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ELECTROMAGNETIC DIATHERMIA: A LYMPHOSCINTIGRAPHIC AND LIGHT REFLECTION RHEOGRAPHIC STUDY OF LEG LYMPHATIC AND VENOUS DYNAMICS IN HEALTHY SUBJECTS

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ABSTRACT

Because electromagnetic diathermia (ED) has been reported to reduce lymphedema, we opted to examine the effects of ED on leg venous and lymph dynamics in healthy subjects. To examine lymph flow, we performed lymphangioscintigraphy (LAS) in 10 subjects without leg edema and used static images at the injection site and at the inguinal region for "control data." Later, we applied ED (2450 MHz, 200W) and then repeated the LAS using the same dosage and volume. Differences between the first and second sessions were examined using two way ANOVA and the differences between the scores with or without ED were analyzed by a Student's t-test. To examine venous flow, we first tested the left lower leg of 15 healthy subjects on two occasions using light reflection rheography (LRR). Venous refill time was recorded after each individual performed 10 dorsiflexions with the left foot on three occasions with an interval of 3 minutes between each recording. Thereafter, 20 minutes ED (2450 MHz, 200W) was applied and using the same protocol venous refill time was recorded and repeated after an interval of one week. The 50% level and the declination angle of the refill time was determined and differences between the experimental and control groups analyzed by ANOVA.

The results between the first and second sessions were consistent and reproducible with or without the electromagnetic application, with no change of radiotracer transport from the injection site or arrival at the inguinal nodes. There was also a high correlation between the scores for the 50% level and declination angle (r=0.97) after LRR. Thus, after ED there was an accelerated venous refill time. In conclusion, after ED there was no increase in lymph flow but there was accelerated venous return.

Complementing the venous circulation, the lymphatic system plays an important role in the transport of fluid and macromolecules from the interstitium. With restriction to free flow of lymph, edema fluid accumulates in the interstitium and this condition is termed lymphedema. Therapeutic methods to reduce lymphedema include manual lymph drainage, external pressure therapy, bandaging, and remedial exercises (1). Hyperthermia has also been suggested to decrease swelling (2,3). Several workers have even suggested that electromagnetic or microwave is an effective method to reduce lymphedema (4-8). It is noteworthy, however, that Liu and Olszewski (9) failed to find a significant increase in radiotracer transport by means of lymphoscintigraphy nor was there a change in tracer migration from the injection site or accumulation in regional lymph nodes after microwave application in patients with peripheral lymphedema (9). Accordingly, we opted to examine the physiologic response to microwave diathermia in healthy subjects to determine whether this treatment alters lymph and/or venous flow using lymphoscintigraphy and light reflection rheology, respectively.

MATERIALS AND METHODS

The following studies were approved by the Medical Ethics Commission of the Vrije Universiteit, Brussel.

Initially healthy human subjects (n=10, 6 men and 4 women) (average age 2 years and average body weight 62 kg) were tested in a room where the temperature was held constant at 20°C. The apparatus for electromagnetic irradiation was a Thermatur® m250 with a frequency of 2450 MHz and a power of 200W, applied for 20 minutes. At this power, a skin temperature of 38-39°C was recorded, which is in accordance with previous workers' ideal therapeutic tissue temperature.

During the first session, static images by lymphscintigraphy were taken over a period of 90 minutes using a Siemens® gamma camera. During the second session, the tracer accumulation at the groin was measured at 30 minutes followed by 20 minutes of electromagnetic irradiation and finally 30 minutes of recording. To counteract interference between the electromagnetic waves and the gamma camera, heat radiation took place in a separate room. To depict lymph transport, each subject was injected with 0.2 ml Tc^{99m} HSA (human serum albumin) in the first interdigital space of both feet. Static recordings (15 minutes) of tracer migration were taken at the injection site, promptly after injection and at the end of the session. Recordings at the inguinal nodes were made every 5 minutes during the entire session. Differences between the first and second session were analyzed with a two way ANOVA; differences between scores with or without electromagnetic irradiation were analyzed via a Student's t-test.

