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Federal Scientific Clinical Center of Sports Medicine and Rehabilitation of the Federal Medico-Biological Agency

Methodological Recommendations for Urgent Mobile Detection of Brain Injury in Highly Qualified Athletes Participating in Summer and Winter Olympic Sports and for Predicting Their Return to Professional Athletic Activity

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The Federal Medical Biological Agency

FGBU "Federal Scientific Clinical Center of Sports Medicine and Rehabilitation of the Federal Medical Biological Agency"

Methodological Recommendations for Urgent Mobile Detection of Brain Injury in Highly Qualified Athletes Participating in Summer and Winter Olympic Sports and for Predicting Their Return to Professional Athletic Activity

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The methodological recommendations have been developed by the FGBU "Federal Scientific Clinical Center of Sports Medicine and Rehabilitation of the Federal Medical Biological Agency", the Autonomous Nonprofit Organization for the Promotion of the Development of Sports "New Sports Technologies".

Approved by The Scientific Board of the FGBU "Federal Scientific Clinical Center of Sports Medicine and Rehabilitation of the FMBA od Russia" as methodological recommendations and recommended for publication (record No. 3 as of March 4, 2016). Introduced for the first time.

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These methodological recommendations have been developed for physicians specializing in sports medicine and other physicians that work in the field of Physical Education and sports, department and sports medicine room managers, massage therapists, as well as graduate students, attending physicians, students of institutions of higher medical education, as well as other specialists directly involved in providing medical and medico-biological services to athletes.

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Introduction

It is very difficult to diagnose cerebral concussion and traumatic brain injury. Only 15-20% cases of light sport-related brain injuries are diagnosed by sports medicine specialists. In 99 % of cases posttraumatic hematomas of the brain are superficial and are located at a depth of 2.5 cm. (Claudia S. Robertson, Shankar P. 1995), and during the first hours after being injured of the brain with hematoma formation the athlete may look quite normal and have no complaints (13-15 points on the Glasgow Coma Scale).

Research has shown that early detection and treatment of traumatic brain injury help prevent the development of secondary injury, which is the main cause of the worsening of patients' condition (Ghajar, 2000; Tang and Lobel 2009).

An athlete's concealing of the existing traumatic brain injuries leads to secondary cerebral hematomas and disability. Secondary lesions can develop within a few hours or days after the injury as a consequence of intracranial complications. Primary and secondary lesion prevention is the main determinant of short- and long-term consequences.

Untimely detection and treatment of traumatic brain injury represents an independent factor that makes it possible to predict the death rate among patients with traumatic brain injury.

1. The symptoms and signs of acute cerebral concussion

As a rule, the diagnosis of sport-related acute cerebral concussion in athletes, includes evaluation of a variety of parameters, including:

- clinical symptoms;
- physical assessment methods;
- cognitive disorders;
- neurobehavioral functions;
- sleep disorders.

Apart from that, the detailed medical history of concussion is an important part of the process of evaluation of the condition of an injured athlete (also during the pre-game testing).

A person may be diagnosed with cerebral concussion when one or several of the following clinical signs are present:

1. Symptoms:

- somatic (for example, headache);
- cognitive (for example, brain fog);
- emotional symptoms (for example, lability);

2. External (physical) symptoms (for example, unconsciousness, amnesia);
3. Behavioral changes (for example, irritability);
4. Cognitive disorders (for example, slow reaction time);
5. Sleep disorders (for example, insomnia).

If any one or several of these components are present, it may be assumed that the patient has concussion and an appropriate care strategy should be chosen.

2. Evaluation of acute cerebral concussion during training or competitions

If the athlete has ANY cerebral concussion signs:

A. The athlete’s condition should be evaluated on the spot by either a physician, or any other medical worker using standard principles of medical care in cases of injury. Special attention should be given to the cervical region of the spine in order to rule out the possibility of trauma in that area.

B. The ability of the athlete to appropriately react to stimulation should be evaluated in a timely manner by the physician providing care. If no physician or medical worker is available, the athlete should be safely removed from the training or game area, and urgently taken to a doctor.

C. After first aid has been provided, the degree of severity of the concussion should be evaluated.

D. The athlete cannot be left alone after injury. Consistent monitoring of the signs of the worsening of the athlete’s health condition and their consciousness is vital within the first few hours after injury.

E. The athlete diagnosed with cerebral concussion must not be allowed to return to training or participation in competitions the day when injury occurred.

Sufficient time for appropriate medical evaluation of the athlete must be provided on the field, as well as outside the field for all injured athletes. The final conclusion with respect to cerebral concussion diagnosis and/or permission for the athlete to return to training or participating in competitions must be made by a physician specializing in sports medicine and based on clinical evaluation.

Evaluation of cognitive functions is an important component of the detection of injury of this type. Brief neuropsychological tests where attention and memory functions are evaluated are the most practical and efficient. Such tests include:

- checklists;
- standardized concussion evaluation.

