J. Phys. Ther. Sci.
26: 557–562, 2014

Original Article

Lack of Maintenance of Shortwave Diathermy Equipment Has a Negative Impact on Power Output

Rinaldo Roberto de Jesus Guirro, PhD[1, 2)*], Elaine Caldeira de Oliveira Guirro, PhD[1, 2)], Natanael Teixeira Alves de Sousa, PT[2)]

[1)] *Laboratory of Physiotherapeutic Resources, Department of Biomechanics, Medicine and Rehabilitation of the Locomotor System, Laboratory of Physiotherapeutic Resources, Ribeirão Preto Medical School of University of the São Paulo: Bandeirantes Avenue, 3900, Monte Alegre CEP 14.049-900, Ribeirão Preto, SP, Brazil*

[2)] *Post-Graduation Program in Rehabilitation and Functional Performance, Ribeirão Preto Medical School of the University of São Paulo, Brazil*

Abstract. [Purpose] Although shortwave diathermy has been widely used by physiotherapists, there are a few studies assessing the performance of the equipment in use. The aim of the present study was to evaluate the procedures adopted by physiotherapists as users of shortwave diathermy continuous (CSWD), as well as to measure the power output and frequency of CSWD equipment. [Subjects and Methods] Twenty-three physical therapists were interviewed and 23 CSWD equipment were evaluated. Admeasurement was carried out by using a standard phantom to simulate the electrode-skin distance, which ranged from 0.5 to 3.0 cm. Data analysis was performed by using descriptive statistics, ANOVA, and a post-hoc Tukey's test or Pearson's correlation coefficient. [Results] The questionnaires showed that 48% of the interviewees use the correct electrode-skin distance, 70% use a single electrical outlet, and 35% use a grounded electrical outlet, and that 48% of the physiotherapy tables and 61% of the plinths were made of wood. However, only 13% of the interviewees perform yearly preventive maintenance. The highest power (95.56 W) was achieved at electrode-skin distances ranging from 1.0 to 1.5 cm, with distances of 2.5 cm and 3.0 cm being null in four and eight equipment, respectively. There was a negative correlation between power output and electrode-skin distance as well as between power output and purchase date. [Conclusion] The physiotherapists involved in this study had inadequate knowledge about the correct use of CSWD equipment, which may adversely affect its performance and patient safety.

Key words: Diathermy, Physical therapy modalities, Measured

(This article was submitted Sep. 10, 2013, and was accepted Nov. 4, 2013)

INTRODUCTION

Although shortwave diathermy (SWD) equipment has been widely used in physiotherapy clinics for more than 40 years, there are a few studies assessing the performance of the equipment in use. Standards for the manufacture of this equipment in Brazil were established by the Brazilian Association of Technical Standards (ABNT) based on the Brazilian Regularisation Standards − NBR IEC 601-1, regulating the safety use of electro-medical equipment and serving as the basis for particular security standards[1)]. More specifically, NBR IEC 601-2-3 (Electro-medical equipment – Part 2: particular security norms for short-wave therapy equipment) determines a maximum operating power output of 500 W[2)], which is an important parameter for minimizing risks to the patient.

In a review of clinical trials with SWD, Shields et al.[3)] noted the emphasis given by researchers on reporting the power selected without considering the electrode-skin distance. Because the absorbed dose is not measured, the level of power is empirically reported as either the equipment's selector position or patient's sensation. This fact is also observed in the clinical practice, where variables interfering with the energy applied are neglected, such as treatment length, pulse setting, and average power, which should be measured at an electrode-skin distance ranging from 1.0 to 1.5 cm, as the average power of interest is not that displayed on the equipment's panel but that the equipment is capable of applying to the patient, considering the resistances of different tissues under the electrodes. The combination of these parameters will determine the amount of energy applied to the tissue, which consequently may or may not generate therapeutic effects.

