Isodose Distribution Curves of Selective Electrotherapy Instruments

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ABSTRACT

Purpose: *This study was conducted to investigate both the electric and magnetic field strength that the physical therapist was exposed to at different distances during the application of selective electrotherapy instruments (interferential current, Russian current, and transcutaneous electrical nerve stimulation current) and to provide the necessary advice to physiotherapist in order to have safe handling of these equipments.* ***Assessment:*** *Electromagnetic fields around the apparatus working in interferential, Russian and transcutaneous electrical nerve stimulation modes were measured using two measuring equipments: Hand Held/ Gauss Tesla Meter and Trifield Meter. Electromagnetic fields were measured at different locations around the apparatus at two conditions: without earthing of the apparatus and/or cables & with good earthing of the apparatus and/or cables.* ***The results*** *revealed that there was a considerable high electric and magnetic field around the electrotherapy equipments which markedly decreased when the apparatus and / or cables was good earthed* ***.Discussion and Conclusion:*** *from the results it could be concluded that the measured values of the electric and magnetic field around the apparatus used for treatment of patients in electrotherapy are higher than international permissible levels recommended by international unions concerned with non-ionizing radiation protection which markedly decreased when the apparatus was good earthed and eliminated to zero value when the electrodes cables was shielded and good earthed.*

INTRODUCTION

Electromagnetic field (EMF) is a propagating coupled from changing electric field and magnetic field. There are different sources of EMFs naturally occurring and man made. The EMF is produced when electric current flows through an electrical conductor such as power lines and power stations. Any electric power device or the electric equipment in physical therapy also produces them. [1]

Electromagnetic wave is a transverse wave which oscillates sinusoidally in time and space with a magnetic field (β) which oscillates in a perpendicular plane with the same frequency. The electric field is always perpendicular to the magnetic field. The speed of propagation (C),according to Maxwell's work is 3×10^{8} ms^{-1} in vacuum and related to the frequency (f) by $C=f\lambda$; where (C) is the velocity of light, and (λ) is the wavelength.[2]

Many years ago, scientists believed that the dangerous effects of electromagnetic exposure came only from very high intensity exposures. It was reported that low frequency, low intensity electromagnetic fields can cause injuries to man.[3]

It was stated that the relation between exposure to electromagnetic fields "EMFs" and human health is more and more in focus. This is mainly because of the rapid increasing use of such EMFs within the modern society.[3,4] Exposure to EMFs has been linked to different cancer forms, e.g. leukemia, brain tumor, neurological diseases such as

Alzheimer's disease, asthma, allergy, and recently to the phenomena of *"electrorsupersensitivity"* and *"screen dermatitis"*.[4]

Recent advances in biomagnetic technology make magnetic fields (MFs) and EMFs useful modalities for treatment of various pathologies and diseases[5] .EMFs have been used for centuries to control pain and other biological problems, but scientific evidence of their effects had not been gathered. [5,6]

On the other hand, electric and magnetic fields have been recorded during treatment of patients in physiotherapy department in a number of hospitals and clinics. Measurement of field strength close to diathermy equipment showed that a value above the reference levels extended to about one meter from electrode and cable of continuous short wave (SW) and microwave (MW) units, and about 0.5 meter from pulsed SW units [7]. In addition, the level of electromagnetic radiation to which a physiotherapist is exposed to is of 2000 V/m and 5 A/m. The value recommended by the National Radiological Protection Board (NRPB) in 1989 for frequencies used for diathermy treatments is 0.18 A/m. These levels apply to occupationally exposed workers and members of the general public[8].

In addition, there is a wide range of parameters concerning magnetic and electromagnetic fields' specifications such as field frequency, pulse duration, waveform and amplitude which are important parameters characterizing the most of interaction of these energies with biological systems. The amount of energy deposited in the tissue (which is simply defined by the dose) by the EM energy is one of the major parameters for successful treatment. Unfortunately, uncontrolled and not well defined dose will lead to centra-effects and complicated results to the patients and may be to the therapist [9].

Moreover, the current study was an attempt to plan a scientific protocol, provide physicians, physical therapists and scientists with the proper location or distance of the equipment from the patient and the therapist which decrease the risk of exposure to EMFs to the permissible level. Therefore, the aim of the current study was to investigate both the electric and magnetic field strength that the physical therapist was exposed to at different distances during the application of selective electrotherapy instruments (interferential current, Russian current, and transcutaneous electrical nerve stimulation current) and to provide the necessary advice to physiotherapist in order to have safe handling of these equipments.

MATERIALS AND METHODS

Both the electric and magnetic field strength that the physical therapist is exposed to at different distances were investigated to provide the necessary advice to physiotherapist in order to have safe handling of the following currents:

1)Interferential Current.
2)Russian Current.
3)Transcutaneous Electrical Nerve Stimulation (TENS) current.