It is worth mentioning that orientation-related questions asked of an athlete (for example, time, place and self-identification) are less reliable in a sport-related situation as compared to memory evaluation situations. However, shortened testing sessions are meant for brief screening of cerebral concussion and are not intended to replace the comprehensive neuropsychological diagnostic testing, which should be performed by qualified neurologists, neurosurgeons and psychologists. Also, the brief tests should not be used as an independent tool when diagnosing sport-related cerebral concussion.

It should also be noticed that the appearance of clinical symptoms or cognitive impairment can be staved off until a few hours after injury, and sport-related cerebral concussion should be viewed as developing acute injury.

3. Additional cerebral concussion assessment methods

Some other additional tests may be used to help diagnose and/or rule out the possibility of a more severe injury. Diagnostic structural neurovisualization tools are routinely used to diagnose head injury.

Computed tomoghraphy is not very helpful in detailed cerebral concussion, however, it should be used when the presence of intracranial or structural lesions (for example, skull fracture) is suspected. Such instances may include prolonged impairment of sonsciousness, localized neurological disorders or the worsening of symptoms).

Magnetic resonance imaging can provide lesion models that correlate with the severity of symptoms and rehabilitation difficulty and provides additional information that helps understand pathophysiological mechanisms.

Alternative visualization technologies (for example, positron emission tomography, diffusion tensor imaging, magnetic resonance spectroscopy) can help identify “diagnostic findings”, however, they are still in their early stages of development and can only be recommended during research.

Functional MRI helps detect neuronal dysfunction during the measurement of local blood oxygen levels during the performance of certain tasks by an athlete (short-term memory, sensorimotor coordination, visuospatial memory) while the patient is inside the CT scanner). Abnormal patterns may be detected during cerebral concussion evaluation.

Diffusion tensor imaging represents cerebral white matter imaging and measures water diffusion within the brain. In healthy athletes, diffusion is ordered (anisotropic). It was found that anisotropic diffusion coefficient changes after the occurrence of sport-related cerebral concussion, even though the relation between performance in vivo and the recovery process has not been determined yet.

Magnetic resonance spectroscopy measures neutrotransmitter concentration levels: N-acetylaspartate, creatine, choline, myo-inositol, lactate.

Computed stabilometry represents an objective method of evaluation of body balance-related characteristics and balance function.

Other methods of study using modern technologies, such as stabilometric platform, as well as less complicated balance test types (for example, the Balance System), have helped detect acute impairments in postural stability within 72 hours after the occurrence of sport-related cerebral concussion. Stability testing represents a helpful tool in the objective evaluation of the motor domain of neurological functioning and needs to be considered a reliable and helpful addition to the evaluation of the condition of an athlete suffering from cerebral concussion, especially when all their symptoms and signs are indicative of a balance component-related disorder.

Various methods of electrophysiological study (for example, evoked potential (ERP), transcranial magnetic stimulation, electroencephalography) have shown reproducible abnormalities in the course of the post-traumatic period. The clinical significance of such changes is yet to be determined.

3.1. Neuropsychological evaluation

The use of neuropsychological testing (NPT) in the detection of cerebral concussion has proven to be clinically efficient and significantly informative during injury evaluation, even though in the majority of cases the period of cognitive function restoration and the period of the restoration of symptoms overlap in many ways.

It was demonstrated that the restoration of cognitive functions can sometimes precede or, in most cases, come after the resolution of clinical symptoms. Cognitive function evaluation should become an important component in the overall evaluation of concussion, particularly, of any record concerning an athlete’s return to professional activity. It is necessary to emphasize, however, that any decision made regarding the athlete’s participation should not be based on NPT results.

It should rather be viewed as an additional method used in the decision-making process in combination with a variety of imaging studies.

All athletes are recommended to undergo neurological assessment (including cognitive function evaluation) as part of their standard (preseason) testing. This can be performed by a physician specializing in sports medicine, a team or club physician, or a treating physician in combination with computer-based neuropsychological screening methods of evaluation.

Technically, NPT is not required for all athletes, however, if need be, it should be performed by qualified neurophysiologists/psychologists.

During sport-related cerebral injury evaluation, it is necessary to use an interdisciplinary method. Although, neurophysiologists/psychologists are highly knowledgeable, the final decision regarding the return of an athlete to their professional activity should be made by a sports medicine specialist professionally trained to do that. If NPT is not possible, it is advisable to extend the time before the athlete is allowed to return to training or participating in competitions.

NPT can be used to help make a decision regarding the return of an athlete to professional activity, and, as a rule, this is done when an athlete has no clinical symptoms. However, NPT may provide vital information during early stages, immediately after cerebral concussion has occurred.

Standard/preseason NPT may be recommended as mandatory. It is very informative when used to interpret all test results.

