## List of Programmes

### Common Treatment

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<th>Categories</th>
<th>Programmes</th>
<th>m-3</th>
<th>m-5</th>
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### Specific Treatment

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</tbody>
</table>
# TABLE OF CONTENTS

- **Fundamental principles**  
  page 9

- **Neurostimulation programmes**  
  page 29

- **Iontophoresis**  
  page 65

- **Denervated muscles**  
  page 81

- **Oedema**  
  page 95

- **Specific indications**  
  page 97

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<table>
<thead>
<tr>
<th>Categories</th>
<th>Programmes</th>
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<th>m-5</th>
<th>m-1</th>
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Fundamental principles
This is the first in a series of articles aimed at Compex users and potential users such as physicians, physiotherapists and others. The field of electrotherapy has recently undergone significant changes of which the different users and potential users are still largely unaware.

Changes and improvements in electrotherapy are so numerous that this discipline seems to be a new concept that can only be effective if applied correctly and efficiently with sophisticated equipment. The purpose of these articles is to set out what is a new concept to potential Compex users and to provide explanations and data for those already working with this equipment, in order to allow optimum utilization of their Compex device using current knowledge and scientific work.

Electrostimulation is a technique consisting in creating action potentials in stimulable cells (neuro- or muscular cells) with an electric pulse.

There is a difference in the potential between the external and internal side of a nerve cell membrane, which is called the resting membrane potential. It is on average -70 millivolts. The internal side of the membrane is negative. In order to excite the membrane of the nerve cell, i.e. create an action potential, the resting potential only needs to drop to -50 mV, the threshold. Once the threshold is reached, the membrane moves from a rest stage to the action stage. This action potential will then run along the nerve cell membranes and either transmit a pulse to the muscles to create a contraction, or transmit a message from the body to the brain (touch, pain, sensations, etc.).

In fact, electrostimulation consists in reducing the membrane resting potential to the threshold, by means of an electrical current applied through the skin. The first obvious question is: what kind of current should be applied? The ideal current is clearly one that will allow for a reduction in the difference in potential to trigger an action potential in the most comfortable way for the patient. In other words, the electrical parameters have to remain minimal (with the lowest intensity, energy and duration possible).

In order to define this ideal current, it is necessary to review the fundamental rules of electrostimulation as summarized in this manual. The following information defines the optimum current, based on the research described in this paper.

As the turn of this century, famous physiologists such as Weiss, Hoorweg, du Bois Reymond and Lapicque discovered the fundamental rules of electrostimulation and its mathematical expression.
Based on Hoorweg’s research, Weiss [a physician and physiologist in Paris] discovered the importance of the quantity of electrical charges created by the stimulation current. His experiments clearly demonstrated that, in order to obtain an excitation, it is not the shape of the pulse, but rather the quantity of electrical charges that counts (this rule is valid if the total duration of the electrical pulse remains the same). In other words, if a quantity of electricity is determined to reach the threshold level (expressed in electrical charges), this value remains equal for any given shape of electrical pulse providing that the overall pulse length remains the same.

Author’s note: Mr. Weiss is to be congratulated for his experiments as he had neither an oscillograph nor electronic equipment to produce or measure pulses. He produced the electrical current in a very precise way by firing a bullet through conductive sheets of paper. This bullet would open and then close the electrical circuit. He could regulate the duration of the pulse by varying the distance between the papers, the speed of the bullet remaining stable.

The conclusion of these experiments indicated that there is a linear relationship between the quantity of charges necessary to reach the threshold level and the duration of the pulse (fig. 2).

As a reminder:
The quantity of electrical charge (Q) provided by an electrical current with a given intensity (I), during a given period of time (t) is calculated the following way:

\[ Q = I \times t \]

Linear relationship between the duration of the electrical pulse applied and the quantity of electrical charges necessary to reach the threshold:

\[ Q = q + it \]

Weiss discovered the mathematical relationship between the duration of the electrical pulse and the quantity of current necessary to produce a stimulation, i.e. to reach the threshold level. This relationship has been named “The Fundamental Formula”.

\[ Q = q + it \]

where \( Q \) = The total quantity of current necessary to reach the threshold level. It is also the quantity of electrical charges provided by the stimulation current. The value of Q is given by \( I \times t \), I being the intensity of the electrical current, \( t \) being the duration of the pulse.

\( t \) = The duration of the pulse.
\( i \) = An experimentally determined coefficient that corresponds to an electrical current (intensity).
\( q \) = An experimentally determined coefficient the size of which corresponds to a certain quantity of electrical charges. \( q \) corresponds to the value at the intersection of the line with the y axis; it can be calculated like the Q value when \( t = 0 \).

Lapicque, who is a well-known electrophysiologist, did not discover a new fundamental formula of electrostimulation, but performed numerous experiments that confirmed this fundamental formula. He also defined it differently mathematically and deduced certain characteristic values of excitability, the rheobase and the Chronaxy. These two new terms have an important physiological significance.

Lapicque developed the fundamental formula the following way:

\[ Q = q + it \]

and \[ Q = It \]

\( I \) = intensity of the stimulation current
\( t \) = duration of the pulse

in other words: \[ It = q + it \]

By dividing both terms by \( t \), Lapicque got:

\[ I = \frac{q}{t} + i \]

This is the relationship between the intensity of the current and the duration necessary to reach the threshold (fig. 3).
Lapicque defined the chronaxy of the nerve as the minimum duration of the pulse necessary to obtain stimulation at an intensity level corresponding to twice the value of the rheobase. He noticed that this chronaxy is a constant pulse duration that characterizes the excitability of a nerve and that its value is \( i \) when \( I = 2 \text{Rh} \).

The following basic definitions can be deduced from this function:

a) The Rheobase (Rh): the minimum intensity necessary for stimulation with an infinite duration of pulse

\[
\text{Rh} = i
\]

b) The Chronaxy (tch): the minimum time necessary to stimulate a nerve at an intensity that is twice the rheobase

\[
tch = \frac{q}{i}
\]

This minimum intensity (the so-called Rheobase) necessary to stimulate a nerve corresponds to the coefficient \( i \) in Weiss’ formula, which corresponds to an electrical intensity.

We can note here that the chronaxy can be calculated mathematically starting with the Weiss formula. This can be seen in figure 4.

**Electrical stimulation**, which consists in the reduction of the resting potential to reach the threshold by means of an electrical current, is a phenomenon that meets a fundamental rule of electrophysiology. This rule indicates that:

1. It is the quantity of electrical charges provided by the current that is the most important factor in stimulation.

   In electrostimulation, we have to think in terms of quantity of current, which is the product of the intensity of the current multiplied by the duration of the electrical pulse (\( I \times t \)).

2. This quantity of current responds to a fundamental formula:

\[
Q = q + it
\]

Where \( Q \) is a linear function of time.

Lapicque expresses this formula in another way, with the relationship

\[
\text{Intensity} - \text{Duration of the pulses}: I = \frac{q}{t} + i
\]

The following basic definitions can be deduced from this function:

a) The Rheobase (Rh): the minimum intensity necessary for stimulation with an infinite duration of pulse

\[
\text{Rh} = i
\]

b) The Chronaxy (tch): the minimum time necessary to stimulate a nerve at an intensity that is twice the rheobase

\[
tch = \frac{q}{i}
\]

**B: Summary**

1. It is the quantity of electrical charges provided by the current that is the most important factor in stimulation.

   In electrostimulation, we have to think in terms of quantity of current, which is the product of the intensity of the current multiplied by the duration of the electrical pulse (\( I \times t \)).

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\]

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**THE OPTIMAL CURRENT**

**A: Introduction**

In order to better understand this section describing the optimal stimulation energies, we recommend that the reader reads the section entitled "The fundamental rules of electrostimulation".

The optimal current can be described as the current capable of reducing the resting potential to the threshold level in accordance with Weiss' rules and with maximum comfort for the patient. This latter condition is fulfilled by minimizing the electrical parameters, i.e. the electrical intensity \(I\), the pulse duration \(t\) and the electrical energy \(W\).

This being said, we will now determine the characteristics of the optimal current.

**B: Characteristics of the optimal current**

1. **Electrical wave produced by current generator**

   We can assert that a current generator must be used for the following reasons:
   
   - The first point demonstrated by Weiss is the importance of the quantity of electrical charges provided by the current. This quantity can only be controlled by a current generator.
   - Only a current generator can ensure stable and reproducible conditions in spite of the variations in skin resistance.
   - Only a current generator can maintain a constant current wave shape throughout the process of the current penetrating through the skin and the soft tissues.

2. **Type of establishment of the electrical pulse**

   Weiss' rule indicates that: 
   \[ Q = i \cdot t + q \]
   
   therefore \( t = (Q - q) / i \)
   
   with \( i = \text{Rheobase} \)
   
   \( i \) is a current resisting against the stimulation current \( I \)

   As long as the current \( I \) is less than \( i \) (Rheobase), it remains useless. It cannot modify the resting potential because there is no accumulation of electrical charges at the level of the excitable membrane (fig. 1).

   

3. **Shape of the stimulation pulse**

   When the electrical current has vertically reached an intensity greater than the rheobase, what characteristics does it require in order to provide the patient with maximum comfort?

   \( I \) has to provide, with a minimum intensity, in a total time of \( t \), the quantity of electrical charges \( Q = I \cdot t \) necessary to trigger an action potential.

   Since \( Q = I \cdot t \), it is clear that a rectangular wave shape is capable of providing the maximum quantity of charges \( Q \) with the minimum intensity \( I \) (fig. 3).

**Figure 1**

Analysis of the different forms of establishing electrical current

\[ t_1, t_2, t_3 \] are useless installation times since \( I \) is less than \( i \)

**Figure 2**

The stimulation current established vertically with an intensity greater than \( i \) (Rheobase) immediately produces an accumulation of charges modifying the resting potential.

**Figure 3**

Comparison between different pulse shapes of equal duration, established vertically and providing the same quantity of electrical charges, i.e. corresponding graphically to identical areas
In order to provide the same electrical charges with pulses other than rectangles, greater intensities have to be used at one point in time. There is a risk that these greater intensities will be a source of pain for patients.

4 Duration of the rectangular pulse

This is a well delimited duration of pulse. The Weiss rules apply for pulse durations close to the excitation constant \( k \).

In the case of motoneurons, the margin pulse duration is between 100 and 3000 microseconds.

The third electrical factor to be minimized for more comfortable stimulation is the electrical energy \( W \). We know that the electrical energy is given by the formula \( W = I^2 \cdot t \cdot R \) where:

- \( I \) : intensity of the current
- \( t \) : duration of application
- \( R \) : skin resistance

With the Weiss or Lapicque relationship, we have

\[
I = \frac{q}{t} + i
\]

and we can replace \( I \) by its value in the energy equation.

We get \( W = \left( \frac{q}{t} + i + i^2 \right) t \cdot R \)

and by developing the formula: \( W = \left( \frac{q^2}{t} + 2qi + i^2 \right) t \cdot R \).

When \( t \rightarrow 0 \), \( W \rightarrow \infty \)

When \( t \rightarrow \infty \), \( W \rightarrow \infty \)

The shape of this curve is given in figure 4.

The electrical energy going through the skin and the tissues is minimum, with a pulse duration that can be found out by calculating the derivative of the curve at its lowest point (fig. 6).

The derivative of \( W = \left( \frac{q^2}{t} + 2qi + i^2 \right) t \cdot R \) is

\[
\frac{dw}{dt} = \left( -q^2 t^{-2} + 2qi t^{-1} + i^2 \right) R
\]

The derivative is the slope of the tangent at any given point on the curve.

At the lowest part of the curve, the value of the derivative is 0 since the tangent is parallel to the abscissa axis.

It is therefore possible to make the following statement:

for \( W \) minimum: \( \frac{dw}{dt} = \left( -q^2 t^{-2} + 2qi t^{-1} + i^2 \right) R = 0 \)

therefore \( q^2 t^{-2} \cdot R = i^2 \cdot R - i^2 \cdot R = q^2 \cdot t^{-2} \cdot \frac{q}{R} \)

As has been seen above, the value of \( R \) has no influence on the determination of the pulse duration corresponding to the minimal energy.

The electrical energy going through the skin and the soft tissues is minimum when the duration of the pulse is equal to \( \frac{q}{i} \), which corresponds to the value of the Chronaxy.

This is the reason why, at the turn of this century, the pioneers of electrophysiology chose the Chronaxy as the characteristic value of the excitability of a tissue, independent of the variations in skin resistance.

In order to reduce the electrical energy to its minimum value, the duration of the rectangular pulse must be equal to the Chronaxy of the nerve we want to excite.
5 Compensation for the rectangular pulse

Each time we want to produce an excitation, we send a rectangular pulse with a duration equal to the chronaxy of the nerve structure we intend to excite. The repetition of the phenomenon will be obtained by the repetition of the electrical pulse.

The repetition of the pulses, if they are not compensated for, will create a polarization phenomenon, since the electrical mean is no longer equal to 0 (fig. 7).

This polarized current is equivalent to a constant current equal to the mean intensity. The application of such current to the skin has the same disadvantages as a galvanic current, with a risk of skin burns [in all cases] and sometimes ionization phenomena if there are metal materials on the bones.

In order to resolve the polarization phenomenon, the positive pulse has to be compensated for by a negative one. Both pulses need to have the same quantity of electrical charge. On a graph, they have equal areas (fig. 8). In this case, the electrical mean is equal to 0, the current is therefore totally compensated for and the risks of polarization are eliminated.

The electrical current capable of producing an excitation (action potential) with maximum comfort for the patient can be called the optimal current. This electrical pulse must have the following characteristics:

1. Constant current pulses i.e. produced by a current generator.
2. Vertical establishment: Immediate efficacy and reduction in the application time of the current.
3. Rectangular shape in order to stimulate with the lowest electrical intensity possible.
4. Duration of the electrical pulse equal to the chronaxy of the nerve in order to reduce the electrical energy to a minimum.
5. Compensated pulse with electrical mean equal to 0 in order to avoid the negative side effects linked to polarization.
### A: Introduction

An electrical current applied to a living excitable tissue can modify its resting potential \(V_0\).

The modified potential is then called \(V\).

If the variation in the local potential is sufficiently high, a phenomenon of excitation will occur. This is known as the action potential. The value that the local potential \(V\) must reach in order to trigger an action potential is called the threshold level \(S_0\).

If the electrical current is stopped, the local potential \(V\), which had been modified by the electrical current into the \(V\) position, will go back to its initial position \(V_0\). This return to normal resting conditions does not happen instantly but gradually. It reacts very much like a capacitor. The mathematical rule for the return of \(V\) to its initial position is:

\[
\frac{dV}{dt} = \frac{V_0}{k} (1)
\]

Where \(k\) has the dimensions of time and is the excitation time constant. The constant \(k\) characterizes the tendency of the local potential to return to its initial value when the neuron is no longer subject to the stimulation current.

While the current is passing through, the local potential \(V\) does not increase instantaneously but in an exponential way, like the charge in a capacitor, with \(k\) as a fixed time constant value. This constant therefore defines the tendency that a neuron has to oppose or resist the variation in potential created by the stimulation current. Again this phenomenon is very similar to those observed in a capacitor.

\(k\) does not depend either on the shape or the characteristics of the stimulation current. It is inherent to the neuron itself and expresses the time element and its tendency to bring the potential back to its resting potential.

The critical value that \(V\) has reached in order to trigger the action potential (threshold level, \(S_0\)) has a constant value only if the stimulation time remains extremely short. If the duration of the stimulation current increases, then the threshold level \(S_0\) will also increase. This phenomenon is demonstrated by the well-known fact that a current that is established slowly has to reach a higher level in order to create comparable stimulation to a current established immediately.

This increase in the threshold level is called accommodation. Accommodation is an increase in the threshold as a result of the modification of the local potential by the electrical current. The increase in threshold level is not instantaneous. It progresses at a certain speed over a period of time. A second time factor \(\lambda\) intervenes in the electrical stimulation process. This factor defines the pace of the increase in the threshold level \(S\).

The question in the stimulation process is: Will \(S\) have enough time to get away?

### B: Stimulation process with a constant current

In order to simplify, we will examine here the stimulation phenomenon produced by a constant current. The same kind of study can be done with exponential, sinusoidal, linear or progressive currents or currents of any other shape. The results would be similar.

When the local potential \(V\) is brought back to its resting value \(V_0\), \(S\) returns exponentially to its initial value \(S_0\), with \(\lambda\) as a time constant in accordance with the mathematical law:

\[
\frac{ds}{dt} = \frac{S - S_0}{\lambda} (2)
\]

This equation is to \(S\) as equation (1) is to \(V\), with \(\lambda\) replacing \(k\).

The electrical charges provided by the current going through the neuron modify the potential of the membrane. They produce a local potential \(V\) which in turn increases the threshold level \(S\). The excitation occurs if the quantity of electrical charges is sufficient in order to increase the local potential to the value of the threshold level, i.e. \(V = S\) (fig. 1).

![Figure 1](image)

The stimulation process is therefore determined by two time constants:

- \(k\): the stimulation constant
- \(\lambda\): the accommodation constant.

These two variables are independent of each other. It is possible to experimentally modify the value of \(\lambda\) independently of \(k\) by changing the ionic concentration of \(\text{Ca}^2+\) in the medium. These two constants have different values, but \(\lambda\) is always much greater (100 to 200 times) than \(\lambda\). In the case of human motoneurons, the average values are 300 microseconds for \(k\) and 50 milliseconds for \(\lambda\).

In order for the stimulation process to happen, \(k\) must be smaller than \(\lambda\). In this way the local potential \(V\) can increase more rapidly than the threshold level \(S\) and so catches it up. If \(k\) was greater than \(\lambda\), the threshold level would increase faster than the local potential, and no stimulation would ever happen.

Let’s take for example the following values:

- \(k = 1\) msec.
- \(\lambda = 50\) msec.

The question in the stimulation process is: will \(V\) catch up with \(S\) or will \(S\) have enough time to get away?
The local potential \( V \) starts at 0 and increases exponentially in accordance with the below formula, with a final value depending on the intensity of the current.

\[
V = V_0 + V_{\text{max}} \left(1 - e^{-\frac{t}{\tau}}\right)
\]

The threshold \( S \) starts at \( S_0 \), and increases with a more complicated curve. The final value of the increase will depend on the stable value of \( V \) in the event that stimulation has not occurred in the meantime.

In figure 2a, the intensity of the current is set so that \( V \) would reach the threshold level \( S \). But in the meantime the threshold level has increased and stimulation will not therefore happen. In order that \( V \) reaches the real threshold value, the current has to be 8% more intense.

This is shown in figure 2b, where the threshold has just been reached in 4 milliseconds (indicated by the arrow), which is the principal useful stimulation time.

In figure 2c, a stronger current with a value of 1.2 is applied, and \( V \) thus reaches the threshold level in 1.85 milliseconds. In figure 2d an even stronger current (value = 2) is applied, and the threshold is thus reached after 0.7 msec.

The threshold \( S \) starts at \( S_0 \), and increases with a more complicated curve. The final value of the increase will depend on the stable value of \( V \) in the event that stimulation has not occurred in the meantime.

In figure 3, the intensity-duration relationship has to be reexamined as the rheobase does not keep its value \( I_0 \). It increases to a value \( I_1 \) determined by the accommodation. The real rheobase \( Io \) is linked to the observed rheobase \( I_1 \) by the following relationship:

\[
\frac{I_1}{I_0} = \left(\frac{\lambda}{k}\right)^{1/0}
\]

This figure shows the intensity-duration relationship, which indicates the time necessary for \( V \) to reach \( S \) with different current intensities. The time decreases when the intensity is increased (fig. 3).

This relationship applies for a very short stimulation time in comparison with the accommodation constant. The accommodation phenomenon can be neglected and the excitation occurs when \( V = S \). Therefore, in the intensity-duration relationship, only the constant \( k \) is really important. This is true if the duration of the currents has values close to \( \lambda \) (0.2 to 3 microseconds).

If the duration of the applied currents was longer, the threshold level would increase. Then the stimulation process would only start when \( V = S \). In this case the intensity-duration relationship has to be reexamined.

C: Stimulation by any other shape of current

It is possible to determine the equation for the local potential \( V \) and to calculate its value at any given point in time with any given shape of current. The same is true for the threshold level. These formulae require a high level of knowledge of basic mathematics and come under the field of specialist electrophysiology. We therefore believe that it is not the purpose of this article to expand upon them. However we can emphasize that it is possible to study the process of excitation by any shape and duration of current with the help of these equations, which give the \( V \) and \( S \) variations.

D: Chronaxy-excitation constant relationship

The chronaxy is a characteristic value of the excitability of a tissue. It is interesting to determine the relationship linking it to another characteristic factor, \( k \).

The chronaxy is the time necessary to obtain excitation with a current twice Rheobase \( 2I_0 \). It is therefore simple to find a relationship between the chronaxy and the excitation constant based on the formula linking intensity and duration.

\[
\frac{t}{I_0} = \frac{1}{1 - e^{-\frac{t}{k}}}
\]

where

\[
t = \ln(2)k
\]

in other words, Chronaxy = 0.693 \( k \).

The chronaxy is a characteristic value of the excitability of a tissue. It is interesting to determine the relationship linking it to another characteristic factor, \( k \).

The chronaxy is the time necessary to obtain excitation with a current twice Rheobase \( 2I_0 \). It is therefore simple to find a relationship between the chronaxy and the excitation constant based on the formula linking intensity and duration.

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\frac{t}{I_0} = \frac{1}{1 - e^{-\frac{t}{k}}}
\]

where

\[
t = \ln(2)k
\]

in other words, Chronaxy = 0.693 \( k \).
E: Hydraulic model of the excitation phenomenon

It is possible to use a hydraulic model corresponding exactly to the excitation phenomenon. This model allows for a better understanding of the excitation and can be used to illustrate the changes in the local potential and the threshold level under the effect of currents of different duration, intensity and shape [fig. 4].

Water flows from tank A to tank B by means of the pump P. The pump can be likened to the stimulator (current generator). The flow of water corresponds to the intensity of the stimulation current. The volume of water moved from A to B corresponds to the quantity of electrical charges. The water level in tank B reaches a certain level representing the value of the potential of the membrane ($V_0$), in the resting position and $V$ local potential). The threshold level is determined by a point D on the float C. Stimulation takes place when the level D in tank B reaches the level D on the float.