To investigate venous flow, we examined 15 healthy subjects (6 women, 9 men; average age 22 years) using non-invasive light reflection rheography (10) (LRR; AV—100 hemodynamics, Zyma). Venous refill time was determined after each subject dorsiflexed the foot 10 times. The subject was seated with the leg in 110° flexion. The recording probe was attached 10 cm above the medial malleolus of the left foot. The speed at which dorsiflexion was done was signaled by visual and acoustic stimuli, and repeated 3 times, at an interval of 3 minutes followed by 20 minutes of electromagnetic diathermia (2450 MHz, 200W). Thereafter, 3 recordings were made. The same protocol was repeated after one week. These results were compared with a control group which consisted of 9 healthy subjects (1 woman, 8 men, average age 22 years), who followed an identical protocol as the experimental group but without electromagnetic irradiation. The 50% level and declination angle of the refill time were then compared and interpreted in the 2 groups and the differences determined by an ANCOVA test. Significance level was chosen at the 5% level.

RESULTS

Experiment I (Lymphoscintigraphy)

Reproducibility

In the first experiments, the radiotracer concentration was expressed not in absolute value but as a percentage of the number of particles injected subcutaneously, with the total amount injected taken as 100%. *Fig. 1* shows the mean tracer evacuation for the first and second session, without electromagnetic irradiation documenting consistency and reproducibility of measurement. Note that there is a simultaneous and parallel tracer transport and an increase in function with time (F=21.33). This increase was significant ($p \leq 0.05$), although both values representing

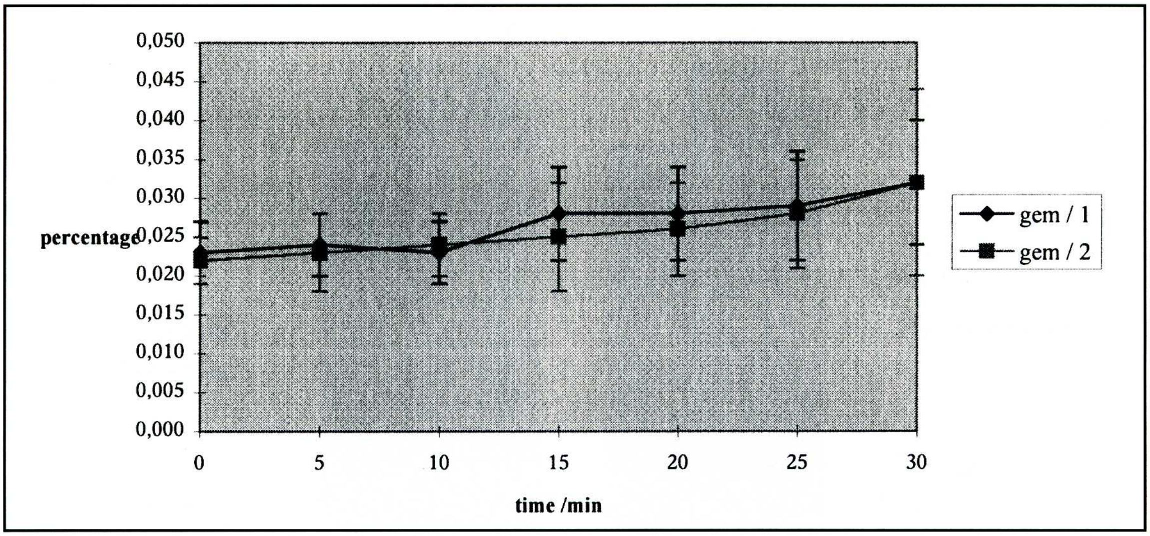

Fig. 1. Mean tracer accumulation between first and second session, with electromagnetic irradiation.