3.2. The diagnostic evaluation of cerebral concussion-related complications

Time is a very important factor during the uncertainty period after brain injury. An athlete may die because of brain stem compression or a major ischemic lesion.

A study performed by Seeling et al. (1985) showed that actions taken within the first 4 hours are extremely important. However, about 90% of athletes with mild traumatic brain injury receive expert care 4 hours after its occurrence. Late injury detection increases the risk of death and the likelihood of the worsening of the condition of an athlete who survived.

At present, computed tomography (CT) and MRI are model methods of post-traumatic cerebral hematoma detection. However, tomography can only be performed in a specialized medical care facility. Frequent CT and MRI procedures presuppose additional exposure to radiation.

Before that happens, it is necessary for a specialist in sports medicine to perform clinical evaluation of the injured athlete’s condition on the spot. It is important to identify any cerebral hematomas during the first 4 hours after injury. If necessary, the athlete should be transported to a specialized neurosurgical care facility.

At present, neurological evaluation is the main method of on-the-spot clinical intracranial hematoma detection, as it is as sensitive as CT. Considering the fact that there are no visible intracranial hematoma signs, it is difficult to visually detect them.

The main symptoms detectible by neurological methods are present only in some patients. Coma is not a clear indication of the presence of a hematoma. Hematomas are not present in 56% of patients diagnosed with traumatic brain injury (Foulkes M, Eisenberg HM, Jane JA et al. 1991).

This period of time can be shortened, when diagnostic evaluation is performed on the spot, as it makes it possible to immediately identify an intracranial hematoma.

Scanning with an Infrascanner device can help detect potentially significant intracranial hemorrhage in athletes within the first few minutes after injury, even when its clinical symptoms are not present. The minimal hematoma volume that can be detected by an Infrascanner device is 3,5 ml of blood. This being said, surgical intervention is not yet necessary.

The use of an Infrascanner device can help detect a supratentorial traumatic hematomas with a volume of over 3.5 cm^3 (3.5 ml) and those located at a 2.5 cm depth from the surface of the brain (3.5 cm from the scalp).

The Infrascanner Model 2000 is a handheld medical device for immediate cerebral hematoma detection in patients with head injury on the spot, which helps prevent the development of secondary complications.

To perform the initial diagnostic evaluation of the condition of a patient with mild traumatic brain injury the use of a handheld infrared spectroscopy device in combination with the neurological evaluation of the patient is recommended. Clinical evaluation combined with monitoring represents a sensitive method to use in order to justify referring a patient to a CT specialist.

The procedure for the preliminary diagnostic evaluation of mild traumatic craniocerebral injury using a handheld infrared spectroscopy device allows to identify cases requiring neurosurgical treatment. Early surgical treatment of hematomas helps achieve better injury outcomes. The authors emphasize the possibility of the use of an infrared spectroscopy device on children, especially those from the most vulnerable group to whom limiting the harmful effect of radiation during CT procedures is indicated (Bartłomiej Tyzo et al.2014).

The easy-to-use Infrascanner can be used directly on the spot in sports or medical care facilities, EMS vehicles, as well as rural areas where CT is unavailable.

The screening of patients with mild traumatic craniocerebral injury in a triage department decreases the number of uninformative CT studies. Sensitivity - 94%, specificity - 93% (J. B. Semenova, A. V. Marshintsev, 2011).

It is especially important to detect intracranial injury symptoms in children with high levels of consciousness (who score 13-15 on the Glazgow Coma Scale) in a timely manner. The Infrascanner is a device with high sensitivity and specificity in cases of the extravasal accumulation of blood. Scanning with an Infrascanner is a screening method used for making decisions concerning hospitalization of an injured person with craniocerebral injury. It can decrease the likelihood of uninformative CTs in triage departments by 58.8 % (Silvia Bressan, Marco Daverio 2013).

The use of the Infrascanner in combination with neurological evaluation provides a model of diagnostic evaluation of athletes with suspected head injury. Scanning with an Infrared imaging device decreases economic expenses and excessive radiation exposure (The neuropsychological test ImPACT™ , a model for medical care and rehabilitation of athletes, USA).

Since 2009 mixed martial arts athletes undergo testing for intracranial hematomas performed by the MMA Teaш before and after fights. If after a fight the results indicate the presence of injury, the athlete gets immediately transported to a hospital (John Mc Gregor 2009).

The following are the types of sports with a high risk of craniocerebral injury:

- Boxing;
- Cycling;
- Football;
- Rugby;
- Hockey;
- Soccer;
- Basketball;
- Skiing;
- Snowboarding;
- Water sports (platform diving);
- Martial arts;
- Olympic gymnastics;
- Trampoline tumbling;
- Combat sports;
- Kickboxing;
- Mixed martial arts;
- Combat sambo.

