4th URSI AT-RASC, Gran Canaria, 19-24 May 2024

Protocols of electromagnetic fields measurement for workers exposure evaluation in rehabilitation centers

G. Burriesci* (1), L. Mainero Rocca(1), G. Rubonello (2), M. Comelli (3), and M. Valentini (1)
(1) Department of Occupational and Environmental Medicine, Epidemiology and Hygiene, Italian National Institute for Insurance against Accidents at Work, Rome, Italy, e-mail: g.burriesci@inail.it, l.mainerorocca@inail.it; m.valentini@inail.it
(2) Technical advisory department for health and safety, Italian National Institute for Insurance against Accidents at Work, Palermo, Italy, e-mail: g.rubbonello@inail.it
(3) Institute of Applied Physics "Nello Carrara", Italian National Research Council (CNR-IFAC), Florence, Italy, e-mail: m.comelli@ifac.cnr.it.

Abstract

The goal of the present work is to develop precise and user-friendly protocols to apply during electromagnetic fields exposure evaluation. This subject, in fact, is characterized by a lack of simple and standardized procedures compromising work of the experts involved in these evaluations. For this project, several physio kinesitherapy equipment have been selected due to their complex signals emission able to cause overexposure to the workers.
With the aim of testing the developed protocols, a monitoring campaign has been conducted on several devices normally used in these working places, i.e. three tecar therapy, three magneto therapy and one radar therapy apparatuses.
All the rehabilitation centers chosen to validate the protocols are internal to our institute (INAIL - National Institute for Insurance against Accidents at Work) and are located in the south of Italy.
Despite the complexity of the measured variables, all the planned goal are achieved in terms of both procedures and exposure evaluation.

1. Introduction

Electromagnetic field assessment is an intricate topic due to the uniqueness of each individual category of instrument studied. Apparatuses emitting complex forms of electromagnetic waves, in fact, present considerable difficulties in assessing the workers' risk. Technical norms [1, 2] are often cumbersome, devices have more than one set up, and the environment around this device strongly influence the risk assessment.
Moreover, experts facing the calculation of emissions produced by these instruments deal with the lack of simple and user-friendly procedures.
With the aim of achieving easier methodologies, three protocols for the evaluation of the emission of three type of electromedical instruments are here proposed.
All these protocols were validated in terms of applicability, replicability and reliability by testing them in a real monitoring campaign.
Measurements were conducted on tecar therapy, magneto therapy and radar therapy devices, all located in rehabilitation centers in south of Italy.
However, both the protocols and the monitoring have been conducted with the aim of protecting the safety of the workers involved in such departments. Therefore, possible overexposure and distance from the source [3] have been carefully evaluated to guarantee the safety and the compliance with legal and safety limits.

2. Regulatory references

Health and safety requirements for workers exposed to electromagnetic fields (EMFs) are established in Dir 2013/35/EU [4]. Among other important features, this directive sets exposure limits (ELVs) and, above all, action levels (ALs). Specifically, annexes II and III list all the values of ALs for exposure to electric fields from 1 Hz to 10 MH and from 100 kHz to 300 GHz that are necessary to be used as reference levels for measurements during experimental tests.
With regards to workers wearing implantable medical devices (or non-occupationally exposed workers) the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines are followed [5]. This publication provides the reference levels for the general population (RLp) that guarantee the protection of the two categories mentioned above.
Levels suggested in the ICNIRP [5] guideline are much more precautionary than the European directive, therefore, compliance with these values is enough to guarantee the safety of all categories of workers.

3. Materials and methods

Microrad NHT 3DL with 33S probe (0 Hz ÷ 1 MHz) and Narda EHP 50F Field Strength Analyzer (1 Hz ÷ 400 kHz) were used to measure the electric and magnetic fields applying the weighted peak method.
For the measurement of the electromagnetic field the Microrad NHT 3DL with 01E probe (100 kHz ÷ 6.5 MHz) was used.

The tested devices were: three Human Tecar HCR801 (Figure 1a); two LED Michelangelo Classic (Figure 1b) and a TEMA MAGNETOBED 4; a Led Bernini Classic (Figure 1c).

Figure 1. Devices examined: a) Human Tecar HCR80; b) LED Michelangelo Classic; c) Led Bernini Classic.

A saline solution placed in a metallic and a plastic bowls was used in substitution of the patient for tecar and radar therapy evaluation respectively (patient replacement PR). Environmental assessments were carried out for all the devices examined, and measurements were made in the positions occupied by workers following their suggestions.

3.1 Protocol for tecar therapy

The return plate is connected with the metallic bowl (filled with the saline solution) placing it under the bowl while the handpiece is maintained in touch with the water surface to switch on the electrical circuit. The centre of the Microrad 33S probe is placed at the height of the tecar handpiece and the first measurement is carried out at 10 cm from the PR. Moreover, compliance has to be verified at this distance (with both the resistive and capacitive handpiece), with the two tecar cables placed close to each other and at the maximum permitted distance.

