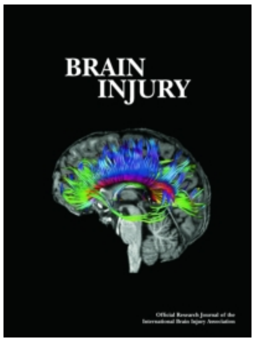


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# Infrascanner™ in the diagnosis of intracranial lesions in children with traumatic brain injuries

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*Research Institute of Emergency Pediatric Surgery and Trauma, Health Department, Moscow, Russia*

**Abstract**

*Background*: The number of traumatic injuries among children is increasing. However, so-called mild TBI might result in unfavourable outcomes. Early diagnosis of intracranial haematomas prior to development of serious complications may be a decisive factor for a favourable outcome. InfraScan company developed and brought to the market the Infrascanner® model 1000, which is a portable detector of blood collections that operates in the near infrared (NIR) band.

*Objective*: To estimate the efficiency of the Infrascanner® model 1000 for detection of intracranial haematomas among children with mild TBI.

*Materials and methods*: Ninety-five patients with mild TBI were examined. An indication for cerebral CT after mild TBI was the presence of risk factors of intracranial lesions. The Infrascanner was used by a neurosurgeon during primary examination. CT was performed in 43 patients (45%), while 52 patients (55%) with a low risk of intracranial lesions were under observation.

*Results*: The results of examination of patients using CT and infrared scanning coincided in 39 cases and intracranial haematomas were detected in eight patients. False-positive results were obtained in three cases. The sensitivity of the procedure used in this group of patients with a medium and high risk of development of intracranial haemorrhages was 1.00 (0.66; 1.00). The specificity was 0.91 (0.81; 1.00)—the proportions and a 95% CI. The false-positive risk is 0.27 (0.00; 0.58). During infrared scanning in patients with low risk of intracranial lesions, false-positive results were obtained in four cases and false-negative results were absent.

*Conclusion*: Infra-scanning might be viewed as a screening technique for intracranial haemorrhages in ambulances and outpatient trauma centres in order to decide on hospitalization, CT scanning and referral to a neurosurgeon. Infra-scanning combined with evaluation of risk factors of intracranial damage might reduce the number of unnecessary radiological examinations.

**Keywords**

Infrascanner, intracranial haemorrhage, mild head injury, near-infrared spectroscopy, paediatric TBI, traumatic brain injury

**History**

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## Introduction

The number of traumatic injuries among children is increasing. The incidence of traumatic brain injury (TBI) in different countries varies from 89–281 per 100 000 inhabitants. Paediatric TBI accounts for 13–37% of total number of TBI [1–4]. Mild TBI is prevalent among children. The number of mild TBI cases is increasing and comprises up to 80% of all neurotrauma cases [2].

However, the so-called mild TBI might result in unfavourable outcomes due to intracranial haemorrhages. Mortality among children with mild TBI is 0.3% [5]. According to the data the incidence of late diagnosed intracranial haematomas in children with Glasgow Coma Scale (GCS) score 13–15 is 0.2%. Early diagnosis of intracranial haematomas prior to development of serious complications may be a decisive factor for a favourable outcome.

Currently, most researchers tend to develop recommendations based on risk factors for intracranial complications of TBI [6, 7]. Their value as indicators for CT scanning has been widely discussed in the literature [8–10]. Opinions are frequently contradictory. The use of CT also increases radiation load [11].

The problem of early diagnosis of intracranial lesions after mild TBI is important for reduction of costs and radiation exposure, justification of hospital admission and choice of optimal treatment strategy.

The InfraScan company developed and brought to the market the Infrascanner® model 1000, which is a portable detector of blood collections that operates in the near infrared (NIR) band. Blood collections (haematomas) are diagnosed by the difference in NIR absorption in haematoma and normal tissue. Experimental studies on intracranial haemorrhage models and clinical trials demonstrated high diagnostic sensitivity of the Infrascanner® [12, 13]. The minimally

Correspondence: Zh. B. Semenova, Research Institute of Emergency Pediatric Surgery and Trauma, Health Department, Moscow, 20 Bolshaya Polyanka, Moscow, Russia. E-mail: jseman@mail.ru

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Table I. Patients' characteristics.

| Characteristics | Recorded data |
|---|---|
| Age (in years) | 7 months–17 years |
| Average ± SD | 9.1 ± 4.6 |
| Sex | |
| Boys | 62 (65.3%) |
| Girls | 33 (34.7%) |
| Mode of injury | |
| Fall ≤ 1.5 metres | 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%) |

detectable amount of blood was 3.5 millilitres (ml) at a depth of less than 25 mm from the surface of the cerebral cortex.

