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Full Length Research Paper

An assessment on the use of infrascanner for the diagnosis of the brain hemotoma by using support vector machine

Figen Coskun[1], Ebru Akcapinar Sezer[2*], Mehmet Akif Karamercan[1], Emine Akinci[1] and Kubilay Vural[1]

[1]Department of Emergency Medicine, Ankara Education and Research Hospital, 06340 Ulucanlar, Ankara Turkey.
[2]Department of Computer Engineering, Hacettepe University, 06800 Beytepe, Ankara, Turkey.

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Diagnosis of the brain hematoma injuries is critical for patients and requires exhaustive processes. For this reason, the practical methods may be attractive for medical applications to reduce time and cost. The purpose of this study is to discuss the applicability of the InfraScanner for the diagnosis of the brain hematoma and to determine the most important factors affecting the positive brain hematoma cases by support vector machine approach. For the purpose of the study, the data of 92 adult and 161 pediatric patients (253 in total) with traumatic brain injury were collected and assessed. The analyses applied in this study gave encouraging results about the use of near Infrared Scanner (NIRS) on practical diagnosis of brain hematoma. When making a comparison between the adult and pediatric patients, it is obvious that the use of NIRS exhibited better results in pediatric patients than adult patients.

Key words: Brain hematoma, Infrascanner, CT, support vector machine

INTRODUCTION

Traumatic brain injury is one of the major health problems throughout the world and it is the most important cause of mortality and morbidity for young adults (< 45 years old) and childhood (1 - 15 years old) (Palchak et al., 2003). According to the statistics published by Jagode et al. (2009), there are more than 1 million emergency department visits annually for traumatic brain injury in the United States. The challenge to the emergency physician is identifying which patients with a head injury have acute traumatic intracranial injury, and which patients can be safely sent home (Jagode et al., 2009). When serious intracranial injury in head traumas is detected, decision on indication of neurosurgical interventions and performing time of these interventions has a crucial importance. During the assessment of head trauma patients in emergency departments, history-physical examination and conventional radiographs are valuable; however, they are not sufficient. Although computerized tomo-graphy (CT) is the gold standard diagnostic test for evaluating children and adults with head trauma, this procedure has some disadvantages, including exposure to ionizing radiation, transport of the patient away from the direct supervision of emergency physicians, the frequent requirement for pharmacologic sedation, additional health care costs and increased time for completing ED evaluation (Palchak et al., 2003). Kupperman et al. (2009) emphasized same disadvantages of the CT by stating that reduction of CT use is important because ionizing radiation from CT scans cause lethal malignancies. The estimated rate of lethal malignancies from CT is between 1 in 1000 and 1 in 5000 pediatric cranial scans, with risk increasing as age decreases (Kupperman et al., 2009). Furthermore, many traumatic brain injuries identified on CT do not need acute interventions, and some are false positives or non-traumatic findings (Kupperman et al., 2009). Therefore, CT scans should be selectively used. Despite

*Corresponding author. E-mail: ebru@hacettepe.edu.tr.

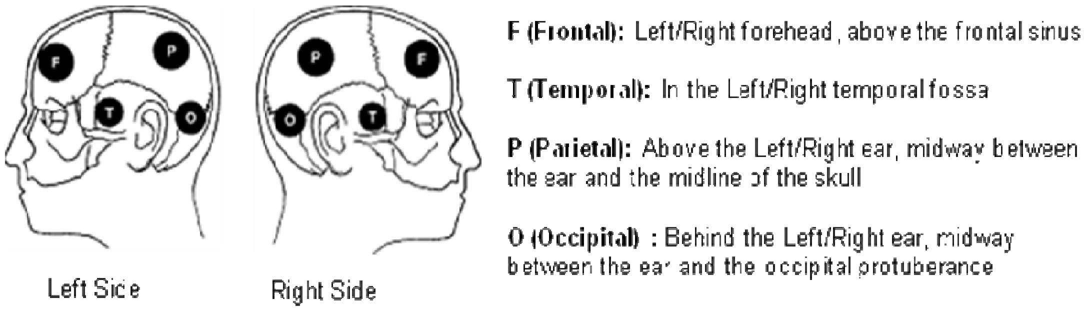

Figure 1. Application points of NIRS system on the head.

its undesirable effects, Kupperman et al. (2009) reported that, between 1995 and 2005, CT used more than doubled.