When the pump P injects liquid from tank A to tank B, therefore increasing the level V, some of the liquid goes back to A through a tap $k$ representing the excitation constant $k$. In tank B, the float C is linked to a water piston $i$ that works by means of the level of liquid in tank F. The latter is linked to B by a tap $\lambda$ representing the accommodation constant $\lambda$.

**TWO EXAMPLES**

A - Currents of long duration and low intensity

In order that the level V reaches the threshold level D, a certain volume of water is necessary [likened to a certain quantity of electrical charges]. If this water is provided slowly by the pump (current of long duration and low intensity), some of the water has the time to go through I, and to raise the water piston $E$, therefore increasing the threshold level [accommodation]. Thus, the quantity of liquid [the current] will have to be greater as the level V has to reach a point D higher up. But a larger amount of liquid returns from tank B to tank A through the tap $K$. It is easy to understand that all these extra quantities that P has to transport indicate that we have an unfavourable stimulation current.

B - Currents of shorter duration and higher intensity

The durations determined here are close to the excitation constant value $k$. In this case, the float is high and the necessary action of the pump is short. Almost no liquid will have gone through tap L, the float will not rise and the accommodation phenomenon is reduced to almost nothing. Nevertheless, a certain quantity of water returns through $K$ and has to be compensated for by P.

The Weiss rules apply to this kind of current (please refer to the section entitled Fundamental Rules of Electrostimulation).

$$Q = q + it \text{ or } It = q + it$$

$Q$ is the total quantity of liquid provided by P with $I$ = intensity of the stimulation current and $t$ = duration of the stimulation

$q$ is the volume of liquid separating $V_0$ and $S_0$, i.e. the quantity of charges that would have to be provided if there was no tap $k$. This would mean that the potential of the membrane would vary instantaneously and not exponentially in accordance with the time constant $k$.

$it$ is the quantity of liquid that returns from B to A through the tap $k$. 
Neurostimulation programmes
When, after an operation or a bone fracture, a limb or a section thereof is immobilized, the muscles of this part of the body suffer rapidly from disuse atrophy.

This rapid decrease of muscle volume is mainly due to a reflex inhibition phenomenon and a total absence of any type of exercise. It is important to note that this atrophy phenomenon concentrates on the slow twitch muscle fibres (type I).

In order to prevent atrophy, NMES has to compensate for the total inactivity of the muscle by reproducing a series of contractions comparable to the normal level of activity of the muscle during a day. The treatment concentrates mainly on the usual functioning frequencies of the slow twitch muscle fibres. Furthermore, to compensate for total inactivity of the immobilized muscle and to combat the postoperative or traumatic inhibition reflex, the treatment has to be relatively long.

The following is necessary to prevent disuse atrophy:

1. Work in monopolar mode with a large indifferent electrode (negative) and a smaller active one (positive) placed on the motor point of the muscle to be stimulated.

2. Use of bipolar symmetrically compensated pulses. These allow maximum space recruitment of the motor units. The contraction is therefore the strongest possible for a given level of electrical current.

3. Use of a pulse width corresponding to the chronaxies of the nerve of the stimulated muscles, to offer patients an optimum level of comfort. In the context of these standard programmes, we offer 7 different pulse widths. The appropriate pulse width for the patient can be determined using m3.

4. Use of frequencies corresponding to the functioning frequencies of the slow twitch muscle fibres.

5. Two levels of intensity are provided to enable the modification of treatment according to the results obtained with the patient.

6. The utilization of maximum energies is seldom possible because of the conditions imposed by the cast or the post-operation period. Nevertheless, the therapist has to make sure that the energy level is sufficient, in order to achieve maximum space recruitment, and therefore to prevent too great a number of motor units from remaining completely inactive.
7 Working with maximum tolerable energy is one of the key factors for the effectiveness of most electrostimulation programmes. The higher the stimulation energy, the greater the number of muscular fibres that are working and, therefore, the greater the progress that will be made. In many clinical situations, a painful syndrome, of variable intensity, affects the regions near the muscle group to be stimulated. This pain may prevent the patient from working with the high stimulation energy required.

Compex 3 enables this programme to be combined with a TENS programme. This combination is optional and must be activated in advance by the user.

- Channels 1 and 2: muscular work imposed by the Prevention of disuse atrophy programme.
- Channels 3 and 4: TENS programme.

When this combination has been activated, the message TENS appears on the screen for the channel or channels on which this treatment is active.

The practical rules of use are the usual rules for muscular electrostimulation (muscular work) and TENS type analgesic treatment programmes. However, they must be adapted with care to the distribution of the stimulation currents.

- Channels 1 and 2: muscular work imposed by the Prevention of disuse atrophy programme.
  - Electrodes positioned as indicated according to the muscle to be stimulated.
  - Maximum tolerable stimulation energy.
- Channels 3 and 4: TENS programme.
  - Two or four large electrodes placed on the painful region.
  - Sufficient stimulation energy to produce a very clear tingling sensation.
- Two or four large electrodes placed on the painful region.
  - Maximum tolerable stimulation energy.

The practical rules of use are the usual rules for muscular electrostimulation (muscular work) and TENS type analgesic treatment programmes. However, they must be adapted with care to the distribution of the stimulation currents.

### Treatment of disuse atrophy

A normally innervated muscle, after a long period of immobilization or diminished movement, suffers from a decrease in its volume. This decrease depends on the degree and duration of the functional deficit.

Slow twitch fibres (type I) are particularly affected by this disuse atrophy. It is therefore logical to use frequencies creating a tetanic contraction of the type I fibres to impose a significant work load on them. This work load will enable rapid recuperation of volume, faster than conventional methods of reeducation. It is also logical to increase the quantity of work imposed on the muscle by changing some parameters of the programme after a certain period of time, generally after one week of treatment.

To get these results, the following is necessary:

1 Work in monopolar mode with a large indifferent electrode (negative) and a smaller active one (positive) placed on the motor point of the muscle to be stimulated.
2 Use of bipolar symmetrically compensated pulses. These allow maximum space recruitment of the motor units. The contraction is then the strongest possible for a given level of electrical current.
3 Use of a pulse width corresponding to the chronaxies of the motor nerve of the stimulated muscles, to offer patients an optimum level of comfort. In the context of these standard programmes, we offer 7 different pulse widths. The appropriate pulse width for the patient can be determined using H-reflex.
4 Use of frequencies producing tetanization of the type I fibres as given in the literature, in order to obtain maximum force of contraction.
5 Use of the maximum possible stimulation energies. The first and second treatment will help the patient to get used to the treatment method by increasing every 3 to 4 contractions (the patient can always tolerate higher energy levels if desired).
6 Working with the maximum tolerable energy is one of the key factors for the effectiveness of most electrostimulation programmes. The greater the stimulation energy every, the greater the number of muscular fibres that are working and, therefore, the greater the progress that will be made.

In many clinical situations, a painful syndrome of variable intensity affects the regions near the muscle group to be

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### Parameters of the Prevention of disuse atrophy programme, level 1

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Warm-up</th>
<th>Contraction</th>
<th>Active rest</th>
<th>Final recovery phase</th>
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</thead>
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<tr>
<td>Frequency</td>
<td>6 Hz</td>
<td>30 Hz</td>
<td>4 Hz</td>
<td>3 Hz</td>
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<tr>
<td>Duration of ramp up</td>
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<td>1.5 s</td>
<td>1.5 s</td>
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<td>Duration of phase</td>
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<td>Duration of ramp down</td>
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### Parameters of the Prevention of disuse atrophy programme, level 2

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<th>Parameters</th>
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<th>Contraction</th>
<th>Active rest</th>
<th>Final recovery phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
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<td>4 Hz</td>
<td>3 Hz</td>
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<tr>
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<td>1.5 s</td>
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<tr>
<td>Duration of phase</td>
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<td>Duration of ramp down</td>
<td>2 s</td>
<td>0.75 s</td>
<td>0.5 s</td>
<td>3 s</td>
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</tbody>
</table>
Muscular reinforcement

In this section muscular reinforcement is used for strengthening healthy muscles. These muscles have a normal or almost normal volume at the beginning of the treatment. Therefore the described protocols are not suitable for the prevention or treatment of disuse atrophy. For instance, they are used to:

1. Obtain increased strength in previously disuse atrophied muscles that have regained their volume through disuse atrophy treatment programmes. Increased strength can also be obtained in muscles that, following an operation or a period of immobilization, have retained almost normal trophicity by means of electrostimulation with disuse atrophy programmes.
2. Strengthen the lateral peroneal muscles for the treatment and prevention of ankle sprains.
3. Strengthen the shoulder muscles used to control the scapulo-humeral joint in order to treat and prevent shoulder dislocations.

To get these results, the following is necessary:

1. Work in monopolar mode with a large indifferent electrode (negative) and a smaller active one (positive) placed on the motor point of the muscle to be stimulated.
2. Use of bipolar symmetrically compensated pulses. These allow for maximum space recruitment of the motor units. The contraction is then the strongest possible for a given level of electrical current.
3. Use of an pulse width corresponding to the chronaxies of the muscles stimulated, to offer patients an optimum level of comfort. In the context of these standard programmes, we offer 7 different pulse widths. The appropriate pulse width for the patient can be determined using Bioman.
4. Use of frequencies creating tetanic contractions of the fast twitch muscle fibres (type IIb), which are the fibres of strength and speed.
5. Use of maximum stimulation energies. The first and the second treatment will help familiarize the patient with the treatment method, the stimulation energy level being increased every 3 or 4 contractions. The patient can resist higher stimulation energies if desired. An intensity of 3/4 of the scale is not unusual. The therapist plays an important role in motivating and convincing the patient to use high intensities with the strongest contractions possible.

A table is provided for each programme, outlining the parameters and settings required:

<table>
<thead>
<tr>
<th>Parameters of the Disuse Atrophy programme, level 1</th>
<th>Warm-up</th>
<th>Contraction</th>
<th>Active rest</th>
<th>Final recovery phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>6 Hz</td>
<td>35 Hz</td>
<td>4 Hz</td>
<td>3 Hz</td>
</tr>
<tr>
<td>Duration of ramp up</td>
<td>1.5 s</td>
<td>1.5 s</td>
<td>0.5 s</td>
<td>1.5 s</td>
</tr>
<tr>
<td>Duration of phase</td>
<td>2 min</td>
<td>6 s</td>
<td>7 s</td>
<td>3 min</td>
</tr>
<tr>
<td>Duration of ramp down</td>
<td>2 s</td>
<td>0.75 s</td>
<td>0.5 s</td>
<td>3 s</td>
</tr>
<tr>
<td>Frequency</td>
<td>6 Hz</td>
<td>45 Hz</td>
<td>4 Hz</td>
<td>3 Hz</td>
</tr>
<tr>
<td>Duration of ramp up</td>
<td>1.5 s</td>
<td>1.5 s</td>
<td>0.5 s</td>
<td>1.5 s</td>
</tr>
<tr>
<td>Duration of phase</td>
<td>2 min</td>
<td>6 s</td>
<td>5 s</td>
<td>3 min</td>
</tr>
<tr>
<td>Duration of ramp down</td>
<td>2 s</td>
<td>0.75 s</td>
<td>0.5 s</td>
<td>3 s</td>
</tr>
</tbody>
</table>
Neurostimulation programs

6

Working with the maximum tolerable energy is one of the key factors for the effectiveness of most electrostimulation programmes. The greater the stimulation energy, the greater the number of muscular fibres that are working and, therefore, the greater the progress that will be made.

In many clinical situations, a painful syndrome of variable intensity affects the regions near the muscle group to be stimulated. This pain may prevent the patient from working with the high stimulation energies required. When this combination has been activated, the message “TENS” appears on the screen for the channel or channels on which this treatment is active. The practical rules of use are the usual rules of muscular electrostimulation (muscular work) and TENS type analgesic treatment programmes. However, they must be adapted with care to the distribution of the stimulation currents.

- Channels 1 and 2: muscular work imposed by the Reinforcement programme.
- Channels 3 and 4: TENS programme.

When this combination has been activated, the TENS combination has been chosen, the RI functions (related to the exception of the RI functions) are no longer accessible. In you want the RI functions to be active, you must make sure that the cable equipped with the RI system is positioned on channel 1 or 2.

7

There are two levels of intensity for this treatment. Level 1 is for the first two weeks and level 2 is for subsequent weeks.

Each programme is made up of three sequences of stimulation that automatically run on from one another:
- The 1st sequence consists of a 2-min. warm-up at a frequency of 6 Hz.
- The second is the work sequence: alternate contractions and rest: tetanic contractions at fast twitch muscle fibre tetanization frequencies, followed by active rest periods that last at least twice as long as the contraction. During this rest period, a very low frequency, known as the relaxation frequency (4 Hz), is used to increase the flow of blood and therefore improve recovery between two tetanic contractions.
- The 3rd is relaxation, which allows, after the work sequence, for improved relaxation of the muscle with faster elimination of metabolites; it diminishes the phenomenon of contracture and muscle ache and lasts 3 min.

- Channels 3 and 4: TENS programme.
- Two or four large electrodes placed on the painful region.
- Sufficient stimulation energy to produce a very clear tingling sensation.

If the TENS combination has been chosen, the RI functions – with the exception of the RI functions – are no longer accessible. In you want the RI function to be active, you must make sure that the cable equipped with the RI system is positioned on channel 1 or 2.

- Maximum tolerable stimulation energy.
- Sufficient stimulation energy to produce a clear tingling sensation.

<table>
<thead>
<tr>
<th>Parameters of the Reinforcement programme, level 1</th>
<th>Warm-up</th>
<th>Contraction</th>
<th>Active rest</th>
<th>Final recovery phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>6 Hz</td>
<td>75 Hz</td>
<td>4 Hz</td>
<td>3 Hz</td>
</tr>
<tr>
<td>Duration of ramp up</td>
<td>1.5 s</td>
<td>1.5 s</td>
<td>0.5 s</td>
<td>1.5 s</td>
</tr>
<tr>
<td>Duration of phase</td>
<td>2 min</td>
<td>4 s</td>
<td>10 s</td>
<td>3 min</td>
</tr>
<tr>
<td>Duration of ramp down</td>
<td>2 s</td>
<td>0.75 s</td>
<td>0.5 s</td>
<td>3 s</td>
</tr>
</tbody>
</table>

- Duration of ramp up: 1.5 s
- Duration of phase: 2 min
- Duration of ramp down: 2 s

- Duration of ramp up: 1.5 s
- Duration of phase: 4 s
- Duration of ramp down: 0.75 s

- Duration of ramp up: 0.5 s
- Duration of phase: 8 s
- Duration of ramp down: 0.5 s

- Duration of ramp up: 1.5 s
- Duration of phase: 3 min
- Duration of ramp down: 3 s

Orthopaedic surgery to the hip and, in particular, the fitting of a prosthesis, entails as a consequence the disuse atrophy of the buttock muscles with loss of strength and reduced active stability of the hip when standing on one leg and walking. In addition to exercise and active physiotherapy, neuromuscular electrical stimulation of the gluteus maximus and medius is a technique particularly indicated for the effective treatment of weakness in these muscles.

The sequences of very low frequencies such as those used in the warm-up, active rest between tetanic contractions and relaxation at the end of treatment sequences generate individualized muscle twitches that produce a vibration phenomenon in the prosthesis material.

The three Hip prosthesis programmes include the following: Disuse atrophy, level 1, Disuse atrophy, level 2 and Reinforcement, level 1 from which very low frequencies have been eliminated. The three Hip prosthesis programmes therefore only induce tetanic contraction phases separated by periods of complete rest.

Patellar syndrome

External subluxations of the kneecap are caused by an imbalance of the different muscular divisions of the quadriceps. A relative weakness of the vastus internus compared with the vastus externus may cause a lateral external displacement of the kneecap and excess pressure between the external femoral condyle and the underlying kneecap surface. Specific work on the vastus internus, which is possible only using electrostimulation, is the preferred treatment for this pathology.

Repeated traumas of the knee joint may entail cartilaginous lesions of the kneecap, entailing, as a consequence, pain of variable intensity and a phenomenon of reflex inhibition leading to a state of disuse atrophy of the entire quadriceps. This disuse atrophy affects the active stability of the joint and increases the pain. This vicious circle can be broken through electrostimulation of the quadriceps.
The parameters of the Patellar syndrome programmes are specially designed to avoid any muscle twitches that could cause unwanted effects on the kneecap (pain).

The three corresponding Patellar syndrome programmes include the following: Disuse atrophy, level 1, Disuse atrophy, level 2 and Reinforcement, level 1 from which very low frequencies have been eliminated.

The three Patellar syndrome programmes therefore only induce tetanic contraction phases separated by periods of complete rest.

**Neurostimulation programmes**

**Rotator cuff**

Due to their anatomical location, which makes them particularly exposed to significant stresses, tendopathies of the rotator cuff constitute a genuine public health problem. A study carried out in the United Kingdom in 1986 showed that 20% of the population had consulted a doctor with shoulder problems. There are many factors in the pathogenesis of these tendopathies: intrinsic factors (deficient vascularisation, structural anomaly in the collagen fibres, etc.) or extrinsic factors (mechanical overload, kinematic defects, etc.), which are sometimes combined, can be held responsible for this tendon dysfunction. Kinematic defects appear to play a decisive role, and are seen most often in the form of restricted range of movement, pain and functional constraint.

The restricted range of movement, highlighted by means of specific tests relates to flexion (antepulsion) and/or abduction. Restricted flexion shows anterosuperior misalignment, whilst restricted abduction shows a misalignment in medial rotation spin.

**ACL**

Ruptures of the anterior cruciate ligament of the knee (ACL) are among the most frequent accidents in sports traumatology. Surgery to repair the ACL has seen constant advances in recent decades, with considerable progress being made in recent traumatology. Surgery to repair the ACL is most frequent accidents in sports.

**Muscle lesion**

Excessive stretching or contraction of a muscle that creates tension greater than the mechanical possibilities of the muscular fibres, for example during abrupt or explosive movements, as well as a sprint start, can cause elongations, or even straining or muscular tears. This muscular lesion can be more or less significant, varying from a mere stretching of a small group of fibres up to a major tear, with bleeding and formation of a haematoma. In addition to the usual treatment that is used under these circumstances (immobilization, cold, compression, etc.), progressive treatment with electrostimulation facilitates a faster return to normal activity.

The Muscle lesion programme is designed to stimulate the muscle very gradually for several seconds, in order to prevent any premature stress on the muscle fibres.

**Parameters of the Muscle lesion programme**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Warm-up</th>
<th>Contraction</th>
<th>Active rest</th>
<th>Final recovery phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of ramp up</td>
<td>1.5 s</td>
<td>6 s</td>
<td>1.5 s</td>
<td>1.5 s</td>
</tr>
<tr>
<td>Duration of phase</td>
<td>2 min</td>
<td>3 s</td>
<td>10 s</td>
<td>3 min</td>
</tr>
<tr>
<td>Duration of ramp down</td>
<td>2 s</td>
<td>1.5 s</td>
<td>1.5 s</td>
<td>3 s</td>
</tr>
</tbody>
</table>

**Parameters of the ACL programme**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1st contraction</th>
<th>2nd contraction</th>
<th>Active rest</th>
</tr>
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<tbody>
<tr>
<td>Frequency</td>
<td>40 Hz</td>
<td>40 Hz</td>
<td>4 Hz</td>
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<tr>
<td>Duration of ramp up</td>
<td>3 s</td>
<td>1.5 s</td>
<td>0.5 s</td>
</tr>
<tr>
<td>Duration of phase</td>
<td>6 s</td>
<td>3 s</td>
<td>8 s</td>
</tr>
<tr>
<td>Duration of ramp down</td>
<td>0.75 s</td>
<td>0 s</td>
<td>0.5 s</td>
</tr>
</tbody>
</table>

The ACL programme is specifically designed for the treatment of ACL reconstruction by implementing an offset co-contraction session. Stimulation begins with hamstring contraction (channels 1 and 2) and, while they are contracted, the stimulation begins on the quadriceps (channels 3 and 4), thus preventing any risk of an anterior drawer.
**Motor point**

Electrostimulation subjects the muscles to work. The progress achieved depends on the kind of work to which the muscles are subjected, that is to say the programme chosen. The electrical pulses generated by these programmes are transmitted to the muscles (via the motor nerve) through self-adhesive electrodes. The positioning of the electrodes is one of the determining factors for ensuring a comfortable electrostimulation session.

It is therefore essential to devote special care to this aspect. The correct placement of the electrodes and the use of significant energy allow a large number of muscle fibres to work. The greater the energy, the greater the spatial involvement, that is to say the number of fibres working, and therefore the greater the number of fibres that make progress.

A stimulation lead wire consists of two electrodes:
- a positive electrode (+): red connection,
- a negative electrode (-): black connection.

The positive electrode must be fixed precisely on the motor point of the muscle. The motor points correspond to an extremely localized area where the motor nerve is more excitable. Although the location of the various motor points is now well known, there may nevertheless be variations, which can extend to several centimetres, between different individuals.

The **Motor point** programme, combined with the use of the motor point pen, allows the user to determine with great accuracy the exact location of the motor points for each individual and thus ensure the greatest effectiveness of the programmes.

It is advisable to use this programme before any initial muscular electrostimulation session. Once located, the motor points can be easily identified using a skin-marker pencil or in any other way, thus avoiding the need to repeat this process before each session.

**Pain relief**

Current studies have revealed that muscular twitches produced by a very low frequency (1 Hz) effectively relieve contraction phenomena or reduce the muscle tension at rest of the muscles stimulated in this way. This type of treatment, called tonolysis, is indicated for relief from acute contractions (torticollis, lumbago, etc.). It allows also for a reduction in the muscular tension at rest of certain muscles and thus facilitates manipulations.

With regard to spasticity, it is recommended that the specific programmes be used and stimulation be applied to the antagonist muscles of the spastic muscles.

To get these results, the following is necessary:

1. Work in monopolar mode with a large indifferent electrode (negative) and a smaller active one (positive), which is located on the area of contracture if appropriate or on the motor point of a muscle if the treatment is to reduce tension.

2. Use of bipolar symmetrically compensated pulses, so as to obtain the best space recruitment of contracted motor units.

3. Selection of pulse widths appropriate to the very low frequency and the chronaxy of the motor nerves of the muscle groups that are to be worked: 7 different zones are available for this programme.

4. Use of a very low frequency (1 Hz).

5. Use of a stimulation energies that are sufficient to activate the motor units affected by the contracture phenomenon.

6. An essential factor for their therapeutic effectiveness is the production of muscular twitches, which, in certain cases, may require the use of high stimulation energies. In some painful situations, especially if the patient is hyperalgesic, the essential progression of the stimulation energy can prove difficult. It is therefore useful to be able to combine these programmes with the TENS programme to produce more quickly and more comfortably the muscular twitches that are the key factor for effective treatment.