Instrumentation

For the measurement of both electric and magnetic fields around the electrotherapy instruments, two types of instruments were used in this study; experimental instrument and measuring instruments.

(A) Experimental Instrument

Phyaction 785 series; manufactured in the Netherlands by Uniphy BV; presents in the Faculty of Physical Therapy, Cairo University was used in the present study.

(B) Measuring Instruments

(1) Hand held Gauss/Tesla Meter:

Hand Held Gauss/Tesla meter (model 4080, with probe type T-4048.001 manufactured by FW Bell in U.S.A), located in the biophysics department, Faculty of Science, Cairo University, was used in the current study to measure the magnetic field intensity (magnetic flux density) around the experimental instrument. The instrument was able to measure both alternating currents (A.C) and direct currents (D.C) of the magnetic field from 0.1 G up to 200 G.

(2) TriField Meter:

TriField Meter, manufactured by Alphalap, U.K, present in the biophysics department. Faculty of Science; Cairo University, was used in the present study to measure both the distribution of magnetic field intensity (magnetic flux density in gauss) and the electric field (V/m) around the experimental instruments.

Procedures

Measurements of the electric field intensity (KV/m) and magnetic component in gauss of the field around the apparatus used for electro-therapy and working at different modalities were done at different locations. This was achieved through fixing a mid point on the surface of the apparatus and considering it as the zero reference point and the scan of the electric and magnetic field components was carried out in the x, y, and z planes with respect to the zero reference point.

The electric field was also measured around the cables carrying current to the transducer electrodes for electrotherapy treatment.

Moreover, both electric and magnetic fields were also measured at different distances form the surface of the transducer electrodes.

Measurements of the EMFs were carried out at two conditions;

1)Without earthing of the apparatus and/or cables,

2)With good earthing of the apparatus and/or cables

In addition, the EF was measured from the electrodes' cables after shielding and connecting the shield to good earth.

Conduction of Measurement

The apparatus was put on the center of a wooden table with the electrodes on the opposite side of the apparatus to eliminate interference. Twenty one points of measurements were chosen around the apparatus from each reference point separated by 5 cm up to 1 meter distance (i.e., 0m, 5cm, 10cm, 15cm, ...etc) to evaluate radiation field distribution at each direction of each plane.

1) Measurement of EMF at Interferential Current Mode

(A) The measurements of both electric and magnetic fields around the apparatus working for interferential current mode generated from a beat oscillator were conducted with the following parameters:

a)Main frequency of 4 KHz.

b)Beat frequency of 100 Hz.

c)Current intensity (amplitude) of 100 mA.

(B) Interferential current were applied by four carbon-rubber electrodes with conducting gel and were held by straps over a water bag i.e. quadripolar technique.

(C) The four electrodes were arranged in a cross arrangement around a rubber bag full of water.

2) Measurement of EMF around the Russian Current Mode

(A) The measurements of both electric and magnetic fields around the apparatus working in the Russian current mode were measured at the following parameters:

a)Main frequency of 2.5 KHz.

b)Modulated frequency (M.F) of 50 Hz.

c)Current intensity (amplitude) of 100 mA.

(B) Russian current were applied by two carbon-rubber electrodes with conducting gel and were held by straps over the water bag.

3) Measurement of EMF around the TENS **Current Mode:**

(A) The measurements of both electric and magnetic fields around the apparatus working in the TENS mode was conducted at the following conventional TENS parameters:

a)Frequency of 60 Hz.

b)Pulse time (duration) of 100 μsec.

c)Current intensity (amplitude) of 100 mA.

(B) TENS current were applied by two carbon-rubber electrodes with conducting gel and were held by straps over the water bag.

Data Collection and Analysis

The values of the electric and magnetic field component around the apparatus working at the different modes of operation were measured and tabulated. Each measurement was repeated five times and the average of each was considered (mean and standard deviation). In each repeatable measurement, the apparatus was switched off and on; left for 10 minutes rewarming then the measurement was carried out.

RESULTS

(I) Interferential Current

The results indicated the presence of stronger magnetic field (500m.G) at the reference point on the apparatus which was markedly reduced with distance till 40 cm. The results also indicated the reduction of the value of the magnetic field component at the reference point from 500mG to about 180mG when the apparatus was connected to earth.

In addition, the results revealed strong DC component of magnetic field of 900mG at the reference point on the apparatus which was completely disappeared when the apparatus was connected to good earth.

Moreover, the variation of the AC component of electric field measured in KV/m at the reference point on the apparatus which was 5 KV/m and completely eliminated with earthing of the apparatus.

The electric and magnetic field distribution around the electrodes used for treatment of the patient were measured. It was clear from figure (1) the presence of very strong AC component of MF at the reference point on the electrodes which was 200 G which was the maximum range of the measuring equipment hand held gauss tesla meter which was reduced with distance up to 10cm. The results also indicated the reduction of the value of the magnetic field component at the reference point to about 1750 mG when the apparatus was earthed.

