Infrascanner in the Diagnosis of Intracranial Damage in Children with Traumatic Brain Injuries

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Relevance

An increase in the rate of traumatic brain injury (TBI), especially among children, is currently being noted around the world. In different countries, the average frequency of TBI fluctuates from 89 to 281 per 100,000 inhabitants. Children account for 13-37% of the total number of TBI incidents, [1, 3, 4, 6]. Mild TBI is the most frequent injury encountered among children. The number of mild TBI cases is increasing from year to year, and is an average of some 80% within the structure of all neurotraumas [2]. According to data from the studies conducted by S. Haskill and A. Merlin among children (1996), the older age groups most often sustain mild TBI injuries, which average 150:100,000 for children from 0 to 4 years of age and 550:100,000 for young people 15-24 years of age.

Despite this data, attention remains riveted on serious traumatic brain injuries. Studies in recent years have shown that mild TBI often have unfavorable outcomes. A related problem with serious repercussions is mild traumatic brain injury complicated by intracranial hemorrhage. [9]. According to J. Snoek, et al. (1995), mortality among children with mild traumatic brain injuries (MTBI's) comes to 0.3%. Based on data from the Clinical and Research Institute of Emergency Children's Surgery and Trauma, the frequency of intracranial hematomas in children with a score of 13-15 points on the Glasgow Coma Scale (GCS) that are not diagnosed in a timely manner, comes to 0.2%. The early diagnosis of intracranial hematomas, before serious complications develop, may be a decisive factor in a favorable outcome.

Currently, most researchers tend to develop recommendations based on risk factors for intracranial injury [8, 10]. The relevance of these risk factors has been widely discussed in literature [11, 17, 18]. The opinions expressed are frequently contradictory in nature. In particular, Shireen M. Atabaki, et al. (2008), in analyzing the results of a prospective cohort study of 1,000 patients who were an average of 8.9 years of age, came to the conclusion that the use of these protocols leads to a high percentage of unwarranted X-ray examinations, which in turn leads to a considerable increase in the cost of medical care without the significant improvement of illness outcomes.

The use of this technique is also being discussed from the standpoint of radiation exposure. The risks of ionizing radiation are currently being given more and more attention [16].

Thus, the question of the timely diagnosis of intracranial damage during mild traumatic brain injuries is becoming increasingly relevant. Clinicians who take part in the diagnosis and treatment of traumatic brain injuries face a difficult task which is how to provide an optimum diagnosis at minimal cost, with minimmum radiation exposure, with objective indications for hospitalization, and with the ability to identify the most effective treatment technique.

InfraScan, Inc. recently developed the Infrascanner Model 1000 scanner, which is a handheld intracranial hematoma detector that operates in the near infrared (NIR) band. The principle of the diagnosis of intracranial hematomas using the infrared scanner is based on the difference in NIR absorption in a hematoma as compared to normal brain tissue. Experimental studies conducted using intracranial hemorrhage models, as well as clinical trials, have demonstrated the Infrascanner's high sensitivity [14, 15]. The minimum detectible quantity of blood was 3.5 milliliters (ml) at a depth of not more than 2.5 centimeters (cm) from the surface of the cerebral cortex.

Objective: To estimate the efficiency of using the Infrascanner Model 1000 scanner during the diagnosis of intracranial hemorrhages among children with mild traumatic brain injuries.

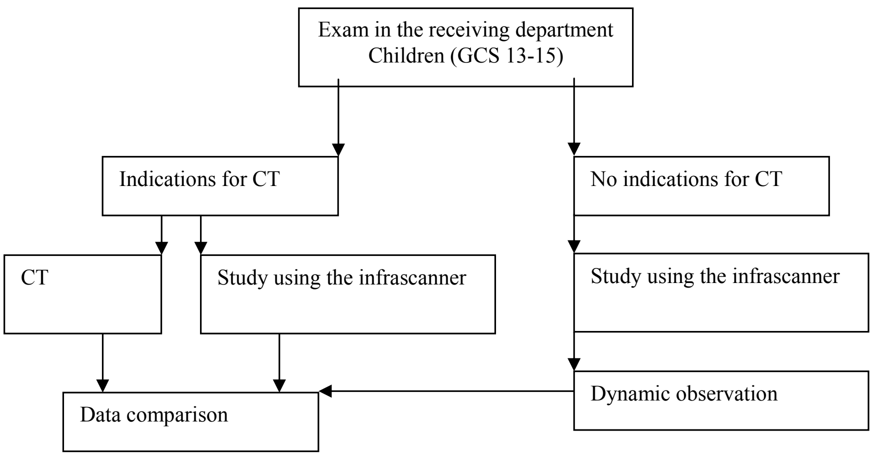
Materials and Methods

The basis for this study consisted of 95 patients with mild traumatic brain injuries. The principal characteristics of the group analyzed are presented in Table No. 1.