## Objective

The objective was o estimate the efficiency of the Infrascanner® model 1000 for detection of intracranial haematomas among children with mild TBI.

## Materials and methods

Ninety-five patients with mild TBI were examined. Their characteristics are presented in Table I.

All patients underwent a standard examination at the emergency department of the clinic, which included a check-up by a neurosurgeon and cranial radiographs in two projections. In the case of combined injuries paediatric surgeons, trauma specialists, etc., were consulted. An indication for cerebral CT after mild TBI was the presence of risk factors of intracranial lesions. The Infrascanner was used by a neurosurgeon during primary examination. When there were no indications for CT, all patients with suspected mild TBI were examined with the Infrascanner®. These patients stayed at the clinic for 72 hours. This group was included in the study since the Infrascanner® might be used for screening outpatients with mild TBI.

The study protocol is presented in Figure 1. The Infrascanner or near infrared (NIR) band device consists of two components: a NIR handheld sensor and a pocket personal computer (PPC) (Figure 2).

The sensor is equipped with a 808-nm laser diode and a silicon detector. The sensor transmits NIR band waves through an optical fibre to the tissue located under the sensor and 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. The optical fibre is so manoeuvrable that it is possible to perform the procedure without shaving hair.

The exclusion criteria were: (1) TBI more than 3 days ago; and (2) large scalp lacerations or obvious scalp lesions in the area under investigation (eight cases). These were mostly infants up to 12 months, whom are prone to extensive subperiosteal haematomas after skull fractures (Figure 3).

When small sections of soft tissue damage were present at the suggested scanning points, it was acceptable to shift the

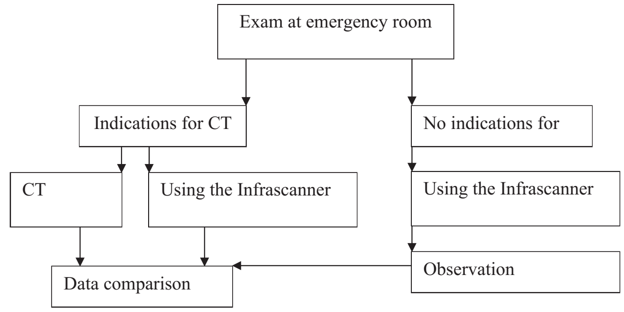


Figure 1. Study protocol.

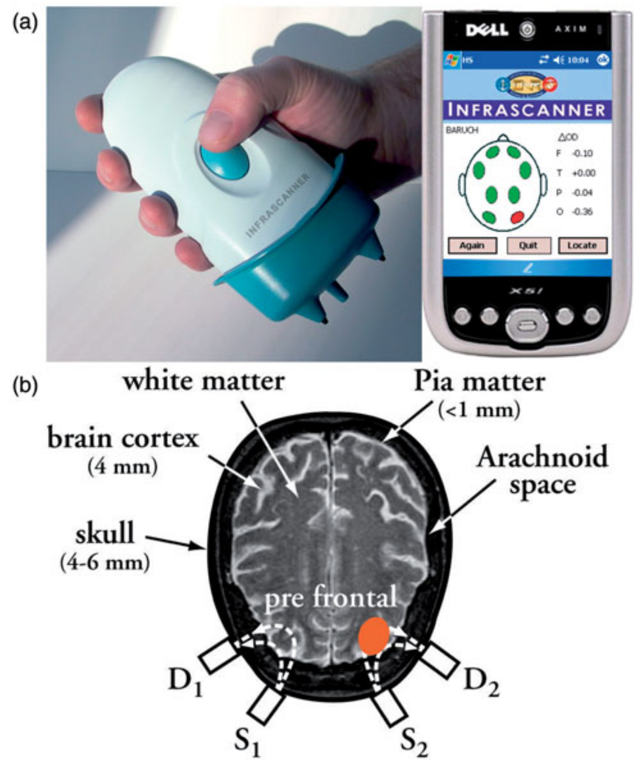


Figure 2. The Infrascanner™ (a) is a portable tomograph. The technique for detecting a haematoma (b) is based on the different levels of light absorption by the left and right hemispheres of the brain. In the normal state, both hemispheres absorb light identically. When an extravascular blood clot is present, the local concentration of haemoglobin 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.

scanning points toward an undamaged area. The main condition for scanning was the fullest possible symmetry of the points scanned (as recommended by manufacturers).

Haematoma was diagnosed 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 3-times in succession for the purpose of confirming the haematoma presence. A ΔOD value of ≤0.2 was considered to be a negative result.

For patients under observation, the dynamics of the clinical manifestations was taken into account.

