The effect of transcutaneous electrical nerve stimulation on the viability of random skin flaps in rats

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The aim of this study was to determine the role of transcutaneous electrical nerve stimulation (TENS) in the viability of random skin flaps. In 30 Wistar-EPM rats, a random 10×4 cm skin flap was raised and a plastic barrier was interposed between the flap and its bed. Immediately after surgery and for two subsequent days, the rats in group 1 (the control group) were anesthetized for 1 h with the electrodes positioned in the base of the flap and without the administration of the electric stimulus. The rats in group 2 (the treatment group) were submitted to TENS for 1 h immediately after the surgery and for two subsequent days.

The percentage of necrotic area (averages of 43.11% in the rats in group 1 and 23.52% in the rats in group 2) was calculated on the seventh postoperative day in both groups.

Statistical analysis proved that TENS was more efficient in increasing random skin flap viability than was the method used in the control group.

Key Words: *Electrical stimulation; Flaps; Rats; Viability*

Skin flaps are used largely in all fields of plastic surgery, especially in reconstruction (1). The main and most feared complication for plastic surgeons in the creation of the flap is ischemia that develops to tissue necrosis in a large number of cases and causes a failure in the proposed treatment (2,3). Due to that complication, a considerable amount of research has been done with the aim of improving the blood flow in flaps, decreasing ischemic conditions and preventing necrosis (3-9).

Effet de la neurostimulation transcutanée sur la viabilité de lambeaux cutanés choisis au hasard chez des rats

RÉSUMÉ : L'étude visait à déterminer le rôle de la neurostimulation transcutanée dans la viabilité de lambeaux cutanés choisis au hasard. Nous avons d'abord soulevé un lambeau cutané de 10 cm sur 4 cm chez 30 rats Wistar-EPM, puis inséré une pellicule de plastique entre le lambeau et son lit. Immédiatement après l'intervention et pendant les deux jours qui ont suivi, nous avons anesthésié les rats du groupe 1 (groupe témoin) pendant une heure et posé des électrodes à la base du lambeau sans toutefois procéder à l'électrostimulation, tandis que nous avons soumis les rats du groupe 2 (groupe expérimental) à la neurostimulation transcutanée pendant une heure.

Sept jours après l'intervention, nous avons calculé le pourcentage de zones nécrosées dans les deux groupes (moyennes de 43,11 % chez les rats du groupe 1 et de 23,52 % chez les rats du groupe 2).

D'après l'analyse statistique, la neurostimulation transcutanée s'est avérée plus efficace que la méthode utilisée dans le groupe témoin pour accroître la viabilité des lambeaux cutanés choisis au hasard.

In the literature, there have been publications about several types of drugs, such as vasodilators, calcium channel blockers, prostaglandin inhibitors, anticoagulants, antiadrenergics and antioxidants (3,10-12). Unfortunately, many of those drugs present undesirable adverse effects, which makes their use in clinical practice unviable (3,6). Therefore, a new research field using nonpharmacological agents such as acupuncture and electroacupuncture (13,14), pulsed electromagnetic energy (15), low-power

Figure 1) Planning flap in pattern sizes (10×4 cm)

Figure 2) Random skin flap raised

lasers (16-18), monophasic electrical currents (6,7,19) and biphasic electrical currents (8,14,20) has emerged.

Transcutaneous electrical nerve stimulation (TENS) is a well defined method of pain management; however, some studies found an increase in skin temperature and perfusion in healthy subjects (21). This important discovery prompted research into the effects of TENS on chronic ulcers and flaps.

The present study was designed to assess the effect of TENS on the viability of random skin flaps in rats.

MATERIALS AND METHODS

Thirty Wistar EPM-1 adult male rats, weighing 260 to 330 g, were randomly assigned to two groups. Rats in group 1 (the control group, n=15) received sham stimulation, while those in group 2 (n=15) were subjected to TENS.

All rats were anesthetized with sodium thiopental (50 mg/kg) intraperitoneally and were then depilated. A random skin flap measuring 10×4 cm was elevated with a cranial base on the back of each rat (11,22,23) (Figures 1,2). A plastic barrier with the same dimensions was placed between the flap and its bed (10,11,23,24) (Figure 3) and was closed with simple nylon 4-0 stitches (Figure 4).

After surgery, the rats in group 1 were kept anesthetized for 1 h, with the electrodes placed on the base of the flap, but without the output of electrical stimulus. This procedure was repeated for two subsequent days. Rats in group 2 were subjected to TENS with high intensity (± 15 mA) and high frequency (80 Hz) for 1 h immediately after surgery

Figure 3) Suture with 4-0 nylon stitches after the flap was raised and a plastic barrier was interpositioned

Figure 4) Electrodes were placed at the base of the flap for the transcutaneous electrical nerve stimulation

and for two subsequent days. The electrodes were placed on the base of the flap, which measured 4.2×1.5 cm. The pulses had a duration of 200 μ s.

On the seventh day after the operation, the distal necrotic area of the flap was checked via the paper template method (25).

RESULTS

The percentage of necrotic areas in the rats in group 1 ranged from 25.35% to 61.92% (average 43.11%), while in the rats in group 2 it ranged from 7.03% to 39.92% (average 23.52%).

The Mann-Whitney test for independent groups showed that the differences between the two groups were statistically significant (Table 1).