Characteristics	Recorded data
Age (in years)	**7 months-17 years**
Average ± the standard deviation (SD)	9.1 ± 4.6
Sex	
Boys	62 (65.3%)
Girls	33 (34.7%)
Mode of injury	
Fall ≤ 1.5 meters	71 (74.7%)
Traffic accident (TA)	4 (4.2%)
Abuse	6 (6.3%)
Other	14 (14.7%)
GCS-15 low risk	**52 (54.7%)**
GCS-13-15 medium-to-high risk	43 (45.3%)

All the patients underwent a standard examination under the conditions in place in the emergency department which included a checkup by a neurosurgeon and cranial radiographs in 2 projections. When associated damage was present, the services of pediatric surgeons, trauma specialists, etc., were enlisted. An indication for the performance of brain computed tomography during mild traumatic brain injuries was the presence of an intracranial damage risk factor*. When there were no indications for the performance of computed tomography (CT), a procedure involving the use of the infrascanner was also performed on all the patients suspected of having mild traumatic brain injuries. This group of patients was subsequently placed under observation in a hospital setting for a period of 72 hours. The study protocol is presented in Fig. 1. It was advisable to include this group of injured persons in the study with an eye toward the prospect of using the Infrascanner as a screening technique for examining patients with mild traumatic brain injuries under outpatient conditions (at trauma centers, clinics, etc.).

Fig. 1 Study protocol



*****Low risk factors*: A *GCS of 15 points, vomiting, no loss of consciousness, amnesia, or neurological semiology, and perhaps headaches, dizziness, contusions, and scrapes of the cranial soft tissue (c/st).*
Middle and high risk factors: *A GCS of 13-15 points and the presence of one or more of the following symptoms – loss of consciousness, amnesia, vomiting, neurological impairment, convulsions, suspicion of a fracture/depressed fracture, basal skull fracture, etc* **(Neurotrauma Collaborating Center , Italy, 2001)**.

The infrascanner, or near infrared (IR) band device, consists of two components: a near IR band sensor and a pocket personal computer (PPC) (Fig. 2).

Fig. 2 *The* ***Infrascanner™*** *(A) is a portable tomograph. The technique for detecting a hematoma (B) is based on the different levels of light absorption by the left and right hemispheres of the brain. In the normal state, both hemispheres absorb light identically. When an extravascular blood clot is present, the local concentration of hemoglobin rises and the optical absorption constant increases in proportion to the decrease in the reflected light component. The difference is established using sensors and detectors that are symmetrically positioned on both sides of the cranium.*

The sensor is equipped with 808-nanometer (nm) laser diode and a silicon detector. The sensor transmits near IR light through an optical fiber to the tissue located under the sensor and the detector receives it following its interaction with the tissue. The detector's signal is then digitized and is transmitted over a Bluetooth wireless link to the PPC. The PPC receives the sensor data, subsequently processes them, and displays the results on the screen. The optical fibers are maneuvered through the hair to the scalp so that it is possible to perform the procedure without shaving off the hair.

