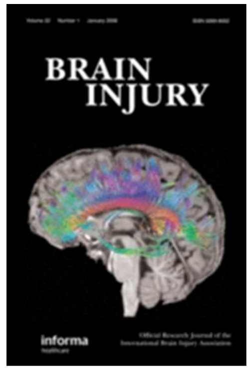


Infrascanner™ in the Diagnosis of Intracranial Lesions in Children with Traumatic Brain Injuries

Journal:	*Brain Injury*
Manuscript ID:	TBIN-2013-0062.R2
Manuscript Type:	Original Paper
Keywords:	pediatric TBI, intracranial hematomas, traumatic brain injury , near-infrared spectroscopy, Infrascanner, mild head injury

Abstract

The number of traumatic injuries among children is increasing. But the so-called mild TBI might result into unfavorable outcomes. Early diagnosis of intracranial hematomas prior to development of serious complications may be a decisive factor for a favorable outcome.

InfraScan company developed and brought to the market Infrascanner® model 1000, which is a portable detector of blood collections that operates in the near infrared (NIR) band.

Objective: to estimate the efficiency Infrascanner® model 1000 for detection of intracranial hematomas 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 presence of risk factors of intracranial lesions. 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 hematomas were detected in 8 patients. False-positive results were 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 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 4 cases and false-negative results were absent.

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

Introduction

The number of traumatic injuries among children is increasing. The incidence of traumatic brain injury (TBI) in different countries varies from 89 to 281 per 100,000 inhabitants. Pediatric TBI accounts for 13-37% of total number of TBI[1- 3, 6]. Mild TBI is prevalent among children. The number of mild TBI cases is increasing and comprises up to 80% of all neurotrauma cases [2].

But the so-called mild TBI might result into unfavorable outcomes due to intracranial hemorrhages. Mortality among children with mild TBI is 0.3% [9]. According to our data the incidence of late diagnosed intracranial hematomas in children with Glasgow Coma Scale (GCS) score 13-15 is 0.2%. Early diagnosis of intracranial hematomas prior to development of serious complications may be a decisive factor for a favorable outcome.

Currently, most researchers tend to develop recommendations based on risk factors for intracranial complications of TBI [8, 10]. Their value as indicators for CT scanning has been widely discussed in literature [11, 17, 18]. Opinions are frequently contradictory. The use of CT also increases radiation load [16].

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.

InfraScan company developed and brought to the market Infrascanner® model 1000 , which is a portable detector of blood collections that operates in the near infrared (NIR) band. Blood collections (hematomas) are diagnosed by the difference in NIR absorption in hematoma and normal tissue. Experimental studies on intracranial hemorrhage models and clinical trials, demonstrated high diagnostic sensitivity of Infrascanner® [14, 15]. The minimally detectable amount of blood was 3.5 milliliters (ml) at a depth of less than 25 mm from the surface of cerebral cortex.

Objective: to estimate the efficiency Infrascanner® model 1000 for detection of intracranial hematomas among children with mild TBI.

Materials and Methods

Ninety five patients with mild TBI were examined. Their characteristics are presented in Table No. 1.

All patients underwent a standard examination at emergency department of our clinic which included a checkup by a neurosurgeon and cranial radiographs in 2 projections. In case of combined injuries pediatric surgeons, trauma specialists, etc., were consulted. An indication for cerebral CT after mild TBI was presence of risk factors of intracranial lesions. 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 Infrascanner®. These patients stayed at our clinic for 72 hours. We included this group in the study since Infrascanner® might be used for screening outpatients with mild TBI

The study protocol is presented in Fig. 1.

Fig. 1 Study protocol

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

*Fig. 2 The **Infrascanner™** (A) is a portable device. The technique for detecting a hematoma (B) is based on the different levels of infrared waves absorption by left and right cerebral hemispheres. In the normal state, both hemispheres absorb infrared waves identically. When blood clot is present, the local concentration of hemoglobin rises and the optical absorption constant increases in proportion to the decrease in the reflected wave 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-nm laser diode and a silicon detector. The sensor transmits NIR band waves through an optical fiber 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 fiber is so maneuverable that it is possible to perform the procedure without shaving hair.