Knowing that maintenance procedures and application techniques, in association with the average power emitted by the equipment, have repercussions on therapeutic responses, the objective of this study was to evaluate the procedures used by physiotherapists for the application of shortwave diathermy and measure the power output and

*Corresponding author. Rinaldo Roberto Jesus Guirro
(E-mail: rguirro@fmrp.usp.br)

Table 1. Characterization of the shortwave diathermy equipment grouped by brand and model (n = 23)

Company	Model	Type of pulse Continuous - C Pulsed - P	Frequency (MHz)	Power Out Potency Informed (W)	Connec-tions	Cables and Electrodes	Sample
BIOSET *	Thermopulse Compact	C	27.12	100	OK	OK	4
BIOSET *	Thermowave	C	27.12	380	OK	OK	3
CARCI #	Diatermed	C	27.12	240	OK	OK	2
CARCI #	Diatermia 4025	C	27.12	---¥	OK	OK	5
IBRAMED §	Thermopulse	C - P	27.12	180	OK	OK	3
KROMAN ♦	Termotron	C	27.12	---¥	OK	OK	1
KLD ∞	Diatermax	C	27.12	200	OK	OK	2
KW ¢	Efrom	C	27.12	400	OK	OK	3

¥ Equipment out of production and value not reported by the manufacturer.
Addresses: * 1212, Avenue 55, Rio Claro, SP, Brazil; # 246, Dr. Siqueira Campos, São Paulo, SP, Brazil; § 50, Milão, Amparo, SP, Brazil; ♦ 35, Joaninha Carpinelli Fortes, Ribeirão Pires, SP, Brazil; ∞ 610, Avenue Europa, Amparo, SP, Brazil; ¢ 1211, Augusto Barassa, Amparo, SP, Brazil

frequency of CSWD equipment.

SUBJECTS AND METHODS

After determining the physiotherapy clinics located in two cities in the state of São Paulo, Brazil, using a telephone directory, 38 physiotherapy clinics were contacted by telephone to determine whether they used continuous shortwave diathermy (CSWD) equipment, and 31 of the clinics had the equipment, with 8 of the clinics not providing CSWD. After personal contact, 23 clinics and 23 pieces of equipment were included in the evaluation.

The study was conducted in two phases: 1) application of a questionnaire to survey use conditions, and verification of user qualifications with regard to common knowledge concerning the application of SWD and 2) evaluation of equipment being used.

Questionnaire application

A self-completion questionnaire developed in Laboratory of Physiotherapeutic Resources (LARF) with open and closed questions regarding the procedures used by the physiotherapists during the use of CSWD equipment as well as questions related to the proper equipment was applied, including maintenance routine and knowledge about technical safety standards for which the practitioner was responsible. All 23 physiotherapists, who were the heads of their respective services, participating in the study received and signed a consent form, and they were informed about the study prior to the start of the present work. The research project was approved by the Committee of Ethics in Research, protocol 12/07.

The questions compiled for this study contemplated the year of purchase of the equipment, electrode-skin distance used, whether or not a single socket and grounded electrical socket were used, material (metal or wood) used for support equipment and the stretcher, positioning of electrodes used more (transverse or longitudinal), type of electrode (plaque or Schliephake), and CSWD interference caused by other equipment (list in descending order). The questions were asked in Portuguese. The average time required to fill out the questionnaire was 10 minutes.

Evaluation of shortwave diathermy continuous equipment

In the second phase of the study, 23 pieces of equipment in continuous mode were evaluated; the sample consisted of eight models from six national manufacturers (Table 1). Measurements of all equipment in this study were carefully performed in the Laboratory of Physiotherapeutic Resources (LARF), with no other equipment being on at the time in order to avoid any possible interference. Collection of measurements was performed between July 2010 and April 2011.

To measure the maximum power emitted continuously, a CSWD wattmeter (Phantom, model 460, Enraf Nonius, Rotterdam, The Netherlands) was used with an analogy scale set for powers ranging from 0 to 500 W. The shortwave electrodes were positioned at each side of the phantom in such way that they could simulate different electrode-skin distances, namely, 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 cm. An oscilloscope (TDS-210, Tektronix, Beaverton, OR, USA) was connected at one of the output cables of the CSWD equipment, thus allowing the frequency to be measured.

After connecting the CSWD equipment to the phantom, the electrode distance was set at 0.5 cm, and the equipment was turned on for three minutes at zero intensity, that is, standby. After this period of time, the maximum power can be achieved, and the maximum syntonization can then be adjusted. Next, the electrodes were positioned at 0.5 cm further, and data collection procedures were resumed.

Descriptive statistics were used for the data obtained from the questionnaire, whereas quantitative analysis was performed by using the Shapiro-Wilk test to demonstrate data normality for power and frequency, including ANOVA followed by a post-hoc Tukey's test. For analysis of correlation, Pearson's test was applied. The BioEstat® 5.3. software was used, and the significance level was set to $p<0.05$.