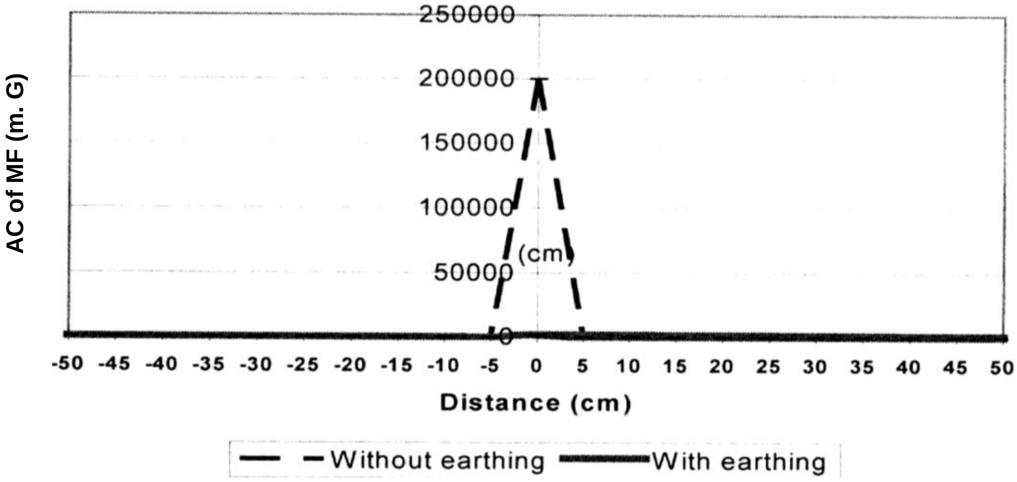

Fig. (1): AC component of MF distribution of I.F current as measured from electrodes.

The results also showed the presence of 12400m.G (12.4G) DC component of magnetic field at the reference point on the electrodes which was markedly decreased with earthing of the apparatus to 2700m.G. as shown in figure (2).

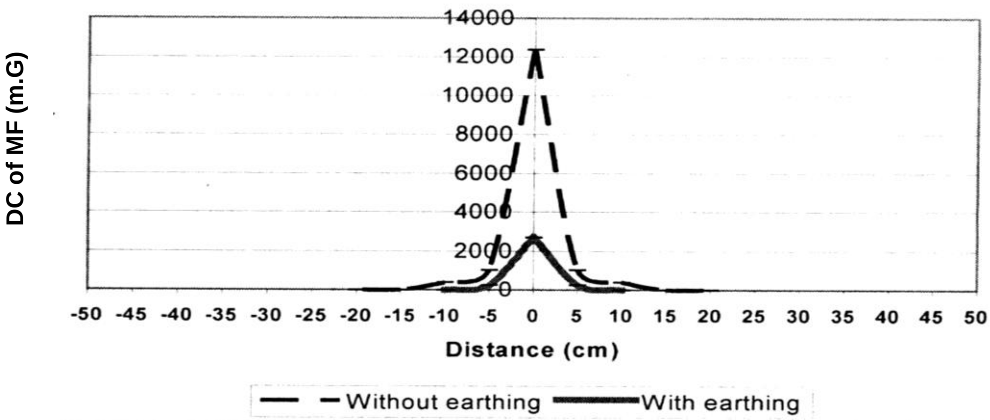

Fig. (2): DC component of MF distribution of I.F current as measured from the electrodes.

It was obvious from figure (3) the presence of strong electric field strength for the unearthed apparatus higher than 100 KV/m which was the maximum range of the measuring equipment (Trifield meter) up to 20 cm, and then reduced (according to the inverse square law) with distance up to 50 cm from the reference point. Moreover, the electric field was reduced at the reference point from 100 KV/m to 90 KV/m when the apparatus was connected to earth. In addition, the electric field was markedly reduced to 35 KV/m after shielding of the cables carrying the electric current to the electrodes. The AC electric field was also measured from the reference point after connecting the shielded cable carrying the electric current to the electrodes to good earth which increased to 38.5 KV/m.