This combination is optional and must be activated in advance by the user. For all programmes, the two stimulation currents are always distributed as follows:

- **Channels 1 and 2:** Decontracture programme.
- **Channels 3 and 4:** TENS programme.

For all programmes, when this combination has been activated, the message "TENS" appears on the screen for the channel or channels on which this treatment is active.

The practical rules of use are the usual rules of muscular electrostimulation (muscular work) and TENS type analgesic treatment programmes. However, they must be adapted with care to the distribution of the stimulation currents.

- **Channels 1 and 2:** Decontracture programme.
  - Electrodes positioned as indicated according to the muscle to be stimulated.
  - Sufficient stimulation energy to obtain clearly visible muscular twitches.

- **Channels 3 and 4:** TENS programme.
  - Two or four large electrodes placed on the painful region.
  - Sufficient stimulation energy to produce a very clear tingling sensation.

If the TENS combination has been chosen, the \( \text{II} \) functions – with the exception of \( \text{II}-\text{max} \) – are no longer accessible. In you want the \( \text{II}-\text{max} \) function to be active, you must make sure that the cable equipped with the \( \text{II}-4 \) system is positioned on channel 1 or 2.

**Parameters of the Decontracture programme**

<table>
<thead>
<tr>
<th></th>
<th>Duration of ramp up</th>
<th>Treatment phase</th>
<th>Duration of ramp down</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decontracture programme</td>
<td>1.5 s</td>
<td>20 min</td>
<td>1.5 s</td>
<td>1 Hz</td>
</tr>
</tbody>
</table>

**TENS (gate control)**

The principle consists in generating a significant quantity of pulses on the tactile nerve system; the pain pulses are reduced at their point of entry into the posterior horn of the spinal cord.

The tactile sensitivity fibres must therefore be stimulated in the area of the cutaneous surface corresponding to the pain region.
Neurostimulation

To get these results, the following is necessary:

1 Bipolar work: 2 large electrodes with the same area for each channel, placed around or over the site of pain.

2 Use of biphasic symmetrically compensated pulses that are suitable for this kind of treatment in bipolar mode; in fact, there is no motor point to be considered, because the sensory receptors and the tactile nerves are present all over the skin’s surface.

3 Use of narrow pulse widths corresponding to the chronaxies of the touch-sensitive afferents, appropriate to the sensitivity of the patient: very sensitive, normal or not very sensitive.

4 Sending of the pulses with frequencies corresponding to the usual frequencies of the tactile nerves, i.e. 50 to 150 Hz.

5 There are several means to avoid accustomization. The first is the gradual increasing of the stimulation energies whenever the patient does not feel the paresthesia strongly enough. The other means is the continuous variation of the stimulation frequency. We therefore also offer a frequency Modulated TENS.

6 Make sure that the patient constantly feels a slight tickling. In no case should there be muscular stimulation, as the muscles must remain completely relaxed.

An essential factor for their therapeutic effectiveness is the production of muscular twitches, which, in certain cases, may require the use of high stimulation energy. In some painful situations, especially if the patient is hyperalgesic, the essential progression of the stimulation energies can prove difficult. It is therefore useful to be able to combine these programmes with the TENS programme to produce more quickly and more comfortably the muscular twitches that are the key factor for effective treatment.

For all programmes, when this combination has been activated, the message “TENS” appears on the screen for the channel or channels on which this treatment is active.

The practical rules of use are the usual rules of muscular electrostimulation (muscular work) and TENS type analgesic treatment programmes. However, they must be adapted with care to the distribution of the stimulation currents.

A study of publications concerning pain reduction by increasing the level of secretion of endorphins shows that the pulses have to be sufficient for excitation of type Aα δ fibres and obtain twitches of the muscles, thus a duration of 200 µs, corresponding to the average chronaxy of the Aα and Aδ fibres.

Endorphinic

In addition to the effect of increasing the production of endorphins at the level of the hypothalamus – which reveals the threshold of pain perception – there exists a local effect of primary importance. The five muscle twitches induced each second by the stimulation produce a very significant hyperaemia which drains the metabolites and free radicals that were accumulated in the chronically contracted muscular zones.

Endorphinic-type anodyne current combines an analgesic action by releasing endorphins and an increase in blood flow to the area. Anodyne current is suitable specifically for neck pain.

Parameters of the TENS programmes

<table>
<thead>
<tr>
<th>TENS programme</th>
<th>Duration of ramp up</th>
<th>Treatment phase</th>
<th>Duration of ramp down</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>1.5 s</td>
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<td>100 Hz</td>
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</table>

Parameters of the Endorphinic programme

<table>
<thead>
<tr>
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<th>Duration of ramp up</th>
<th>Treatment phase</th>
<th>Duration of ramp down</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.5 s</td>
<td>20 min</td>
<td>1.5 s</td>
<td>5 Hz</td>
</tr>
</tbody>
</table>
Neurostimulation programs

**Thoracic back pain**
- **Endorphinic**-type anodyne current, combines an analgesic action by releasing endorphins with an increase in blood flow to the area. Anodyne current is suitable specifically for pain in the upper back region.

**Low back pain**
- **Endorphinic**-type anodyne current, combining an analgesic action by releasing endorphins with an increase in blood flow to the area. Anodyne current is suitable specifically for pain in the lower back region.

**Lumbosciatica**
- **Endorphinic**-type anodyne current, combining an analgesic action by releasing endorphins with an increase in blood flow to the area. Anodyne current is suitable specifically for low back pain associated with irradiating pain in the buttocks, back of the thigh, behind the leg to the foot.

**Torticollis**
- **Decocontracture**-type anodyne current, reduces muscle tension. Anodyne current is suitable specifically for acute and sudden pain in the neck region.

**Lumbago**
- **Decocontracture**-type anodyne current, reduces muscle tension. Anodyne current is suitable specifically for acute and sudden pain in the lower back region.

**Epicondylitis**
- **Modulated TENS**-type anodyne current, blocking the transmission of pain at a medullar level (Gate Control phenomenon). Anodyne current is suitable specifically for persistent elbow pain.

**Arthralgia**
- **Modulated TENS**-type anodyne current, inhibits pain transmission at a spinal level (closure of the Pain Gate phenomenon), blocking the transmission of pain at a medullar level (Gate Control phenomenon). Anodyne current is suitable specifically for persistent pain in a joint, such as in arthritis and rheumatism.

**VASCULAR**
- **Modulated TENS**-type anodyne current, inhibits pain transmission at a spinal level (closure of the Pain Gate phenomenon), blocking the transmission of pain at a medullar level (Gate Control phenomenon).

**Thoracic back pain**
- **Endorphinic**-type anodyne current, combines an analgesic action by releasing endorphins with an increase in blood flow to the area. Anodyne current is suitable specifically for pain in the upper back region.

**Low back pain**
- **Endorphinic**-type anodyne current, combining an analgesic action by releasing endorphins with an increase in blood flow to the area. Anodyne current is suitable specifically for pain in the lower back region.

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- **Endorphinic**-type anodyne current, combining an analgesic action by releasing endorphins with an increase in blood flow to the area. Anodyne current is suitable specifically for low back pain associated with irradiating pain in the buttocks, back of the thigh, behind the leg to the foot.

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- **Decocontracture**-type anodyne current, reducing muscle tension. Anodyne current is suitable specifically for acute and sudden pain in the lower back region.

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- **Modulated TENS**-type anodyne current, blocking the transmission of pain at a medullar level (Gate Control phenomenon). Anodyne current is suitable specifically for persistent elbow pain.

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**VASCULAR**
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**Low back pain**
- **Endorphinic**-type anodyne current, combining an analgesic action by releasing endorphins with an increase in blood flow to the area. Anodyne current is suitable specifically for pain in the lower back region.

**Lumbosciatica**
- **Endorphinic**-type anodyne current, combining an analgesic action by releasing endorphins with an increase in blood flow to the area. Anodyne current is suitable specifically for low back pain associated with irradiating pain in the buttocks, back of the thigh, behind the leg to the foot.

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**VASCULAR**
- **Modulated TENS**-type anodyne current, inhibiting pain transmission at a spinal level (closure of the Pain Gate phenomenon), blocking the transmission of pain at a medullar level (Gate Control phenomenon). Anodyne current is suitable specifically for persistent pain in a joint, such as in arthritis and rheumatism.


**Parameters of the Heaey Legs programme**

<table>
<thead>
<tr>
<th>Sequence</th>
<th>1st sequence</th>
<th>2nd sequence</th>
<th>3rd sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>7 Hz</td>
<td>5 Hz</td>
<td>3 Hz</td>
</tr>
<tr>
<td>Duration of ramp up</td>
<td>1.5 s</td>
<td>1 s</td>
<td>1 s</td>
</tr>
<tr>
<td>Duration of phase</td>
<td>7 min</td>
<td>7 min</td>
<td>7 min</td>
</tr>
<tr>
<td>Duration of ramp down</td>
<td>0.5 s</td>
<td>0.5 s</td>
<td>8 s</td>
</tr>
</tbody>
</table>

**Venous insufficiency**

In venous insufficiency there is an organic attack on the wall of the veins that clinically takes the form of more or less large varicose veins. These are the result of a permanent expansion, secondary to the hyperpressure and stasis of the venous blood, to which is added progressive hypoxia of the intima [inner layer of the wall].

The deficiency of the valves of the deep veins and gastrocnemius muscles is behind this process. Their role of preventing regurgitation of venous blood is no longer guaranteed. The hydrostatic pressure is accentuated and muscle contractions are no longer sufficient to clear away the venous blood. It stagnates and swells the surface veins until varicose distensions are produced.

A stasis oedema is often associated with venous insufficiency, but not always. Moreover, this oedema can be present or absent in the same patient, depending on the time of day and how much time has been spent standing up. We must therefore distinguish between venous insufficiencies with and without oedema.

The implications for the nature of the electrical stimulation programme are different depending on whether there is or there is not an oedema associated with the varicose veins.

### 1. Venous insufficiency without oedema

On the one hand, electrical stimulation must allow for an increase in the general flow of blood (arterial as well as venous) so as to improve the circulation of the interstitial fluid and increase oxygenation of the tissues and of the intima of the veins. On the other hand, it is necessary to achieve maximum draining of the veins in order to combat the stasis. The increase in the arterial flow (and therefore capillary flow, and therefore venous flow) is achieved by means of the optimum low frequency for increase of flow, i.e. 8 Hz. Drainage of the deep veins is achieved by means of compression of the veins, which is brought about by tetanic contractions of the leg muscles. The programme therefore consists of short tetanic contractions of the leg muscles, separated by long active pauses to increase the flow.

**To carry out a Venous insufficiency without oedema session, we shall:**

1. **Work on monopolar mode:** A large indifferent [negative] electrode is placed crosswise under the popliteal hollow and two small active electrodes with positive polarity are placed one at the level of the lateral popliteal nerve (under the head of the patella) and the other at the level of the inside popliteal nerve (in the popliteal hollow above the soleus arcade). This arrangement of the electrodes allows overall working of the leg muscles and therefore maximum compression of the deep veins when there are tetanic contractions.

2. **Use biphasic symmetrically compensated pulses** because, for a given electrical current strength, it is with pulses of this type that maximum space recruitment is achieved, i.e. the largest number of motor units will be activated and therefore the effects will be more marked.

3. **Set the stimulation energy level** in order to obtain an appropriate muscle response in both the tetanic contraction and the active rest phase.

4. **Place the patient comfortably in a lying down position.**
2 Venous insufficiency with oedema

The presence of oedema completely changes the electrical stimulation programme. In this case, it is not possible to use the low arterial flow increase frequencies because they reduce the peripheral vascular resistances, increase the perfusion pressure of the capillaries and risk aggravating the oedema. On the other hand, tetanic contractions encourage drainage of the deep veins and drainage of the oedema, provided they are carried out in a certain order and under certain conditions. The most efficient way consists in producing an initial ejection effect at the leg and then at the thigh, without releasing the compression of the deep veins of the leg. This way, the venous blood is thrust in the first stage towards the thigh by a contraction of the leg muscles. Then, in the second stage, the contraction of the thigh muscles ejects the blood upward, provided however that the leg muscles remain contracted in order to prevent regurgitation.

To carry out a venous insufficiency with oedema session, we shall:

1. **Work in monopolar mode and in staggered contractions mode.** This means that only channels 1 and 2 start to produce a tetanic contraction while channels 3 and 4 are at rest. After 3 secs. of tetanic contraction via channels 1 and 2, the contraction starts only on channels 3 and 4 while the contraction induced by channels 1 and 2 continues. After 3 secs. of simultaneous contraction on the four channels, there follows a complete rest phase of 20 secs. on the 4 channels. It is therefore vital that the changes be positioned correctly on the muscles: Channels 1 and 2 for the calves, channels 3 and 4 for the thighs; definitely not the other way round!

- For the leg (channels 1 and 2): A large indifferent (negative) electrode is placed crosswise on the popliteal hollow (on the head of the popliteal nerve under the head of the ischium) and the other at the inside popliteal nerve (in the popliteal hollow above the ischium arcedue).
- For the quadriceps (channel 3): A large active electrode is placed crosswise on the lower third of the quadriceps, the large negative electrode being placed at the root of the thigh.
- For the ischiopopliteal muscles (channel 4): A large active electrode is placed crosswise on the lower third of the ischiopopliteal muscles, the large negative electrode being placed crosswise on the upper third of these muscles.

2. **Use biphasic symmetrically compensated pulses** because, for a given electrical current strength, it is with pulses of this type that maximum space recruitment is obtained, i.e. the largest number of motor units will be activated and therefore the effects will be more marked.

3. **Use pulse widths** that correspond to the chronaxies of the motor nerves of the lower limbs, to give the patient maximum comfort. The appropriate pulse width for the patient can be determined using the Blalock function.

4. **Send these pulses so as to cause tetanic contractions to empty first of all the deep veins of the calf and then those of the thighs, while maintaining the tetanic contraction at the level of the calves.** The tetanic contractions last a total of 6 secs. on the calves and 3 secs. on the thighs. They are carried out with a tetanic frequency of 50 Hz. The rest periods between the contractions are complete and last for 19 secs.

5. **Set the stimulation energy** to a higher level on channels 1 and 2 than on channels 3 and 4.

6. **Place the patient comfortably in a lying down position.**

### Parameters of the venous insufficiency without oedema programme

<table>
<thead>
<tr>
<th>Contraction</th>
<th>Active rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
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<td>Duration of ramp up</td>
<td>1.5 s</td>
</tr>
<tr>
<td>Duration of phase</td>
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</tr>
<tr>
<td>Duration of ramp down</td>
<td>1.5 s</td>
</tr>
</tbody>
</table>

### Parameters of the venous insufficiency with oedema programme

<table>
<thead>
<tr>
<th></th>
<th>1st contraction</th>
<th>2nd contraction</th>
<th>Active rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>50 Hz</td>
<td>50 Hz</td>
<td>5 Hz</td>
</tr>
<tr>
<td>Duration of ramp up</td>
<td>1.5 s</td>
<td>1.5 s</td>
<td>0 s</td>
</tr>
<tr>
<td>Duration of phase</td>
<td>6 s</td>
<td>3 s</td>
<td>19 s</td>
</tr>
<tr>
<td>Duration of ramp down</td>
<td>0 s</td>
<td>1.5 s</td>
<td>0 s</td>
</tr>
</tbody>
</table>

### Arterial insufficiency

We will limit this chapter to insufficiency of the arteries of the lower limbs. High blood pressure, smoking, cholesterol and diabetes are among the main causes of progressive deterioration of the arterial walls [arteriosclerosis]. This takes the form of shrinkage of the caliber of the arteries with, consequently, a reduction in the blood flow in the tissular areas downstream of the narrowed arteries. The less well irrigated tissues suffer and become hypoxic, all the more so because the caliber of the arteries has shrunk and more intense activity requires more oxygen.

Conventionally a distinction is made between four clinical stages of arterial insufficiency of the lower limbs. These four stages (I, II, III, IV) are a function of the greater or lesser severity of the reduction in blood flow and of the seriousness of the tissular consequences.

#### Stage I

Asymptomatic. In a clinical examination, an arterial breath can be heard that is evidence of shrinkage, but the patient has no complaints.

#### Stage II

The reduction in the flow causes pain in the leg when walking. At rest, the flow is sufficient but it cannot provide for tissular requirements when there is effort involved: the patient suffers from "intermittent claudication or limping" (I3). This means that the pain appears after walking for a certain distance (the shorter the distance, the more severe the condition) in the end this pain makes the patient stop; then, after a recovery period, the pain lessens and the person can resume walking until the cycle starts again.

#### Stage III

Is characterized by pain when at rest. The flow of blood is so reduced that the tissues suffer constantly from hypoxia with the continual presence of acid metabolites.

#### Stage IV

Corresponds to suffering that is so advanced that tissular necrosis with gangrene occurs. This is then called critical ischaemia, a condition that often leads to amputation.

Only stages II and III can benefit from treatment by electrical stimulation. Stage IV is in the nature of an emergency and surgery is required. Stage I is asymptomatic and the patient does not have any complaints.

With intermittent claudication (Stage II), the muscle fibres suffer from a shortage of oxygen when an effort is made. The fibres’ requirements for oxygen, which increase with walking, cannot be met by the arteries, the caliber of which is reduced. With chronic reduction of the flow and a lack of oxygen, the system of capillaries degenerates and the fibres lose their oxidative power. They use the little oxygen that they still receive increasingly poorly. Thus, the problem becomes twofold: very little oxygen provided and poor use of what oxygen there is. Low frequency stimulation can act on the capacity of the fibres to use the oxygen. The considerable amount of work done has shown that low frequency stimulation enables oxidative enzymes and mitochondria to be developed. Hudicks has also shown that this increase in oxidative power is also achieved by stimulation of muscles in a state of ischaemia.
Electrical stimulation therefore allows for an improvement in the tolerance of effort of muscle fibres in the case of arterial insufficiency and thus an increase in the walking range of patients suffering from intermittent claudication. The same beneficial effect can be achieved through low frequency electrical stimulation in Stage II. In this case, in view of the more severe reduction in the calibre of the arteries, lower stimulation frequencies than in intermittent claudication must be used (see below).

To carry out a Stage II arterial insufficiency session, we shall:

1. Work on monopolar mode: A large indifferent (negative) electrode is placed crosswise under the popliteal hollow and two small active electrodes with positive polarity are placed one at the lateral popliteal nerve (under the head of peroneous) and the other at the inside popliteal nerve (in the popliteal hollow above the soleus arcade). This arrangement of the electrodes allows overall work on the leg muscles and therefore an improvement in all these muscles when there is effort.

2. Use biphasic symmetrically compensated pulses because, for a given electrical current strength, it is with pulses of this type that maximum space recruitment is obtained, i.e. the largest number of motor units will be activated and therefore the effects will be more marked.

3. Use pulse widths that correspond to the chronaxies of the lateral and inside popliteal nerves, to give the patient maximum comfort. The appropriate pulse width for the patient can be determined using the Ir-Mean function.

4. Send these pulses so as to cause the highest possible low frequency activity (9 Hz), without producing tetanisation, which would reduce the flow still further. As the fibres are suffering from insufficient provision of oxygen when there is effort, to avoid the rapid onset of considerable fatigue it is necessary to alternate activity at 9 Hz with periods of lower activity at 3 Hz. This programme lasts 14 minutes.

5. Set the stimulation energy to the maximum tolerable level so as to recruit the largest possible number of fibres and achieve progress on a maximum number of fibres when effort is being made.

6. Place the patient comfortably in a lying down position.

To carry out a Stage III arterial insufficiency session, we shall proceed in the same way as for points 1), 2), 3), 4) and 5) in Stage II, but use a programme suitable for even greater deterioration of the arteries, i.e.:

1. Work in monopolar mode with a large indifferent electrode (negative) and a smaller active one (positive) placed on the motor point of the muscle to be stimulated.

2. Use of biphasic symmetrically compensated pulses because, for a particular electrical current strength, it is with pulses of this type that maximum space recruitment is obtained, i.e. the greatest number of motor units is activated.

3. Use of pulse widths that correspond to the chronaxies of the motor nerves of the muscle to be stimulated, to give the patient a feeling of well-being. The programme lasts 40 minutes.

To prevent cramps, the following is necessary:

Many people suffer from cramps in the calves, which can occur spontaneously when they are at rest during the night, or following prolonged muscular effort. This cramp phenomenon can in part be the result of an imbalance in blood circulation in the muscles. Slowing of cellular exchanges and blood circulation.

Compex 3 has a special stimulation programme to improve blood circulation and prevent the occurrence of cramps. This programme consists of two different sequences: one sequence at 8 Hz, to increase blood flow and develop the capillaries, and one sequence at 3 Hz to relax muscle tone and give the patient a feeling of well-being. The programme lasts 40 minutes.

Parameters of the Stage II arterial insufficiency programme

<table>
<thead>
<tr>
<th>Parameters of the Stage II arterial insufficiency programme</th>
<th>1st sequence</th>
<th>2nd sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>9 Hz</td>
<td>3 Hz</td>
</tr>
<tr>
<td>Duration of ramp up</td>
<td>1 s</td>
<td>1 s</td>
</tr>
<tr>
<td>Duration of phase</td>
<td>15 s</td>
<td>15 s</td>
</tr>
<tr>
<td>Duration of ramp down</td>
<td>1 s</td>
<td>1 s</td>
</tr>
</tbody>
</table>

Parameters of the Cramp prevention programme

<table>
<thead>
<tr>
<th>Parameters of the Cramp prevention programme</th>
<th>1st phase</th>
<th>2nd phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>8 Hz</td>
<td>3 Hz</td>
</tr>
<tr>
<td>Duration of ramp up</td>
<td>1.5 s</td>
<td>1.5 s</td>
</tr>
<tr>
<td>Duration of phase</td>
<td>8 s</td>
<td>2 s</td>
</tr>
<tr>
<td>Duration of ramp down</td>
<td>1.5 s</td>
<td>1.5 s</td>
</tr>
</tbody>
</table>
Experiments on animals have clearly demonstrated, with supporting biopsies, that the use of very low stimulation frequencies brings about an increase in the capillaries surrounding the muscle fibres. With two 20 minute sessions per day, this increase in the capillary vessels appears after four to eight days of stimulation.