Exclusion criteria: 1. TBI more than 3 days ago;

2. large scalp lacerations or obvious scalp lesions in the area under investigation (8 cases). These were mostly infants up to 12 months which are prone to extensive subperiosteal hematomas after skull fractures (Fig. 3).

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

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 manufacturers).

Hematoma 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 three times in succession for the purpose of confirming the hematoma 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.

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 hematomas – in 8 cases (craniotomy was performed in 1 case of epidural hematoma) (see Fig. 4)

Fig. 4 Epidural hematomas in children with a high risk of intracranial damage (↑) .

The infrared spectroscopy results are presented in table 2 .

Table 2. Patients that required CT (with high intracranial hemorrhage risk factors)

The results of the examination of patients using CT and infrared scanning coincided in 39 cases, and intracranial hematomas were detected in 8 patients. False-positive results were 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 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).

The false-positive risk is 0.08(0.00;0.17)

During infrared scanning in patients with low risk of intracranial lesions a false-positive result was obtained in 4 cases patients and no false-negative result was observed. We would like to draw attention to 5 children with scalp lesions (painful palpation and moderate oedema with our skin laceration. In one case, CT was performed which revealed a subcutaneous hematoma.

Discussion

Early diagnosis of intracranial hemorrhages (epidural and subdural hematomas) 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 1,000 patients (average age was 8.9 years) revealed a high percentage of unnecessary radiological examinations (an intracranial hemorrhage was detected in only 65 observations, 9% (6 patients) required surgical treatment), which in turn leads to a considerable increase of cost of medical care without significant improvement of outcomes (17).

Infrascanning is not helpful in infants. Extensive subperiosteal hematomas that accompany skull fractures are typical for these patients. Accumulation of a considerable volume of extracranial blood and the motor anxiety significantly diminishes diagnostic value of Infrascanner®. From this standpoint, the most effective technique for pediatric practice today consists of neurosonography and CT scanning if necessary [2,3].

Scalp lesions that often accompany TBI also reduce the relevance of infrascanning. Its high sensitivity and specificity to extravasal accumulation of blood in small lesions of scalp frequently results into false-positive data. What is diagnosed – an extracranial blood collection or an intracranial hematoma? Infrascanner® does not provide information about depth of a lesion. However this method has high specificity and sensitivity and it is simple.

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

Conflict of interests: none declared.

References

1. 1. Артарян А.А., Лихтерман Л.Б., Банин А.В., Бродский Ю.С. Клиническая классификация черепно-мозговой травмы у детей / Черепно-мозговая травма. Клиническое руководство. Под ред. А.Н. Коновалова, Л.Б. Лихтермана, А.А.Потапова, Т.1. — М.: Антидор, 1998. — С.69 - 76. [ArtaryanA.A., Likhterman L. B., Banin A. V., and BrodskiyYu. S. Klinicheskaya klassifikatsiya cherepno-mozgovoi travmy u detei = Clinical classification of traumatic brain injuries in children/ In: A. N. Konovalov, L. B. Likhterman, and A. A. Potapov (Eds): Cherepno-mozgovaya travma. Klinicheskoe rukovodstvo = Traumatic brain injuries. A clinical guide, T. 1.–, Moscow *Antidor*, 1998, ss. 69-76.] (Rus)

2. Иова А.С и соавт. Совершенствование медицинской помощи детям с легкой черепно-мозговой травмой (Методические рекомендации) Санкт-Петербург, 2008. 25 с. [Iova AS et al. Sovershenstvovanie meditsinskoi pomochshi detyam s legkoi cherepno-mozgovoi

travmoi = Improvement of medical care of children with mild head injury. St. Petersburg, 2008, 25 p.] (Rus).