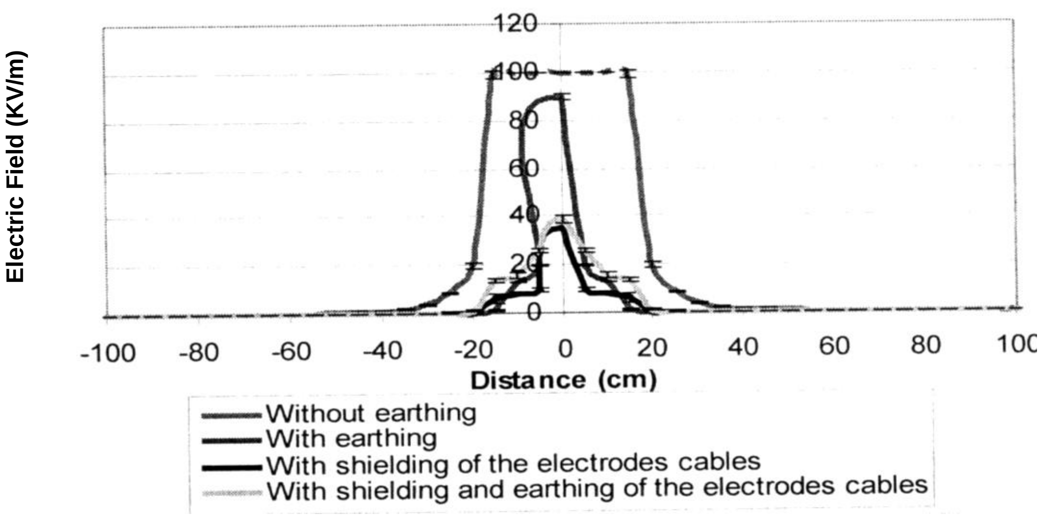

Fig. (3): AC component of EF distribution of I.F current as measured from the electrodes.

Furthermore, it was clear from figure (4) the presence of strong electric field strength at the reference point on the cables for the unearthed apparatus higher than 100 KV/m; which was the maximum range of the measuring equipment; even when the apparatus was connected to earth and reduced (according to the inverse square law) with distance up to 15 cm from the reference point. Moreover, the electric field was decreased to 90 KV/m after shielding of the cables. No electric field was measured around the cables carrying the electric current to the electrodes when the shield was good earthed.

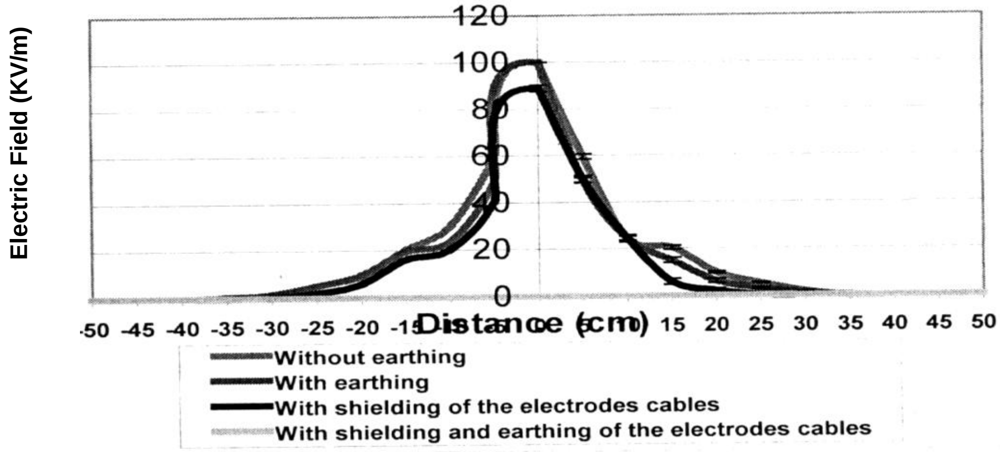

Fig. (4): AC component of EF distribution of I.F current as measured from the electrode's cables

(II) Russian Current:

The results of the current study indicated the presence of strong magnetic field (500m.G) at the reference point on the apparatus which was markedly reduced with distance till 20 cm. The results also reported the reduction of the value of the magnetic field component at the reference point from 500m.G to about 120m.G when the apparatus was connected to earth.

In addition, the results revealed strong DC component of magnetic field of 500m.G at the reference point on the apparatus which was completely disappeared when the apparatus was connected to good earth.

Moreover, the variation of the AC component of electric field measured in KV/m at the reference point on the apparatus which was 4.5 KV/m and completely eliminated with earthing of the apparatus.

On the other hand, the electric and magnetic field distribution around the electrodes used for treatment of the patient were measured. It was clear from figure (5) the presence of very strong AC component of MF at the reference point on the electrodes which was 51.4 G which reduced with distance up to 10cm. The results also indicated the reduction of the value of the magnetic field component at the reference point to about 1550 m.G when the apparatus was earthed.