3.3. The experimental part

The objective of using an Infrascanner device is:

To identify cases of potentially significant intracranial hemorrhage that had no abnormalities during the on-the-spot neurological evaluation of an athlete.

To detect hematomas with a minimal size of less than 20 ml that require no surgical intervention and can be efficiently treated using conservative methods.

When to perform a screening by way of scanning:

- On children that attend children's sports schools and workshops and practice sports with a high risk of head injury: during training.

- During competitions: before competitions to exclude the possibility of existing head injury in an athlete with a high level of consciousness

- During combat sports competitions: after each fight or when head injury is suspected

- After competition: on each member of the team whose sport is associated with a high risk of cerebrocranial injury

The screening should be performed in 1 hour, 2 hours, 4 hours, and 24 hours immediately after injury, or when head injury is suspected.

If a hematoma is detected after Infrascanner testing, it is necessary to urgently transport the injured person to a specialized medical care facility for further diagnostic evaluation and treatment.

Scanning with an Infrascanner device can be done as frequently as it is necessary for a sports medicine specialist to detect the presence of a cerebral hematoma in a timely manner (without exposing the patient to radiation).

Who needs to undergo head scanning? Indications:

- Any athlete in who cerebral concussion is suspected;
- Any athlete who lost consciousness during training or competitions
- Any athlete whose sport falls under the category of those with a high risk of cerebrocranial injury. Infrascanner testing should be done after training or competitions;
- An athlete who has been hit one or multiple times in the head, but is still conscious and has no complaints (who scored 13-15 on the Glasgow Coma Scale);

- Any athlete that now have/previously had concussions or head injury, which is reflected in their medical history for the current year;
- Any athlete with persistent headache and a history of head trauma;
- Any athlete having bleeding from the nose or ears during training or competitions;
- Any athlete with a blot clotting disorder or cardiovascular condition: before and after training or competitions.

3.4. The operating principle of the Infrascanner

The Infrascanner Model 2000 represents a handheld screening device that uses near-infrared (NIR) technology.

All biological tissues absorb electromagnetic radiation waves of different frequency and intensity to varied degrees.

Near-infrared (NIR) light can penetrate human tissue to a depth of 3.5 cm.

Different molecules absorb electromagnetic (EM) waves of various lengths. Similarly, EM waves are reflected by human tissues to varied degrees.

The operating principle of the Infrascanner is based upon processing the image of a hemoglobin molecule received by means of exposing the tissue to near-infrared waves.

Photons from the light source travel along a predetermined path through the studies tissue back to the detector placed at the same level with the source. Even though the light waves significantly fade due to the processes of dissipation and absorption, they preserve the spectroscopic characteristics of the molecules through which they had passed on their way to the detector. Once you have set the length of the wave emitted by the light source, you can determine the relative hemoglobin concentration levels in the tissue that is being evaluated.

As the results received are compared to normal levels for the given tissue, it becomes possible to make conclusions regarding its condition.

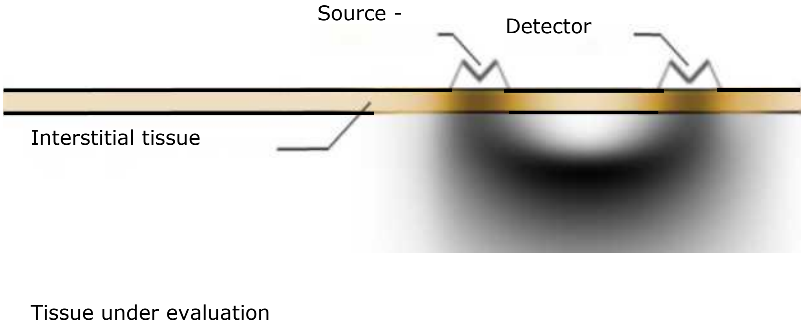


Figure 1. The pictorial representation of the penetration of photons through the tissue under evaluation on their way from the light source to the detector.

What the principle of diagnostic evaluation of intracranial hematomas using an Infrascanner device is based upon is the observation that extravasal blood absorbs near-infrared (NIR) light to a greater degree compared to intravasal one due to the fact that the concentration of hemoglobin in an acute hematoma is greater compared to the normal cerebral tissue (usually 10 times that amount) in which blood stays within the blood vessels.

The Infrascanner compares the left and right hemispheres by studying four different zones. The amount of NIR that is absorbed is greater (while the amount of the light that is reflected is lesser) in the hemisphere of the brain where a hematoma has been detected (compared to the uninjured hemisphere).

Figure 2. NIR absorption

808 nm long waves are sensitive only to the volume of blood, but not oxygen saturation levels of blood. The Infrascanner is successfully moved from the left and right hemisphere zones to the frontal, temporal, parietal and occipital zones of the head where 808 nm long light waves are detected and light wave absorption is analyzed.