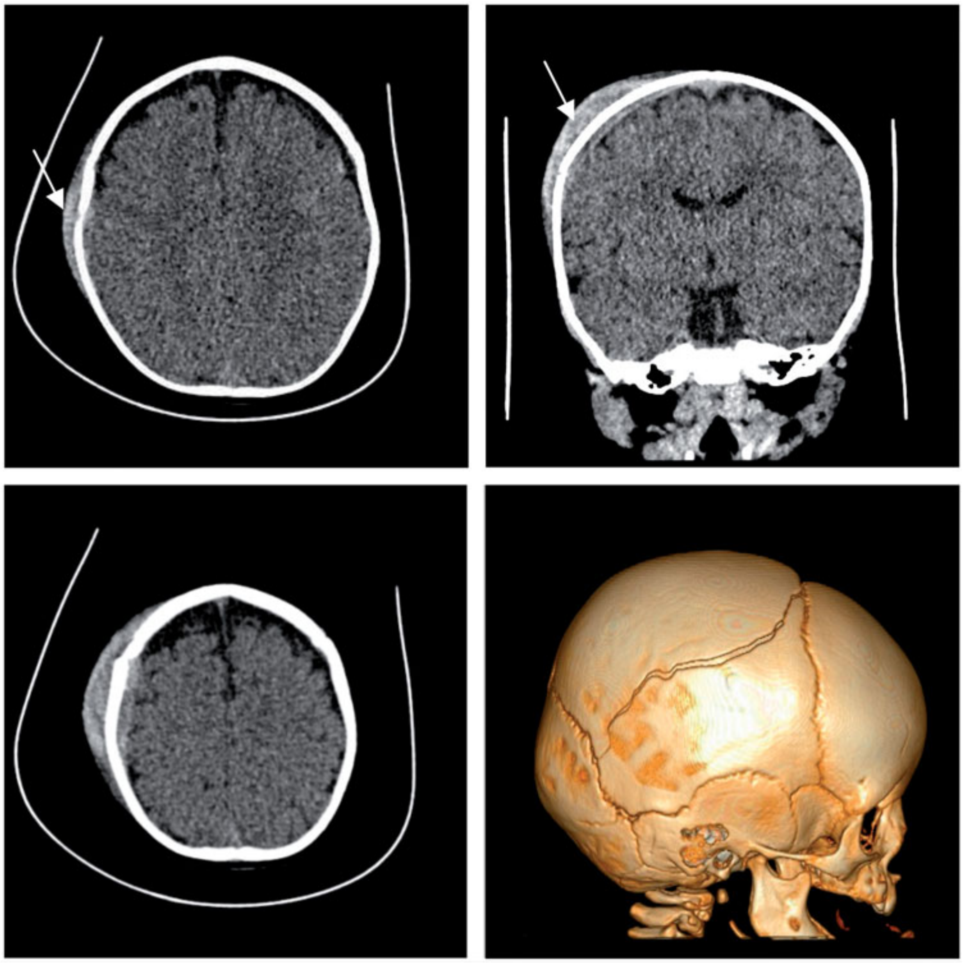

Figure 3. CT of an 8-month-old patient with a parietal bone fracture and an extensive subperiosteal haematoma.



## Results

CT was performed in 43 patients (45%), while 52 patients (55%) with a low risk of intracranial lesion were under observation, with the exception for one patient when CT was performed 24 hours later due to repeated vomiting and headaches. In this case a Sylvian fissure arachnoid cyst was diagnosed. CT scans were normal in 34 patients. Focal cerebral contusion was detected in one case and epidural haematomas—in eight cases (craniotomy was performed in one case of epidural haematoma) (see Figure 4).

The infrared spectroscopy results are presented in Table II. The results of the examination of patients using CT and infrared scanning coincided in 39 cases and intracranial haematomas were detected in eight patients. False-positive results were obtained in three cases.

The sensitivity of the procedure used in this group of patients with a medium and high risk of development of intracranial haemorrhages was 1.00 (0.66; 1.00). The specificity was 0.91 (0.81; 1.00)—the proportions and a 95% CI. The false-positive risk is 0.27 (0.00; 0.58).

During infrared scanning in patients with low risk of intracranial lesions a false-positive result was obtained in four patients and no false-negative result was observed. This study draws attention to five children with scalp lesions (painful palpation and moderate oedema with skin laceration). In one case, CT was performed which revealed a subcutaneous haematoma.

## Discussion

Early diagnosis of intracranial haemorrhages (epidural and subdural haematomas) associated with mild TBI has always been a high priority for clinicians.