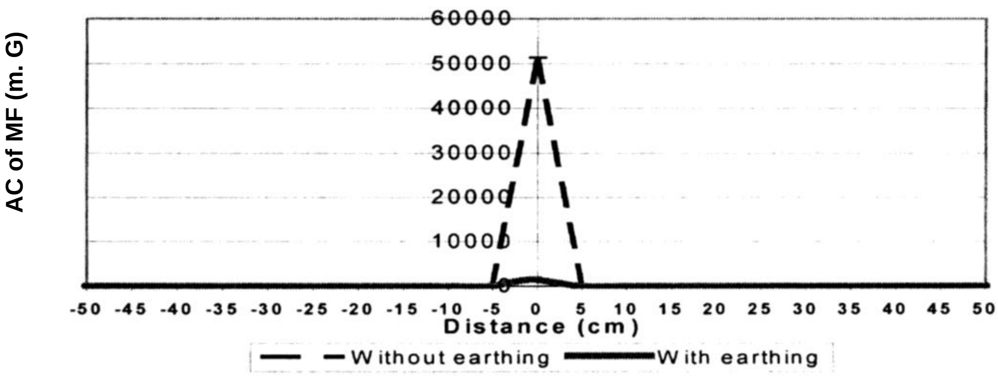

Fig. (5): AC component of MF distribution of Russian current as measured from electrodes.

The results also showed the presence of 11400m.G (11.45G)compound of magnetic field at the reference point on the electrodes which was markedly decreased with earthing of the apparatus to 200 m. G. Figure (6).

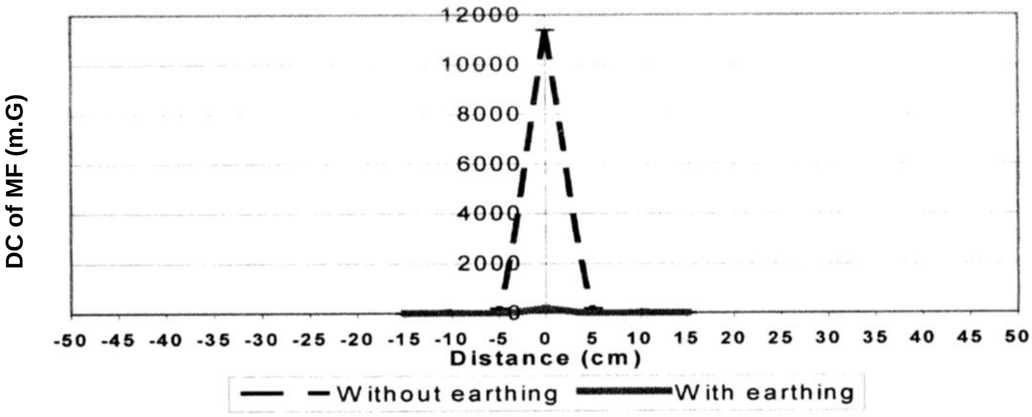

Fig. (6): DC component of MF distribution of Russian current as measured from the electrodes.

As regards, it was obvious from figure (7) the presence of strong electric field strength for the unearthed and earthed apparatus higher than 100 KV/m which was the maximum range of the measuring equipment (Trifield meter) up to 20 cm, and then reduced (according to the inverse square law) with distance up to 50 cm from the reference point. In addition, the electric field was markedly reduced to 25 KV/m after shielding of the cables carrying the electric energy to the electrodes. The AC electric field was also measured from the reference point after connecting the shielded cable carrying the electric current to the electrodes to good earth which decreased to 21 KV/m.

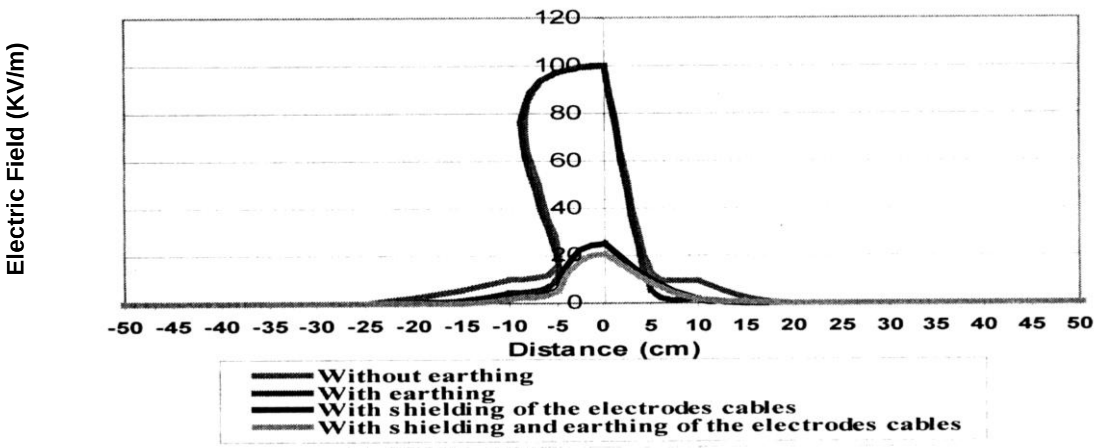

Fig. (7): DC component of EF distribution of Russian current as measured from the electrodes.