There are still no reliable and easy-of-use risk classification scales for emergency evaluation of head traumas, and universal protocols for indication of CT. Due to lack of these protocols and refraining from malpractice, most of physicians require inessential CT, although the trauma is minor and physical examination results are normal.

Infrascanner™ is a hand-held, non-invasive, near-infrared (NIR) based mobile imaging device to detect brain hematoma at the site. Initially, Gopinath et al. (1993) showed that intracranial hematoma localizations could be determined on the patients having serious head trauma by Infrascanner™. NIRS that can be used both as bed head unit for traumatic brain injury and in emergency services and bring positive results may provide a fast-track assessment of emergency and prehospital patients. Besides, it may reduce the usage of CT, especially for childhood group, and eliminate the side effects.

This current study examines the effect of NIRS on the decision process for CT indication by using Support Vector Machine (SVM). The performance of NIRS has been statistically assessed by considering the difference in optical density (ΔOD) threshold that is designated by the producer. To this end, trauma mechanism anamnesis, physical examination findings, Glasgow Coma Scores (GCS), NIRS and CT results of the pediatric and adult patients with traumatic brain injury have been used in this study.

MATERIALS (PATIENTS)

This study was carried out on 92 adult and 161 pediatric patients (253 in total) with traumatic brain injury that were admitted to Ankara Training and Research Hospital, Emergency Service between 01.06.2009 - 01.10.2009. All the patients who were applied Standart Advanced Trauma Life Support (ATLS) protocol, and whose informed consents were received for brain CT were included in this current study. Before the study, advanced practical critical care paramedics and specialists participated to a standard 3-hour training on the use of NIRS. Those executives obtained NIRS measurements of the patients before they underwent a CT scan. The socio-demographic characteristics, severity and mechanism of trauma, anamnesis and physical examination findings of the patients were registered to standardized forms. The CCT (Cerebral Computerized Tomography) was measured by computerized tomography (*Hitachi Pronto RSGD-TO5332*) in the Emergency Radiology unit with a 5 mm incisions and was reported by the radiologist who was uninformed of NIRS results.

Principles of NIRS

The InfraScanner™ gives a practical solution to the problem of early identification of intracranial hematomas because of the unique light-absorbing properties of hemoglobin and the non-invasive, non-ionizing nature of near infra-red technology. The basic method for hematoma detection is based on the differential light absorption of the injured vs. the non-injured part of brain. Under normal circumstances, the brain's absorption should be symmetrical. When additional underlying extravascular blood is present due to internal bleeding, there is a greater local concentration of hemoglobin and consequently the absorbance of the light is greater while the reflected component is commensurately less. This differential can be detected via sources and detectors placed on symmetrical lobes of the skull. The science of diffused optical tomography used by the Infrascanner™ enables the conversion of light differential data into interpretative scientific results.

The NIRS system is placed successively in the left and right frontal, temporal, parietal (Figure 1) and occipital areas of the head and the absorbance of light at selected wavelengths is recorded.
The difference in optical density (ΔOD) in the different areas is calculated by using the Eq.1 where I_N = the intensity of reflected light on the normal side, I_H = the intensity of reflected light on the hematoma side:

$$\Delta OD = \log_{10}\left(\frac{I_N}{I_H}\right) \qquad (1)$$

In order to interpret the NIR examination, the absorption of light which is related to hemoglobin content within the four scanned areas on the left side of the head was compared with the absorption of light obtained on the corresponding locations on the right side, obtaining a difference in optical density (ΔOD) for each location. The optical density measurement is a logarithm of the measured light intensity: OD = $\log_{10}$I. With each examination, the ΔOD for each of the four brain regions was recorded, and the ΔODmax, defined as the greatest absolute value for ΔOD among the various regions examined, was recorded. The presence or absence of a hematoma was determined by comparing the ΔODmax measurement to a pre-defined threshold. In each head region where the ΔOD was more than the threshold of 0.2, the measurement was

Table 1. Number of NIRS and CCT results.