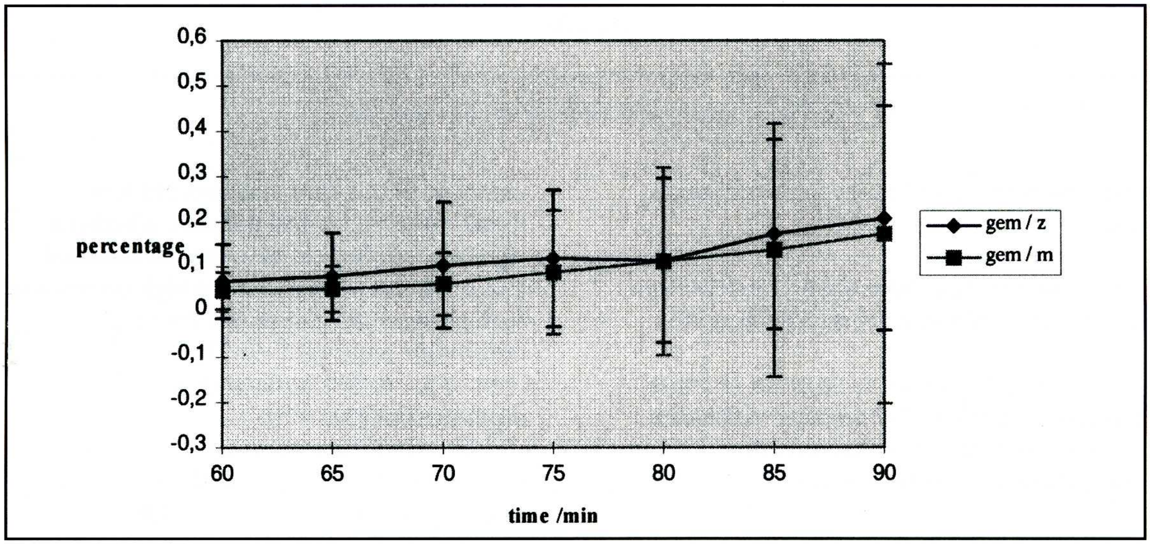

Fig. 2. Comparison of the mean tracer accumulation between the sessions with or without electromagnetic irradiation at the inguinal lymph nodes.

the first and second session are closely matched in the beginning and after 30 minutes of treatment. The two curves are not different ($p \leq 0.05$).

The effect of electromagnetic diathermia on the radiotracer accumulation at the groin

Fig. 2 shows the comparison of the mean radiotracer accumulation in inguinal lymph nodes between sessions with or without electromagnetic irradiation. As in *Fig. 1*, there was a significant increase ($F=5.87$; $p \leq 0.05$) of radiotracer accumulation over time but without difference ($F=0.45$) between the curve with and without electromagnetic diathermia. Note no significant increase ($p \leq 0.05$) of lymph flow after electromagnetic