It was clear from figure (8) the presence of strong electric field strength at the reference point on the cables for the unearthed apparatus higher than 100 KV/m; which was the maximum range of the measuring equipment; even when the apparatus was connected to earth and reduced (according to the inverse square law) with distance up to 30 cm from the reference point. Moreover, the electric field was decreased to 50 KV/m after shielding of the cables. No electric field was measured around the cables carrying the electric current to the electrodes when the shield was good earthed.

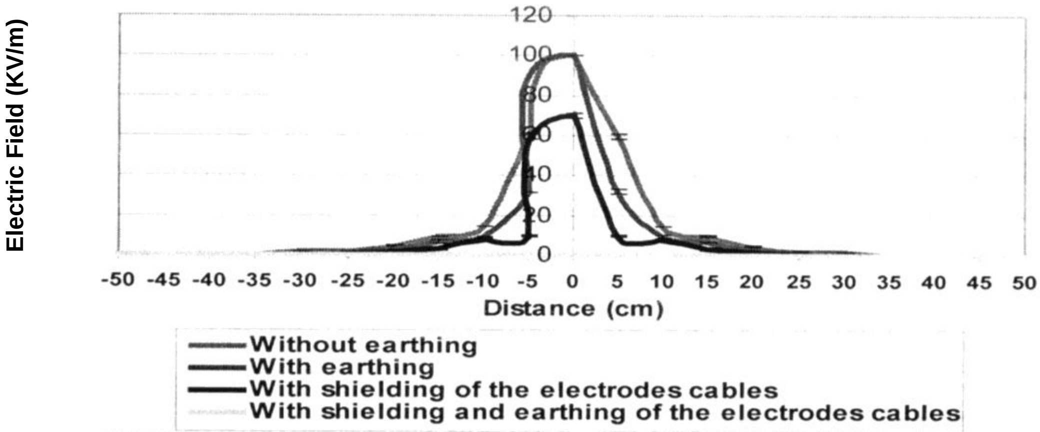

Fig. (8): AC component of EF distribution of Russian current as measured from the electrodes.

(Ill) TENS Current

The results of the present study revealed the presence of AC magnetic field component of 450m.G at the zero point of reference on the apparatus which was reduced with distance up to 50 cm and decreased to l00m.G with earthing of the apparatus. While, the value of the electric field for the unearthed apparatus was 2 KV/m which reduced (according to the inverse square law) with distance up to 20 cm from the reference point. No electric field was measured around the apparatus when it was earthed.

Figure (9) illustrated that the AC component of magnetic field distribution around the point of reference on the electrodes 3200 m.G (3.2G) which was reduced with distance up to 5 cm and was decreased to about 250m.G when the apparatus was connected to earth.

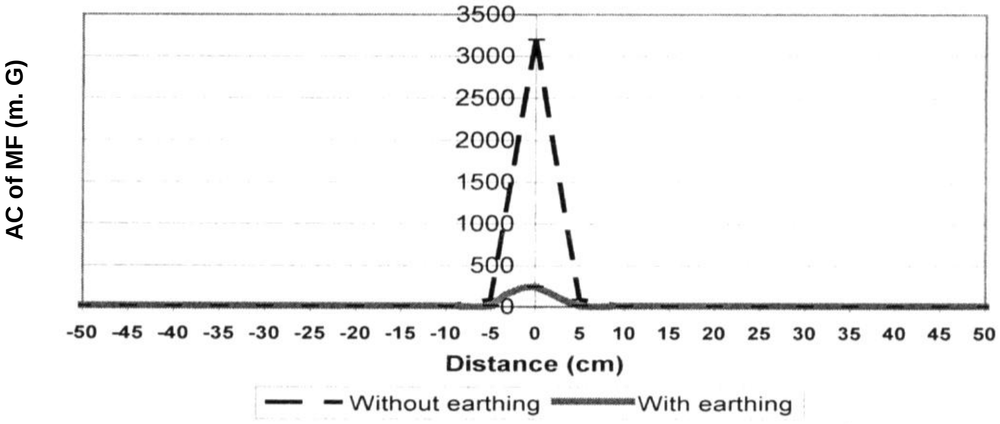

Fig. (9): AC component of MF distribution of TENS current as measured from the electrodes.

It was clear from figure (10) the presence of strong electric field strength higher than 100 KV/m which was the maximum range of the measuring equipment and reduced (according to the inverse square law) with distance up to 40 cm from the reference point even with earthing. Moreover, the electric field was decreased to 20 KV/m after shielding of the cables carrying the electric energy to the electrodes. The AC electric field was also measured from the reference point after connecting the shielded cable carrying the electric current to the electrodes to good earth which increased to 25 KV/m.