Unary	NIRS (+)	NIRS(-)	CCT(+)	CCT(-)
Pediatric	65	96	14	147
Adult	59	33	8	84

Table 2. Binary occurrences of NIRS and CCT results.

Binary	Pediatric	Adult
NIRS (-) and CCT (-)	94	32
NIRS (+) and CCT (-)	53	52
NIRS (-) and CCT (+)	2	1
NIRS (+) and CCT (+)	12	7

Table 3. Comparison of NIRS and CCT results.

	Pediatric (%)	Adult (%)
Total correct NIRS positives	18.5	11.2
Ratio of correct couples (CCT-NIRS)	65.8	42.3
Ratio of missed alarm by NIRS	1.2	1.1
Ratio of mis-alarm	32.9	56.5

repeated to confirm the finding and reduce the chances of a false reading due to trapped hair under the light guides.

Statistical assessments and interpretations on the NIRS

In this phase, the numbers of positive and negative results obtained by NIRS and CCT for brain injury have been presented in Table 1. Table 1 introduces the patient group with brain injury. Table 2 is significant for the performance of NIRS. While NIRS was (-) CCT was also (-) in 32 of the 92 adult patients, and 94 of the 161 pediatric patients. The application of NIRS method may hinder CCT scan in 34.3% of adult, and 58.3% of pediatric patients. In this study, 2 pediatric and 1 adult patient were observed whose NIRS was (-) whereas, CCT was (+). Linear skull fractures were observed in those patients and without any problems they were discharged from the hospital with full recovery. A total of 105 cases were observed where NIRS was (+) whereas, CCT was (-). This connotes that the false alarm rates for NIRS are high. However, it is known that external hemorrhage and subgaleal hematoma may give false positive alarms.

As can be seen in Table 3, the results of NIRS and CCT produce paired results as (+, +) or (-, -) in 65.8% of the pediatric patients and 42.3% of the adult patients for brain injury. The most important point is that the existing brain injury cannot be detected by NIRS and the rate is 1.2% for pediatric patients and 1.1% for adult patients. The related cases have been explained above. NIRS gives positive results for 32.9% of pediatric patients without brain injury, whereas, this rate is 56.5% for adult patients. 18.5% of the positive results obtained from NIRS in pediatric patients were also positive in CCT scans, whereas, the rate is 11.2% for adult patients. When the Table 3 is examined closely, it is observed that total performance for pediatric patients is better than the adult patients.

Importance of the Parameters

The second assessment regarding whether the NIRS can be a protocol for the CCT scans of the patients was carried out with Support Vector Machine (SVM). SVM is a data mining technique. SVM can model complex, real-world problems such as text and image classification, hand-writing recognition, and bioinformatics and biosequence analysis. SVM is a state-of-the-art method that serves powerful discriminative features in linear and non-linear classification problems. Generally speaking, SVM is designed to enlarge the boundary of any two classes in pattern space by searching an optimal hyper plane that has maximum distance to the closest points between two classes which are termed support vectors (Liu et al., 2007). However, SVM has support for multiclass predictions via different developed kernel functions. Different kernel functions identify the different non-linear transform and feature space, the choice of kernel functions will affect the assessment performance of SVM, and affect learning ability and generalization ability of machine learning (Zhao et al., 2009). The general principle of classification of oriented SVM approach is revealing optimal separating hyper plane(s) which separates two or more classes with lowest error rate and maximum true classification performance.

Two different data set were examined with SVM. Figure 2 presents the variable importance graph of the pediatric patients, whereas, Figure 3 presents the model for adult patients. The data for pediatric and adult patients are given separately due to the differences in diagnosis process and physiological properties.

Age, the mechanism of the trauma, symptom, GCS, pathologic sign on physical examination, NIRS and CCT parameters were used in all the models. Three different models were formed both for pediatric and adult patients: In the first model, CCT was used as output and all other parameters were used as input (Figure 1a and 2a); in the second model, CCT parameter was ignored and NIRS was used as an output parameter (Figure 1b and 2b); in the third model, NIRS was ignored and CCT parameter was used as output (Figure 1c and 2c). The aim for constructing such a model was to determine the parameters that affect NIRS independent of CCT and similarly, to determine the parameters that affect CCT independent of NIRS. Besides, it is also aimed at determining the sequence of NIRS among the parameters that affect CCT. Performances of the models are listed in Table 4.