Of particular interest is the fact that this capillarization occurs first of all, and preferentially, around the fast fibres. This is contrary to what is found with voluntary endurance training where capillarization appears essentially around the slow fibres. This more marked capillarization around the fast fibres, thanks to the very low frequency stimulation, is explained by the fact that such very low frequency work is unusual for fast fibres. When there are voluntary contractions, fast fibres do not trigger off their activity at less than 30 Hz and, at that frequency, tetanic contraction of the muscle is accompanied by a drop in the blood flow. Conversely, when a muscle is stimulated at very low frequency, the separate tremors are accompanied by a considerable increase in the blood flow in the muscle and all the activated fibres, fast or slow, work at the frequency imposed by the stimulation.

This increase in capillaries around the fast fibres gives a larger area of exchange and distribution of oxygen and metabolites. Thus, rephosphorylation from ADP into ATP and from creatine into phosphocreatine will be faster. Therefore, when there is a particular effort, the capillarization allows for a higher rate of phosphocreatine and decreased production of lactic acid. This means that very low frequency stimulation, by developing capillaries around the fast fibres, makes these fibres more resistant to fatigue.

The work done on animals has shown that the factor responsible for capillarization is the increase in the blood flow produced during stimulation. It is the mechanical effect connected with the increase in flow, itself due to the stimulation, which induces capillary development. Therefore, the greater the increase in flow under stimulation, the greater and faster the capillary development will be. The frequency of 8 Hz was chosen for the Capillarization programme because flow-metering measurements have shown a maximum increase in flow at that frequency.

To develop capillaries, the following is necessary:

1. Work in monopolar mode with a large indifferent electrode and a smaller active electrode with positive polarity placed at the motor point of the muscle to be stimulated.

2. Use of biphasic symmetrically compensated pulses because, for a particular electrical current strength, it is with pulses of this type that maximum space recruitment is obtained, i.e. the greatest number of motor units is activated.

3. In order to give the patient maximum comfort, the use of pulse widths that correspond to the chronaxies of the motor nerves of the muscles to be stimulated. In the context of these standard programmes, we offer 7 different pulse widths. The appropriate pulse width for the patient can be determined using the Nmax function.

### Parameters of the Capillarization programme

<table>
<thead>
<tr>
<th>Programme</th>
<th>Duration of ramp up</th>
<th>Treatment phase</th>
<th>Duration of ramp down</th>
<th>Frequency</th>
</tr>
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<tbody>
<tr>
<td>Capillarization</td>
<td>1.5 s</td>
<td>25 min</td>
<td>1.5 s</td>
<td>8 Hz</td>
</tr>
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</table>

The 2 agonist/antagonist programmes consist in an alternation of contractions controlled by channels 1 and 2 then by channels 3 and 4. In this sequence, contraction is obtained first with the muscles stimulated by channels 1 and 2, and, once this contraction is completed, the muscles stimulated by channels 3 and 4 then contract. This alternation of contractions, first with two channels and then with the other two, continue throughout the duration of the treatment.

The value of the 2 agonist/antagonist programmes is that they enable dynamic work by mobilizing one limb segment in one direction and then in the other: thereby working the entire range of motion. This contraction sequence is particularly effective because of the phenomenon that this muscle and also inhibits the α motor neurons of the antagonist muscle [reciprocal inhibition reflex]. It is this last point that is exploited in the 4 agonist/antagonist programmes: electrostimulation of a muscle not only results in its contraction but leads to a reduction in the tone of the antagonist muscle via the reciprocal inhibition reflex.

This phenomenon of inhibition of the α motor neurons by electrostimulation has been demonstrated clearly in electromyography. A muscle’s H response (Hoffman reflex), produced by a stimulus, is in fact reduced in amplitude when the motor nerve of the antagonist is stimulated ([Waters R., J. Bone Joint Surg Am 57, 1047-54, 1975]).

There are 4 agonist/antagonist programmes:

- **Treatment of atrophy and strengthening with contraction of twice the duration for agonist and antagonist:**
  - 1 : 1/1 Ago/Antago treatment of atrophy
  - 2 : 1/1 Ago/Antago reinforcement

- **Treatment of atrophy and strengthening for the upper or lower limbs with contractions of twice the duration for the agonist compared with the antagonist, or vice versa:**
  - 3 : 2/1 Ago/Antago treatment of atrophy
  - 4 : 2/1 Ago/Antago reinforcement

Apart from the aspects specific to the agonist-antagonist system, the programming follows the principles derived from the physiology of muscle contraction, which are set out in the chapters on the treatment of atrophy and muscle reinforcement.
As usual in muscle excitation, the following is necessary:

1 Work in monopolar mode with a large indifferent electrode and a smaller active one with positive polarity placed at the motor point of the muscle to be stimulated.

2 Use of bipolar symmetrically compensated pulses because, for a given electrical intensity, it is with this type of pulse that space recruitment is greatest, that is to say that the greatest number of motor units is activated.

3 To provide maximum comfort for the patient, the use of pulse widths that correspond to the chronaxies of the motor nerves of the muscles to be stimulated. In the context of these standard programmes, we offer 7 different pulse widths. The appropriate pulse width for the patient can be determined using the m-3 function.

4 Use of Type I fibre tetanization frequencies for the treatment of atrophy and Type II fibre tetanization frequencies for muscle reinforcement.

5 Use of maximum energy. The first and second sessions will be used to acclimatize the patient to the protocol, by increasing the intensity every 3 or 4 contractions (the patient can always tolerate a higher energy than they think). Achieving a high energy level is an essential condition for space recruitment of the largest number of fibres and for obtaining efficacious treatment. In any event, sufficient intensity must be used to obtain mobilization up to the maximum range of motion.

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**Parameters of the 2/1 Ag/Antra electromagnetic atrophy programme**

<table>
<thead>
<tr>
<th></th>
<th>PHASE 1 AGO</th>
<th>PHASE 1 ANTRA</th>
<th>PHASE 2 AGO</th>
<th>PHASE 2 ANTRA</th>
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<td>35 Hz</td>
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<td>1.5 s</td>
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<td>0 s</td>
<td>1.5 s</td>
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<tr>
<td>Duration of phase</td>
<td>6 s</td>
<td>6 s</td>
<td>6 s</td>
<td>6 s</td>
</tr>
<tr>
<td>Duration of ramp down</td>
<td>0.75 s</td>
<td>0 s</td>
<td>0 s</td>
<td>0.75 s</td>
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**Parameters of the 2/1 Ag/Antra electromagnetic reinforcement programme**

<table>
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<th>PHASE 1 ANTRA</th>
<th>PHASE 2 AGO</th>
<th>PHASE 2 ANTRA</th>
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<tbody>
<tr>
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<td>75 Hz</td>
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<tr>
<td>Duration of phase</td>
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<td>4 s</td>
<td>3 s</td>
<td>3 s</td>
</tr>
<tr>
<td>Duration of ramp down</td>
<td>0.75 s</td>
<td>0.5 s</td>
<td>0.5 s</td>
<td>0.75 s</td>
</tr>
</tbody>
</table>

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**Treatment of urinary incontinence**

The aim of this programme is to strengthen the sphincter muscle of the bladder. The objective is therefore to produce tetanic contractions of the paraurethral components of the striated muscle of the pelvic floor, using the optimum tetanization frequencies of the fast fibres.

**1 STRESS INCONTINENCE**

To achieve this, the following is necessary:

1 Work in bipolar mode with a vaginal electrode: Use of an electrode of this kind does not allow an active electrode to be placed on the motor point.

2 Use of bipolar symmetrically compensated pulses in order to obtain the greatest space recruitment of the motor units for a given electrical intensity.

3 Use of a pulse width that is close to the chronaxy of the motor neurons of the pudendal nerve, which is 250 μs.
To achieve this, the following is necessary:

1. Work in bipolar mode with a vaginal electrode: Use of an electrode of this kind does not allow for an active electrode to be placed on a motor point.

2. Use of biphasic symmetrically compensated pulses in order to obtain the greatest space recruitment of the motor units for a given electrical intensity during tetanic contractions.

3. Use of a pulse width that is close to the chronaxy of the motor neurones of the pudendal nerve, which is 250 µs for tetanic contractions and 150 µs for the very low frequency pulses for inhibition of the detrusor.

4. Use of fast fibre tetanization frequencies (75 Hz) during tetanic contractions and a low frequency (5 Hz) between these for detrusor inhibition.

5. Use of the maximum energy level tolerated during the tetanic contraction phases in order to obtain the maximum possible space recruitment and therefore maximum possible efficacy. The intensity will be increased regularly during the session, every 3 or 4 contractions. During the rest phase, the low-frequency intensity should be adjusted to at least three times the intensity of the perception threshold. This programme lasts 30 minutes.

### Parameters of the Stress incontinence programme

<table>
<thead>
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<th>Parameter</th>
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<th>Rest</th>
</tr>
</thead>
<tbody>
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<td>Duration of ramp up</td>
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</tr>
<tr>
<td>Duration of phase</td>
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</tr>
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<td>Duration of ramp down</td>
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</table>

### Parameters of the Mixed incontinence programme

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rest phase</th>
<th>Contraction phase</th>
</tr>
</thead>
<tbody>
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<tr>
<td>Duration of ramp up</td>
<td>0.5 s</td>
<td>1.5 s</td>
</tr>
<tr>
<td>Duration of phase</td>
<td>23 s</td>
<td>4 s</td>
</tr>
<tr>
<td>Duration of ramp down</td>
<td>0.5 s</td>
<td>0.75 s</td>
</tr>
</tbody>
</table>

### 2 URGE INCONTINENCE

This treatment relies on the reduction of detrusor activity by stimulation of an inhibitory reflex from sensory nerve endings in the perineal region.

The electrical parameters must therefore be created so as to excite these myelinated afferent nerve fibres at the frequency that produces optimum activation of the inhibitory reflex.

To achieve this, the following is necessary:

1. Work in bipolar mode with a vaginal electrode: The arrangement of sensory fibres is such that there is no motor point to be taken into account.

2. Use of biphasic symmetrically compensated pulses, since this type of pulse combined with the bipolar operating mode allows for simultaneous excitation of the myelinated afferent fibres in the vicinity of both electrodes.

3. Use of a pulse width close to the chronaxy of the fibres to be excited: 150 µs.

4. Use of a frequency of 5 Hz which, via the sympathetic and central pathways, brings about the greatest inhibition of the detrusor.

5. Use of an intensity level triple that of the stimulus threshold. This programme lasts 30 minutes.

### Parameters of the Urgo incontinence programme

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Duration of ramp up</th>
<th>Treatment phase</th>
<th>Duration of ramp down</th>
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<tr>
<td>Urgo incontinence programme</td>
<td>1.5 s</td>
<td>30 min</td>
<td>1.5 s</td>
<td>5 Hz</td>
</tr>
</tbody>
</table>

### 3 MIXED INCONTINENCE

(Urge + Stress Incontinence)

This programme treats both aspects of this form of incontinence at the same time. Firstly, using tetanic contractions at the frequency of fast fibres (75 Hz), it strengthens the parasuerothral components of the striated muscle of the pelvic floor, so increasing the pressure of urethral closure. Secondly, during the resting phases between contractions, it inhibits the activity of the smooth muscle of the bladder using very low frequencies (5 Hz).

To achieve this, the following is necessary:

1. Work in bipolar mode with a vaginal electrode: Use of an electrode of this kind does not allow for an active electrode to be placed on a motor point.

2. Use of biphasic symmetrically compensated pulses in order to obtain the greatest space recruitment of the motor units for a given electrical intensity during tetanic contractions.

3. Use of a pulse width that is close to the chronaxy of the motor neurones of the pudendal nerve, which is 250 µs for tetanic contractions and 150 µs for the very low frequency pulses for inhibition of the detrusor.

4. Use of fast fibre tetanization frequencies (75 Hz) during tetanic contractions and a low frequency (5 Hz) between these for detrusor inhibition.

5. Use of the maximum energy level tolerated during the tetanic contraction phases in order to obtain the maximum possible space recruitment and therefore maximum possible efficacy. The intensity will be increased regularly during the session, every 3 or 4 contractions. During the rest phase, the low-frequency intensity should be adjusted to at least three times the intensity of the perception threshold. This programme lasts 30 minutes.
1 INTRODUCTION

Haemophilia is a congenital blood disease characterized by a deficiency in the coagulation factor which is carried by the X sex chromosome. Haemophilia patients suffer from a haemorrhagic syndrome of varying severity involving haemarthrosis (intra-articular bleeding) and muscular haematomas.

Haemarthroses are responsible for muscular disuse atrophy by inhibition reflex and absence of voluntary activity. The result of this disuse atrophy is reduced protection of the joint, which therefore becomes more exposed to recurrent haemarthroses, and the setting up of a vicious circle.

Neuromuscular electrical stimulation is a particularly suitable method for the treatment of disuse atrophy and for muscle reinforcement in haemophilia patients. However, conventional programmes cannot be used, in view of the risk of haemorrhage.

Tests have been performed with strain gauges and isokinetic equipment to define the stimulation parameters that cause contractions, with very gradual increases in muscle tension. By avoiding sudden applications of current and shocks, the risk of haemorrhage can therefore be limited as far as possible, both in muscle fibres and in the osteo-tendinous structures. Essentially, these programmes always use frequencies above 25 Hz and current gradients equal to or greater than 4.5°.

Programmes developed in this way have been tested successfully in a population of haemophilic volunteers.

2 TREATMENT OF DISUSE ATROPHY

Histologically, disuse atrophy is identical in haemophilic patients and others.

This phenomenon does not affect the different muscle fibres in the same way. It is mainly slow fibres (type I) that are affected by atrophy. It is therefore logical to use type I fibre tetanization frequencies when attempting, by means of tetanizing excitomotor currents, to impose a considerable work load on an atrophied muscle in order to recover its volume.

It would also seem logical to increase the work load imposed on the muscle after a few training sessions (generally after one week).

To achieve this, the following is necessary.

1. Work in monopolar mode with a large neutral electrode and a smaller positive electrode which is placed on the motor point of the muscle to be stimulated.

2. Use of biphasic symmetrically compensated pulses, since for a given electrical current this type of pulse gives the greatest spatial recruitment, i.e. the greatest number of motor units is activated.

For maximum patient comfort, use of pulse widths that correspond to the chronaxies of the motor nerves of the muscles to be stimulated. In the context of these standard programmes, we offer 7 different pulse widths.

3. MUSCULAR REINFORCEMENT

Reinforcement implies an increase in the power of a muscle, once a satisfactory volume has been attained. Reinforcement programmes are therefore used only after the disuse atrophy treatment programmes have been completed.

To achieve this, the following is necessary.

1. Work in monopolar mode with a large neutral electrode and a smaller positive electrode placed on the motor point of the muscle to be stimulated.

2. Use of biphasic symmetrically compensated pulses to obtain the greatest spatial recruitment for a given electrical current.

3. Use of pulse widths that correspond to the chronaxies of the motor nerves of the muscles to be stimulated, so that the pulse current is as comfortable as possible for the patient. In these standard programmes, for haemophilic patients, we propose 7 different pulse widths.

4. Use of fast fibre (IIb) tetanization frequencies; these are the fibres for strength and speed.
5 Use of the maximum energy level. The first and second sessions will help to accustom the patient to the method, with the energy being increased every 3 or 4 contractions. The patient can tolerate a much stronger current than he/she imagines. The therapist plays a decisive role in reassuring the patient and encouraging him to work with the strongest possible contractions.

In order to modify the programme in response to the patient’s progress, we suggest one programme for the first two weeks and one programme for subsequent weeks.

### Parameters of the Reinforcement level 1, Haemophilia programme

<table>
<thead>
<tr>
<th>Parameters</th>
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<th>Active rest</th>
</tr>
</thead>
<tbody>
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<td>Frequency</td>
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</tr>
<tr>
<td>Duration of ramp up</td>
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<td>0 s</td>
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<tr>
<td>Duration of phase</td>
<td>3 s</td>
<td>15 s</td>
</tr>
<tr>
<td>Duration of ramp down</td>
<td>1.5 s</td>
<td>0 s</td>
</tr>
</tbody>
</table>

### Parameters of the Reinforcement level 2, Haemophilia programme

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Contraction</th>
<th>Active rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
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<tr>
<td>Duration of phase</td>
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</tr>
<tr>
<td>Duration of ramp down</td>
<td>1.5 s</td>
<td>0 s</td>
</tr>
</tbody>
</table>

### Hemiplegia Spasticity

#### 1 DORSIFLEXION OF THE FOOT IN HEMIPLEGICS

In hemiplegic patients, spastic hypertonia of the calf muscle with a greater or lesser degree of paresis or even paralysis of the flexor muscles of the foot (anterior tibial muscle and extensor muscles of the toes) cause the foot to drop when walking. Foot drop can be prevented by electrically induced tetanic contraction of the levator muscles of the foot, synchronized with the phase of the gait during which the foot concerned is lifted from the ground.

The electrical stimulation parameters must be selected so as to obtain a short-term tetanic contraction of the anterior compartment of the leg to prevent the foot from dropping, at the appropriate moment and with maximum comfort for the patient.

To achieve this, the following is necessary:

1. Work in monopolar mode with a large indifferent electrode (negative) and a smaller active one (positive) which is located in the area of the nerve trunk which supplies the levator muscles of the foot.

2. Use of biphasic symmetrically compensated pulses since, for a given electrical current intensity, this is the type of pulse that allows for maximum space recruitment, so that the greatest number of motor units is activated.

3. Use of a pulse width that corresponds to the chronaxy of the motor nerve to be excited, 400 µs in the case of the peroneal nerve, to allow optimum comfort for the patient. The appropriate pulse width for the patient can be determined using the I-400 function.

4. Use of a tetanization frequency of 50 Hz, which is the lowest tetanization frequency that develops the maximum strength of contraction (the increase in strength by raising temporary recruitment peaks at 50 Hz).

5. Use of just the energy necessary to prevent the foot from dropping when the patient is walking.

6. Starting of contractions with trigger to start contractions at the appropriate moment (see specific applications).

7. Starting of contractions with trigger in order to obtain a psychological benefit for the patient because he controls the occurrence of contractions (see specific applications).

### Parameters of the hemiplegic foot programme

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Contraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
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<tr>
<td>Duration of ramp down</td>
<td>0.25 s</td>
</tr>
</tbody>
</table>

### 2 TREATMENT OF SPASTICITY

In various types of lesions of the central nervous pathways, of which hemiplegia is the most common example, spastic hypertonia develops. Since it is no longer under the control of the higher nervous centres, the myotatic reflex (monosynaptic stretch reflex) becomes hyperactive and hypertonia develops predominantly in the antigravity muscles, which are richer in neuromuscular bundles (flexors of the upper limbs, extensors of the lower limbs). Spastic hypertonia is caused by hyperactivity of the α motoneurons and spasticity can therefore be reduced by inhibiting these. The large type I myelinated afferent nerve fibres arising from the neuromuscular bundles of the antagonist to the spastic muscle have an inhibitory effect on the α motoneurons of the spastic muscle by way of interneurons. In this way, a reduction in spasticity is achieved by stimulating the antagonist to the spastic muscle by reciprocal inhibitory reflexes.

In addition, stimulation of the antagonist muscle not only allows this to be strengthened but also progressively stretches the spastic muscle so as to combat the tendency towards contracture and retraction.

To achieve this, the following is necessary:

1. Monopolar work: A large indifferent electrode (negative) and a smaller active one (positive) which is located on the area of the motor point of the antagonist to the spastic muscle.

2. Use of biphasic symmetrically compensated pulses in order to obtain the greatest space recruitment for a given electrical current intensity.

3. Use of a pulse width that corresponds to the chronaxy of the motor nerves of the muscles to be stimulated. In these standard programmes, we offer 7 different pulse widths. The appropriate pulse width for the patient can be determined using the I-400 function.

4. Use of the optimum tetanization frequency for type I fibres, which is the frequency generally used by authors who have worked on spasticity and is also adequate for treatment of the relative atrophy in the antagonists to the spastic muscles.

5. Programming of a very gradual current application gradient (45°) in order to avoid the myotatic stretch reflex on the spastic muscle.

6. No use of very low relaxation frequencies between tetanic contractions to prevent the stretch reflex on the spastic muscle.

7. Starting of contractions with trigger in order to obtain a psychological benefit for the patient because he controls the occurrence of contractions (see specific applications).
8 Use of the energy necessary to obtain a dynamic contraction up to the maximum amplitude of movement but below the level that would cause stimulation of the spastic muscles.

<table>
<thead>
<tr>
<th>Parameters of the Spasticity programme</th>
<th>Contraction</th>
<th>Active rest</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>Duration of phase</td>
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<td>5 s</td>
</tr>
<tr>
<td>Duration of ramp down</td>
<td>3 s</td>
<td>0 s</td>
</tr>
</tbody>
</table>

3 SHOULDER SUBLUXATION

Paralysis or paralysis of the deltoid, its weakness and atrophy, combined with spastic hypertonia of the pectoralis major muscle in hemiplegic patients, frequently result in subluxation of the shoulder, which is often painful and increasingly stiff. This situation can be treated effectively by stimulating the deltoid and supraspinatus muscles. This strengthens them and allows spasticity of the pectoralis major to be reduced by reciprocal inhibitory reflex. Therefore, in addition to a marked analgesic effect on the shoulder, subluxation is corrected or prevented.

To achieve this, the following is necessary:

1 Work in monopolar mode with a large indifferent electrode (negative) and a smaller active one (positive) which is located on the area of the motor point of the muscle to be stimulated.

2 Use of biphasic symmetrically compensated pulses in order to obtain the greatest space recruitment for a given electrical current intensity during tetanic contractions.

<table>
<thead>
<tr>
<th>Parameters of the Shoulder subluxation programme</th>
<th>Contraction</th>
<th>Active rest</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>Duration of ramp up</td>
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<td>Duration of phase</td>
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<td>8 s</td>
</tr>
<tr>
<td>Duration of ramp down</td>
<td>1.5 s</td>
<td>0 s</td>
</tr>
</tbody>
</table>

A sedentary lifestyle is very bad for the figure, especially if you have a poorly balanced diet. Those muscles that are not used much lose their qualities: loss of strength, reduced tone, slackness. They can no longer carry out their tasks of supporting the body and holding the organs in place. The body becomes soft and loose, with clear consequences on body shape: Insufficient muscular activity also leads to disruption of blood circulation. Cellular exchanges slow down, fat storage increases and the supportive skin tissues lose their elasticity. Due to their great diversity and specificity, the ‘AESTHETIC’ programmes provide the solution for anyone who wants to regain and keep the benefits of intense muscular activity. These programmes allow you to restore and maintain a firm body, shapely figure and toned skin. Note that these programmes are not suitable for the prevention or treatment of muscular atrophy (wasting) nor for strengthening the muscles.