3. Потапов А.А. и соавт Доказательная нейротравматология. М.,2003.-517стр.[Potapov A.A, et al. Evidence based neurotraumatology. M.,2003-517p] (Rus).

4. Реброва О.Ю. «Статистический анализ медиц данных» Изд. Медиа Сфера, Москва, 2003г. стр 305. [Rebrova O.U. Statistichesky analiz meditsinskich dannich = Statistical analyze of medical dates Media Sphera, Moscow, 2003, 305p.] (Rus)

5. Calzavacca P. et al.: A prospective study of factors influencing the outcome of patients after a medical emergency team review// Intensive Care Med. - 2008.- V.34, pp 2112-2116.

6. Browne GJ, Lam LT: Concussive head injury in children and adolescents related to sports and other leisure physical activities //British Journal of Sports Medicine – 2006, V. 40, pp.163-168.

7. Guidelines for the surgical management of traumatic brain injury // Neurosurgery. – 2006, V. 58, N. 3. SUPPLEMENT.

8. Hamilton M. et al. Incidence of delayed intracranial hemorrhage in children after uncomplicated minor head injuries//Pediatrics. – 2010, V.126, pp.33-39.

9. Hawley, C.A., Ward, A.B., Magnay, A., Long, J. Outcomes following head injury: A population study// J.Neurol, Neurosurg and Psychiat. - 2004, V. 75, pp.737-742.

10. National Collaborating Centre for Acute Care (UK). Head Injury: Triage, Assessment, Investigation and Early Management of Head Injury in Infants, Children and Adults. London: National Collaborating Centre for Acute Care (UK); 2007 Sep. (NICE Clinical Guidelines, No. 56.) Available from: http://www.ncbi.nlm.nih.gov/books/NBK53036

11. Lavelle JM, Shaw KN. Evaluation of head injury in a pediatric emergency department pretrauma and posttrauma system // Arch Pediatr Adolesc Med. 1998, V. 152, pp. 1220 – 1224.

12. Borg J., Holm L, Cassidy JD et al. Diagnostic procedures in mild traumatic brain injury: Results of the WHO collaborating centre task force on mild traumatic brain injury // J Rehabil Med 2004; Suppl. 43: 61–75.

13. Gruskin KD, Schutzman SA. Head trauma in children younger than 2 years. Are there predictors for complications? // Arch Pediatr Adolesc Med. 1999; 153: 15 – 20.

14. Robertson C. et al. Clinical evaluation of a portable near-infrared device for detection of traumatic intracranial hematomas// J. Neurotrauma. - 2010, V. 27, N.9, pp. 1597-1604.

15. Leon-Carrion J., Dominguez-Roldan JM, Leon-Dominguez U, Murillo-Cabezas F //Brain Injury. – 2010, V.24, N.10, pp.1193-201.

16. Schynol W., Overton D., Krome R., Wesolowski D. A prospective study to identify high-yield criteria associated with acute intracranial computed tomographic findings in head-injured patients// Am. J. Emerg. Med. – 1993, N.11. – pp. 321-326.

17. Atabaki SM, Stiell IG et al. A clinical decision rule for cranial computed tomography in minor pediatric head trauma // Arch Pediatr Adolesc Med. – 2008, V.162, N.5, pp.439-445.

18. Stiell IG, Wells G, Vondemheem K, et al. The Canadian CT head rule for patients with minor head injury// Lancet – 2001, V.357, pp.1391-1396.