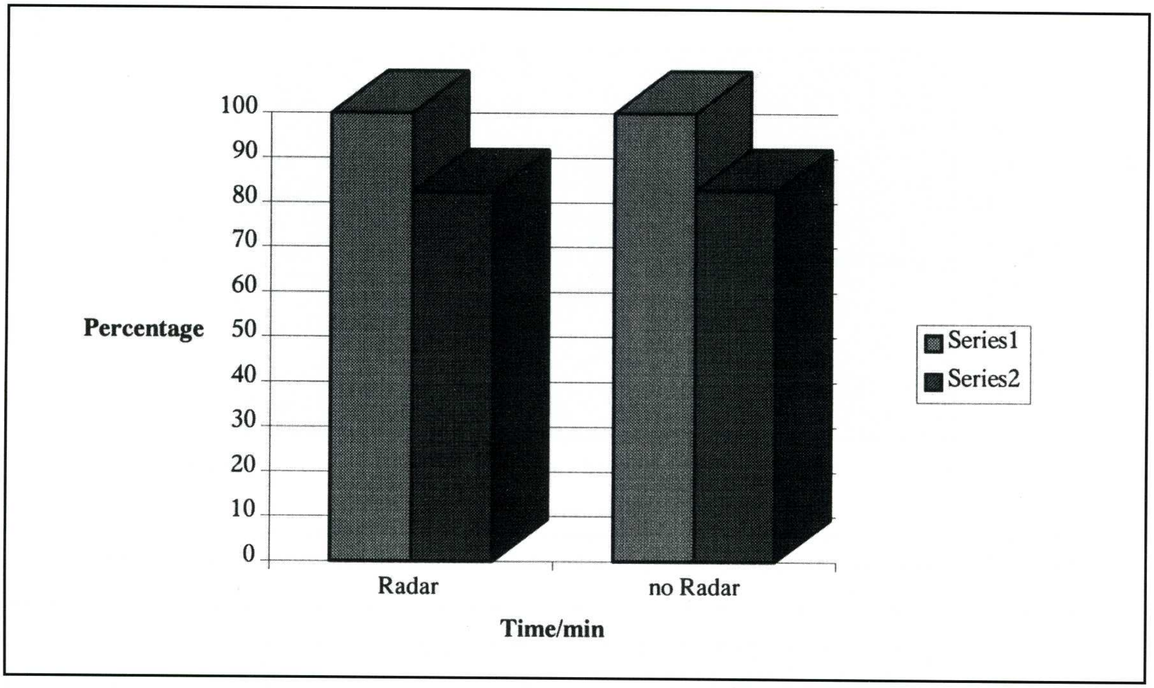

Fig. 3. Mean tracer course at the injection site.

diathermia treatment at the inguinal lymph nodes.

The influence of electromagnetic diathermia on radiotracer transport from the injection site

Whereas there was an increase of tracer transport over time, there was no difference ($p \leq 0.05$) in lymph flow between the experimental and control groups *(Fig. 3)*.

Experiment 2 (Light Reflection Rheography or LRR)

To investigate the influence of electromagnetic diathermia on venous dynamics, we examined venous refill time. To interpret the curves obtained by LRR, we used the 50% level or the time at which the reflection amplitude was reduced to one half and the declination angle to the baseline; this point represents a straight line between the point of maximal reflection and the 50% level.

We determined, after executing 3 consecutive standard exercises (10 foot dorsiflexion) in control patients, whether a significant difference between the recorded curves appeared. We found a high correlation both between the curves and for the declination angle (ICC=0.97), as for the 50% level (ICC=0.094), indicating that LRR was reproducible *(Figs. 4,5)*.

The experimental group were studied twice separated by a one week interval. At week 1, there was a significant difference ($p \leq 0.05$) in the declination angle (i.e., 3.4°) between the experimental and control group before and after electromagnetic diathermia treatment. Similar results were obtained with the 50% level, i.e., the experimental group had a decrease of refill time after electromagnetic diathermia treatment of 4.30 s compared with the control group. Compare *Fig. 6 and 7* (experimental) with *Fig. 8 and 9* (control).

The results after the second session (week 2) were similar to week 1. For the declination angle, there was a decrease of 6.044° in the

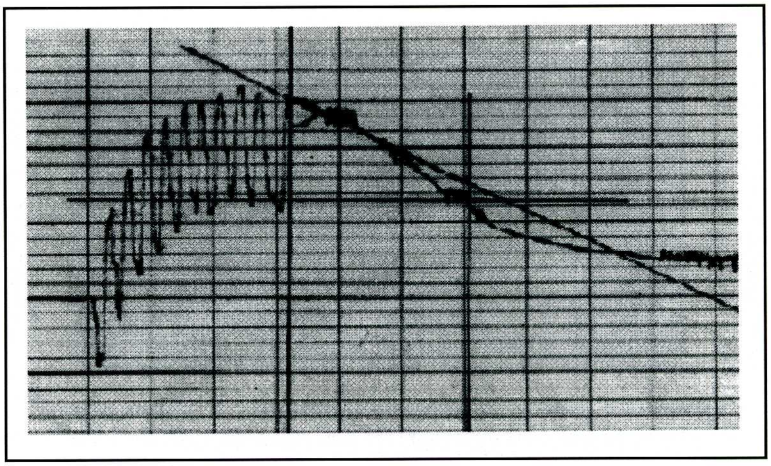

Fig. 4. LRR registration 1st session.