The programmes:

- **Toning**: To tone the muscles. The aim of this programme is to tone the muscles and prepare them initially before the more intensive firming work. It is therefore used during the first two weeks of a firming cycle.

- **Firming**: To regain muscle firmness and restore the support function of the muscles. This programme is to be used as the main treatment to firm the muscles.

- **Shaping**: To define and sculpt the body when the muscles are already firm. This programme is to be used when the firming phase has been completed.

- **Elasticity**: To improve the circulation and skin elasticity. This programme is to be used as a complement to the Firming or Shaping programme.

- **Refinement**: To work specifically on the waist, rolls of fat, “love handles”, etc. This programme is to be used on the waist muscles after firming the stomach.

- **Ribs**: Encourage slimming of the waist by improving abdominal muscular support.

- **Caloritaxis**: To increase calorie expenditure. This programme is designed to cause maximum energy consumption during the stimulation session. However, it cannot by itself create enough consumption to lead to significant weight loss. On the other hand, it is a useful addition within the general context of a weight loss strategy. This programme should therefore be used as a complement to a low-calorie diet to increase the calorie deficit.

- **Adipostress**: To increase electric stress and vasodilatation in fat cell masses and areas of cellulite. This programme can be used in addition to other anti-cellulite treatments to enhance the fight against the accumulation of fat cells.

To do this, the following is necessary:

1 Work in monopolar mode with a large indifferent electrode and a smaller active electrode with positive polarity placed at the motor point of the muscle to be stimulated (see the booklet showing the electrode positions for various areas of the body). However, for the Adipostress programme, work in a bipolar mode and cover the skin of the body area to be treated with the large electrodes.

2 Use of biphasic symmetrically compensated pulses to prevent any risk of burning the skin and to achieve the greatest possible space recruitment for a given electrical current.

3 In order to provide maximum comfort for the patient, use of pulse widths that correspond to the chronaxies of the motor nerves of the muscles to be stimulated. In these programmes, we offer 7 different pulse widths. The appropriate pulse width for the patient can be determined using the B-again function. The Adipostress programme operates in accordance with its own particular logic. The pulse widths are between 60 µs and 100 µs depending on the level.

4 Use of maximum energy. The first and second sessions will serve to accustom the patient to the method, with the energy being increased every three or four contractions. The patient can tolerate much higher energy levels than he/she thinks. The therapist plays a decisive role in reassuring patients and encouraging them to tolerate the strongest possible contractions. This aspect is of fundamental importance since it determines the number of muscular fibres that are working and consequently determines the efficacy of the treatment.
Iontophoresis
A source of electric current applied to any part of a patient’s body sets up an electric field between the electrodes and through the tissues. In this electric field, the positive particles are attracted to the negative pole while the negative particles are attracted to the positive pole. This means that migration of charged particles (electrophoresis) is produced in the tissues crossed by an electric field. This migration is significant, provided the electric current is kept stable at an adequate intensity and for a sufficiently long time.

Direct current [also referred to as galvanic current] at a constant intensity over time enables charged particles to be mobilized through tissues. If the charged particles are medicines, the direct current acts as a vector allowing for the introduction and penetration of medicinal substances. This technique is internationally known as “iontophoresis.”
Passing a direct current through an aqueous solution containing dissolved mineral salts leads to a number of reactions and changes that are referred to as electrolysis. This phenomenon of electrolysis involves the chemical decomposition of certain substances in solution owing to the passing of an electric current. Studying electrolysis helps to explain the reactions that occur under electrodes placed on the skin, given that the skin is always in contact with an aqueous saline solution, namely the product of perspiration.

When the two terminals of a source of electric current are immersed in a vessel containing absolutely pure water, i.e. without any dissolved substances [distilled water], the current does not flow. Pure water does not allow the current to flow, acting as an insulator. If a substance such as sugar is added to the water, the current still does not flow. However, if salt (sodium chloride - NaCl) is added, the current does flow. Some substances, such as salt, can turn the medium into a conductor when dissolved in water. These substances (known as electrolytes) allow the current to flow because they dissociate into ions in the water. This dissociation is known as ionization. The dissolved ions are attracted to the opposite pole, resulting in ionic migration. Ionic migration explains why the electric current flows through the solution.

Positive ions attracted to the negative pole (the cathode) are called cations. Negative ions attracted to the positive pole (the anode) are called anions. Cations are involved in chemical changes when placed in contact with the cathode. The same occurs when anions come into contact with the anode.

### B: Electrolysis

- **At the cathode**: Na+ captures an electron and becomes Na. Na+ + 1 electron → Na
- **At the anode**: Cl− gives up an electron and becomes Cl. Cl− − 1 electron → Cl

When NaCl dissolved in water is ionized into Na+ and Cl−, Na+ is attracted by the cathode and Cl− by the anode.

In total, the cathode has given up one electron and the anode has captured one electron, in other words, the electric current has circulated. An alkaline reaction [production of sodium hydroxide NaOH] is produced at the cathode with release of hydrogen. At the anode an acidic reaction [production of hydrochloric acid HCl] is produced with release of oxygen.

Therapists should concern themselves with the alkaline reaction at the cathode because an accumulation of sodium hydroxide on the negative electrode may cause a chemical burn to the skin in contact with the electrode.

Thus the burn that may be caused during iontophoresis treatment is primarily a chemical burn due to sodium hydroxide accumulating on the cathode. The quantity of accumulated sodium hydroxide depends on the size of the skin-electrode contact area, i.e. it depends on density. How well the skin tolerates the galvanic current, for the same intensity, depends on dispersion of the current over a surface area that can vary in size. Likewise, the accumulation of sodium hydroxide at the cathode and its concentration on the skin depends on the intensity, as well as on the size of the skin-electrode contact area.

### C: Direct current

Direct current (DC) or galvanic current has a constant intensity over time. The graph of this consists of a straight line parallel to the time axis (x-axis). It is the intensity of the current (I) that is constant over time, not necessarily the tension or voltage (U).

- slight heating of the tissues
- vasodilation in the skin which is evident as erythema under the two electrodes and disappears spontaneously 20 to 60 minutes after treatment.
- a slight prickling sensation or irritation under the electrodes
- at the cathode: - alkaline reaction [NaOH] - increased excitability of the nerves - reduced protein density [sclerolytic]
- at the anode: - acidic reaction [HCl] - reduced excitability of the nerves - increased protein density [sclerolytic]

The current of choice for iontophoresis treatment is direct current because it ensures maximum ionic transfer. All studies evaluating penetration and chemical research demonstrating efficacy have been performed with direct current. Other forms of electric current have never demonstrated any efficacy for iontophoresis and their use in this application is insubstantial.

### D: Density of the current

With regard to the efficacy or the safety of the treatment, electric density must be discussed. The degree of ionic transfer depends on the intensity of the current, as well as on the size of the skin-electrode contact area, i.e. it depends on density. How well the skin tolerates the galvanic current, for the same intensity, depends on dispersion of the current over a surface area that can vary in size. Likewise, the accumulation of sodium hydroxide at the cathode and its concentration on the skin depends on the intensity, as well as on the size of the skin-electrode contact area.

\[
D = \frac{I}{S}
\]

Where:
- \( D \) is the electric density (mA/cm²)
- \( I \) is the intensity (mA)
- \( S \) is the surface area (cm²)
To monitor efficacy and safety properly, we need to work with strict checks on electric density. The equipment must, therefore, control the intensity of the current in relation to the size of the electrodes being used. Furthermore, this equipment must be a perfect generator of constant current. In this way, the intensity and hence the density, will not change during treatment when skin resistance decreases as a result of heating and vasodilation of the skin.

### E: Safety (allergies, burns and shocks)

Safety must be the therapist’s primary concern during iontophoresis treatment. It is important to prevent not only accidents, such as allergic reactions to medicines and burns, but also incidents of shock on initiation and cessation of the treatment.

In order to avoid allergic reactions to medicines, therapists must question patients before first using iontophoresis treatment. If there is the slightest doubt, an allergy test with the chosen medicine should be performed. This aspect is covered in detail in the practical part of this section on iontophoresis.

Burns can be prevented by checking that the electric density being used is tolerated by the skin. Although some studies do use a density of 1 mA/cm², this value is too high because it is at the upper limit of tolerance for normal, highly resistant skin. On normal skin, properly prepared beforehand for application of iontophoresis treatment, such a high density of current (1 mA/cm²) for 10 minutes will produce an accumulation of sodium hydroxide under the cathode, leading to a chemical burn.

The cathode, leading to a chemical burn. In accumulation of sodium hydroxide under beforehand for application of iontophoresis On normal skin, properly prepared
tolerance for intact, highly resistant skin. high because it is at the upper limit of equipment must be a perfect generator of electrodes being used. Furthermore, this therefore, control the intensity of the electric density. The equipment must, equipment must be a perfect generator of constant current. In this way, the intensity, and hence the density, will not change during treatment when skin resistance decreases as a result of heating and vasodilation of the skin.

### F: Penetration

Penetration by the ionized medicinal substance depends on several factors:

1. **Solubility of the medicinal substance**
2. **Concentration of the medicinal solution**
3. **Absence of ions competing with the medicine in the solution**
4. **pH of the solution**
5. **The solution being placed on the correct electrode**
6. **Absence of grease on the skin’s surface**
7. **Quantity of sweat gland ducts in the skin**
8. **Density of the electric current**
9. **Duration of treatment**

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7. **Quantity of sweat gland ducts in the skin**
8. **Density of the electric current**
9. **Duration of treatment**

The size or molecular weight of the medicine: it is often said, mistakenly, that molecular weight is a factor that affects penetration. Although it is true at the cellular level for cell membrane penetration, it has nothing to do with penetration of the skin during iontophoresis treatment. The medicine penetrates the skin via the sweat gland ducts which are approximately 10 microns (10 thousandths of a millimeter) in diameter. Proportionately, this is gigantic when compared to the diameter of the largest molecules.

### 1. Solubility

The medicine being used to penetrate by ion migration obviously has to be an electrolyte, in other words it must be soluble in water and ionizable. The recommended substances and how to use them are given in the practical section.

### 2. Concentration of the Solution

The concentration of the medicine in the solution affects the quantity of ions transferred; the concentrations usually recommended are 1% to 2% (or 1 to 2 g/100 ml). However, some substances with very strong biological activity (i.e. potent at very weak concentrations) can be used in solutions diluted to as little as 0.01% (0.1 mg/ml).

### 3. Competing Ions

Ionic migration indiscriminately affects all ions present in the solution, ions being attracted by the anode and cations by the cathode. If ions other than the medicinal substance are present in the solution, they will compete for migration. Therefore, the greater the quantity of competing ions in relation to the quantity of medicinal ions, the lower the penetration by the medicine. This is why it is desirable for the medicine to be in solution in distilled water and for the active electrode to be impregnated with that solution only.

### 4. The pH

The pH plays a part because it can influence not only the polarity of the ionized medicinal substance, but also the charge of the pores of the skin. Some medicinal substances are called amphoterics because their molecules have both an acidic and a basic function and consequently their ionization varies according to the pH of the medium. In an acidic medium (pH < 7) the basic function fixes an H⁺ and the medicine has positive polarity, whereas in a basic medium (pH > 7) the acidic function releases an H⁺ and the medicine has negative polarity. The charge of the pores of the skin is also influenced by the pH: when the pH is less than 3 the charge of the pores is positive and when it is greater than 4 the charge becomes negative. As most solutions have a pH > 4, the pores are negatively charged and a positively charged medicine interacts with the pores in the form of attraction, whereas a negatively charged medicine is repelled by the pores.

### 5. The Solution Being Placed on the Correct Electrode

The solution must be placed on the cathode or anode, depending on the polarity of the ionized medicine. Positively charged medicines must be placed on the positive electrode (anode) and negatively charged medicines on the negative electrode (cathode). The ionized medicine is therefore placed on the electrode of the same polarity so that it is repelled by that electrode and attracted towards the other. A table in the practical section gives the charges of various medicines.

### 6. Absence of Grease on the Skin

A layer of grease between the medicinal solution and the skin will prevent penetration of the ionized medicine. This is why proper preparation of the skin that is going to be covered by the electrodes is so important. A description of the preparation method is given in the practical section.

### 7. Quantity of Sweat Gland Ducts

The skin, with its top layer of keratin, is impermeable to water and substances that are dissolved in it, so penetration can only take place through the pores of the skin and, the more abundant the sweat glands ducts in the skin, the greater the penetration. The skin beneath the active electrode can be seen as being pierced by a number of micro-pipettes from which the ionized medicine will penetrate into the tissues.

### 8. Density of the Electric Current

The greater the current density, the greater the penetration. However, if the density is too high, there is a risk of burning. The most appropriate density appears to be 0.05 mA/cm².

### 9. Duration of Treatment

Owing to the inertia inherent in any dynamic phenomenon, effective mobilization of ionized medicines requires a certain amount of time. The first 30 seconds are necessary for effective activation of the migration process. Thereafter, as more time elapses, more medicine will penetrate the tissues. However, the increase in the quantity penetrating over time is obviously not infinite since the substance disappears from the active electrode as it penetrates the tissue.
The quantity \( N \) of ionized medicine penetrating the tissues depends on all the factors described above. Once the treatment conditions are established, however, penetration only depends on the current density and the duration of treatment. The quantity \( N \) of ionized medicine penetrating the tissues is a function of density and duration; \( N \) is proportional to the cube root of density \( D \) multiplied by time \( t \).

\[
N \propto \sqrt[3]{D \cdot t}
\]

The graph shows that penetration is greater in the first few minutes of treatment. After six minutes, the gain in penetration is not significant unless the duration of treatment is greatly prolonged. In fact, doubling the duration of treatment increases the penetration index by about 25% and the duration needs to be multiplied by 8 to double penetration!

**A: Precautions prior to iontophoresis treatment**

**Do not perform the treatment if the patient is suffering or has suffered from asthma, hay fever, food allergy, eczema, allergy to penicillin or aspirin.**

**Do not carry out the treatment on allergic patients, whatever form their allergy may take: hay fever, eczema, or food allergy. The more likely the medicinal product is to cause strong reactions in an allergic subject (e.g. aspirin), the more vigilant one should be.**

Properly conducted iontophoresis treatment (using a generator of constant current, checking electric density and strictly following the directions for use) will bring about tissue penetration by the ionized medicine. The treatment therefore involves introducing a medicine into the body by means of a galvanic current acting as a simple vector. This method of administering a drug is not without its risks. The most dangerous complication of iontophoresis is an allergic reaction to the medicine being administered. Allergic reactions can vary greatly in severity from a simple mild, localized reaction (itching, redness, and slight oedema) to dramatic anaphylactic shock. This should not be taken lightly and it is essential to ensure that there is no risk of an allergic reaction developing. When planning to start a patient on iontophoresis treatment, the therapist must first question the patient to find out whether or not he is allergic. If there is any doubt, a test can be performed before the treatment is first used. This means taking the smallest iontophoresis electrodes available [maximum 20 cm²] and applying them to the skin on the inside of the forearm. The solution of ionized medicine should be placed on the electrode of the same polarity and the current applied for 2 minutes at a density of 0.02 mA/cm². The therapist should then check that no local allergic reaction [redness, itching or swelling] has developed during the 5 minutes following the test.

**Make sure that the medicine is not contraindicated.**

Iontophoresis treatment must not be performed if the patient has a disease or is taking other treatments that are listed among the contraindications for the ionized medicine.

Iontophoresis is simply a method of local drug administration. Provided the treatment is performed correctly, the medicine will penetrate the tissues, then be absorbed by the capillaries and find its way into the systemic circulation. The medicine will cause systemic effects as if it were injected or given orally. The only difference would be the dosage and speed of absorption. Consequently, side-effects of the medicine may occur when it is delivered by iontophoresis. The contraindications applicable to the medicine must be respected in the same way as if it were delivered by any other route. When iontophoresis is the parenteral route of administration, the dose is generally lower than if the drug were given orally or by injection, so the incidence of side-effects should be lower. However, given identical electric density and duration of treatment, side-effects are more likely to occur when the surface area of the electrodes is larger.
Stop the treatment immediately and do not repeat it with the same medicine if a local allergic reaction is identified.

Do not repeat iontophoresis treatment if any local allergic reaction, however mild, was observed during the last treatment.

Despite thorough questioning of the patient, it is possible for the patient to be allergic to (or become allergic to) the medicine used in iontophoresis treatment. In such cases a local allergic reaction will be observed under the active electrode (of the same polarity as the ionized medicine): erythema, itching and oedema under the active electrode only is a clear indication of a local allergic reaction. Once this is identified, it is important not to repeat iontophoresis treatment with the same medicine. Each renewed contact with an allergen can increase a patient’s potential for an allergic reaction, so the reaction to subsequent treatment is likely to be more severe with more pronounced local signs and possibly even systemic signs.

No iontophoresis treatment near a metal implant.

Electrodes for iontophoresis treatment must not be placed close to metallic bone or joint implants (prosthesis or bone fixing).

Direct (or galvanic) current is polarized by definition and hence has an electric mean different from zero. It is responsible for ionic migration and the phenomenon of electrolysis. Electrolysis means the chemical decomposition of certain substances in solution owing to the passage of an electric current. This phenomenon can have various consequences:
- Decomposition of water with release of hydrogen and oxygen
- Constituents of the substance in solution become deposited on the electrodes
- Material is transported from the anode to the cathode
- Movement by the patient can displace or detach the electrodes partly or completely. If the electrodes are completely detached, the sudden interruption of the circuit can cause a shock. This is not dangerous, but can be very unpleasant and can create anxiety for the patient. If the electrodes are partly detached (the skin is no longer in contact with the entire surface of the electrode), the density of the current increases and there is a risk of burning.

C: Preparing the electrodes and solution of ionized medicine

1 Apply the solution of ionized medicine to a dry electrode previously rinsed with distilled water.

The active electrode, the one with the same polarity as the ionized medicine, should have been rinsed in distilled water at the end of the preceding treatment, then dried.

At the end of an iontophoresis treatment the electrodes must be rinsed. Rather than tap water, which contains ionized salts, use distilled water: for this final rinse as it is devoid of such salts, by definition. When the electrodes wet with distilled water are allowed to dry, the water evaporates and there is nothing left on the electrodes. By contrast, when tap water evaporates, the ions dissolved in it crystallize and remain on the electrode. If proper rinsing with distilled water does not take place, ions will remain in the electrodes and, at the next treatment, these ions will compete for ionic migration with the medicinal ions and the treatment will be less effective.

To reduce this layer of dead cells, rub vigorously enough to achieve slight mechanical abrasion. This cleaning must be done with medicated soap, then the skin should be rinsed and cleaned properly.

2 Degrease the skin with ether.

Correct cleaning of the skin is not enough. It must also be degreased with a fat solvent (such as ether) applied to swabs.

The solution of ionized medication impregnating the electrode forms a thin liquid filter on the skin. From the pores this liquid filter has to spread through the epidermis via the sweat gland ducts. Penetration by the ionized medicine hence depends on the variable permeability of these glands and their openings in the skin. If fatty substances clog these ducts, this will hinder penetration by the medicine and render the treatment ineffective. However, fatty materials are normally present on the epidermis. Sebum, a fatty material produced by the sebaceous glands, is permanently found on the epidermis.

To ensure good permeability of the sweat gland ducts, deep clean with a highly fluid fat solvent such as ether.

Do not shave the area of skin onto which the electrodes are placed.

Hair does not interfere with iontophoresis treatment. If treatment is done in an area where hair is shaved, there is a risk of causing small skin wounds. These wounds form points of low electrical resistance where the current will flow preferentially.

3 Place the patient in a relaxed position so that he moves as little as possible during treatment.

For iontophoresis treatment, the therapist should ensure that the patient is placed in a comfortable position which is as unlikely as possible to change.

Movements by the patient can displace or detach the electrodes partly or completely. If the electrodes are completely detached, the sudden interruption of the circuit can cause a shock. This is not dangerous, but can be very unpleasant and can create anxiety for the patient. If the electrodes are partly detached (the skin is no longer in contact with the entire surface of the electrode), the density of the current increases and there is a risk of burning.

B: Preparing the patient and the area to be treated by iontophoresis

1 Thoroughly clean the area of skin to be treated, then rinse and dry.

The surface of the skin where the electrodes are placed must be absolutely clean. There must be no layer, even a minute or invisible layer, between the skin and the solution of ionized medication impregnating the electrode. The epidermis, which continuously renews itself, forms a desquamating surface layer of keratin.

Unlike the chemical reactions that can occur in metal implants (if they are included in the electrical circuit of a direct current), the third point mentioned above shows that material can be carried from the anode towards the cathode. The metal implant material may behave like an anode and, if a salt of the same metal is in the solution, this anode will lose mass that finds its way to the cathode or into adjacent tissue. The result can be chemical disintegration of metal implants with “erosion” and intra-tissue metal deposits.

To reduce this layer of dead cells, rub vigorously enough to achieve slight mechanical abrasion. This cleaning must be done with medicated soap, then the skin should be rinsed and cleaned properly.

2 Degrease the skin with ether.

Correct cleaning of the skin is not enough. It must also be degreased with a fat solvent (such as ether) applied to swabs.

The solution of ionized medication impregnating the electrode forms a thin liquid filter on the skin. From the pores this liquid filter has to spread through the epidermis via the sweat gland ducts. Penetration by the ionized medicine hence depends on the variable permeability of these glands and their openings in the skin. If fatty substances clog these ducts, this will hinder penetration by the medicine and render the treatment ineffective. However, fatty materials are normally present on the epidermis. Sebum, a fatty material produced by the sebaceous glands, is permanently found on the epidermis.

To ensure good permeability of the sweat gland ducts, deep clean with a highly fluid fat solvent such as ether.

Do not shave the area of skin onto which the electrodes are placed.

Hair does not interfere with iontophoresis treatment. If treatment is done in an area where hair is shaved, there is a risk of causing small skin wounds. These wounds form points of low electrical resistance where the current will flow preferentially.

3 Place the patient in a relaxed position so that he moves as little as possible during treatment.

For iontophoresis treatment, the therapist should ensure that the patient is placed in a comfortable position which is as unlikely as possible to change.