Indications for cerebral CT based on Infrascanner® results look promising. A prospective cohort study of 1000 patients (average age was 8.9 years) revealed a high percentage of unnecessary radiological examinations (an intracranial haemorrhage was detected in only 65 observations, 9% (six patients) required surgical treatment), which in turn leads to a considerable increase of cost of medical care without significant improvement of outcomes [9].

Infra-scanning is not helpful in infants. Extensive subperiosteal haematomas that accompany skull fractures are typical for these patients. Accumulation of a considerable volume of extra-cranial blood and the motor anxiety significantly diminishes the diagnostic value of the Infrascanner®. From this stand-point, the most effective technique for paediatric practice today consists of neurosonography and CT scanning if necessary [2, 3].

Scalp lesions that often accompany TBI also reduce the relevance of infra-scanning. Its high sensitivity and specificity to extravasal accumulation of blood in small lesions of scalp

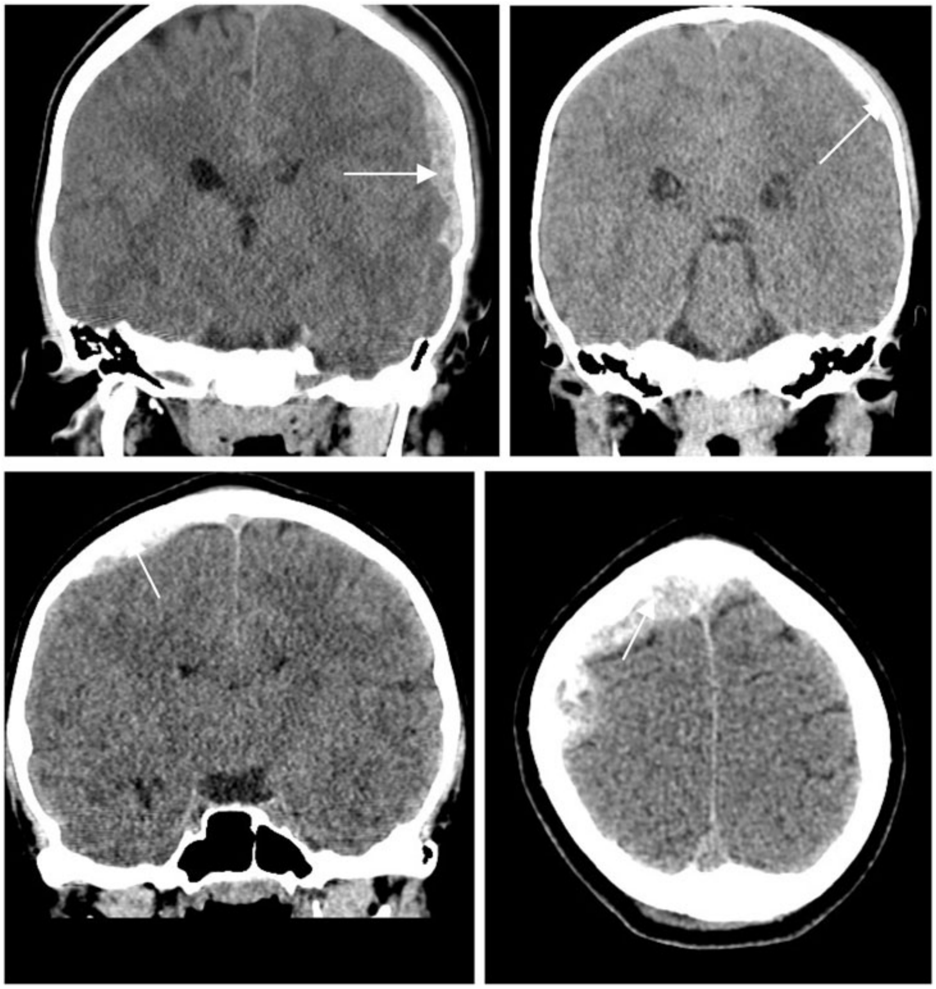

Figure 4. Epidural haematomas in children with a high risk of intracranial damage (↑).

Table II. Patients that required CT (with high intracranial haemorrhage risk factors).

| | Presence of haematoma | Absence of haematoma | 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%) |

frequently results in false-positive data. What is diagnosed—an extracranial blood collection or an intracranial haematoma? The Infrascanner® does not provide information about the depth of a lesion. However, this method has high specificity and sensitivity and it is simple.

## Conclusions

Infra-scanning might be viewed as a screening technique for diagnosis of intracranial haemorrhages during first aid (in ambulances and outpatient trauma centres) in order to decide on hospitalization, CT scanning and referral to a neurosurgeon. Infra-scanning combined with evaluation of risk factors of intracranial damage might reduce the number of unnecessary radiological examinations.

## Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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