DISCUSSION

The observation of the increase in blood flow as the result of TENS caused us and other authors to study its effect on the healing of chronic ulcers and on skin flap viability.

According to Kerrigan (2), the loss of a skin flap can be attributed to both extrinsic and intrinsic factors. Extrinsic factors include systemic (infection, arteriosclerosis, hypotension or malnutrition) and local (compression, tension or thrombosis of anastomosis) alterations, while inadequate blood flow is the only intrinsic factor.

Therefore, we agreed with Kerrigan (2) that treatment modalities that increase arterial inflow to the skin flap or

stabilize cellular membranes in ischemic tissue should be chosen.

In our study, we used a model of skin flaps that develops ischemia in the distal portion, with measurements of 10×4 cm (11,22,23). Plastic film was interposed between the flap and the bed to impede the revascularization of the flap through the bed vessels, thus guaranteeing homogeneous conditions of ischemia and necrosis (10,11,23,24). The paper template method (25) was selected to evaluate the percentage of necrotic area, because it is simple and quick and requires only transparent paper and an accurate scale.

In the rats in group 1, the average percentage of necrotic area was 43.11%. In the rats in group 2, it was 23.52%. The use of TENS was effective according to the model used, reducing the necrotic area of the distal portion of the flap in the rats in group 2 more than those in group 1. This result was in accordance with the findings of other studies (6,7,14), although those studies involved different methods of surgical procedures and different types of electrical currents. The skin flap used in those studies (6,7,14) was 7×2 cm and no barrier was positioned between the flap and the bed.

According to Alon (26), any electrical stimulation accomplished by surface electrodes attached to the surface of the skin represents a form of TENS, except in cases of denervation. Therefore, it is indispensable that we describe the type of electrical stimulation that was used in the present study. The current was pulsed and biphasic, with rectangular symmetrical pulses, and was, therefore, a nonpolarized current. Some authors (6,7,19,27) used polarized currents in their studies. The disadvantages of this include the time limitation of application and care with intensity utilized. This may be very problematic, mainly due to the possibility of sensibility alterations in regions where the flap was accomplished (28), and therefore, it is possible for chemical burns of the skin to occur, harming the flap viability.

In our study, the pulse duration was fixed at 200 µs, as was the case with other researchers (6,7,14). This pulse duration made it possible for the rats to provide a motor or sensory response, depending on the amplitude of the current.

An increase in blood flow has been demonstrated with motor and sensory stimulation. In the present study, we opted for the sensory stimulation because muscle contractions in the postoperative period can be painful and can cause some flap damage. The amplitude of the current was increased until we could see muscle contractions, and was then decreased by 1 mA. Therefore, we were able to guarantee that the stimulation was being made at the sensory level. In the majority of the rats, the amplitude was close to 15 mA. It did not seem correct to use a fixed amplitude because small variations in the positioning of the electrodes may have influenced the obtained responses.

Although we did not measure the blood flow in the skin, we believe that the increase in the survival of the flaps in the stimulated group was due to an increase in blood flow.

TABLE 1
Percentage of necrotic area on the seventh postoperative day

Rat	Group 1 (%)	Group 2 (%)
1	41.97	22.26
2	55.29	12.00
3	37.04	28.52
4	38.18	9.85
5	39.43	13.12
6	34.15	37.81
7	45.60	22.13
8	24.35	7.03
9	38.85	32.18
10	45.07	12.68
11	41.48	38.22
12	39.46	27.75
13	51.06	22.00
14	52.89	27.34
15	61.92	39.92
Average	43.11	23.52

Mann-Whitney Test, Ucalculated=18.0 (statistically significant), P<0.0001

It is well known that TENS has the capacity to increase blood flow in the skin; however, the exact mechanism through which this happens is unknown. Two hypotheses to explain that discovery have been described in the literature. The first is that TENS, through the stimulation of the large-caliber mechanosensitive fibres, may cause an inhibition of the sympathetic vasoconstrictory neurons, resulting in a cutaneous vasodilation. Several authors have tried to demonstrate the effects of electrical stimulation on the sympathetic nervous system. Although some have alleged that there is an increase or no alteration of sympathetic responses (29,30), the majority have found a sympathetic inhibition effect (31-33).

The other, and more accepted theory involves the liberation of some neuropeptides as the substance P and calcitonin gene-related peptide (CGRP), which are found in the terminations of afferent C-fibres. Those peptides can be released through the antidromic stimulation, also called the axon reflex. The stimulation occurs in the following order: sensory, motor and painful (26). Based on this principle, when a sensory stimulation occurs, there is no activation of

nociceptive C-fibres. However, when a lesion occurs, just as with the surgical incision, the pain threshold can be reached immediately after the sensitive stimulation – that is to say, before the threshold motor (34).

Another possible explanation for the stimulation of this fibre type was the interaction with the beta-type A fibres through interneurons (35). That theory, however, was criticized by other researchers (36).

Aside from these peptides (substance P and CGRP), Kaada et al (37,38) found a relationship between TENS

and the release of vasoactive intestinal polypeptide. According to the Kaada et al (37,38), there may be a relationship between the liberation of this peptide and the cutaneous vasodilation.

New horizons are envisioned to enlarge the knowledge of the physical agents that are used with the purpose of minimizing the complications of surgical flaps. New experiments with different types of electrical currents and other physical agents can be performed so that we can better understand this unexplored field.

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