RESULTS

In the present study, 23 pieces of CSWD equipment for physical therapy use (from BIOSET, CARCI, IBRAMED, KLD, KW and KROMAN) were evaluated. As these pieces of equipment were already being used in the clinics, the brands were not taken into account in the measurement procedures because the use conditions were not controlled. On visual inspection, it was noted that all the pieces of equipment were in good use condition, with their connections intact and adjusted and cables and electrodes having proper electrical isolation (Table 1).

A continuous pulse setting was present in 100% (n=23) of the equipment, with only 13% (n=3) presenting a pulsed setting, and 43% (n=10) had complete documentation from the manufacturer. Further information on the equipment was obtained from websites or by consulting the manufacturer directly. It was found that the equipment purchase dates ranged from 10 to 107 months, with a median of 60 months.

The results of the questionnaire showed that 26% (n=6) of the interviewees used an electrode-skin distance of 0.5 cm, 48% (n=11) used an electrode-skin distance of 1.0 cm, and the remaining used an electrode-skin distance between 1.5 and 3.0 cm. It was notable that 70% (n=16) of the interviewees used a single electrical outlet and that 35% (n=8) used a grounded electrical outlet, and only 48% (n=11) of the physiotherapy tables and 61% (n=14) of the plinths were made of wood. With regard to the positioning of the electrodes, 48% of the interviewees used a longitudinal position, and the other 52% (n=12) used a transversal position. The most frequently cited interferences were radio (100%), low-frequency electrical therapy devices (63.6%), and wireless telephones or mobile phones (63.6%). Plaque-type electrodes were the most used type of electrodes (80.7%).

When the physical therapists were asked about maintenance procedures, only 13% reported that they sent the equipment to the manufacturer for maintenance or preventative maintenance each year, 52% reported that they examined the functioning of their equipment qualitatively before deciding that maintenance was needed, 22% reported that they sent their equipment for maintenance only after observing that the patient warming had decreased, and 13% did not respond. When asked about whether their equipment was in good conditions for clinical use, all the interviewees answered positively, with 70% basing their determinations on patient warming, 21.5% performing qualitative tests with fluorescent lamps, and 8.5% reporting nothing at all.

All the physical therapists recognized the need to syntonize their equipment in order to achieve the desired heat, but few (21%) could explain what that meant to integrate the resistance of biological tissues to the capacitive circuit of the equipment.

With regard to the quantitative assessment, the results demonstrated that there is a relationship between power generated in the patient circuit and electrode-skin distance, with a significant positive correlation (r = 0.85) between the distances of 0.5 and 1.0 cm. From distances of 1.0 and 1.5 cm (95.5 ± 37.7 W and 95.1 ± 37.9 W, respectively), there was a constant decrease in the average power at the distances of 2.0, 2.5 and 3.0 cm (73.5 ± 41.2 W; 57.1 ± 37.2 W and 46.8 ± 36.0 W), thus demonstrating an almost perfect negative correlation (r = − 0.98). At the electrode-skin distances of 2.5 and 3.0 cm, it was found that 17.4% and 34.8% of the equipment emitted no energy at all, respectively (Table 2), with the equipment being comprised of three models from three manufacturers.

Table 2. Maximum power (watts) emitted by shortwave diathermy equipment considering the different simulated electrode-skin distances by equipment (n = 23)

Equipment	Simulated electrode-skin distances (cm)					
	0.5	1.0	1.5	2.0	2.5	3.0
1	163	176	173	173	120	71
2	98	147.5	150	154	121	138.5
3	102	141	144	84	30	0
4	118	138	143	47	0	0
5	97	135	135	76	0	0
6	64	132.5	124	110	68	45
7	75.5	122.5	121	105	104	71.5
8	45	120	126	119.5	92.5	49
9	75.5	115.5	104	63	25	25
10	54	98	91.5	91	70.5	42
11	89	95	97	95	92.5	95.5
12	74	81	73.5	18	0	0
13	76	78.5	79	84	91	90
14	30	78	84	23	0	0
15	46	76.5	81	76	75	58
16	64	71.5	72	75.5	91.5	95
17	72	69	71	40	25	0
18	52	69	61	66	65	66
19	60	65	78	70	45	0
20	14	54	56	13	12	42
21	32.5	48	46	35	30	0
22	46	46	41.6	40	32.5	32.5
23	47	40	37.5	32.5	30	25