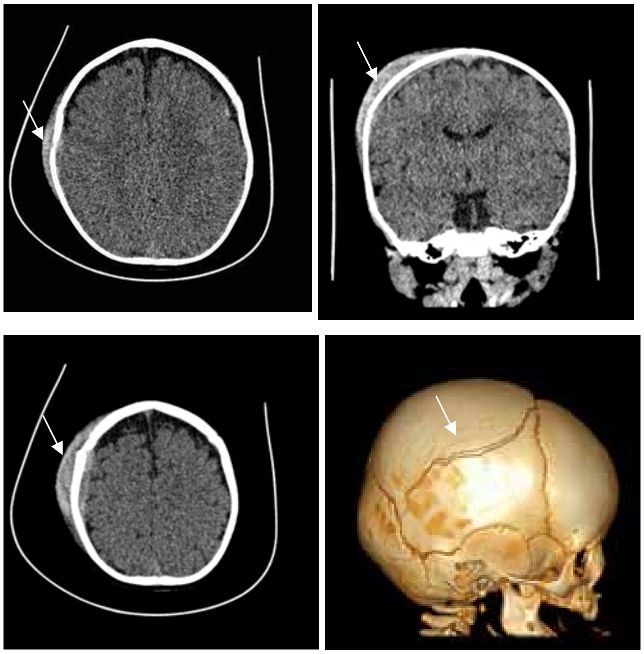
The following patients were excluded from the study involving the use of the Infrascanner:

1. Those with a history of injuries more than 3 days old, and;

2. Those with large scalp lacerations or with obvious soft tissue damage in the area being studied (8 observations).

To a considerable extent, these exclusions involved children up to one year of age, for whom extensive subperiosteal hematomas are typical during skull cap fractures due to their anatomical and physiological makeup (Fig. 3).

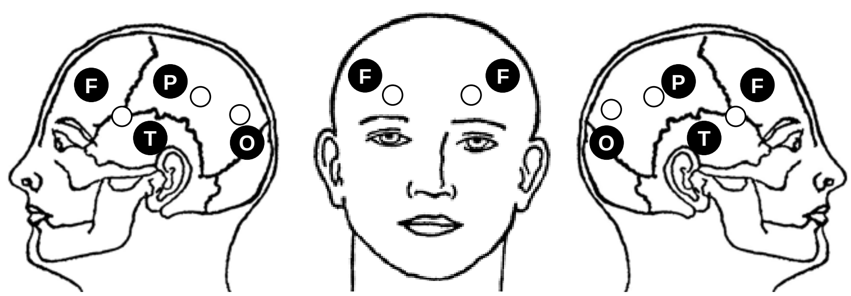
Fig. 3 CT of an 8-month-old patient with a parietal bone fracture and an extensive subperiosteal hematoma



The neurosurgeon on duty performed a near infrared scan using the Infrascanner. (Fig. 4).

Fig. 4 Suggested and permissible scanning locations

LEFT VIEW MIDDLE VIEW RIGHT VIEW



○ - *the permissible scanning locations when soft tissue damage is present in the vicinity of the suggested locations are marked.*

● - *the recommended scanning locations*[1]

When small sections of soft tissue damage were present at the suggested scanning points, it was acceptable to shift the scanning points toward an undamaged area. The main condition for scanning was the fullest possible symmetry of the points scanned (as recommended by the developers).

[1] [Translator's Note: Л F – frontal; Т P – parietal; В T – temporal, and; ЗO – occipital.

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An instance of the detection of an intracranial hematoma was regarded as having been established if a difference in optical density (ΔOD) of > 0.2 units was recorded in a specific pair of bilateral measurements. If a measurement result showed an OD difference of 0.2 or more, the pair of measurements was repeated three times in succession for the purpose of confirming the presence of a hematoma. A ΔOD value of ≤ 0.2 was considered to be a negative result. During the evaluation of the brain CT data, allowance was made for the size of the hematoma and its location.

For the group of patients placed under dynamic observation, the dynamics of the clinical manifestations were taken into account.

Analyses of overall sensitivity and specificity was conducted by means of comparing the near infrared spectroscopy results to the computed tomography results and the clinical manifestations. The truly positive, false-positive, truly negative, and false-negative results were tallied and were used to evaluate sensitivity (truly positive/truly positive + false-positive) and specificity (truly negative/false-negative + truly negative). The 95% confidence interval was computed for these parameters.