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%)

Fig. 1 Study protocol

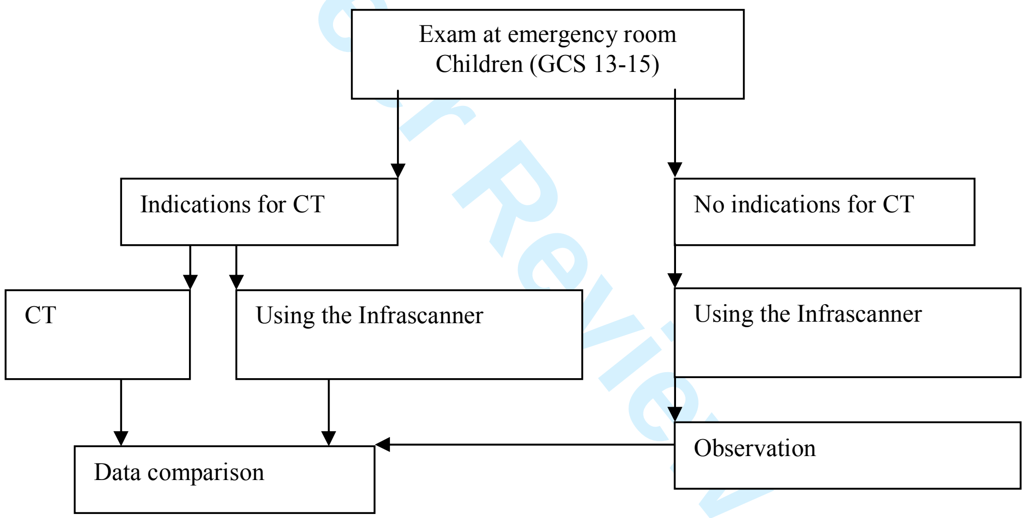
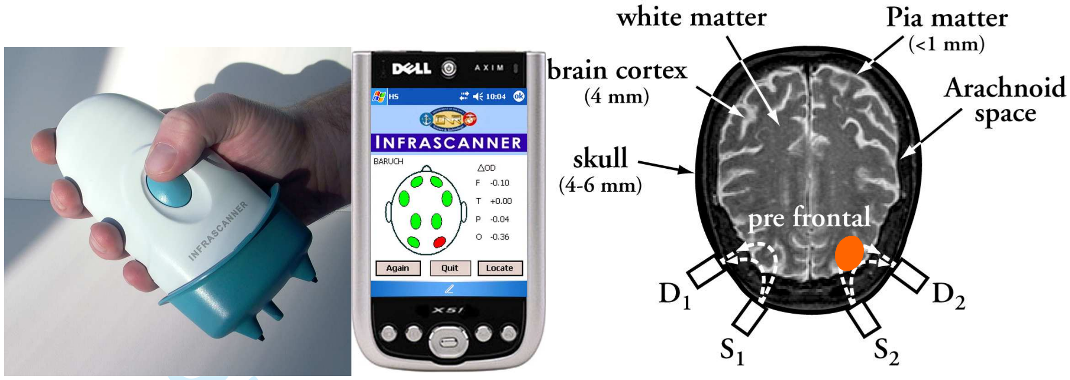