Because our sample of CSWD equipment was heterogeneous, with great variation in the power emitted, we opted to analyze them individually by simulating the electrode-skin distance. CSWD equipment numbers1 to 9 emitted enough power to warm depths of 1.0 to 1.5 cm at a power higher than 100 W (Table 2), and were comprised of four models from four manufacturers, which were ordered by column representing the simulated distance of 1.0 cm − informed by the manufacturers as being the ideal distance for generating high power. Among these pieces of equipment, only CSWD equipment 1, 2, and 7 were capable of emitting power higher than 100 W as the electrode-skin distance increased up to 2.5 cm. On the other hand, it is worth emphasizing that the majority of the equipment exhibit a great reduction in power generation as the distance increases, thus indicating their incapacity to heat deeper tissues.

The frequency of the electromagnetic waves showed no variation during the different simulations of electrode-skin distances, with the average being 29.81± 0.41 MHz and minimum and maximum values being 24.25 MHz and 32.43 MHz, respectively.

It is expected that the wear of any electrical electronic equipment is influenced by its use over time. Within this context, there was a strong correlation between the variables of “purchase date” and “mean power” (r = − 0.77).

DISCUSSION

The date of purchase of SWD equipment is of paramount importance for preventive maintenance, since lack of knowledge about that and absence of a secure guarantee make it difficult to identify usage time and wear. In the present study, 23 pieces of CSWD equipment in use for up to 107 months from the purchase date were evaluated, and only 13% of the physical therapists sent their equipment for preventive maintenance every year. Better results were found by Gruber et al.[4], who found that of the 20 pieces of CSWD equipment evaluated, 10% were sent for maintenance every six months or when they presented some failure, and 60% of the therapists said they did it yearly. Among the others, 20% never sent their equipment for preventive maintenance, and 10% did not know when the equipment had last been sent for maintenance. The Chartered Society of Physiotherapy (CSP) in the United Kingdom has recommended that the maintenance of SWD equipment should be performed at regular intervals of six months[5], whereas the Brazilian Standards (NBR IEC 601-1 − Electric medical equipment − Part 2: General safety requirements) indicate annual maintenance[1]. Some factors such as constant use of the equipment, purchase date, lack of maintenance, or incorrect usage can influence their functioning and lead to a drop in power generation, thus interfering with the desired therapeutic response.

The frequency of the patient circuit is rigorously controlled according to the tolerance specified by the Brazilian Association of Technical Standards. The diathermy equipment commercially available in Brazil operates at a frequency of 27.12 MHz. In the present study, however, the examined pieces of SDW equipment exhibited great variation in their frequencies (24.25 to 32.43 MHz), and only one was found to be in accordance with the current standards. This parameter interferes with the therapeutic effects and expected results from the application of CSWD, since it is known that the higher of the frequency of electromagnetic waves the greater the energy generated[6].

During therapy, the most important power is that converted into heat in the tissue, that is, the patient circuit power. This power depends on both correct tuning and the power generated by the equipment, which may vary depending on the manufacturer and electrode-skin distance. The greater the distance, the greater the effect of deep heat, and the smaller the distance, the higher the energy on the surface layers[7]. However, it was found that the highest power occurred at simulated distances of 1.0 and 1.5 cm, decreasing at distances greater than 2.0 cm until reaching zero emission in some pieces of equipment. It is worth emphasizing that in Brazil, according to the manufacturers, CSWD equipment is regulated to generate the highest power at electrode-skin distances ranging from 1.0 to 1.5 cm, which was confirmed in the present study. The lack of knowledge of such information in practitioners can be seen in the answers given to this questionnaire item, for which approximately 50% of the respondents reported that they would not be using the correct distance to obtain the maximum power.

There is a diversity of electrodes worldwide, both of capacitive and inductive types as well as of several sizes and formats. However, only capacitive plates or Schliephake electrodes are commercially available in Brazil. In the present study, plate-type electrode was the most widely used by the interviewees, a finding also reported by Gruber et al.[4], who reported that 65% of their subjects used this type of electrode, and by Shields et al.[8], who reported that 80% and 65% of their subjects used, respectively, inductive and capacitive electrodes. These findings are different from those of the study by Shah et al.[9], who found that 65% of their subjects used inductive electrodes and only 10% used capacitive ones, thus showing that the variability in the use of different types of electrodes is related to their availability in the market, as well as to their costs. It should also be considered that capacitive electrodes generate a more superficial heating than inductive ones, and consequently, the thermal sensation felt by the patient cannot be taken into account as a parameter of sufficient generation of energy.