3.2 Protocol for magneto therapy

The probe centre (EHP50F) is placed at 72 cm from the ground (i.e. at the centre axis of the coil, x) and along the axis of the applicator (see Figure 2, y axis). The first value is taken at 10 cm from the edge of the coil, and the subsequent are obtained in incremental intervals as shown in the diagram in Figure 2. Once the compliance with the reference levels is established for the general population, no further measurements are necessary. Furthermore, values of the magnetic field have to be evaluated in the areas nearby the room where the device is placed.

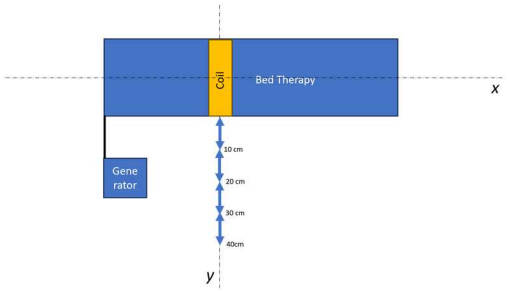

Figure 2. Protocol scheme for magneto therapy measurement

3.3 Protocol for radar therapy

A PR, placed in a plastic bowl, is used to evaluate the radar therapy emission and the center of the probe (Microrad 01E) is placed at 90 cm from the ground.
Subsequent measurements in steps of 30 cm each from the emitter are performed along the two main axes of field propagation (x and y) until compliance with ICNIRP guideline is achieved. Figure 3 schematize both the intervals and the two directions where the probe is placed.

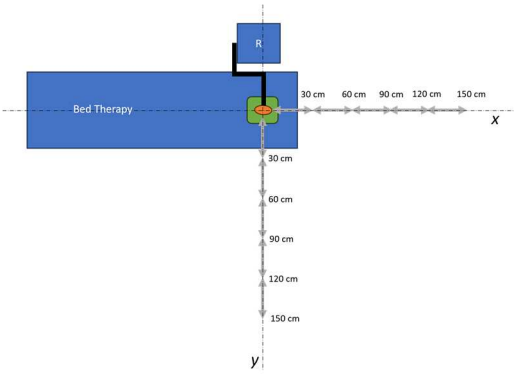

Figure 3. Radar therapy measurement protocol scheme. The green area represents the 'patient' and the orange oval the applicator.

4. Results and discussions

The three selected devices are generally used to treat pain and inflammatory condition in rehabilitation of patients. These treatments are non-invasive, and they use the electric field (tecar therapy), the magnetic field (magneto therapy) and the electromagnetic field (radar therapy) to produce therapeutic effects. All of them have in common complex signal emissions and they can have different set up for the various treatments (work frequencies and/or power).
For these reasons, the most difficult aspect to handle during preliminary evaluations is to establish the 'worst case scenario' for each device in order to simplify the entire measurement procedure.
Schematizing, the three electromedical equipment have in common a signal generator (current or voltage) that supplies different types of applicators.

The tecar device possess two applicators, resistive or capacitive type, and the emissions are approximately 500 kHz.

With the aim of mimicking a patient, measurements at the highest power were conducted using a PR (Figure 4a), and, at lower power, on a volunteer (Figure 4b).

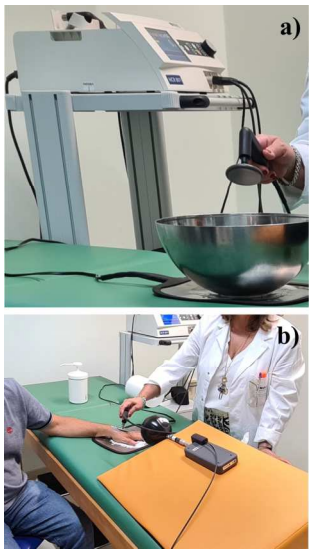

Figure 4. Picture of the tecar therapy device with the PR (panel a) and with a volunteer (panel b).

Two steps are propaedeutic for the beginning of the procedure: measurements to evaluate the electric and magnetic field levels of the background, and the workstations identification and evaluation. Then the developed protocol was set up to assess exposure at increasing distances from the applicator in order to obtain the minimal compliance distance.
Since the electric field is almost radial, the procedure requires that measurements are performed on one direction along the radius; distances from the source were set every 10 cm. Measurements were performed varying the position of the two tecar cables: side by side and maximum distance. Three identical tecar devices are included in the project (Palermo, Messina and Caltanissetta) and results proved to be full compliant from the first test (near the applicator). Table 1 shows the outcomes obtained as an example.

Table 1 Results obtained from tecar therapy measurement campaign.

Human Tecar HCR801			
Setting	**Probe position** (cm)	**Power** (%)	**Index protection of the population E-Field** (%)
Handpiece in contact with the PR	10	100	33
Handpiece in contact with a volunteer's hand	10	23	21

Magnetotherapy emits mainly magnetic field in the range of 50 ÷ 100 Hz. The highest magnetic field emission is inside of the solenoid; however, this area is occupied by the patient and not by the workers. Hence, it must be excluded from the evaluation.
The developed procedure for magnetotherapy device is similar to that followed for the tecar; likewise, measurements are taken every 10 cm on a straight line from the solenoid (applicator). Since the magnetic field is not altered by objects or barriers, the procedure requires that the magnetic field value is also assessed in nearby areas (Figure 5). Magnetotherapy equipment are constituted by different applicators; however, as the developed protocol is intended to be user friendly, measurements are conducted only on the solenoid used for the total-body scan (worst case scenario).