Results

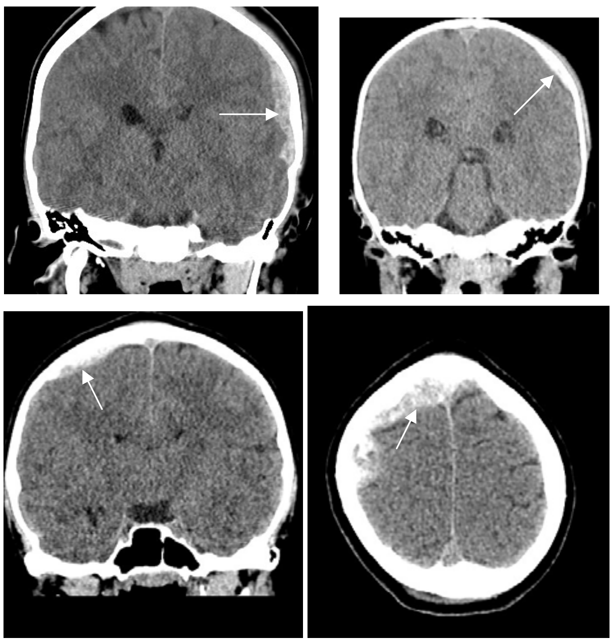
Computed tomography was performed on 43 patients (45%), while 52 patients (55%) with a low risk of intracranial damage were placed under dynamic observation, with the exception of one patient on whom brain CT was performed 24 hours later due to complaints of repeated vomiting and headaches. During the CT study, a sylvian fissure arachnoid cysts was diagnosed for the first time and no data were obtained that pointed to intracranial hemorrhages, as was also the case when scanning was performed using the Infrascanner (Fig. 5).

Fig. 5 Sylvian fissure arachnoid cysts in a patient examined for TBIs

The detection of intracranial hemorrhages during computed tomography was represented as follows: a negative CT result – 34 patients, contusive foci – 1, and epidural hematomas – 8, one of which required surgical treatment.

Four examples of intracranial hemorrhages based on computed tomography data that were detected using the Infrascanner over the course of our study are presented in Figure 6.

Fig. 6 Examples of intracranial hemorrhages in children with a high risk of intracranial damage (↑) .



Infrascanner results are presented in tables 2 and 3.

Table 2. Group of patients that required the performance of CT (with high intracranial hemorrhage risk factors)

	Presence of a hematoma	Absence of a hematoma	**Total**
$\Delta OD_{max} > 0.2$	8 (19.05%)	3 (7.14%)	11 (26.19%)
$\Delta OD_{max} \leq 0.2$	0 (0.0%)	31 (73.81%)	31 (73.81%)

Total	8 (19.05%)	34 (80.95%)	**42 (100%)**

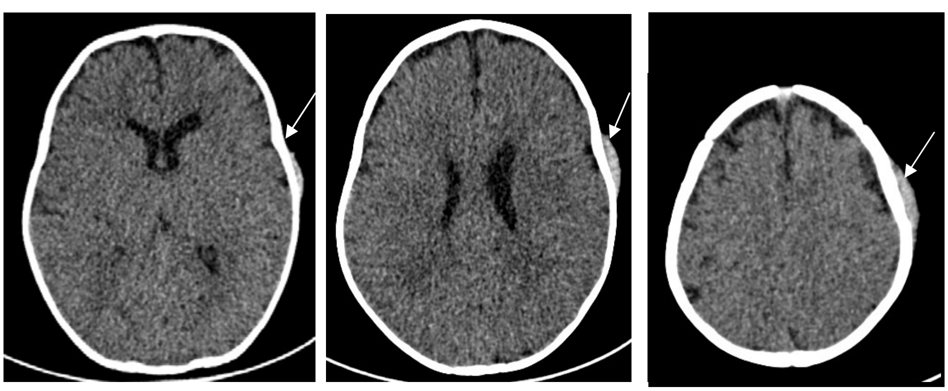
The results of the examination of patients using CT and infrared scanning agreed in 39 cases, among which intracranial hemorrhages were detected in 8 patients. A false-positive result was obtained in 3 cases.

The sensitivity of the procedure used in this group of patients with a medium and high risk of development of intracranial hemorrhages came to 1.00 (0.66; 1.00). The specificity was 0.91 (0.81; 1.00) – the proportions and a 95% confidence interval. The false-positive risk equaled 0.27 (0.00; 0.58).

The outcome of a study among patients with a low risk of development of intracranial damage is presented in Table 3. Clinical signs indicating intracranial damage (a hemorrhage) were not detected in a single case. The rapid regression of overall brain semiology and the absence of focal neurological manifestations were typical of this category of patients.