Fig. 2

A



B

*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.*

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

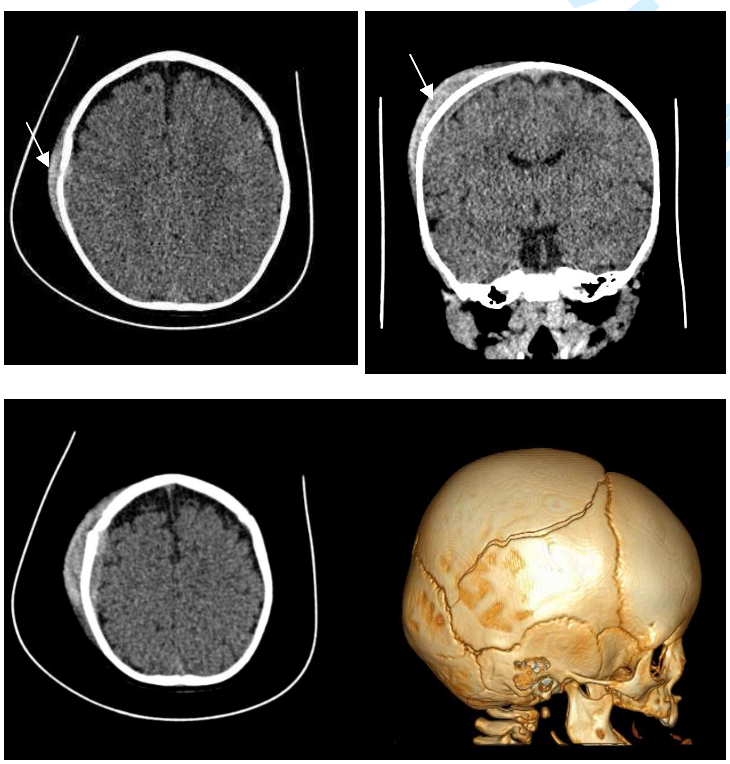


Fig. 4 Epidural hematomas in children with a high risk of intracranial damage (↑).

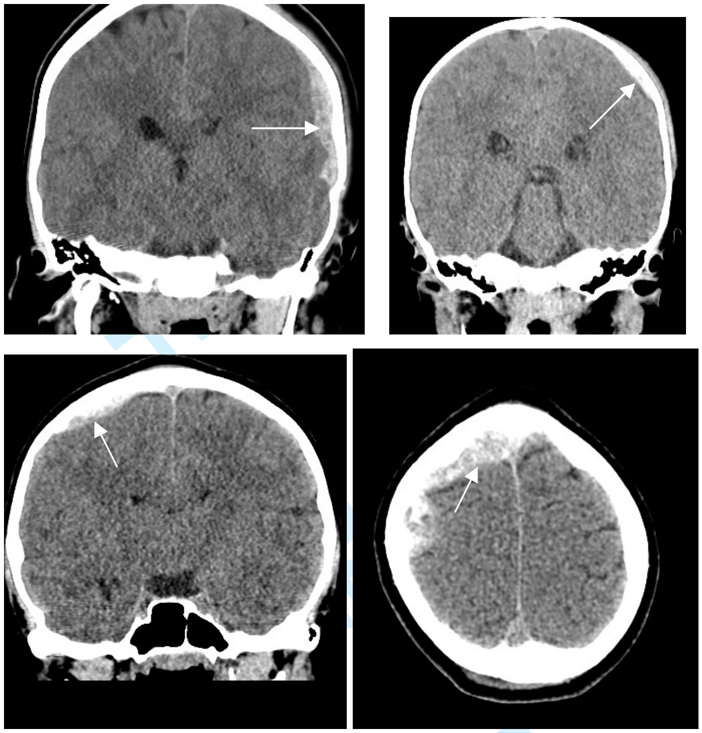


Table 2. Patients that required CT (with high intracranial hemorrhage risk factors)

	Presence of hematoma	Absence of 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%)**