Figure 5. Picture of the measurements conducted near the magneto therapy device (panel a) and outside the room with the equipment (panel b).

Three different magnetotherapy devices were evaluated (two in Palermo and one in Caltanissetta). Results show compliance to workers limits at each step; while, for general population compliance is reached at 40 cm. Table 2 reports the most significant outcomes.
During magnetic field evaluation in Palermo (on Tema Megnetobed 4 model), an intense electric field was observed. This unexpected phenomenon is probably due to the aging of the instrument or, more likely, to the generator control equipment. Values for this type of field show a compliance for general population at 50 cm, for workers at 30 cm.
A similar result highlights that workers are exposed to an electric field more intense than a magnetic one.

For both tecar and magnetotherapy equipment the electric and magnetic fields evaluation has been performed using the weighted peak method in the range 1 Hz ÷ 10 MHz as per Dir 2013/35/EU.

Table 2 Results obtained from magneto therapy measurement campaign.

TEMA MAGNETOBED 4		
Probe position (cm)	**Workers' protection index H-Field** (%)	**Index protection of the population H-Field** (%)
10	30	333
20	16	204
30	9	142
40	5	88

Radar therapy device emits in the range of GHz and electric field and magnetic field are mutually coupled. Therefore, the developed protocol involves measuring of only one of the two measurand.
Since radar therapy equipment are complex and show non-uniform electromagnetic field, during the protocol development two directions (x and y axes) are chosen for measurement and a PR is used instead of the patient. Moreover, identification of instrument positioning, in order to give a reliable and realistic protocol, is complex; after several attempts, the probe (Microrad) has been moved in steps of 30 cm on the two axes (see Figure 2). This length was achieved with a series of test conducted changing the size of the interval depending on the obtained results.
With the aim of simplifying the test, the more realistic positioning of the radar therapy applicator is found to be near the plastic bowl (i.e. the patient). Therefore, the protocol is simplified inserting only one trial.
A single radar therapy device was included in the project (Caltanissetta) and results showed, along y axis, a compliance length of 60 cm for workers and of 150 cm for general population. Whereas, along x axis, the compliance was reached at 60 cm for workers and at 120 cm for general population. These values led to the need of recommendations for the workers involved in such treatments. In particular to remain near the device strictly for the set-up operations whit the apparatus maintained in stand-by mode and, quickly to leave the room during the therapy administration.
Table 3 reports the most significant results for radar therapy.

Table 3 Outcomes of radar therapy equipment monitoring.

Led Bernini Classic				
Probe position (cm)	**Axes**	**Measured E-Field** (V/m)	**ALs(E)** (V/m)	**RLp** (V/m)
60	*x*	112	140	61
90	*x*	78	140	61
150	*x*	39	140	61
60	*y*	97	140	61
90	*y*	77	140	61
120	*y*	57	140	61

Summarizing, a total of more than 150 measures were conducted during the monitoring campaign and results are collected in a free access database (PAF [6]) containing emission data from hundreds of sources and operated by a network of national and regional institutes specialized in studies and research on physical risks in occupational places.

5. Conclusions

The proposed protocols are found to be reliable and applicable, furthermore, they proved to be user-friendly and easy to apply. Outcomes arising from the monitoring campaign are collected inside the PAF and they are accessible and available to the experts.
At the same time, application of the protocols was used to establish the compliance distance for the exposed workers (and general population) for the specific equipment.
Moreover, it was observed an unexpected electric field emission as a side result during the magnetotherapy monitoring highlighting the necessity of a complete assessment.

6. Acknowledgements

We thank the staff of the rehabilitation centres that were extremely proactive during the monitoring campaign.

References

[1] EN 50413:2019, Basic standard on measurement and calculation procedures for human exposure to electric, magnetic and electromagnetic fields (0 Hz - 300 GHz); European Committee for Electrotechnical Standardization: Bruxelles, Belgium, 2019.
[2] IEC 60601-1, Medical Electrical Equipment - Part 1: General Requirements For Basic Safety And Essential Performance; International Electrotechnical Commission: Geneva, Switzerland, 2020.
[3] EN 50499:2019, Procedure for the assessment of the exposure of workers to electromagnetic fields; European Committee for Electrotechnical Standardization: Bruxelles, Belgium, 2019.
[4] European Union, "Directive No. 2013/35/EU, of 26 June 2013, on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields)," Off. J. Eur. Union, vol. L179, no. June, pp. 1–21, 2013.
[5] ICNIRP. Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300GHz). HEALTH PHYSICS 74 (4):494-522; 1998.
[6] Database PAF-Portale agenti fisici available at: https://www.portaleagentifisici.it/fo_campi_elettromagnetici_list_macchinari_avanzata.php?lg=IT&page=0.