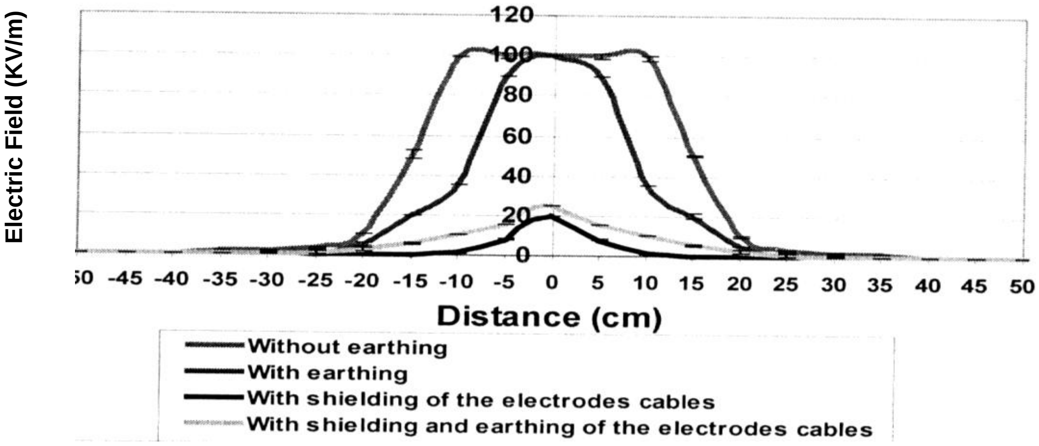

Fig. (10): AC component of MF distribution of TENS current as measured from the electrodes.

In addition, figure (11) showed the presence of electric field strength for the unearthed apparatus of 35 KV/m at the reference point on the electrodes' cables carrying the current to the electrodes and reduced (according to the inverse square law) with distance up to 25 cm from the reference point. Moreover, the electric field was decreased to 14 KV/m after connecting the apparatus to earth. No electric field was measured around the cables carrying the electric current to the electrodes when the cables were shielded.

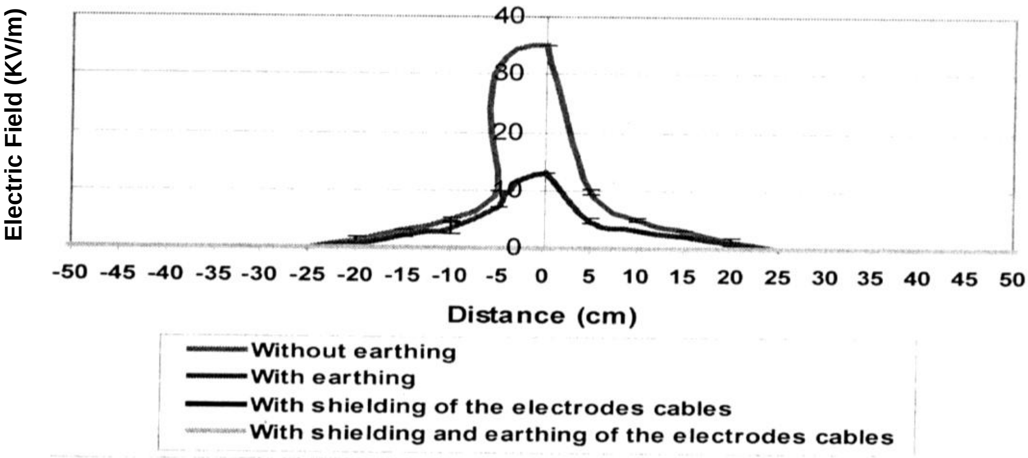

Fig. (11): AC component of EF distribution of TENS current as measured from the electrodes.

DISCUSSION

The purpose of the present study was to investigate both the electric and magnetic field strength that the physical therapist is exposed to at different distances during the application of selective electrotherapy instruments (interferential current, Russian current, and TENS) and to provide the necessary advice to physiotherapist in order to have safe handling of these equipments.

At developed countries electric wiring for electric appliances is done through three electrodes; two of them are for providing the equipment with electric power and the third is the earthing electrode. This electrode is connected to the metallic body of the equipment to conduct electric field generated from the operator of the equipment to earth. Without this third well earthed electrode connection, the electric and magnetic fields generated in the electric equipment will be transmitted in space around its body to form non-ionizing radiation hazards to the user or those in the field area. This was the main objective of carrying the present work.

The results represented in the current work indicated that there was considerable high levels of the electric and magnetic fields arising from the equipment during its operation for interferential, Russian, and TENS current modes. The electric field strength was higher than the maximum range of the field meter which was l00 KV/m. Inaddition, connecting the equipment to earth caused remarkable reduction in the electric field intensity and even no electric field was measured in most of the cases.

On the other hand, the DC magnetic field component was very high and got values up to 900m.G which was reduced to be approximately zero with earthing the apparatus. Furthermore, the magnetic field strength around the apparatus indicated that it depends on the mode of its operation and current density. The width of the electric and magnetic fields around the apparatus showed radiation risk to operator at distance up to 30cm from the reference point which present on the apparatus, this risk found in the study had an agreement with the work of many investigators. [10,11,12]

The present work also indicated the presence of DC magnetic field up to 12.4 G around the electrodes used for the patient treatment and markedly reduced with earthing of the apparatus.