When NIRS was ignored for pediatric patients, "pathologic sign on physical examination" and "GCS" parameters were found to be the most important parameters that affect the results of CCT (Figure 1c). When CCT was ignored “mechanism of trauma” and “pathologic sign on physical examination" affect the results of NIRS (Figure 1b). When the factors that affect CCT, including NIRS, were examined, it was observed that NIRS had a dominant effect on CCT along with "pathologic sign on physical examination" (Figure 1a). The most important factors that affect the positivity of CCT among pediatric patients were that pathological findings were observed in physical examination and GCS < 14 (Figure 1c). The existence of pathological findings and mechanism of trauma affect the positivity of NIRS (Figure 1b). The positivity of NIRS along with the pathological findings in physical examination significantly affects the positivity of CCT (Figure 1a).

The results are different for the adult patients. As can be seen in Figures 2b and 2c, symptom has a dominant effect both on NIRS and CCT. While NIRS has a significant effect on CCT in pediatric patients, it has an insignificant effect in adult patients and comes after the symptoms such as "pathologic sign on pyhsical examination", "GCS", and "symptom". The parameter that most affect the positivity of CCT and NIRS results is the existence of “symptom” in adult patients (Figures 2b and 2c). The positivity of NIRS among pediatric patients significantly increase the positivity of CCT when it exists along with pathological findings in physical examination. However, as there exists pathological findings in

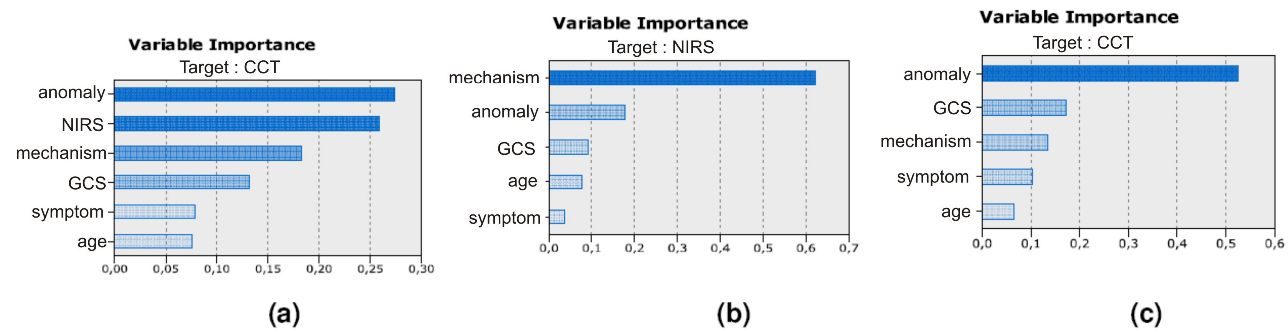

Figure 2. For pediatric cases (a) variable importance for CCT including NIRS (b) variable importance for NIRS excluding CCT (c) variable importance for CCT excluding NIRS.