Movements by the patient can displace or detach the electrodes partly or completely. If the electrodes are completely detached, the sudden interruption of the circuit can cause a shock. This is not dangerous, but can be very unpleasant and can create anxiety for the patient. If the electrodes are partly detached (the skin is no longer in contact with the entire surface of the electrode), the density of the current increases and there is a risk of burning.

C: Preparing the electrodes and solution of ionized medicine

1 Apply the solution of ionized medicine to a dry electrode previously rinsed with distilled water.

The active electrode, the one with the same polarity as the ionized medicine, should have been rinsed in distilled water at the end of the preceding treatment, then dried.

At the end of an iontophoresis treatment the electrodes must be rinsed. Rather than tap water, which contains ionized salts, use distilled water: for this final rinse as it is devoid of such salts, by definition. When the electrodes wet with distilled water are allowed to dry, the water evaporates and there is nothing left on the electrodes. By contrast, when tap water evaporates, the ions dissolved in it crystallize and remain on the electrode. If proper rinsing with distilled water does not take place, ions will remain in the electrodes and, at the next treatment, these ions will compete for ionic migration with the medicinal ions and the treatment will be less effective.

To reduce this layer of dead cells, rub vigorously enough to achieve slight mechanical abrasion. This cleaning must be done with medicated soap, then the skin should be rinsed and cleaned properly.

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Iontophoresis

Place the active electrode on the area to be treated. In this way, the medicinal ions are repelled from that electrode. To make the circuit conductive, the active electrode has been impregnated with a conducting gel, physiological liquid, or simply tap water.

The medicinal solution must be placed on the electrode of the same polarity (which is then called the active electrode). In this way, the medicinal ions are repelled from that electrode. The situation becomes totally unacceptable if the electrodes are rinsed with tap water, left to dry and then re-wet with tap water before the medicinal solution is applied. In these conditions, not only is the medicinal solution diluted by the water impregnating the electrodes but there is also competition between the medicinal ions, the ions from the tap water and those which remained in the electrodes after evaporation of the rinsing water.

Apply the ionized medicinal solution to the electrode of the same polarity. The medicinal solution must be placed on the electrode of the same polarity (which is then called the active electrode). In this way, the medicinal ions are repelled from that electrode.

The inactive or indifferent electrode, of the opposite polarity to the ionized medicine, must be wet with tap water or covered with conducting gel. In order to make the circuit conductive, the active electrode has been impregnated with the solution of ionized medicine and the inactive electrode has to be soaked with a conductive substance of the therapist’s choice: a conducting gel, physiological liquid, or simply tap water.

2 Apply the ionized medicinal solution to the electrode of the same polarity.

The electrode surface area of 40 cm² with the skin. With Compex 3, if an electrode surface area of 40 cm² with electric density of 0.05 mA/cm² is introduced and poor placement of the electrode reduces the skin-electrode interface to an area of 20 cm², the real density will be 0.1 mA/cm². Poor placement of an electrode will therefore expose the patient to a risk of burning.

3 The inactive or indifferent electrode, of the opposite polarity to the ionized medicine, must be wet with tap water or covered with conducting gel.

The electric current flows through sites of least resistance to electricity. If skin resistance is not uniform because of a lesion, the current will flow preferentially through the lesion where resistance is weakest. Current density will then fall in the normal skin and increase in the lesion, rendering the treatment ineffective and dangerous with a risk of burning at the lesion site.

D: Attaching the electrodes

1 Place the active electrode on the area to be treated.

If the area to be treated is painful, find the chosen pain point by palpation and center the active electrode on that point. When treating a joint, center the active electrode on the central axis of the joint.

Avoid placing the active electrode over scarred areas.

Unless the iontophoresis treatment is intended to soften a scar or improve a keloid, avoid placing the active electrode on an area of skin with scarring.

The ionized medicine penetrates via the sweat gland ducts, which are absent in scar tissue. Place the active electrode over areas of skin that are rich in sweat glands and avoid areas poor in sweat glands. An area such as the anterior surface of the knee, which often has scarring, should be avoided.

In man the estimated number of sweat glands totals around two million. There are nearly 400 per cm² on the palms of the hands and on the soles of the feet and 130 to 200 per cm² over the rest of the skin covering.
E: During treatment

Do not move or remove the electrodes without stopping the treatment first.

Compex 3 is programmed so that the current increases gradually at the start of the treatment and decreases gradually at the end or when the treatment is stopped. This means that there can be no excitation phenomenon and the patient will never be surprised by a shock or a painful electrical discharge. If, by contrast, the electrodes are disconnected as a result of ill-timed handling, the sudden break in the circuit may give rise to an excitation phenomenon.

1. Ask the patient to move as little as possible during the treatment and not to remove the electrodes.

For the same reasons as in the previous point.

2. Warn the patient that a pricking sensation from the electrodes is normal and harmless.

This is a normal effect of the galvanic current which has nothing to do with burning.

3. If there is an electrode fault during treatment.

The Compex 3 measures the impedance of the circuit and, when this is too high, the equipment stops and indicates "ELECTRODE FAULT" as well as the number of the channel on which there is a problem. There are a number of possible reasons for this safety and efficacy check system coming into operation:

- electrode disconnected
- poor connection
- channel reversal
- defective cable
- defective electrode
- solution not conducting (non-ionizable medicine or concentration too low)

F: After treatment

1. Thoroughly clean the skin over the treated area using tap water.

During iontophoresis treatment, acids and bases form on the electrodes and hence come into contact with the skin. If the concentration of these substances is too high and they stay on the skin for too long, chemical burns may result. It is advisable to clean the patient’s skin immediately after the treatment to remove these chemical substances.

2. Clean the electrodes thoroughly with tap water, then rinse with distilled water before leaving them to dry.
Denervated muscles
First of all, one should not confuse denervated muscle and paralyzed muscle, as these two terms are not synonymous. A paralyzed muscle is one that presents a deficiency or loss of its motor function, most often because of central or peripheral nerve lesions. That is to say, a paralyzed muscle cannot contract at will, because of an injury to the central nervous system or because of damage to the peripheral nerve. If the injury involves the central nervous system exclusively, the muscle is paralyzed, but, as the peripheral nerve is intact, it is not denervated. If on the other hand there is a comprehensive lesion of the peripheral nerve, in this case the muscle is not only paralyzed but also denervated.

A muscle that is paralyzed but not denervated is stimulated in the same way as a healthy muscle by means of the neurostimulation programmes. With these, muscle contractions can be obtained by excitation of the motor nerve. As a paralyzed and denervated muscle has lost the function of its motor nerve, it can be stimulated only by direct excitation of its muscle fibres. This technique requires the use of neurostimulation and denervated muscles programmes.

When a muscle’s loss of motor function is only partial and a certain degree of voluntary contraction is still possible, the term paresis is used, that is to say a weakening of contractility. Paresis may be due to a central or peripheral lesion. In the case of a partial lesion of the peripheral nerve, the muscle affected by paresis comprises a mixture of denervated and innervated muscle fibres. In the case of paresis due to a central lesion, on the other hand, all the muscle fibres are normally innervated.

A muscle affected by paresis because of a central lesion will be stimulated by means of the “neurostimulation” module, which produces pulses of current to excite the motor neurons. On the other hand, in the case of a muscle made paretic as a result of damage to the peripheral nerve, the neurostimulation programmes or the denervated muscles programmes can be used, depending on whether the innervated fibres or the denervated fibres are to be stimulated. To act exclusively on the innervated part of the muscle, the motor neurons will be excited using the neurostimulation programmes. If, on the other hand, only the denervated muscle fibres are to be excited, the ramped pulses of the denervated muscles programmes will be used.

Although stimulation of normally innervated muscle is of obvious benefit in many clinical situations and has been claimed to be a particularly efficient technique in modern re-education medicine, this is not true of stimulation of the denervated muscle. Opinions are very divided and the results of the studies carried out conflict considerably as to the benefit and efficacy of stimulation of the denervated muscle. A careful reading of the numerous publications on the subject reveals total anarchy as to the choice of parameters employed, and this means that any comparison between these different studies is impossible. One is also struck by the incredible weakness and lack of reliability of the technical resources employed. Thus, for example, triangular pulses are programmed at random, without any ramp detection test being performed beforehand. With its denervated muscles programmes, the Compex 3, unlike the apparatus usually available, makes it possible to work cleanly and logically without risk of burning, when necessary carrying out genuine automatic ramp detection before starting a treatment.
B: Excitability of muscle fibre

The only cells that are excitable, that is to say capable of producing an action potential, are the nerve cell and the muscle cell. Excitation is obtained by the supply of a certain quantity of electrical charges, which reduces the resting potential to a value called the excitation threshold. The action potential in the nerve cell can easily be triggered by supplying a small amount of current. It is more difficult with a muscle cell; however, muscle cells are less easily excitable and require a larger quantity of current to reach the excitation threshold.

The greater or lesser excitability of a cell is expressed in Lapicque’s law. This describes the relationship between the intensity of a rectangular current and the minimum period during which this current must be applied to obtain excitation (see the fundamental law of electrostimulation in the "Fundamental rules of electrostimulation" chapter). It is the mechanical response of the muscle or its absence which determines whether excitation has occurred or not. However, this mechanical response reveals either excitation of the motor nerve or direct excitation of the muscle fibres. When rectangular pulses are used on a normally innervated muscle, the mechanical response observed always reflects the excitation of the motor nerve, because the motor neurons are more easily excitable than the muscle fibres. The mechanical response observed with rectangular pulses is due to direct excitation of the muscle fibres only if the latter are withdrawn from nerve control, as is the case in denervation. However, experimentally, one can analyze the excitability of the muscle fibres and obtain their intensity/duration curve by curarizing the patient. In this way, synaptic transmission between motor neuron and motor end plate is blocked. The graph below gives an average of the i/t ratio for motor neurons and for muscle fibres.

The only cells that are excitable, that is to say the raising of the excitation threshold, is preferred. It is in fact accommodation, is obsolete and the term accommodation as with rectangular pulses, it is supplied in a slowly progressive manner (ramped current or triangular pulse), the intensity that has to be achieved to obtain excitation must be higher. From a certain ramp onwards, the gentler the initial ramp, the more so the less recent the denervation. Moreover, with time, denervated muscle tissue may evolve towards sclerosis and lose its properties of excitability.

Thus, if rectangular pulses of a width of 10 ms are capable of exciting healthy muscle fibres, much longer pulses, of the order of 100 ms, are required to excite denervated muscle fibres.

C: Accommodation

If, instead of supplying the current vertically, as is the case with a rectangular pulse, it is supplied in a slowly progressive manner (ramped current or triangular pulse), the intensity that has to be achieved to obtain excitation must be higher. From a certain ramp onwards, the gentler the intensity of the current will have to be. This phenomenon is sometimes called climalysis, but this term is obsolete and the term accommodation is preferred. It is in fact accommodation, that is to say the raising of the excitation threshold (see Fundamental notions of excitation electrophysiology) that explains why the gentler the initial ramp the greater the intensity of the current must be.
The difference in the values for motor neuron and muscle fibre is so great that the comparison between the two curves is clearer with a log scale of the time (see the graph below).

The above graph shows an average accommodation curve for motor neurons. Elevation of the rheobase appears at around 20 to 30 ms, that is to say the phenomenon of accommodation of the motor neurons is recorded visibly for ramps generally gentler than 10 mA in 25 ms (or 40 mA in 100 ms or 1 mA in 2.5 ms, etc.). The graph also shows that there is a limit to the ramp below which excitation of the motor neurons can no longer be obtained.

Where the muscle fibres are concerned, the same type of accommodation curve is obtained, but it is shifted appreciably towards the right and upwards. The left part of this curve can be observed only if neuromuscular transmission has been blocked as in a curarized patient. Note the difference in the scale of the x-axis: accommodation is recorded between 20 and 100 ms in the case of the motor neurons and between 100 and 300 ms in the case of the muscle fibres.

If we draw the two curves on the same graph, we can see something remarkable: the two curves cross. The curves never cross with rectangular pulses. With triangular pulses, it is only possible to excite the motor neurons initially. With triangular pulses with a sufficient ramp, on the other hand, the muscle fibres can be excited immediately without exciting the motor neurons.

Excitability differs between a healthy muscle fibre and a denervated one, and the same is true of accommodation. The accommodation curve of a denervated muscle fibre is shifted towards the right and downwards. This shift varies according to whether denervation is more or less recent. If the denervated muscle fibres are sclerosed, they lose their excitability and the curve goes upwards, flattening out and finally disappearing.

The graph below shows the accommodation curves for the three different types of cell: motor neuron, healthy muscle fibre and denervated muscle fibre. One can also see that a ramped pulse of 4 mA in 100 ms makes it possible to obtain excitation of the denervated muscle fibres without exciting the motor neurons or the healthy muscle fibres. If intensity is increased in order to accentuate the spatial recruitment of the denervated fibres that are being stimulated, the pulse has to be widened in order to retain the same ramp. For example, with an intensity of 8 mA instead of 4 mA, the pulse duration must be 200 ms instead of 100 ms!
A rectangular shape is always the most suitable for triggering an action potential in an excitable cell. It is in fact the rectangular shape that makes it possible to reduce the electrical parameters to their minimum value and thus to ensure maximum comfort and safety for the patient (see the “Fundamental principles of electrostimulation” chapter). A triangular shape is justified in order to obtain excitation of denervated muscle fibres selectively in cases where a muscle is partially denervated or when the denervated muscle is surrounded by innervated muscles.

If a muscle is innervated normally, it is stimulated by excitation of its motor nerve by means of biphasic rectangular pulses of short duration (between 0.15 and 0.35 ms), which are available with the neurostimulation programmes.

If, on the other hand, stimulation of a muscle that is totally denervated is required, much longer rectangular pulses must be used (between 50 and 200 ms) because the denervated fibre is of low excitability and it therefore requires a large quantity of electrical charges to reach its excitation threshold. These pulses of long duration must not be biphasic, otherwise the time taken for the current to pass would be doubled, resulting in a considerable reduction in comfort for the patient. To avoid the problem of chemical burns from polarization, the pulses must be alternatively in one direction and then in the other (balanced pulses). This type of pulse, known as a balanced pulse, suits the bipolar mode of work of the denervated muscle since the motor point no longer exists.

When there is a partially denervated muscle, according to the clinical circumstances and one’s school of thought, a choice will be made from the different stimulation options available. One may:

1. Work only on the innervated part by means of biphasic rectangular pulses provided by the neurostimulation module, in such a way as to obtain hypertrophy of the innervated fibres to compensate for the denervated ones (compensatory hypertrophy).

2. Work only on the denervated part by means of ramped pulses in the hope of partially preventing atrophy and limiting the phenomenon of sclerosis while awaiting re-innervation. The ramp to be used to excite specifically the denervated fibres and not the innervated fibres or the motor neurons must then be determined. Ramp detection is therefore essential; this will be carried out by the Compex 3’s automatic system with a pulse of 100 ms or, better still, after establishing the accommodation curve that will make it possible to choose possibly a shorter pulse duration. Once the ramp has been established, the Compex 3 will automatically adjust the width of the pulse to the intensity used so as to keep the ramp constant (see graph below). These ramped pulses must be balanced in order to have a zero electrical mean so as to avoid chemical burns.

3. Work simultaneously on the denervated and innervated part by means of rectangular pulses of long duration (100 ms). This option appears of little value however, because the mechanical response obtained is initially from the innervated part and one cannot know whether the intensity is sufficient to obtain good spatial recruitment of the denervated fibres. Moreover, the innervated part is stimulated with pulses that are much too wide which, on the one hand, prevents good spatial recruitment because of the pain and on the other hand, does not allow normal physiological operating frequencies of the motor units.

4. Work alternatively on the innervated fibres [as in 1] and on the denervated fibres [as in 2].
2 Total or partial denervation?

How can we find out if the muscle is partly or totally denervated?

- An electromyogram examination is of course preferable but it must be recent and the results must be passed on to the physiotherapist, which does not always happen in day-to-day practice.
- Muscular testing is often worthwhile. However, with certain muscles, especially if there are only very few innervated fibres left, the really analytical contraction of the muscle is difficult to obtain by reason of the inevitable activity of the agonist muscles.
- Nevertheless, there is a simple and easily reproducible way to find out the state of denervation of a muscle. Biphase rectangular micro-pulses (lasting between 0.15 and 0.35 ms) are only capable of exciting the nerves but not of directly exciting the denervated muscle fibres. It is sufficient, therefore, to test by means of a disuse atrophy treatment. If no response is observed in spite of significant current strengths, the muscle can then be considered as completely denervated; if, on the other hand, a contraction, even of low intensity, is achieved, then the muscle is partly denervated.

C: Practical therapeutic approach

It is therefore actually easy to find out the two fundamental factors that will guide our therapeutic approach:

- There is hope of re-innervation or, on the contrary, denervation is final.
- The muscle is partly or totally denervated.

Four situations can thus arise:

- We are OUTSIDE the re-innervation time
  - Denervation is total
  - Denervation is partial

- We are WITHIN the re-innervation time
  - Denervation is total
  - Denervation is partial
The practical therapeutic approach must be adapted to each situation:

Situation 1: Total denervation outside the time

Electrostimulation by means of the *Denervated* programmes is pointless, since a muscle definitively without any innervation will always end up atrophying and sclerosing.

Situation 2: Partial denervation outside the time

It is not possible to avoid atrophy and sclerosis of muscle fibres that are definitively denervated. Stimulation of these fibres by means of the *Denervated* programmes is therefore not indicated here. It is possible, however, to work on the innervated part of the muscle by means of neurostimulation rectangular biphasic micropulses in order to achieve compensatory hypertrophy of the innervated fibres.

Situation 3: Total denervation within the time

Pending possible re-innervation, it is important to prevent atrophy as much as possible and limit the sclerosis phenomenon. Stimulation of muscles deprived of innervation, by means of wide rectangular pulses in the *Denervated* programmes is the preferred technique here.

Situation 4: Partial denervation within the time

It is important to try and prevent atrophy and to limit the phenomenon of sclerosis of the denervated fibres; to do this it is necessary to use the triangular gradient pulses in the *Denervated* programmes. Depending on the circumstances it may also be worthwhile working on the innervated part of the muscle using the rectangular biphasic micro-pulses in the neurostimulation programmes.

### D: Summary

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<td>stimulation is pointless</td>
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<td>Long triangular pulses</td>
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<td>PARTIAL DENERVATION</td>
<td>Rectangular biphasic</td>
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The use of interrupted direct current can reduce post-traumatic oedema in 3 to 4 days. Although Taylor HAS shown that a single 30-minute session can successfully reduce oedema, the effects are short-lived (lasting only about 6 hours). To achieve long-lasting results, the current must be applied 3 times daily. For optimum results, other methods designed to reduce oedema formation (cold therapy, compression bandaging, elevation, etc.) should be used between sessions.

The mechanisms by which interrupted direct currents act (consisting of monophasic pulses) are still unclear. Karnes has ruled out a vasoconstrictor mechanism and the most plausible hypothesis is that the currents reduce local protein substrate density by reducing vascular membrane permeability, also preventing the arrangement of protein molecules, or a combination of both mechanisms.

Consequently, it is important to:

A - Work with monophasic rectangular pulses delivered at a continuous frequency of 120 Hz.

B - Place one or more negative electrodes (cathodes) on the swelling and positive electrodes above the swelling.

C - Set pulse duration to 150 µs (optimum level determined in tests).

D - Set current intensity to 90% of the motor evoked potential (MEP) threshold. 1 session = 0.9 MEP threshold.

E - Ensure that each treatment lasts at least 30 minutes.
Rehabilitation of disuse atrophy (standard protocol) page 99

Rehabilitation of peroneus muscles following ankle sprain page 100

Back muscle reinforcement in the prevention and treatment of low-back pain page 101

Treatment of patellar chondromalacia
A External subluxation page 102
B Post-traumatic condition page 103

Ligamentoplasty of the ACL page 103

Gluteal muscle rehabilitation following total hip prosthesis page 105

Rehabilitation of the shoulder page 106

Locating a motor point page 111

Reflex sympathetic dystrophy page 113

Endorphinic treatment of rachialgia and radiculalgia page 116

Urinary incontinence page 122

Hemiplegia - Spasticity page 125

Treatment of hyperhidrosis with iontophoresis page 131

Traumatic oedema page 131

Denervated muscle page 133

Rehabilitation of disuse atrophy (standard protocol)

Traumas of the locomotor apparatus may have extremely varied consequences (fractures, sprains, dislocations, etc.) and may entail different functional repercussions.

Despite the spectacular progress of orthopaedic medicine, the various treatments usually applied are always accompanied by a more or less strict period of immobilization, of variable duration, of the part involved. This always entails a major decrease, if not a complete interruption, of the usual activity of the muscles of the traumatized area. As a consequence, rapid disuse atrophy (decrease of the volume and contractile qualities of the muscle tissue) may jeopardize the person’s future functional performance.

The physiological mechanisms of the alteration of the various muscle fibres in such circumstances are now fully known and extremely specific treatments can therefore be applied that, alone, will allow the patient to obtain the most benefit.

This standard protocol is recommended for the majority of functional atrophic states. However, this protocol can be adapted according to the pathology, the treatment objectives and the speed of the patient’s recovery.

METHOD

1 - Protocol

- **Disuse atrophy**, level 1: weeks 1 – 2.
  - In the first two weeks of treatment, it is necessary to work toward and achieve the following 3 objectives:
    - **Eliminate muscle wastage**. Accustom the patient to the NMES technique so that he/she can work with significant stimulation energies.
    - **Recover the first signs of muscle bulk** (slight increase in volume, improvement in tone...).
  - **Disuse atrophy**, level 2: weeks 3 – 6.
  - The objective is to restore muscular volume that is close to normal.

  - The objective is to develop the maximum strength capacity that can be expressed by the muscle or muscle group.

2 - Treatment frequency

One or two sessions every day [in the case of two daily sessions, it is necessary to leave enough rest time between the two sessions].

Minimum: 3 sessions per week.

3 - Electrode position

To achieve nerve stimulation intended for muscle fibre recruitment, the rule consists of positioning one or more small positive electrode(s) on the muscle’s motor point(s) and a negative electrode at one end of that same muscle [see picture n°7]. The precise placement of the positive electrode on the motor point ensures maximum comfort, optimum muscle fibre involvement and therefore maximum treatment efficacy. To this end, it is recommended that the motor point of that muscle be located in the first session, and then marked with a dermographic pencil for the following sessions. To find the motor point, refer to page 111 of this manual.