During infrared scanning, a false-positive result was obtained in 4 patients and no false-negative result was observed. We deemed it important to draw attention to a group of patients made up of 5 injured persons who had clinical signs of soft tissue damage in the form of painfulness to the touch and moderate puffiness without outward signs of skin-hair cover damage. In one case, CT was performed with the visualization of a lesion in the soft tissues (Fig. 7).

Fig. 7 Brain CT of an 8-month-old child 12 hours after injury. The arrow denotes the focus of a soft tissue contusion in the parietotemporal region.



A positive result was obtained in all cases, which demonstrated the high sensitivity of the Infrascanner to the presence of blood in the soft tissues of the skull cap, but at the same time, this can also be erroneously regarded as an intracranial hemorrhage.

Table 3 Group of patients under dynamic observation (72 hours)

	Soft tissue damage	No soft tissue damage	**Total**
$\Delta OD_{max} > 0.2$	5 (9.43%)	4 (7.55%)	9 (16.98%)
$\Delta OD_{max} \leq 0.2$	0 (0%)	44 (83.02%)	44 (83.02%)
Total	5 (9.43%)	48 (90.57%)	**53 (100%)**

The sensitivity of the Infrascanner used in this group of patients with a low risk of development of intracranial hemorrhages came to 1.00 (0.89; 1.00). The specificity in this group equaled 0.92 (0.84; 0.99). The false-positive risk equaled 0.44 (0.06; 0.82), while the false-negative risk equaled 0.0 (0.0; 0.1).

Discussion

One of the most significant conclusions arising from our work concerns the high sensitivity and specificity of the Infrascanner during the determination of hemorrhagic foci. The instrument's specificity reaches 0.91, while its sensitivity reaches 1.00 (0.89; 1.00); i.e., we are talking about a high probability of the detection of a hemorrhagic focus.

The possibility of the early diagnosis of intracranial hemorrhages (epidural and subdural hematomas) associated with mild traumatic brain injuries that pose a threat to vital functions has always been a high-priority objective of clinicians. For this reason, a secondary task was set in our work – to evaluate the Infrascanner's capabilities for ruling out intracranial hemorrhages in children with mild traumatic brain injuries.

The prospect of pinpointing indications for brain CT using the Infrascanner as a first diagnostic step looks encouraging. According to bibliographic data, the question of more precisely defining the severity of damage and identifying indications for CT remains open. Specifically, according to the data obtained by Shireen M. Atabaki (2008) among 1,000 injured persons, an intracranial hemorrhage was detected in only 65 observations, 9% (6 patients) of which required surgical treatment. What are the capabilities of the Infrascanner in such situations is the question that we addressed.

The experience acquired during our work made it possible to define the Infrascanner's capabilities for this category of injured persons. It is obvious that such an examination was not very effective among children up to 2 years of age for the purpose of making a decision

concerning further diagnostic steps. The extensive subperiosteal hematomas that accompany skull cap fractures are typical of the patients who fall into this age-related risk group.
The accumulation of a considerable volume of blood extracranially and the motor anxiety of young patients significantly diminishes the diagnostic capabilities of the infrascanner. From this standpoint, the most effective technique for pediatric practice today consists of neurosonography and the subsequent resolution of the question of the need for a CT examination [3,4].

This still leaves the problem of the damage (contusions) of the soft tissues of the skull cap that also accompany traumatic brain injuries. The infrascanner's high sensitivity and specificity relative to the occurrence of an extravasal accumulation of blood when even small lesions are present in the soft tissues (Table 3) frequently constitute the reason for what is called a false-positive response. Certain discrepancies arise – has a hemorrhagic focus been detected or has intracranial damage been diagnosed? Essentially, both of the examples being discussed pose a new problem for the manufacturer, the resolution of which might appreciably alter the result – controlling the scanning depth.

Furthermore, taking the high specificity and sensitivity of the technique into account, together with the simplicity of its use, the result obtained makes it possible to view the Infrascanner as a screening technique for the diagnosis of intracranial hemorrhages during initial specialized medical care (in ambulances and at trauma centers) in order to make a decision concerning stabilization, the performance of CT, and referral to a neurosurgeon. The Infrascanner's use in conjunction with the evaluation of intracranial damage risk factors could facilitate a decrease in the number of "blank" examinations. The resolution of these problems requires further study of the Infrascanner.

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