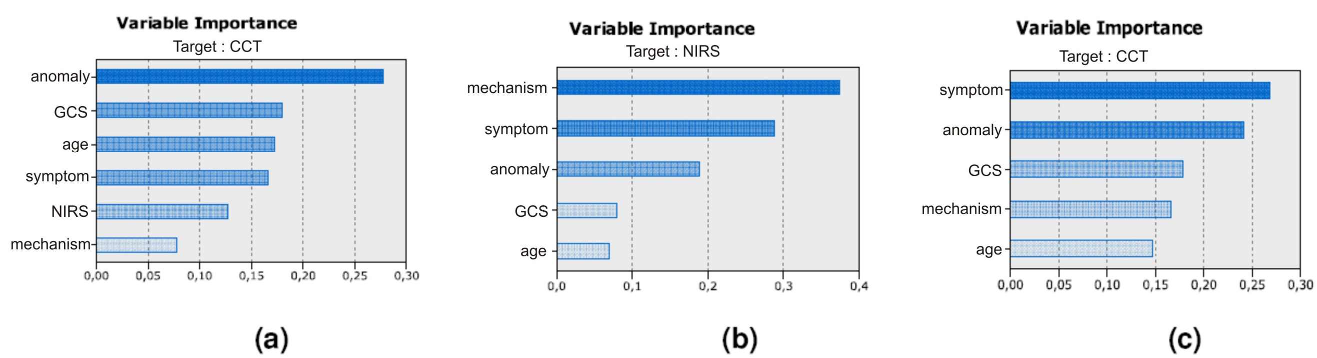

Figure 3. For adult cases (a) variable importance for CCT including NIRS (b) variable importance for NIRS excluding CCT (c) variable importance for CCT excluding NIRS.

Table 4. Performance of the models.

	Model –a(%)	Model-b (%)	Model-c (%)
Pediatric	96.89	68.32	95.65
Adult	97.83	%79.35	96.74

physical examination and GCS < 14 in adult patients, it is more affective than NIRS on CCT results (Figure 2a).

DISCUSSION

An early diagnosis of intracranial hematoma on the field in emergency clinics can hasten the triage of the patient and quickens the early management of intracranial hematomas and as a result, patient's outcome can improve.

Klassen et al. (2000) retrospectively reviewed pediatric patients CCT scanning who had history of minor head trauma and they found that mechanism of injury, GCS, and loss of consciousness were significantly related with the presence of an abnormal CCT scan. Palchak et al. (2003) whose studied on clinical predictors of traumatic brain injury on CCT scan stated that abnormal mental status, clinical evidence of skull fracture, a history of vomiting, scalp hematoma (in children ≤2 years), and headache are important signs for traumatic brain injury on CCT scan. Similar to those studies, this current study indicates that the most important factors that affect the positivity of CCT are the pathological findings observed in physical examination and the case where GCS < 14 in pediatric patients and symptoms that were observed during hospitalization process (loss of consciousness, nausea, headache) in adult patients. However, there is no consensus in literature on an objective parameter that affects the decision of patients for a CCT scan in minor head trauma.

Robertson et al. (1997) studied on NIRS identification of traumatic intracranial hematomas and showed that NIRS can detect intracranial hematomas prior to an increase in intracranial pressure or a change in the neurological examination and early diagnosis of intra-cranial hematomas by using NIRS may allow early treatment and reduce secondary injury caused by delayed hematomas. This current study also indicates that the positivity of NIRS, especially in pediatric patients, significantly affect the CCT results.

However, there are several limitations for identifying intracranial hematomas with NIRS. First of all the size, type and location of the hematoma cannot be as precisely determined as with a CCT scan. Intracerebral hematomas tend to absorb light less intensely than extracerebral hematomas and a ΔOD > 0.6 strongly suggests an extracerebral hematoma, but there is considerable overlap when the ΔOD is ≤ 0.6 (Robertson et al., 1997). Zhang et al. (2000) reported several of the most important limitations of NIRS technology for hematoma detection such as the dynamic range of detection, hair absorption, optical contact, layered structure of the head and depth of the detection in their article.

Conclusion

In the present study, a set of data collected from brain hematoma patients was assessed by conventional statistical methods and SVM approach. The analyses yielded some promising results about the use of NIRS on practical diagnosis of brain hematoma patients. However, the use of NIRS gives better results in pediatric patients than adult patients. The performance values indicate this result in Table 3. It is believed that, if the results of NIRS are taken into consideration, especially in pediatric patients, non-essential demands will decrease.

Diagnosis of traumatic brain injury with CCT is still the gold standard; however, supporting health staff such as paramedics and emergency medicine physicians on field or emergency clinics that can use NIRS will shorten the time for diagnosis and improve the outcome of the patients.

Conclusively, the NIRS should be applied on much more patients and the results obtained from the present study should be checked. If a standard can be obtained, it will be a highly useful tool for early diagnosis of brain hematoma patients.

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