4 - Patient position

Stimulating a muscle when it is at its maximum inner range is uncomfortable and quickly becomes painful due to the cramping sensation associated with this position. Therefore, this position should be avoided, by placing the patient in one that potentializes a mid range position. It is also important to ensure that the extremity of the stimulated limb is securely fixed, in order that the electrically induced contraction does not produce movement. Stimulation will therefore be carried out by means of isometric contractions.

5 - Stimulation energy

In NMES, the stimulation energy is directly responsible for spatial recruitment: the higher the stimulation energy, the greater the percentage of motor units recruited and the greater the progress.
The peroneus muscles maintain the stability of the talocrural articulation and prevent the ankle from rotating inwards. After a sprain, due to the functional disability and the inhibition phenomenon, these muscles suffer from partial disuse atrophy. The proprioceptive reflex and the strength of the muscles also diminish drastically. Rehabilitation after such an accident should therefore be focused essentially on the lateral peroneal muscles, in order to prevent recurrences.

In order to fulfill their function successfully, the peroneus muscles have to put up resistance to brief and powerful stresses. They must therefore be capable of responding with a short, powerful contraction at the precise moment or the stress that is applied to the foot can cause the ankle to tilt inward. There are therefore two main aspects of the reeducation of these muscles:

1 - The proprioceptive reflex

It allows the peroneus muscles to contract at the right moment. This aspect of the rehabilitation consists of appropriately performing exercises on classic “balance boards” such as Freeman wobble boards a sufficient number of times (per session).

2 - Muscular reinforcement

It allows the peroneus muscles to contract with sufficient vigor to combat the forces encountered by the ankle. This part of the reeducation consists in creating contractions of the peroneus muscles with electrostimulation using programmes aimed at developing explosive force. This method is the only one that can develop the strength of these muscles effectively, as all active methods with a significant change are difficult to execute.

To conclude, the Hi-Action function is a beneficial tool because it requires the patient to contract the muscle voluntarily to a certain defined intensity in order to initiate the electrically-induced contraction and according to the given setpoint (see User Manual).

**Back muscle reinforcement in the prevention and treatment of low-back pain**

Many well-documented studies show the importance of the strength and endurance of the paravertebral low-back muscles (erector spinae) in patients suffering from low-back pain and acute lumbo-sciatical pain. These pathologies appear much more often in patients who do not have strong muscles that are resistant to fatigue. The reinforcement of the low-back muscles is therefore an essential goal in the treatment of such patients, in order to reduce chronic pain and the frequency of periods of acute pain.

Dynamic active exercises of the back for low-back pain patients obviously create serious problems! This is why the electrostimulation of paravertebral muscles shows great efficacy in developing the strength and endurance of these muscles.


The rule therefore consists of always working to increase the energy level to the maximum that the patient can tolerate. The therapist plays a fundamental role by encouraging and reassuring the patient, who can thus tolerate energies producing powerful contractions. There must be progression in the energies reached within a session as well as from one session to the next, because patients quickly get used to the technique.

When the patient encounters difficulties in reaching satisfactory stimulation energy levels, it may be beneficial to ask him/her to combine voluntary cocontractions, which improves the lesser quality muscle fibre recruitment and also makes the stimulation more comfortable. It then becomes possible to gradually increase the energy levels.

**METHOD**

1 - Protocol

Early treatment:
- **Reinforcement**, level 1: weeks 1 – 2.

Late treatment:
- **Disuse atrophy**, level 2: weeks 3 – 6.

In painful situations, it is recommended to combine muscle stimulation with the TENS programme in order to reduce discomfort during the session and more easily increase the stimulation intensities for greater efficacy during stimulation.

2 - Treatment frequency

Three sessions a week after the proprioceptive treatment, or every other day.

3 - Electrode position

Only one channel is necessary for this type of stimulation. A small, positive electrode is placed under the head of the fibula at the passage of the lateral popliteal nerve. The large, negative electrode is placed at the mid point on the outer lateral side of the leg (see picture n°2).

4 - Patient position

Initially the patient is seated on the rehabilitation table, barefooted and not touching the ground. In this position, the therapist gradually increases the stimulation energy until a motor response involving pronation of the foot is obtained. When this response is obtained (usually after 2 or 3 contractions), the patient, again barefooted, is placed in a standing position. This position is particularly beneficial insofar as it requires an associated proprioceptive effort, which can be of increasing difficulty (two feet, one foot, balance board, etc.).

**METHOD**

1 - Protocol

Disuse atrophy level 1:
- weeks 1 – 4.

In painful situations, it is recommended that muscle stimulation be combined with the TENS programme to decrease the discomfort during the session and more easily increase the stimulation energy for greater efficiency during stimulation.

2 - Treatment frequency

5 sessions per week.

3 - Electrode position

We use two channels, one for the right side and the other for the left side. Two
small, positive electrodes are placed on the muscle body at the level of the 4th lumbar vertebrae. They are placed at one finger’s breadth distance from the spinous process. The negative electrode, which has a larger area, is placed two inches above the relief of the paravertebral muscles [see picture n°12].

4 - Patient position
The patient is either seated correctly on a firm seat, or lying down on a medical table with a big cushion under his stomach that elevates the pelvis 15 to 20 cm above the surface of the table.

A distinction must be made between two types of patellar chondromalacias:
1. With patellar static imbalance, which means external incomplete dislocation of the patella with external lateral hyperpressure.
2. Without patellar static imbalance, which means that the patellar chondromalacia is due to a trauma.

The proposed protocols are based mostly on the studies carried out by Dr. Gobelet [University Hospital of Lausanne, Switzerland, Physical Medicine Department] and by Dr. Dhraegens [College of Physiotherapy, Liège, Belgium].

1) External subluxation
An essential cause of the static imbalance of the patella is determined by an imbalance between the different parts of the quadriceps muscle. A particularly significant weakness of the vastus medialis in comparison with the vastus lateralis creates a lateral external displacement of the patella with hyperpressure between the external condyle and the surface of the patella. The specific reinforcement of the vastus medialis is the ideal way to treat this pathology. It can only be carried out efficiently with electrostimulation.

2) Post-Traumatic condition
Repeated traumas to the knee joint, like those caused by the practice of certain sports, may entail cartilaginous lesions of the kneecap, consequently leading to pain of variable intensity and a phenomenon of reflex inhibition leading to a state of disuse atrophy of the entire quadriceps. The resulting insufficiency of the quadriceps negatively affects the static stability of the joint and increases the pain. This vicious circle can be interrupted through electrostimulation of the quadriceps using the Patellar syndrome programme, the parameters of which are specially adapted to avoid any unwanted effects on the kneecap. However, for irreversible cartilaginous lesions, it is always recommended that the benefits obtained be maintained through “maintenance” treatment.

The protocol detailed below is also suitable for the rehabilitation of femoral-patellar gonarthrosis.

METHOD
1 - Protocol
• Patellar syndrome, level 1: week 1.
• Patellar syndrome, level 2: weeks 2 – 3.
• Patellar syndrome, level 3: week 4, then maintenance.

In painful situations, it is recommended that muscle stimulation be combined with the TENS (channel 4) programme to decrease the discomfort during the session and more easily increase the stimulation energy for greater efficiency during stimulation.

2 - Treatment frequency
5 sessions per week during the first four weeks, then one session per week to maintain the results after week four.

3 - Electrode position
In this programme, 3 stimulation channels are used for the quadriceps. This is because of the need to work with the knee extended in order not to cause excessive pressure on the posterior side of the patella. Indeed, this position places the quadriceps in inner range, which is not generally favourable to electrostimulation techniques, since, in this position, the patient very often feels the contraction as being uncomfortable and even painful (cramp sensation). Using high stimulation energies ensures significant recruitment and can therefore be difficult in some patients. The third stimulation channel overcomes this disadvantage, by optimizing the recruitment involvement and therefore the efficacy of the treatment. The three small, positive electrodes are placed respectively on the motor points of the vastus medialis, the vastus lateralis and the rectus femoris. Two negative poles are connected to a large electrode placed at the stem of the thigh. The third small, negative electrode is positioned just above [see picture n°41].

4 - Patient position
The patient is lying supine, with the knee extended.

41

Ligamentoplasty of the ACL
Ruptures of the Anterior Cruciate Ligament [ACL] of the knee are among the most common accidents in sports traumatology. Reconstructive surgery of the ACL has been subject to continuous developments in recent decades, with considerable progress, in particular owing to the use of arthroscopic techniques. Associated with the improvement in the rehabilitation treatment of injured athletes,
the return time to athletic activity has decreased significantly, and today is practically half what it was around ten years ago. The return to athletic activity requires both satisfactory solidity of the tendon graft, which must be capable of supporting significant mechanical stresses, and, more importantly, good active joint stability. This active joint stability requires muscles capable of opposing sometimes phenomenal stresses in the shortest time periods possible, by activating the proprioceptive reflex. One of the consequences of the operative procedure is always significant quadriplanar muscle atrophy, the treatment of which is one of the primary objectives of the rehabilitation therapist. However, the rehabilitation of the quadriceps must rule out, for the first 3 - 4 months, open kinetic chain exercises due to the anterior drawer component of the tibia, which can endanger the tendon graft during the avascularisation phase. The method described in this chapter is intended to describe an NMES protocol suitable for this particular problem of the reconstruction of the ACL, avoiding any risk of a secondary lesion to tissue. This safety is ensured by using specific ACL programmes that consist of appropriate sequential activation of the quadriceps and hamstrings.

NB: This particular stimulation mode does not allow for work in M-stim mode. For reconstruction using the patellar ligament as the graft, the NMES can be started promptly. When using doubled semitendinosus and gracils tendons for anterior cruciate ligament reconstruction, NMES must not be used before the standard healing period of these tendons.

**METHOD**

1 - Protocol

- **ACL**: weeks 1 – 16.
  - In the first two weeks of treatment, it is necessary to work toward and achieve the following 3 objectives:
    - Eliminate muscle wastage.
    - Familiarize the patient with the NMES technique so that he/she can work with significant stimulation intensities.
    - Obtain the first signs of trophicity (slight increase in volume, improvement in tone, etc.).

  During the following weeks, the aim is to restore muscle volume close to the norm.

2 - Treatment frequency

One or two sessions daily (in the case of two daily sessions, it is necessary sufficient rest time must be left between the two sessions). Minimum: 3 sessions per week.

3 - Electrode position

The stimulation sequence means that the channel numbers must be complied with, as the stimulation of the hamstrings must start before that of the quadriceps. Channels 1 and 2 are used to stimulate the hamstrings, and channels 3 and 4 are used to stimulate the quadriceps. For each muscle group, it is recommended that the positive electrodes be placed precisely on the motor points, as shown in picture n°53, or better yet, that the motor points be found using the instructions on page 111 of this manual.

4 - Patient position

The very first sessions, the primary objective of which is to eliminate muscle wastage, can be performed with the lower limb extended with a small cushion placed under the popliteal fossa. For the subsequent sessions, the patient will be placed in a sitting position with the knee bent at a comfortable angle. After satisfactory recovery of joint mobility, the knee is ideally bent between 90° and 90°.

5 - Stimulation energy

As always in NMES, the objective of the rehabilitation therapist is to motivate the patient to tolerate the highest possible stimulation energy level. With the ACL programmes, and in consideration of the particular sequential stimulation mode, it is not possible to adjust the energy levels of channels 3 and 4, without having previously increased levels on channels 1 and 2. This is an additional safety feature that prevents contraction of the quadriceps if it is not preceded by contraction of the hamstrings. As usual, a patient who tries to work with the maximum energies he/she is capable of tolerating will reach higher currents for channels 3 and 4 (quadriceps) than for channels 1 and 2 (hamstrings).

**Gluteal muscle rehabilitation following total hip prosthesis**

Orthopaedic surgery to the hip and, in particular, the fitting of a prosthesis, results in amyotrophy of the gluteus muscles with loss of strength in the active stability of the hip when standing on one foot and walking.

In addition to exercise and active physiotherapy, neuromuscular electrical stimulation of the gluteus maximus and medius is a technique particularly indicated for the effective treatment of weakness in these muscles.

Treatment should be started as soon as possible after the operation. The very low frequency sequences such as the warm-up, active rest between tetanic contractions and final recovery phase at the end of the treatment sequences generate individualized muscle batches producing a vibration phenomenon in the prosthetic material. The three levels of the Hip prosthesis programme correspond respectively to the programmes: Bisuse atrophy, level 1; Bisuse atrophy, level 2; and Reinforcement, level 1 from which the very low frequencies are eliminated. The three levels of the Hip prosthesis programme therefore induce only tetanic contraction phases separated by complete rest phases.

**METHOD**

1 - Protocol

- **Hip prosthesis, level 1**: week 1.
- **Hip prosthesis, level 2**: weeks 2 – 3.
- **Hip prosthesis, level 3**: week 4.

2 - Treatment frequency

Once daily, 5 days per week, for 4 weeks.

3 - Electrode position

2 channels are used, one for stimulation of the gluteus maximus and the other for the gluteus medius. A small, positive electrode is placed at the intersection of the orthogonal axes dividing the buttock into four quadrants with the same area [motor point of the gluteus maximus]. A second small, positive electrode is placed upwards and outwards of the upper external quadrant of the buttock on the gluteus medius at the point where it passes over the gluteus maximus. One large, negative electrode is used for both channels; it is placed diagonally in the lower-lateral quadrant of the buttock, taking care to avoid placing this electrode on a scarred/wounded area [see picture n°9].

4 - Patient position

If the patient’s state allows, the patient is placed in a standing position, which requires him/her to exert an additional effort that is beneficial for proprioceptive control. If this is not possible, all or part of the session can be conducted in a sitting or prone lying position.
Specific indications

- Unstable shoulder
- Tendopathies of the rotator cuff

These three conditions are established rehabilitation techniques that must be preferred among the various management options for these pathological conditions of the shoulder.

Owing to the numerous advances in the fields of biomechanics, physiology and physiotherapy, the therapeutic approach to shoulder rehabilitation has evolved considerably in recent years. In this chapter, we will discuss three pathological conditions of the shoulder for which neuromuscular electrostimulation is a preferred treatment among the established rehabilitation techniques.

These three conditions are:

- Tendopathies of the rotator cuff
- Unstable shoulder
- Retractile capsulitis

The protocols proposed have been developed on the basis of the following publications:


1) Tendopathies of the rotator cuff

The anatomical location of the rotator cuff exposes it in particular to significant stress and tendopathies of the rotator cuff therefore constitute a real public health problem. A study conducted in the United Kingdom in 1986 shows that 20% of the population has consulted a doctor for shoulder problems. The pathogenesis of these tendopathies is associated with multiple factors: intrinsic factors (vascularisation deficiency, structural abnormality of collagen fibres, etc.) or extrinsic factors (excessive mechanical stress, kinematic defects, etc.) sometimes combined, can be considered as causes of these tendon dysfunctions. Kinematic defects appear to play an important role, and most often involve limitations in range of motion, painful phenomena and functional constraint.

The limitations in range of motion observed by specific tests involve flexion (antepulsion) and/or abduction. A limitation in flexion shows anterior or posterior misalignment, while a limitation in abduction shows misalignment in medial rotation spin. Recovery of range of motion is obtained after correction of the joint misalignment, which must be performed using appropriate techniques. Neuromuscular control work must be focused on the coaptation muscles, the muscles depressing the humeral head and the lateral rotators. The priority given for many years to the latissimus dorsi and pectoralis major muscles is strongly disputed today due to the medial rotation component of these muscles. In fact, the only muscles enabling these mechanical requirements to be satisfied are the supraspinous and infraspinous muscles, which neuromotor rehabilitation, including electrostimulation, will focus on as a primary objective.

METHOD

1 - Protocol

- Phase 1: Rotator Cuff level 1 + TENS
- Phase 2: Rotator Cuff level 2 (* R+ #action mode)

2 - Treatment frequency

- Phase 1: 3 to 5 sessions per week until disappearance of pain.
- Phase 2: 3 to 5 sessions per week until the end of treatment.

When the patient has recovered good motor control of the stabilizing muscles, it is beneficial to perform the last sessions of the treatment in R+ #action mode (see details on this function in the User Manual). When this function is active, the initiation of the electrically-induced contraction requires voluntary contraction on the part of the patient. For this exercise, it is recommended that the R+ #action be positioned on the electrode placed on the infraspinous muscle and to ask the patient to perform a voluntary isometric contraction of his/her lateral rotators.

3 - Electrode position

- Phases 1 and 2: Stimulation of the infraspinous and supraspinous muscles: A stimulation channel (see pictures no. 38 & 52). A small electrode positioned on the fleshiest part of the infraspinous fossa connected to the R+ #action [positive pole]. A small electrode positioned on the external part of the supraspinous fossa connected to the negative pole.

4 - Patient position

The patient is seated with the arm against his/her body, the forearm and the hand resting on an armrest, the upper limb is placed in the reference position with neutral rotation. In phases 2 and 3, and on the condition that the position remains unpainful, the arm can gradually be placed in slight abduction, not exceeding 30°.

5 - Stimulation energy

The stimulation energy must be gradually increased to the maximum of the patient’s sub-painful threshold.
## Shoulder instabilities

Shoulder instabilities are one of the most common complications of the treatment of which remains a difficult challenge. Trauma, repeated microtraumas or a constitutional laxity can compromise the stability of the shoulder either by injuring the passive structures (distension or tear of the inferior glenohumeral ligament, detachment of the labrum, progressive stretching of the capsule, etc.) or by disturbing the motor control systems, causing a reduction in the coaptation component resulting from the action of the scapular and thoracohumeral muscles. The supra- and infraspinous muscles are the main coaptation muscles of the glenohumeral joint; however, their efficacy is reinforced by the tone and muscle mass of the deltoid (bulk effect or composite beam). Unlike in the rehabilitation of tendopathies of the rotator cuff, in which the work of the deltoid must be prescribed due to the subacromial interference, combined muscular electrostimulation of the deltoid and the supra- and infraspinous muscles is beneficial in this case because it allows for the stabilizing musculature of the shoulder to be optimized.

### METHOD

#### 1 - Protocol

- **Phase 1:** *Bisuse atrophy*, level 1 until full, painless mobility is obtained.
- **Phase 2:** *Bisuse atrophy*, level 2 (MEMO symbol) until there is no pain during clinical examination.
- **Phase 3:** Stimulation of the infra- and supraspinous muscles can be performed simultaneously with active work, such as, for example, proprioception exercises. The patient can be placed in the push-up position, with the hands resting on a trampoline. In this position, he/she is asked to bounce in synchronization with the phase of electrically-induced contraction of the spinal muscles. This exercise is always performed after warm-up and will first be performed with 2-handed support, then 1-handed support.

#### 2 - Treatment frequency

3 to 5 sessions per week.

#### 3 - Electrode position

- Phases 1 and 2: 3 channels for stimulation of the deltoid and the spinal muscles. For the deltoid: a small, positive electrode is placed on the anterior bundle of the deltoid, another small positive electrode is placed on the middle bundle. The two negative connections are connected to a large electrode positioned on the shoulder above the acromion.

### 3) Retractile capsulitis

The SECEC (European Society for Surgery of the Shoulder and the Elbow) gives the following clinical definition for retractile capsulitis: limited active and passive mobility, by a minimum of 30%, in the 3 planes, for more than 3 years.

This limitation results from the thickening (inspissation) and fibrosis of the joint capsule with recession disappearance, which translates into a loss of active and passive shoulder mobility. This affliction is idioptic in a third of cases, but in the other two thirds there is a prior shoulder affliction that can be of a highly variable nature (shoulder trauma, shoulder surgery, hemiplegia, subacromion-coracoïd impingement, etc.). Note that the initial development is a sympathetic algodystrophy (even if this does not exactly conform with a strict definition of the term, since it essentially affects the limb extremities); this sympathetic algodystrophy then regresses as the capsule fibrosis and the joint ankylosis develop.

Clinically, we see the development of a first entirely painful acute phase, then the shoulder gradually loses mobility as the pain recedes; then, the shoulder is just stiff where motion is reduced to at least 50% compared to the healthy side. There is spontaneous evolution towards recovery for a period of time that varies from 3 months to 2 years, depending essentially on the quality of the rehabilitation treatment employed.

The objectives of rehabilitation are first to relieve pain in the acute phase, and then to restore the biomechanical and neuromuscular qualities of the shoulder.
Specific indications

110

• Phase 2: A single stimulation channel for the infraspinatus and supraspinatus muscles. A small electrode is placed on the fleshiest part of the infraspinous fossa connected to the m-4 (positive pole). A small electrode positioned at the external part of the supraspinous fossa is connected to the negative pole (see picture no. 52).

4 - Patient position

• Phase 1: The patient is placed in the most comfortable position for him or her.
• Phase 2: The patient is seated with the arm against the body, the forearm and the hand resting on an armrest, the upper limb is placed in the reference position with neutral rotation. In phase 2, and on the condition that the position remains pain-free, the arm can be gradually placed in slight abduction not exceeding 30°.

5 - Stimulation energy

The stimulation energy must be gradually increased to the maximum threshold that can be tolerated by the patient.

Locating a motor point

Electrostimulation subjects the muscles to work. The progress achieved depends on the kind of work to which the muscles are subjected, that is to say the programme chosen. The electrical pulses generated by these programmes are transmitted to the muscles (via the motor nerve) through self-adhesive electrodes. The positioning of the electrodes is one of the determining factors in ensuring a comfortable electrostimulation session. It is therefore essential to devote special care to this aspect. The correct placement of the electrodes and the use of significant energy allow a large number of muscle fibres to work. The greater the energy, the greater the spatial involvement, that is to say the number of fibres working, and therefore the greater the number of fibres that make progress.

A stimulation lead wire consists of two electrodes:
- a positive electrode (+): red connection,
- a negative electrode (-): black connection.

The positive electrode must be fixed precisely on the motor point of the muscle. The motor points correspond to an extremely localized area where the motor nerve is more excitable. Although the location of the various motor points is now well known, there may nevertheless be variations, which can extend to several centimetres, between different individuals. The Motor point programme, combined with the use of the motor point pen, allows the user to determine with great accuracy the exact location of the motor points for each individual and thus ensure the greatest effectiveness of the programmes. It is advisable to use this programme before any initial muscular electrostimulation session. Once located, the motor points can be easily identified using a skin-marker pencil or in any other way, thus avoiding the need to repeat this process before each session.