The INFRASCANNER MODEL 2000 kit components:

The Infrascanner Model 2000 is a handheld infrared imaging device for the diagnostic evaluation of intracranial hematomas.

The system includes the following components:

- The Infrascanner Model 2000;
- Charging device;
- Protective removable fiber optic cover;
- Carrying case;
- User guide;
- USB cable for connecting the charger to a PC;

- Power adapter for 5VDC charger.

Carrying case with components

Model 2000 with the charging device

Figure 3. The Infrascanner Model 2000 kit

The sensor consists of an eye-safe infrared laser diode with an infrared laser and an optical detector. The IR laser and detector come in contact with the patient’s head through two beam mode waveguides. The signal of the detector is digitized and analyzed by a single-board computer (SBC) in the sensor. The SBC receives the data transmitted from the detector and automatically adjusts the settings. These data undergo additional processing by the SBC, and the results of the processing are displayed on the screen.

To power on the sensor, the removable fiber optic top of the Infrascanner Model 2000 needs to be put in place. To power off the Infrascanner, the top needs to be removed. The Infrascanner can be powered by either a Nickel Metal Hydride rechargeable battery, or 4 single-use AA batteries.

The charging device is used to charge the battery power unit and the transmission of data from the Infrascanner Model 2000 to a personal computer (PC).

Figure 4. The Infrascanner Model 2000. Front and back view.

There are two measure keys on the back panel of the Infrascanner. To begin the test, press and then release one of them.

On the front panel of the Infrascanner there are five buttons used to control the software of the scanner.

The Infrascanner includes a laser diode (Class 1) emitting 808 nm long waves, as well as a silicon-based detector. Laser emission is directed towards the patient's head by two fiber optic beam mode waveguides each 19 mm long. They guide the laser emission towards the detector. The length of the beam mode waveguides is sufficient to allow the waves to pass through the hair and come in contact with the skin of the scalp. The beam mode waveguides are located 4 cm apart from each other for optimal hematoma detection.

Electronic circuitry is used to control laser power and the detector signal enhancement coefficient. The signal of the detector is digitized and analyzed by a single-board computer (SBC) in the Infrascanner. The SBC receives the data transmitted from the detector and automatically adjusts the settings of the Infrascanner for improved data quality. Then the data is processed by the SBC, and the results are displayed on the screen.

4. The methodology of the diagnostic evaluation of the head

1. Put the fiber optic top of the Infrascanner in place to power it on.
2. Begin measurement in symmetrical areas of the head. Move the Infrascanner sequentially (according to the Fig. 5 scheme) from the left frontal to the right frontal, then to the temporal, parietal and occipital zones of the head where the light waves are detected and their absorption is analyzed.

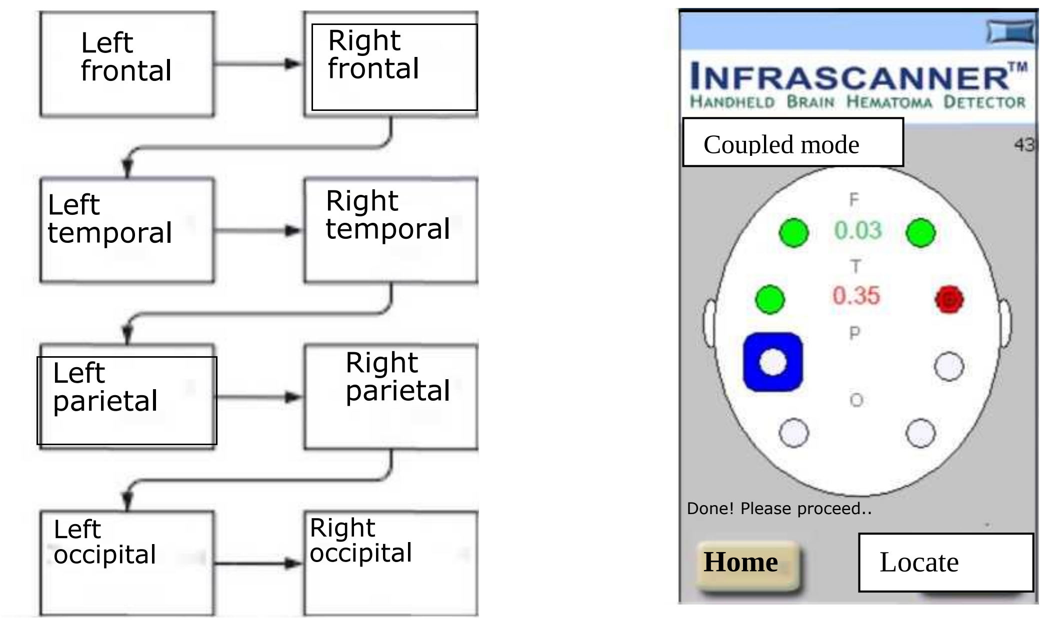


Figure 5. Evaluation method

3. If there are small areas of injury to soft tissues in the areas suggested for scanning, a small shift of the scanning point towards the uninjured area is acceptable.