There is no current consensus on which dosage is ideal for the treatment of different types of pathologies involving several types of tissues. Of course, all the parameters − frequency, peak power, average power, and treatment length − contribute to the amount of total energy deposited during application, thus interfering with the therapeutic outcome.

That is the importance of having reliable and trustworthy equipment regarding the parameters in question. Otherwise, equipment generating power inferior to that specified at an inadequate frequency could not yield the desired therapeutic effects, thus resulting in waste of time and financial harm to both practitioner and patient. Gruber et al.[4] reported that non-calibrated equipment and equipment out of the standards can also result in damage to patients and therapists.

In addition, there exist a greater number of issues to be discussed if we consider the risks out-of-standard equipment can bring to the health of the practitioner who uses them, since relatively large and potentially dangerous electromagnetic fields are found in the surroundings of SWD equipment and micro-wave devices used in the physical therapy services[10].

It is not possible to safely determine the risks and effects of this type of radiation on human body in the long term. Therefore, it is important that physical therapists take care to maintain a minimum distance of 1.5 m from the electrodes and cables and 2.0 m from the equipment during treatments. With regard to the pulsed setting, they should maintain a minimum distance of 1.0 m from electrodes and cables and 1.5 m from the equipment. In this way, the danger of excessive exposure can be minimized. Such information is not known by the majority of the practitioners[9, 11].

In Brazil, there is no regulation limiting the exposure of physical therapists to electromagnetic fields generated by diathermy equipment. However, many countries have adopted standards close to those established by the International Commission on Non-Ionizing Radiation Protection, which recommends limits of 61 V/m and 0.16 A/m for frequencies ranging from 10 to 400 MHz[12]. These limits are not met in many countries worldwide[11, 13], including Brazil[10].

Electromagnetic fields generated by SWD equipment can reach neighbouring regions and represent a risk to patients and therapists[14]. These fields can cause interferences with adjacent electronic devices, thus compromising the treatment of other patients and harming equipment and even patients[15]. In the present study, interference was a complaint reported by the physical therapists. Another very important issue is the presence of metallic materials in the treatment facilities, present in 100% of the clinics studied, which can cause perturbation in the electromagnetic field[6]. Therefore, one should ensure that physical therapy tables, chairs, and supports for the equipment are not made of metal. However, it was found that only 48% of the physical therapists used wooden tables during CSWD treatment, a percentage close to that reported by Gruber et al.[4] and Shah et al.[9], who found that 40% and 33% of their subjects used metallic tables, respectively. It is of great importance to keep the CSWD equipment at a minimum distance of 3.0 m from other devices and metallic materials or to place them in another room whenever possible[16, 17].

In addition to the cautions mentioned above, a single grounded electrical outlet should be used, which was not observed in the clinics studied. This is mandatory as a result of classification by the NBR IEC 601 and 601-2-3 standards for Class I equipment, in which protection against electrical shock is not based only on isolation but is also based on provision of additional safety by preventing accessible metallic parts from undergoing tension due to isolation failure, particularly with regard to the acceptable leakage current and reliability of the grounding connection[1, 2].

The results of the present study are in agreement with those reported by Gruber et al.[4], who showed that 75% of the pieces of equipment they evaluated were neither grounded nor working well. On the other hand, Shields et al.[17] reported that all the pieces of equipment they evaluated were within the limits of normality in terms of electrical standards.

Therefore, based on the results of the present study and issues discussed, it appears that in addition to exposing their health to the risks associated with electromagnetic fields, the physical therapists employ CSWD equipment expecting outcomes that cannot be determined or predicted by them due to the lack of measured resulting from the lack of maintenance of their equipment. We believe that the lack of preventive maintenance is related to a lack of information among physical therapists, lack of disclosure of such a necessity by the manufacturers, and lack of control by governmental agencies. The point favouring preventive maintenance is that the useful life of the equipment is increased; that is, its performance and safety during application are enhanced, and its costs are reduced. Professional councils and control agencies should promote campaigns aimed at making physical therapists aware of the need for preventive maintenance of their CSWD equipment so that this can be realized within a short time.

