impact on Chinese society. In addition, awareness about TBI among the general public is limited [2].

An estimated 3–4 million people experience traumatic brain injury each year in China or an annual rate of 230–300 per 100,000 people [3]. Another study showed that the incidence of traumatic neurological injury was 55.4 patients per 100,000 population per year in the six big cities in China and 64.1 patients in the rural areas [4]. We believe that those two reports underestimate

Abbreviations: AUC, area under the curve; CI, confidence interval; CT, computerized tomography; ΔOD, difference in optical density; ΔOD_{max}, the greatest absolute value for ΔOD among the various regions examined; GCS, Glasgow coma score; MRI, magnetic resonance imaging; NIR, near infrared; NPV, negative predictive values; PPV, positive predictive values; ROC, receiver operating characteristic; TBI, traumatic brain injury.

* Corresponding author at: Department of Neurosurgery, Beijing Tiantan Hospital, Capital Medical University, 6 Tiantan Xili, Dongcheng District, Beijing 100050, China. Fax: +86 10 67096523.

E-mail address: zhaojz205@163.com (J. Zhao).

[1] These authors contributed equally to this work.

http://dx.doi.org/10.1016/j.jocn.2017.02.056
0967-5868/

the size of the TBI epidemic in China as many individuals with mild TBI will not be admitted to hospitals and are often overlooked in hospital-based TBI studies [5].

Secondary brain injury, which occurs in minutes to days following primary injury, is the main cause of TBI mortality. Early identification, prevention, and correction of these events in the pre-hospital setting can lower the risk of secondary brain injury and reduce the case-fatality rate of TBI. For patients with moderate-to-severe TBI in particular, diagnosis within the first ("golden") hour of the traumatic event is critical. Since pre-hospital care is the weakest part of Chinese emergency care, suboptimal practices in TBI management may exist in pre-hospital settings [1].

One hallmark pathological process in TBI is intracranial hemorrhage, which occurs in 40–50% of severe head trauma cases [6]. Early diagnosis and surgical evacuation of intracranial hematomas are fundamental management principles for traumatic hematomas [7]. Early identification of intracranial hematomas in TBI patients allows early surgical evacuation, which can be an important determinant of outcome. In one study, Seelig et al. showed that a delay of more than 4 h between injury and the evacuation of a traumatic subdural hematoma increased mortality and worsened outcome in survivors [8].

A practical adjunct to this goal of early identification of intracranial hematomas in the field and emergency center may be the use of a portable NIR technology. A NIR based, hand held medical screening tool (Infrascanner by InfraScan, Inc., Philadelphia, PA, USA) has been developed to screen for a brain hematoma at the site of injury [9]. In laboratory tests with phantom models of intracranial hematomas, the smallest volume of blood that can be detected with the device was 3.5 ml, and the hematoma must be within 2.5 cm of the brain surface to be detected.

In a multi-center study (431 patients) conducted with a prototype Infrascanner, sensitivity for intracranial hematomas was 88% as compared to CT scan readings [10]. Specificity in the per protocol population was 90.7%. The type of hematoma could not be determined with certainty in this study; however it was possible to detect the presence of any type of traumatic intracranial hematoma.

Other groups have reported similar experiences with the use of NIR technology to identify intracranial hematomas. Leon-Carrion et al. studied the use of the Infrascanner in 35 patients with intracranial hematomas and found an overall sensitivity of 89.5% and specificity of 81.2%, as compared to CT scanning [11]. Bressan et al. evaluated 110 children at intermediate or high risk for intracranial injury. There was only one brain hematoma case in this group (it was successfully detected) [12]. The Specificity in this test was 93%. The use of Infrascanner would have led to the avoidance of ten CT scans, reducing the CT scan rate by 58.8%. Tyzo et al. evaluated 94 children with mild TBI. The Sensitivity in this test was 86.7% and Specificity was 90% [13]. The aim of the study was to propose a new protocol of screening patients using Infrascanner as a complement to repeated neurological examination and medical history review. The results of this study led to the adoption of the Infrascanner as part of the standard of pediatric care in Poland [14]. Semenova et al. evaluated the Infrascanner's ability to detect intracranial hemorrhages among 95 children having experienced mild head trauma [15]. 42 children with associated medium–high risk (GCS 13–14) received an evaluation by neurosurgeon, Infrascanner, and a CT. 53 children with associated low risk (GCS 15) received a scan with the Infrascanner and were clinically monitored for 72 h. Among the medium–high risk category the sensitivity was 100% and the specificity was 91.2%. In the low risk group, the specificity was 91.7%.

The purpose of this clinical study was to evaluate the performance of this NIR based portable device, Infrascanner by InfraScan, Inc, in the detection of intracranial hemorrhage due to trauma in Chinese population. The high incidence of TBI, and especially of severe TBI in China, coupled with suboptimal pre-hospital care, increases the special need in China for pre-hospital brain hematoma detection ability. Therefore, we believe that the first-hand sensitivity and specificity evaluation of the Infrascanner in Chinese population is necessary. The endpoint of the study was a description of the test characteristics (sensitivity, specificity, positive and negative predictive values) of the portable NIR based device in identification of hematomas within its detection limits (volume > 3.5 ml, and depth < 2.5 cm) compared to CT scan as the gold standard.

2. Methods

2.1. Study design

The study was a single-center observational study to test the performance of the new portable NIR device to screen for intracranial hemorrhage, comparing the findings of the NIR exam to those of the admission CT or MRI scan. The endpoint of the study was a description of the test characteristics (sensitivity, specificity, positive and negative predictive values) of the portable NIR based device in the identification of hematomas within its detection limits (volume > 3.5 ml, and depth < 2.5 cm) when compared to CT and MRI scans results as the gold standard.

2.2. Theoretical basis for detection of hematomas with NIR technology

Due to its unique light-absorbing properties, hemoglobin molecules within tissue have the highest absorption rate in the NIR range (700–900 nm) [16–18]. The principle used in identifying intracranial hematomas with NIR is that extravascular blood absorbs NIR light more than intravascular blood. This is because there is a greater (usually 10-fold) concentration of hemoglobin in an acute hematoma than in normal brain tissue where blood is contained within vessels. The NIR based device, Infrascanner Model 2000 (InfraScan, Inc., Philadelphia, PA, USA), compares light absorption in both the left and right sides of the brain in four different areas. The absorbance of NIR light is greater (and therefore the reflected light less) on the side of the brain containing a hematoma, than on the uninjured side. With specified wavelength ranges, optical light source(s) or emitter(s) and a photo-detector are placed at a distance, which allows proper NIR absorption measurements in a desired volume of tissue. The used wavelength of 805 nm, the isosbestic point of hemoglobin, is sensitive only to blood volume, not to oxygen saturation in the blood.

The device is placed successively in the left and right frontal, temporal, parietal, and occipital areas of the head in a predefined sequence and the absorbance of light is recorded (see locations in Fig. 1). The difference in optical density (ΔOD) in each of the four symmetrical areas is calculated on a pair-wise basis using the following formula:

$$\Delta OD = log_{10}\left(\frac{I_L}{I_R}\right)$$

where I_L = the intensity of reflected light on the left side of the head, I_R = the intensity of reflected light on the right side. With each examination the ΔOD for each of the four brain regions was recorded, and the ΔOD_{max}, defined as the greatest absolute value for ΔOD among the various regions examined, was recorded.

Intracranial hematoma detection was established when a $\Delta OD > 0.2$ units occurred in a particular pair of bilateral measurements. The presence or absence of a hematoma in a patient was determined by comparing the ΔOD_{max} measurement to the pre-defined threshold of 0.2. When any single pair measurement