The main condition for scanning is the maximal symmetry of the scanned areas.

4. After each successful measurement session, the Infrascanner would emit an audio signal, and the blue square indicator would show you that it needs to be moved to the next area on the head.
5. After the successful testing of two paired zones on the head, the scanner displays the optical density ratio between the left and right sides of the head. The absolute optical density value is not significant. What is important is just the OD ratio between the left and right hemispheres.
6. After performing measurements for each pair, look at the screen. If one of the areas under evaluation is highlighted in red, select it and repeat the measurement of that pair two more times to confirm the results and decrease the likelihood of a false alarm that may arise due to hair getting under the beam mode waveguide. Continue the measurement until the whole head is completely scanned. To help users that are unable to identify colors, red points also have a pattern that makes them different from the green ones. In addition, OD difference is displayed, for example, 0.35.
7. After completing the test, you can determine if a hematoma is present, its location, as well as the dynamics of its growth during further testing.
8. Upon completion of the evaluation, remove the fiber optic top to power off the Infrascanner.
9. Evaluations take 2-3 minutes.
10. The Infrascanner automatically saves and archives all measurement results. The results of each measurement session are saved as a text file. The name of each file includes the date, time and order of each measurement session.

Figure 6. Evaluation methods

Using near-infrared spectroscopy to detect hematomas (Infrascanner Model 2000)

TEST RECORD No. ________________________ date
Patient (ID of the athlete)

Age_______________ Sex _____________ Diagnosis at the time of admission

Descriptive status of the patient □ Conscious □ Unconscious

Subcutaneous hematomas □ Yes □ No

Open wounds □ Yes □ No

Time elapsed since trauma occurred: days hours
The Glasgow Coma Score
Infrascanner test results: Specify the degree of asymmetry

Final evaluation result: (presence/absence of hematomas)
Initial check-up
Check-up performed 1 hour later____
Check-up performed 4 hours later____
Check-up performed the next day____
Conclusion____

4. The sequence of measurements and the positioning of sensors

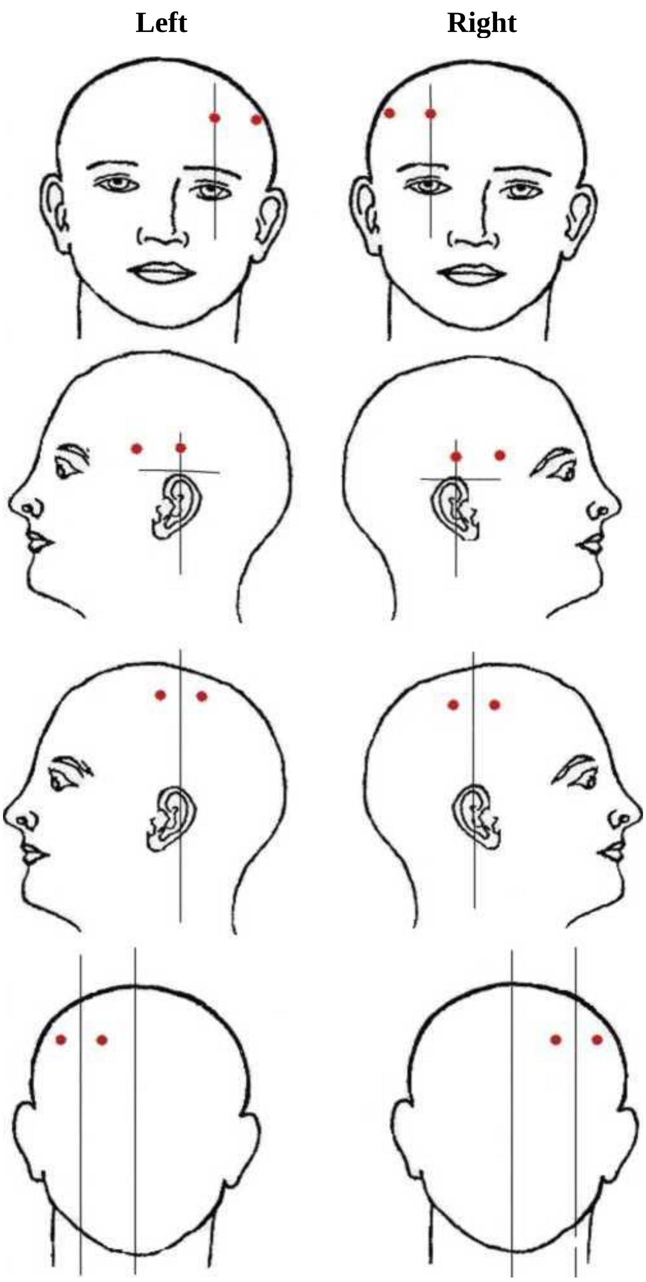


Figure 7. The positioning of the sensors

Always start the measurement from the left side of the patient.