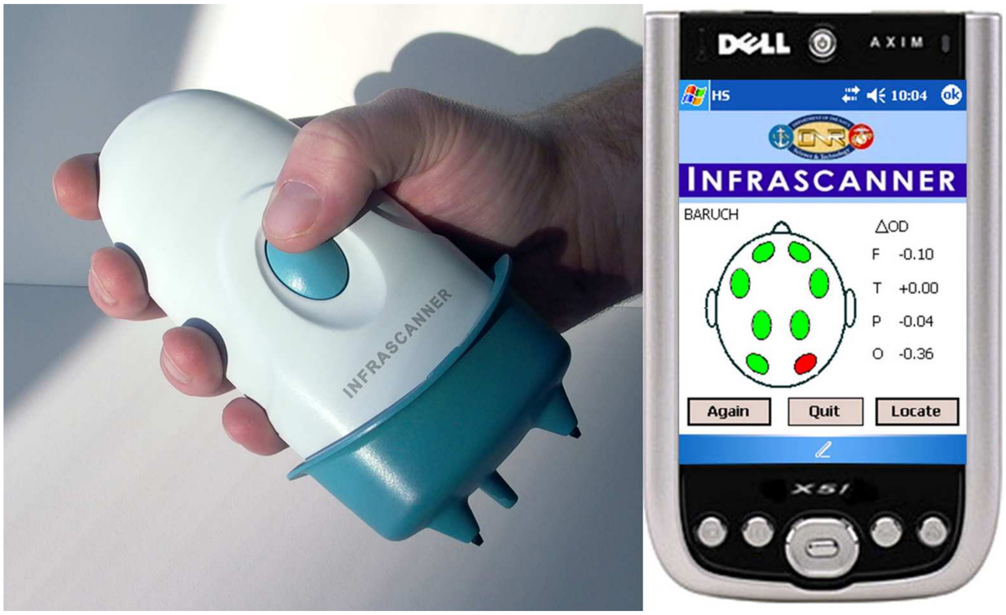


Figure 2
100x60mm (300 x 300 DPI)

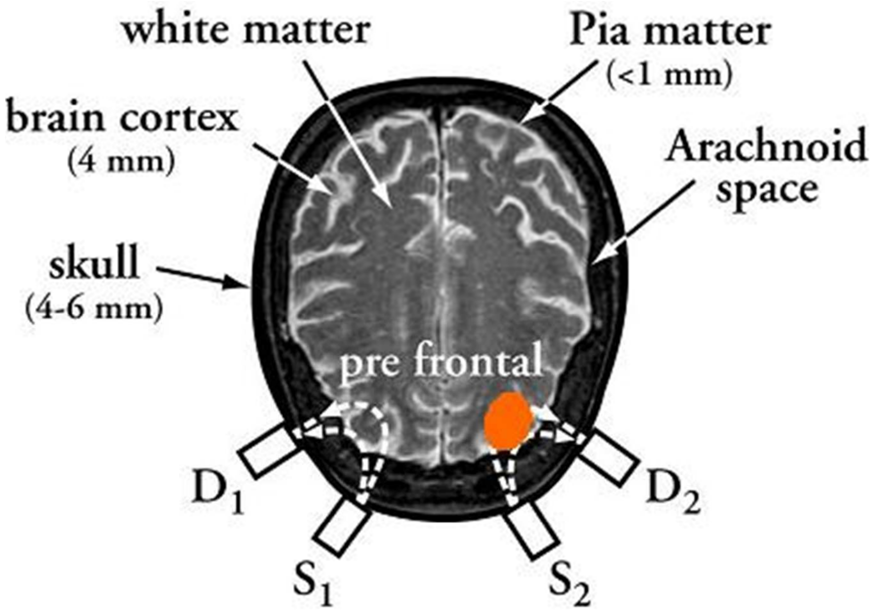


Figure 2b
73x52mm (150 x 150 DPI)

49x49mm (150 x 150 DPI)

Figure 3b
50x50mm (150 x 150 DPI)

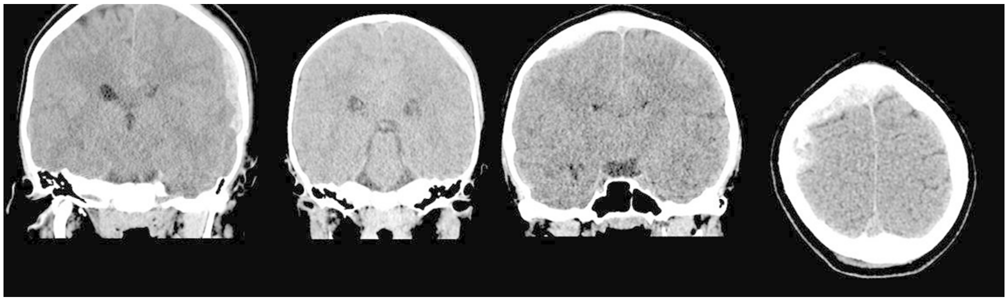


Figure 4
196x57mm (150 x 150 DPI)