We hope that these results can inform teachers of undergraduate courses in physical therapy about the need for discussion concerning the contents of technical standards for construction and maintenance of equipment, as well as safety professional and patient during use of SWD equipment. Thus, we hope that our results deepen the knowledge base of physical therapists who will be involved with this issue during their professional activities. Furthermore, manufacturers must monitor certain information about their equipment, such as, the time of sale and the trader responsible for remembering the need for periodic maintenance. We believe that these actions could improve the worrisome scenario presented today.

The results point to poor use of CSWD equipment, which may adversely affect its performance and patient safety. This finding is inconsistently demonstrated by physical parameters, such as the frequency and power output in the current standards and lack of environmental control CSWD where the equipment is used. More research should be conducted to analyze the electrical safety of equipment, including investigation of quality control systems and standards of good practice that should be followed by manufacturers.

ACKNOWLEDGEMENT

The present study received financial assistance in the form of a grant from the Coordination for the Improvement of Higher Education Personnel (CAPES) Foundation.

REFERENCES

1) Brazilian Association Technical Standards (1994). NBR IEC 601-1: Medical electrical equipment − Part 1: General Requirements for Safety. Rio de Janeiro.
2) Brazilian Association Technical Standards (1997). NBR IEC 601-2-3: Medical electrical equipment − Part 2: Particular Requirements for the Safety Equipment Therapy Shortwave. Rio de Janeiro.
3) Shields N, Gormley J, O'Hare N: Short-wave diathermy: a review of existing clinical trials. Physiother Res Int, 2001, 6: 101–118.
4) Gruber CR, Gewehr PM: Evaluation of short wave therapy equipment based on brazilian standards. Braz Arch Biol Technol, 2006, 49: 9–15.
5) Shields N, Gormley J, O'Hare N: Short-wave diathermy in Irish physiotherapy departments. Br J Ther Rehabil, 2001, 8: 331–339.
6) Grandolfo M, Spinelli MC: Occupational exposure to shortwave and microwave electromagnetic fields during diathermy treatments. 2nd International Workshop on Biological Effects of Electromagnetic Fields, 2002: 202 − 209.
7) Kitchen S, Partridge C: Review of shortwave diathermy continuous and pulsed patterns. Physiotherapy, 1992, 78: 243–252. [CrossRef]
8) Shields N, Gormley J, O'Hare N: Short-wave diathermy: current clinical and safety practices. Physiother Res Int, 2002, 7: 191–202. [Medline] [CrossRef]
9) Shah SG, Farrow A: Investigation of practices and procedures in the use of therapeutic diathermy: a study from the physiotherapists' health and safety perspective. Physiother Res Int, 2007, 12: 228–241. [Medline] [CrossRef]
10) Teixeira SR, Messias IA, Pena AF, et al.: Electromagnetic fields produced by equipment used in short-wave therapy: an evaluation in Presidente Prudente. Braz J Phys Ther, 2001, 5: 35–40.
11) Shields N, O'Hare N, Gormley J: An evaluation of safety guidelines to restrict exposure to stray radiofrequency radiation from short-wave diathermy units. Phys Med Biol, 2004, 49: 2999–3015. [Medline] [CrossRef]
12) International Commission on Non-Ionizing Radiation Protection: Guide-

lines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health Phys, 1998. 74: 494–522. [Medline]
13) Maccà I, Scapellato ML, Carrieri M, et al.: Occupational exposure to electromagnetic fields in physiotherapy departments. Radiat Prot Dosimetry, 2008, 128: 180–190. [Medline] [CrossRef]
14) Benetazzo L, Bertocco M, Fanas M, et al.: Evaluation of the Electromagnetic Field Radiated by Shortwave and Microwave Diathermy Equipment. In: Proceedings of the 20th IEEE Instrumentation and Measurement Technology Conference, 2003, 2: 930–3.
15) Robinson MP, Bozec D, Marshman CA: Healthcare engineering and electromagnetic compatibility. In: Proceedings of the I Mech E Conference on Healthcare Engineering: Latest Developments and Applications, 2003: 53–61.
16) Crevenna R, Stix G, Pleiner J, et al.: Electromagnetic interference by transcutaneous neuromuscular electrical stimulation in patients with bipolar sensing implantable cardioverter defibrillators: a pilot safety study. Pacing Clin Electrophysiol, 2003, 26: 626–629. [Medline] [CrossRef]
17) Shields N, O'Hare N, Boyle G, et al.: Development and application of a quality control procedure for short-wave diathermy units. Med Biol Eng Comput, 2003, 41: 62–68. [Medline] [CrossRef]