If a hematoma is detected, perform 3 additional tests in this area.

The frontal zone

The left/right side of the forehead, above the frontal sinus with the beam mode waveguide above the eye.

The temporal zone

In the left/right temporal fossa before the upper part of the middle-ear space.

The parietal zone

Above the left/right ear, in the middle between the ear and the middle line of the skull.

The occipital zone

The occipital protuberance behind the upper part of the left/right ear.

5. The algorithm of care for athletes with head injury

- Identify head injury or potentially significant intracranial hemorrhage cases in athletes that look quite normal
- Perform neurological evaluation.
- Perform diagnostic evaluation using the Infrascanner Model 2000.
- If the results are positive, the athlete must be transported to a specialized medical care facility for further diagnostic evaluation and treatment.
- If no hematomas are present, monitor the athlete's condition. The post-concussion symptoms last 24 hours.
- Perform scanning 1 hour, 2 hours, 4 hours, and 24 hours later. If the results are positive, the patient must be urgently transported to a specialized medical facility for further diagnostic evaluation and treatment.
- If hospitalization is not necessary, scanning can be performed every 2-4 hours. This should be combined with neurological evaluation in order to measure the levels of consciousness (for example, the size of the pupils, arm/leg strength etc).
- The scanning and neurological evaluation of the athlete should be performed before the athlete returns to training or participating in competitions.

Experimental study results:

A study has been conducted on 38 athletes with suspected cerebral trauma practicing sports with a high risk of craniocerebral injury during training and competitions. After injury, the athletes had to undergo the necessary neurological assessment, their symptoms were evaluated, and diagnostic testing using the Infrascanner was performed on each one.

After that, each injured athlete's condition was dynamically monitored by a sports medicine specialist. The results of the diagnostic Infrascanner tests showed no hematomas in those athletes.
In the course of a 24-hour period the injured athletes had to go through additional evaluation of their condition and Infrascanner testing (the copies of the study records are available as an addendum).

Thus, during this experimental study, the sports medicine specialist had an opportunity to diagnose a post-traumatic intracranial hematoma on the spot immediately after it occurred and perform dynamic monitoring of the patient's condition. The scanning was performed as many times as it was needed for the sports medicine specialist to accurately diagnose the condition and confirm the diagnosis.

In addition to neurological evaluation, each athlete had to undergo Infrascanner 2000 testing performed by the physician. The scanning allowed the physician to rule out the possibility of an intracranial hematoma and dynamically monitor the athlete's condition throughout the day without exposing the patient to additional doses of radiation (CT).

The Infrascanner testing allowed to identify cases of potentially significant intracranial hemorrhage in the athletes within the first few minutes after the occurrence of trauma with no clinical symptoms present.
The minimal hematoma volume detected by the Infrascanner was 3.5 ml, which does not require surgical intervention.

The quick diagnosis and dynamic monitoring of the patients' condition with cerebral injury helps to objectively evaluate their health condition and select appropriate care strategies.

The advantages of using the Infrascanner:

- Represents a handheld device for the screening of patients with a high risk of intracranial hemorrhage;
- Detects intracranial hemorrhage on the spot

(an athletic field, stadium, or boxing ring);

- The easy-to-use device provides information regarding the presence or absence of hematomas and their location;
- Helps identify cases of acute intracranial hematoma in athletes, in which case they need to be urgently transported to a neurosurgical facility for further diagnostic evaluation and surgical treatment;
- No exposure to radiation needed. The dynamic monitoring of the patient’s condition can be performed by a physician specializing in sports medicine as many times as needed.

Example of an Infrascanner 2000 test record

TEST RECORD No. ______________________________Date

Patient (First name, last name, patronymic)