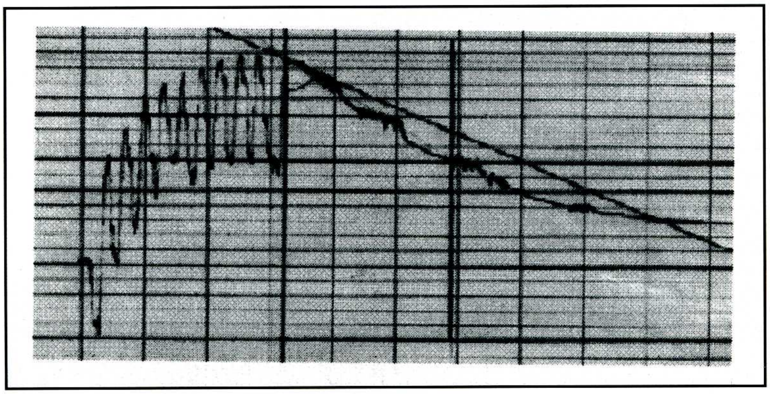

Fig. 5. LRR registration 2nd session.

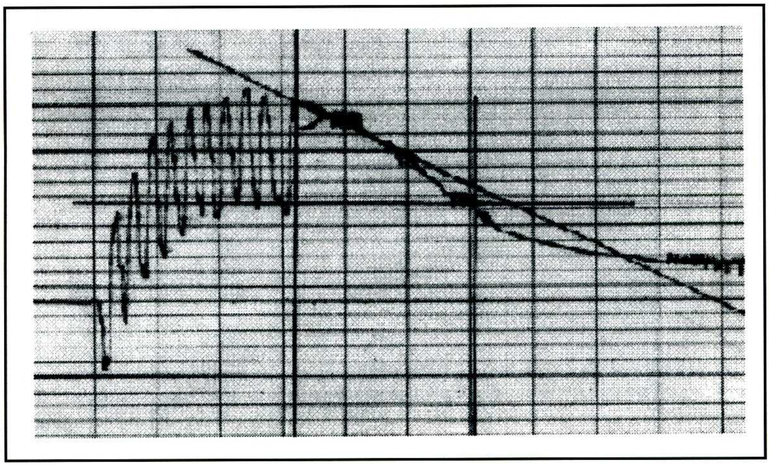

Fig. 6. Declination angle and 50% level in experimental group before electromagnetic irradiation.

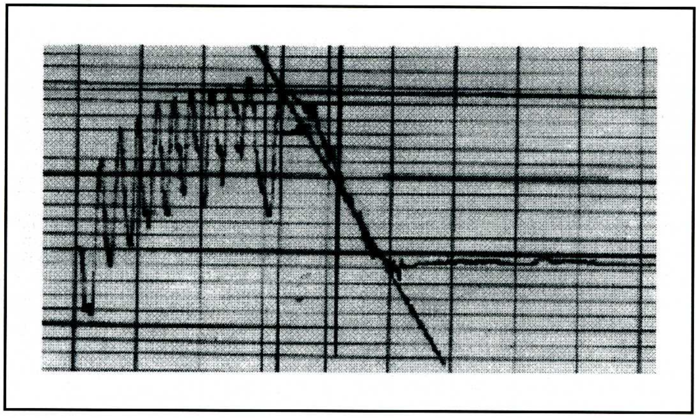

Fig. 7. Declination angle and 50% level experimental group after electromagnetic irradiation.