Moreover, in the current work the AC magnetic field strength up to 200 gauss were measured around the electrodes which used for interferential therapy. The value of the magnetic field was diminished after applying good earth of the apparatus. These data indicated the needs of earthing the apparatus for safe usage.

Moreover, the present study revealed that both the electric and magnetic fields around the apparatus working in the Russian current mode still had values lower than that measured while the apparatus working in the interferential current mode which may be attributed to the lower carrier frequency of the Russian current.

Unfortunately, the measured values of the electric and magnetic field around the apparatus used for treatment of patients in electrotherapy were higher than international permissible levels recommended by National Council on Radiation Protection and Measurements (NCRP), International Commission on Radiological Protection (ICRP) and World Health Organization (WHO). International Commission Concerned with Non-Ionizing Radiation Protection (ICNIRP) established guidelines for occupational exposure to magnetic field by 500 μT (5 G) for workers and 100 μT (1 G) for public. [13,14] These guidelines are intended to protect against maximum external magnetic field and maximum internal induced currents.

Furthermore, it was stated that prolonged exposure to 50Hz 2G magnetic fields caused pronounced changes in the physical structure and physiological properties of red blood cells (RBCs) collected from the exposed rats. The heart of the exposed rat was severely injured. [15,6]

On the other hand, the measured electric fields around the apparatus and cables used for interferential therapy indicated strong electric field which had values higher than 100 KV/m; the maximum measuring limit for the used meter. This very strong electric field forms health risk to operators since the maximum limit of exposures recommended by the different unions were in the range of 1.5KV/m.

It was reported that, exposure to such strong electric fields can cause disturbance of cell to cell communication and Ca++ ions efflux. A noise to cell communication can occur at very weak electric field such as 0.1 V/m.[17].

Therefore, it is necessary to recommend the unuse of all apparatus in electrotherapy without earthing. That means through the proper use of the third earthed electrode.

One more important finding in the present study was the high electric and magnetic field strength measured around the cable carrying current to the four electrodes for interferential therapy. When this cable was surrounded with external earthed shield, the field strengths around it was eliminated and reached zero value. The power at the treating electrodes was increased when the carrying cable was shielded. This result indicated that part of the transmitted energy for the patient is received by the operator.

Furthermore, the magnetic field measured around the apparatus working in the TENS mode showed no DC component, and the electric field around the electrodes cables was completely eliminated when the cables were shielded.

Conclusion

From the results of this study it was concluded that the values of electric and magnetic fields around the electro-therapy instruments (interferential current, Russian current, and TENS current) used by the physical therapists are not safe. Good earthing of these electrotherapy modalities during handling of equipments is important. Moreover, shielding of the electrodes' cables used to transfer the energy to the transducer electrodes prevented energy dissipation through these cables and insure that whole energy was transferred to the patient.

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الملخص العربى

تخطيط منحنيات الجرعات الأشعاعية حول بعض أجهزة العلاج الكهربائي

في محاولة لأستكشاف كلا من المجالين الكهربائي والمغناطيسي الذين يتعرض لهما أخصائي العلاج الطبيعي علي مسالفات مختلفة أثناء استخدام لأجهزة العلاج الكهربائي في علاج المرضي وأيضا لأعطاء النصائح اللازمة للمعالج لضمان استخدام أمن للآجهزة أثناتء العلاج وتجنب المخاطر الناتجة عن استخدام هذه الآجهزة نتيجة للتعرض للمجالين الكهربائي والمغناطيسي المنبعث منهما: تم قياس المجال الكهرومغناطيسي لكل من التيار المتداخل، والتيار الروسي وتيار التنبيه الكهربي العصبي عبر الجلد باستخدام نوعين من أجهزة القياس. وقد أسفرت النتائج عن أن انبعاث مجال كهرومغناطيسي عالي من أجهزة العلاج الكهربي السابق ذكرها يتعرض لهما المعالج أثناء استخدامه لهذه الأجهزة في العلاج. وأن المجال الكهرومغناطيسي المنبعث من تلك الاجهزة أعلي من المعدلات المسموح بها دوليا والموصي بها من الاتحادات الدولية المعنية بالحماية من التعرض للاشعة غير المتأنية. وقد لوحظ انخفاض المجال الكهرومغناطيسي المنعث من تلك الأجهزة بعد توصيلها بأرضي مناسب. وبهذه الطريقة يمكن ضمان وصول الطاقة كاملة إلي المريض وإنخفاض قيمة المجال الكهرومغناطيسي إلي أدني مستوياته وذلك بعد عمل شبكة تصفية للأسلاك الموصله للطاقة إلي الأقطاب الكهربائية.