Age Sex _________ Diagnosis at the time of admission

Descriptive status of the patient □ conscious □ unconscious

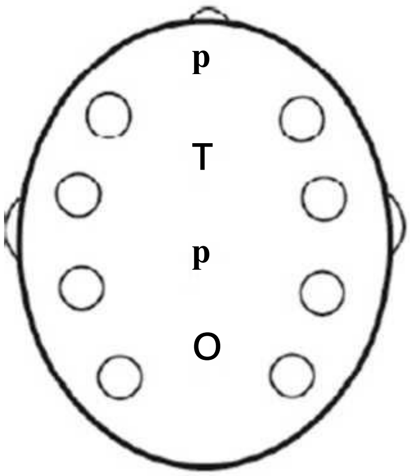
Subcutaneous hematomas □ yes □ no

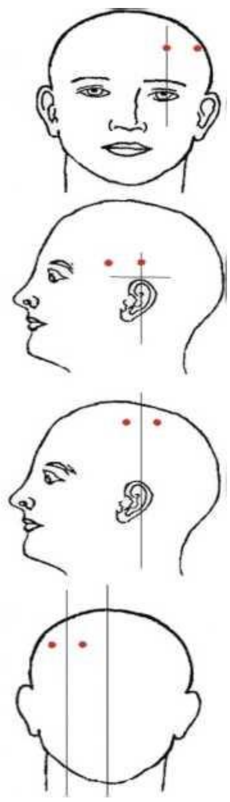
Open wounds □ yes □ no

Time elapsed since trauma occurred: __ days___ hours

The Glasgow Coma Score

Infrascanner test results: Specify the degree of asymmetry





Final evaluation result: (presence/absence of hematomas)

Initial checkup

Check-up performed 1 hour later

Check-up performed 4 hours later

Check-up performed the next day

Conclusion

6. The rehabilitation plan with further evaluation of recovery progress

The cornerstone of caring for athletes with cerebral concussion is the period of their physical and psychological (emotional) rest when acute symptoms are present, as well as the development of an activity program presupposing gradual increase in the physical and psychological loads before an athlete receives medical clearance necessary for their return to professional activity.

Before the final decision regarding allowing an athlete with craniocerebral trauma to return to training and participating in competitions is made, it is necessary to compare testing results with the assessment results recorded before the beginning of the sports season and/or training and competition.

At present, there is little evidence of an effect that a post-concussion rest period has upon the health condition of an athlete, and it is also rare. The duration of the initial rest period during the acute stage after injury is 24-48 hours. It is necessary to perform additional testing in order to evaluate long-term outcomes of resting, as well as its qualitative and quantitative characteristics.

When no recommendations based on scientific research are available, a reasonable approach that presupposes gradual return to regular athletic participation (excluding contact sports) can be used, so as to avoid an increase in the severity of an athlete's symptoms.

For those who recover slowly non-intensive/low-intensity training loads may be helpful.

Most patients will be back to normal in a few days. In the majority of cases trauma naturally heals itself within a few days. In this case an athlete is expected to gradually recover if a step-by-step care algorithm is followed.

In order to return to athletic participation, an athlete should follow a rehabilitation plan with further evaluation of recovery progress.

In accordance with this plan, the athlete is supposed to move to the next stage if no symptoms are seen at the current stage. As a rule, each stage is about 24 hours long, so it would take an athlete about a week (7 days) to completely recover, provided no cerebral concussion symptoms are seen during rest and exercise.

If any symptoms occur at a certain stage of the recovery process, the athlete should go back to the previous asymptomatic stage and try to move to the next, higher stage after a 24-hour period of rest.

Table 1. The step-by-step method of safely facilitating the return of an athlete with traumatic brain injury to athletic participation

Rehabilitation stage	Functional exercise for this rehabilitation stage	Objective of this rehabilitation stage
1.No exercise	Physical and mental rest	Recovery
2. Light cardio exercise	Walking, swimming, or exercise using a cycling machine with constant increase of intensity. 70% of the maximum heart rate. No strength training.	Increasing the heart rate
3. Sport-specific exercise	Skating training for hockey, running training for soccer. Make sure the athlete avoids hits to the head.	Increasing motor activity

4. Non-contact game skills	Improving more complex game skills, for example, delivering angle shots in soccer or hockey. It is allowed to begin strength training.	Additional exercise, better movement coordination, cognitive load increase
5.Returning to all-inclusive training	Participation in all-inclusive training after medical evaluation	The assessment of the functional outcomes by the coaching staff; increasing athletic confidence
6.Returning to participating in competitions	The return of the player to all-inclusive professional activity	

Each rehabilitation stage should last no less than 25 hours. If the symptoms occur again at a certain stage, the athlete should rest until they completely disappear and then go back to the previous, asymptomatic rehabilitation stage. Strength training should be added during the last rehabilitation stages. If any concussion symptoms are still present after 10 days, it is recommended that the athlete consult a specialist.

Conclusion

The methodological recommendations for urgent mobile detection of traumatic brain injury in highly qualified athletes participating in summer and winter Olympic sports and for predicting their return to professional athletic activity may be useful for medical workers, athletic trainers, as well as parents of an athlete.

To sum up our discussion of this topic, we have made the following conclusions:

- Traumatic brain injury is the main cause of athletes' death and disability;
- Mild traumatic craniocerebral injury and cerebral concussion cases are hard to identify and are often concealed by athletes;

Special attention should be given to the diagnostic evaluation of head injury-related complications, most specifically, intracranial hematomas at their early stages;

- The rehabilitation of an athlete should always be supervised by a physician;
- The process of returning an athlete to athletics should go step by step, with training loads increased gradually;
- Special attention should be given to head injury prevention.