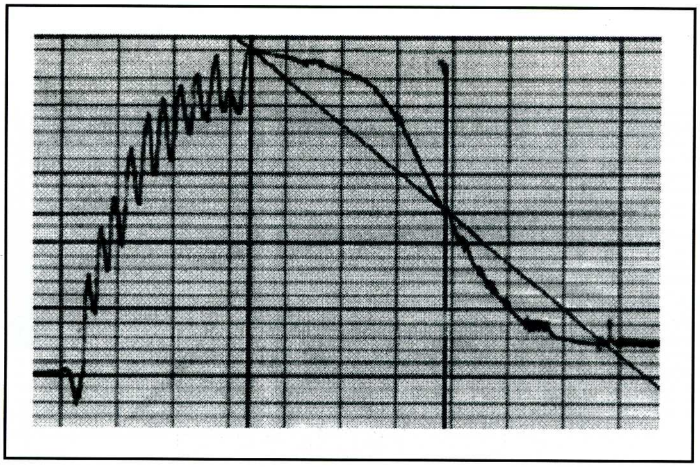

Fig. 8. Declination angle and 50% level control group before "placebo" electromagnetic irradiation.

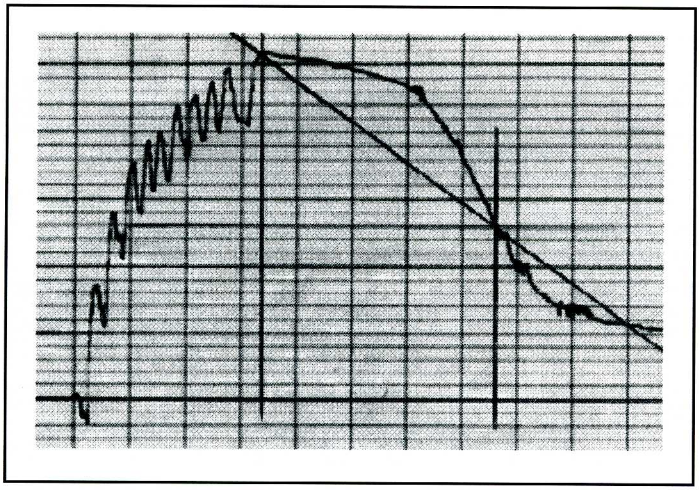

Fig. 9. Declination angle and 50% level control group after "placebo" electromagnetic irradiation.

experimental group compared with the control group. For the 50% level, a decrease in the refill time of 6.42 s was significantly greater compared with the control group.

DISCUSSION

Diathermia has been suggested to alleviate lymphedema presumably by increasing lymph transport (4). Our lymphoscintigraphic findings in healthy subjects with intact lymphatics, however, fail to show increased lymph flow after electromagnetic irradiation. Specifically, at the injection site, there was no increase in tracer migration, and no greater accumulation of radiotracer was detected at the inguinal lymph nodes compared with no treatment. The findings are in accordance with studies of Liu and Olszewski (9) in patients with lymphedema in whom no change in lymph flow was detected using electromagnetic irradiation (9). Although our subjects showed a wide variation in lymph flow, the measuring technique as outlined was consistent and reproducible.

As opposed to unchanging lymph dynamics after heat application, we observed a significant acceleration of venous return. LRR curves showed faster refill time and a sharper declination angle. Because the temperature of deeper tissues rise after electromagnetic irradiation, there is likely dilatation of the venous system. Increased venous refill time derives either from more blood in the dilated vessel as with venous stasis or there is accelerated venous flow. Because we used healthy subjects in our experiments with a competent and patent deep venous system, it is much more likely that the increased refill time was due to increased venous return.

These findings suggest that electromagnetic diathermia applied to the legs of healthy subjects with intact lymphatic and venous systems has little effect on lymph dynamics but likely accelerates venous return. It seems unlikely, therefore, that heat therapy could accelerate lymph return with obstructed or underdeveloped lymphatics as in lymphedema since it has no notable effect on normal subjects with intact lymphatics. If thermal therapy is, in fact, having a salutary benefit on lymphedema, it must be operating through some other physiologic mechanism perhaps involving greater venous return.

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