1. Apply a large electrode at the top of the thigh.
2. Connect the negative terminal (black connection) of channel 1 to the output of this large electrode located towards the inner surface of the thigh.
3. Spread a thin but even layer of Compex conductive gel in the position indicated for the positive electrode positioned over the vastus internus, spreading the gel a few extra centimetres in all directions.
4. Connect the positive connection (red) to the tip of the motor point pen and bring the tip of the pen in contact with the conductive gel (see User Manual, motor point pen chapter).
5. Before using the motor point pen, clean and disinfect the tip of the pen.
6. Select the Motor Point programme and set the area for the thighs; then, start the programme by pressing the “+” or “-” keys on channel 1.
7. Very gradually increase the energy of channel 1, until a value between 5 and 15 is reached, while continuously moving the pen tip over the gel layer, but without ever losing contact with the gel, to avoid triggering off an electrode fault message.
Specific indications

1. To locate the motor point of the vastus externus, proceed as described below:

7. Connect the positive connection (red) of channel 2 to the other output of the large electrode, which should be left in place.

8. Remove the pen from the positive electrode that should be centred over the motor point, and apply a small triggering off an electrode fault message.

2. Spread a thin but even layer of Compex conductive gel in the position indicated for the positive electrode positioned over the vastus externus, spreading the gel a few centimetres in all directions.

3. Use a pair of tweezers to introduce the positive pen tip over the gel layer, without pressing it down. The gel should be compressed between the pen tip and the skin.

4. Using the pen to point to the skin, proceed as described below:

5. Connect the negative terminal (black) connection (red) of channel 2 and connect the small electrode to this connection.

6. Remove the pen from the positive electrode positioned over the vastus internus motor point. Visually locate this motor point and apply a small triggering off an electrode fault message.

7. Connect the negative terminal (black) to the other output of the large electrode, which should be left in place.

8. Remove the pen from the positive electrode positioned over the motor point, and apply a small triggering off an electrode fault message.

9. If this causes an electrode fault, ignore the message and do not exit the programme.

10. As soon as you observe a muscle response in form of twitching, you have located the motor point, and contact the small electrode to this connection.

11. Very gradually increase the energy of stimulation of peripheral nerve.

12. The skin becomes cold with sweating, the muscles begin to cramp, and the patient is calm and resting. Mobilization and massage accelerate it.

13. The underlying bone becomes angulated, the muscle becomes acutely painful, and the skin may be very painful.

Reflex sympathetic dystrophy (RSD) is a disease that physiotherapists frequently diagnose and treat at an early stage. This section deals with the diagnostic definition and which they must be able to diagnose and treat as an early stage.

1) Diagnostic definition

- RSD is a complication to the therapy in form of localizing the region concerned.
- The skin becomes cold with sweating, the muscles begin to cramp, and the patient is calm and resting. Mobilization and massage accelerate it.
- The underlying bone becomes angulated, the muscle becomes acutely painful, and the skin may be very painful.

- The syndrome is based on the following criteria:
  - Reflex sympathetic dystrophy (RSD) is described as the articular and muscular sympathetic dystrophy.
  - It is the role of the peripheral nervous system, playing a major role in the development of the symptoms.
  - It is characterized by the muscle response in form of twitching, which is described by the patient as burning.
  - The syndrome is based on the following criteria:
    - The skin becomes cold with sweating, the muscles begin to cramp, and the patient is calm and resting. Mobilization and massage accelerate it.
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    - The underlying bone becomes angulated, the muscle becomes acutely painful, and the skin may be very painful.
Specific indications

2) Treatment

There are two aspects to the treatment of RSD:

1 - Pain limitation

This means that any movement, massage or other technique that increases pain should be avoided, since it aggravates the RSD.

2 - Reduction in the activity of the orthosympathetic system

The main object of the treatment of RSD is to reduce or block the sympathetic nervous system supplying the extremity of the limb affected. The various methods available are as follows, in increasing order of aggressiveness:

1 Transcutaneous electrical stimulation of the large myelinated nerve fibres of the tactile sensory system (Aß) = TENS.

2 Calcitonin injections.

3 Anaesthetizing infiltration of the sympathetic nerve.

These different therapeutic options are used progressively. Only after one method has failed should one resort to another more aggressive method.

Therefore, the first treatment of choice available to the physiotherapist in treating RSD is transcutaneous electrical stimulation of the myelinated nerve fibres of the tactile sensory system (Aß) = TENS.

It is essential here to use high-quality equipment that generates very clean pulses of constant current, so that stimulation reaches only the type Aß fibres. Otherwise there is a risk of exciting the pre- or post-ganglionic fibres of the sympathetic nervous system [types B and C respectively in the classification of peripheral nerve fibres]. The effect of this would be to increase sympathetic activity, and therefore to aggravate the RSD (see the literature).

METHOD

1 - Protocol

TENS

NB: The intelligent TENS function will enable you to measure the sensitivity threshold of your patient, who will benefit from the most suitable programme this way. You can choose the sensitivity by yourself as well. In this case, we recommend TENS level 1.

If you have activated the Intelligent TENS function, the programme starts with a test in which the stimulation energy increases automatically. The rehabilitation therapist asks the patient to indicate the threshold at which he/she begins to feel a sensation of paresthesia. As soon as this threshold is reached, the therapist presses one of the “+” or “-” keys on one of the channels used [MEMO symbol], and the TENS programme can then begin with stimulation parameters [pulse duration] appropriate to the patient’s sensitivity.

2 - Treatment frequency

A minimum of 20 minutes of treatment daily. If there is no improvement after a week, it may be necessary to add another more aggressive treatment method.

3 - Electrode position

Use three channels. Two channels are used with four large electrodes to cover the painful area. The third channel, using small electrodes, is to excite the nerve path[s] supplying the extremity of the limb concerned.

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Use three channels. Two channels are used with four large electrodes to cover the painful area. The third channel, using small electrodes, is to excite the nerve path[s] supplying the extremity of the limb concerned.

4 - Patient position

The most comfortable position for the patient.

5 - Stimulation energy

1 The stimulation energy must first be adjusted on the third channel, which stimulates the nerve trunk[s] at the axilla, supraclavicular, popliteal or inguinal regions. The energy level is gradually increased until the patient feels paresthesia (tingling) at the proximal end of the limb to be treated.

2 Then, the energy level is adjusted on the other two channels so that the patient feels an increase in tingling sensation.

3 During the session, because of the habituation phenomenon, the sensation of paresthesia will gradually be reduced and even disappear. It is then recommended that the energy be increased slightly to maintain the sensation, but without causing muscle contractions. Using the sensor, the TENS function eliminates this possibility by automatically reducing the stimulation energy to below the motor excitation threshold.

RSD of the knee:
A small electrode is placed at the level of the inguinal fossa just beside the femoral artery, and another small electrode is placed similarly one finger’s breadth above it.

NB: The polarity of the electrodes is irrelevant for TENS-type programmes.

Upper limit:
Distal RSD of the upper limb:
Two small electrodes separated by a finger’s breadth are placed as high as possible on the inner side of the arm; the upper electrode is thus positioned at the level of the brachial wall of the axilla.

Lower limit:
Distal RSD of the lower limb:
A small electrode is placed in the middle of the fossa poplitea; another small electrode is positioned on the bony protrusion of the acromion.

RSD of the shoulder:
A small electrode is placed at the level of the supraclavicular cavity, and another small electrode is positioned on the bony protrusion of the acromion.

RSD of the knee:
A small electrode is placed at the level of the inguinal fossa just beside the femoral artery, and another small electrode is placed similarly one finger’s breadth above it.

NB: The polarity of the electrodes is irrelevant for TENS-type programmes.
This chapter deals with the analgesic treatment of spinal pain and nerve root pain. The practical methods of treatment discussed in this chapter have been established on the basis of the following reference publications:


1) Endorphinic treatment of cervical pain

**Chronic contractures of the levator scapulae and/or superior trapezius are often responsible for the painful symptoms in patients with neck pain. The application of endorphinic treatment to these contracted muscles is thus the treatment of choice in this condition.**

**However, it must be ensured that the stimulation energy levels are sufficient to obtain clearly visible muscle twitches (leading to a marked hyperaemic effect) so that the acid metabolites and free radicals.** The major analgesic effect obtained in this way during each session should not, however, lead to premature termination of treatment. Indeed, in order to restore the atrophic capillary network, the treatment must be continued for a minimum of ten sessions or so.

**METHOD**

1 - Protocol

**Cervical pain:** 10 to 12 weeks.

2 - Treatment frequency

Three to five sessions a week for two or three weeks (10-12 sessions in total). Each session must last for no less than 20 minutes. Ideally, it may be advantageous to perform two successive stimulation sessions with the *Cervical pain* programme, ensuring however that there is a ten-minute rest period between the two sessions to allow the stimulated muscles to recover.

**TABLE 1**

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**Figure 1**

- **METHOD**
- **1 - Protocol**
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- **1 - Protocol**
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Three to five sessions a week for two or three weeks (10-12 sessions in total). Each session must last for no less than 20 minutes. Ideally, it may be advantageous to perform two successive stimulation sessions with the *Cervical pain* programme, ensuring however that there is a ten-minute rest period between the two sessions to allow the stimulated muscles to recover.
2) Endorphinic treatment of thoracic back pain

Whatever their triggering factor, chronic contractures of the dorsal paravertebral muscles (erector spinae) are responsible for the pain that incapacitates patients suffering from thoracic back pain.

As long as sufficient stimulation energy levels to obtain clear muscle twitches are used, the dorsalgal treatment - through the remarkable hyperaemia caused - will be particularly effective for draining the metabolic acids that have accumulated in the contracted muscle. A significant analgesic effect will thus normally be observed during even the earliest treatment sessions.

However, this treatment must be continued for at least ten sessions in order to restore the capillary network, which is habitually atrophic in chronically contracted muscles.

METHOD

1 - Protocol
Thoracic back pain: 10 to 12 sessions.

2 - Treatment frequency
Three to five sessions a week for two or three weeks [10-12 sessions in total]. Each session must last for no less than 20 minutes. Ideally, it may be advantageous to perform two successive stimulation sessions with the Thoracic back pain programme, ensuring however that there is a ten-minute rest period between the two sessions to allow the stimulated muscles to recover.

3 - Electrode position
The points of maximum contraction are usually bilateral but not always symmetrical; two stimulation channels are therefore used.

Two small positive electrodes are placed on these points, which can be easily located by palpatory examination of the painful area.

Two small negative electrodes are placed on the relief of the erector spinae muscles, above or below the positive electrodes depending on whether the pain irradiates toward the cervical region or the lumbar region.

4 - Patient position
The patient is installed in the position most comfortable for him/her: ventral or lateral decubitus, or seated.

5 - Stimulation energy
The stimulation energy level must be increased gradually until it causes clearly visible muscle twitches, which are required in order to induce the hyperaemia effect. When the 

When the 

The stimulator prompts you to increase the energy: a beep accompanies the flashing "+" symbols. When it has detected the ideal setting range, a hook will appear on the screen. This hook indicates the energy level range, in which you should work in order to obtain the best therapeutic results.

At the end of the treatment, or during a break, a statistic indicating the percentage of time spent in the effective range will appear on the screen.

3) Endorphinic treatment of low back pain

Chronically contracted lumbar paravertebral muscles are often the source of the pain felt by patients with lumbago. While the physiotherapist must of course search for the cause and treat it, the treatment of these chronic contractures with the Low back pain programme brings about significant pain relief very quickly. In the lumbar region, the stimulation currents necessary to obtain visible (or at least palpable) muscle twitches are generally high and some patients find them hard to tolerate. This is why it is generally recommended that TENS treatment be combined with the Low back pain programme so as to make it more comfortable for the patient.

This treatment must be continued for at least ten sessions in order to restore the capillary network, which is habitually atrophic in chronically contracted muscles.

METHOD

1 - Protocol
Low back pain + TENS: 10 to 12 sessions.

To combine TENS with the Low back pain programme, it is necessary to personalize the Low back pain programme by activating the TENS. To do this, you must press the + key on the second channel. The Low back pain [endorphinic] programme is active on the first two channels, while the TENS programme is active on the third and fourth channels.

2 - Treatment frequency
Three to five sessions a week for two or three weeks [10-12 sessions in total]. Each session must last for no less than 20 minutes. Ideally, it may be advantageous to perform two successive stimulation sessions with the Low back pain programme + TENS, ensuring however that there is a ten-minute rest period between the two sessions to allow the stimulated muscles to recover.

5 - Stimulation energy
The stimulation energy level must first be adjusted on the third channel [TENS]. The energy is then increased gradually until the patient clearly feels paraesthesia (tickling, tingling) in the lumbar region.

Then, the energies on channels 1 and 2 are adjusted [Low back pain]. The energy level is gradually increased in order to obtain muscle twitches, if possible visible [or at least palpable].

If the patient finds it hard to tolerate the energy increase, it is then recommended that the energy increase on the first two channels is stopped temporarily. The energy level will then be increased again on the third channel [TENS] in order to accentuate the paresthesia in the lumbar region.

After one or two minutes, the energy level can be increased again on the first two stimulation channels so that muscle twitches can be seen.
4) Treatment of lumbosciatica

Patients suffering from lumbosciatica present lumbar pain that often originates from chronic contractures of the lumbar paravertebral muscles. In addition, involvement of the spinal nerve root leads to irradiation of pain a greater or lesser distance along the path of the sciatic nerve and, in some cases, one or other of its branches (common peroneal or tibial). The combination of the lumbosciatica programme with the TENS programme is the preferred treatment as it brings about – through its endorphinic effect (lumbosciatica programme) – a marked analgesic effect on chronic lumbar contractures in the lumbar region and – through the TENS programme – a reduction in medullar input of the nociceptive influx (Gate Control) due to painful irradiation of the sciatic nerve.

4 - Patient position

The patient is placed in the position most comfortable for him/her: ventral decubitus (with cushion to straighten lordosis) or lateral decubitus.

5 - Stimulation energy

The stimulation energy level is gradually increased on the third channel (TENS), in order to obtain marked tickling along the painful irradiation of the sciatic nerve. The gradual energy increase on channels 1 and 2 must be sufficient to obtain visible (or at least palpable) muscle twitches causing hyperaemia.

NB: When the TENS is combined with an endorphinic programme (as in this case, with the lumbosciatica programme), the m-5 and m-6 functions are inactive.
## Urinary incontinence

This section deals with the treatment of female incontinence. It describes the practical method established on the basis of the following publications:


Two types of urinary phase are recognized: short voluntary micturition phases separated by long collecting phases during which the bladder gradually fills. Continence, i.e. the absence of urine loss during the collecting phase, requires firstly a relaxed bladder and secondly a permanent closure of the sphincter urethrae. Impairment of one of these two elements results in urinary incontinence. Clinically, a distinction is made between three types of incontinence:

1. **Urine incontinence**: The bladder contracts abnormally [detrusor overactivity] and presses on the urethra, increasing the pressure within the bladder.

2. **Stress incontinence**: The sphincter urethrae is deficient and cannot remain closed in the event of a sudden and significant increase in abdominal pressure [exertion, coughing, etc.].

3. **Mixed incontinence [urge and stress incontinence]**: Combination of urge and stress incontinence in greater or lesser proportions.

### 1) Urge incontinence

Since this type of incontinence is due to detrusor [smooth muscle of the bladder] overactivity, the treatment is concerned with reducing the activity of this muscle. The detrusor is controlled by the parasympathetic nervous system, which increases its activity, and by the orthosympathetic system, which reduces it. Various mechanisms act to inhibit detrusor activity. These include an inhibitory reflex originating in the sensitive nerve fibres of the vaginal area. Excitation of these afferent fibres (originating in branches of the internal pudendal nerve) has a dual inhibitory effect on the detrusor:

1. By activating the inhibitory orthosympathetic neurones.
2. By central inhibition of activation of parasympathetic motor neurones.

Electrical excitation of these afferent fibres produces an optimum inhibitory effect with:
- A frequency of 5 Hz by the orthosympathetic system. The intramural striated sphincter is composed exclusively of slow fibres (type I), while the parasympathetic components also contain fast fibres (type IIb).
- A frequency of 5 to 10 Hz by the central route.

### 2) Stress incontinence

Three concentric elements operate in the area of the sphincter urethrae:

1. The smooth muscles of the urethra. The intramural striated sphincter.
2. The pararectal components of the striated pelvic floor musculature.

The intramural striated sphincter is composed exclusively of slow fibres [type I], while the pararectal components also contain fast fibres [type IIb].

The intramural striated sphincter is therefore resistant to fatigue but not strong. It is able to maintain a prolonged closure of the bladder; but it is unable to withstand a sudden and intense increase in pressure within the bladder, for example during coughing. In this case, it is the fast fibres of the pararectal muscle that have to maintain continence by contracting strongly during the brief moment when pressure is increased.

Normally, the pararectal components of the striated muscle of the pelvic floor are capable, by contracting, of generating a urethral closing pressure well above that produced in the bladder during coughing. But when these muscles are unable to develop sufficient strength rapidly enough at the appropriate moment, urine escapes from the bladder. This is stress incontinence.

The objective of any treatment of this type of incontinence is to strengthen the sphincter. In order to do this, it is necessary to use a programme that brings about tetanic contractions of the pararectal components of the pelvic floor musculature, using fast fibre tetanization frequencies.

### 3) Mixed incontinence (urge and stress incontinence)

Many patients do not exhibit well defined urge or stress incontinence. Often a mixture of the two forms is present in varying proportions; it is difficult in these situations to establish which is the predominant symptom.

Electrical stimulation treatment is particularly advantageous in this type of incontinence, particularly with Compex equipment. The stimulator is able to provide combined treatment to inhibit the detrusor and strengthen urethral closure in the same session and using the same stimulation programme.

The sphincter urethrae is strengthened by means of tetanic contractions with the optimum fast fibre tetanization frequency. Between the tetanic contractions, during the resting phase, a very low frequency pulse (5 Hz) allows for detrusor inhibition.

### METHOD

#### 1 - Protocol

#### Urge incontinence:

- **Weeks 1 – 3.**
- **Method:**
  - **Electrode position:**
  - **Patient position:**

#### Stress incontinence:

- **Weeks 1 – 3.**
- **Method:**
  - **Electrode position:**
  - **Patient position:**
  - **Treatment frequency:**

#### Mixed incontinence (urge and stress incontinence):

- **Method:**
  - **Electrode position:**
  - **Patient position:**
  - **Treatment frequency:**

### 5 - Stimulation energies

- Gradually increase the energies until the patient feels the stimulation, i.e. five pulses per second. Then, increase the energies again to a value equal to three times that of the perception threshold.

### 5 - Stimulation energies

- Use of an intravaginal probe.

### 5 - Stimulation energies

- Use of an intravaginal probe.

### 5 - Stimulation energies

- **Frequency:**
  - Five sessions per week.

### 5 - Stimulation energies

- **Frequency:**
  - Weeks 1 – 3.
**Postpartum prevention**

Pregnancy, and, to an even greater extent, delivery, cause significant trauma to the pelvic region. The consequences of this trauma are varied: strained muscles, torn muscles, partial denervation, loss of body image, loss of strength and control of the striated muscles of the pelvic floor; etc. Urinary incontinence is a relatively common problem in this situation, which is why prophylactic pelvic re-training treatment by neuromuscular electrostimulation is indicated.

**METHOD**

1) **Protocol**

**Mixed indications**

weeks 1 – 3.

2) **Treatment frequency**

Five times per week.

3) **Electrode position**

Use of an intravaginal probe.

4) **Patient position**

The patient reclines on her back on a couch with a cushion under the buttocks and the knees flexed at 90°, feet flat on the couch.

5) **Stimulation energy**

The energy levels are set separately, starting with the energy level of the very low-frequency inhibition of the detrusor at the beginning of the session. Then between contractions, the energy level of the tetanic reinforcement contractions is adjusted.

1) During the very low frequency inhibition of the detrusor [duration 24" at the beginning of the session and between the contractions]: it is necessary to use an energy equal to three times that of the perception threshold. The energy will gradually be increased until the patient feels 5 pulses per second. Once this threshold value has been determined, the energy will gradually be increased until three times the initial energy is reached.

2) During tetanic contractions [duration of contraction 4"]: it is necessary to work with the maximum tolerable energy at all times. Therefore, it is important to regularly increase the energy during the session every 3 or 4 contractions. The therapist plays a decisive role in reassuring the patient and encouraging her to work with the strongest possible contractions.

**Hemiplegia - Spasticity**

**1) Dorsiflexion of the hemiplegic foot**

One of the problems in hemiplegic patients is the greater or lesser degree of difficulty that they encounter when raising the foot voluntarily, or even the total inability to do so. For this reason, the foot drops when walking, during the phase when it is lifted from the ground.

Neuromuscular electrical stimulation (NMES) in the area of the flexor muscles of the foot (tibialis anterior and long extensors of the toes) allows for dorsiflexion to be achieved. This NMES is functional (FNMES) if the dorsiflexion that it achieves is synchronized with the gait so as to stop the foot from dropping when lifted from the ground.

FNMES therefore allows for the hemiplegic patient to be taught to walk again. By using the manual trigger, he can control the onset of contraction and therefore produce dorsiflexion of the foot at the appropriate moment.

This type of rehabilitation not only allows for the levator muscles of the foot to be strengthened and reduces the spasticity of the soleus muscle of the calf, but also produces a psychological benefit to the patient in making him realize that the levator muscles of his foot and toes can still function. Moreover, it has been observed that following a session of FNMES, the patient retains the improvement in voluntary dorsiflexion and in his gait for a certain period.

However, this method of gait rehabilitation by FNMES is not suitable for use in all hemiplegic patients. Two types of case must be considered:

1. **If the stimulation of the muscles lifting the foot produces a spasm reflex in the muscles of the lower limb, it is necessary to stop using this technique (this phenomenon is rare in hemiplegics but more common in paraplegics).**
2) Spasticity

A - Reminder

Spasticity or spastic hypertonia is a term describing the condition of paretic or paralyzed muscles showing different symptoms to varying degrees, including in particular: an increase in muscular tonus mainly in the antagonistic muscle, hyperreflexia and clonus. During passive stretching of a spastic muscle, there is resistance at the beginning of the movement, which then diminishes in the course of extension. The more rapid the passive stretching movement, the more pronounced this resistance. If passive stretching is very rapid and maintained, clonus may occur, that is, a contractile oscillation of 5 to 7 Hz which persists for 40 to 60 cycles as long as stretching is maintained.

Spasticity is due to a lesion of the central nervous system affecting the tractus pyramidalis (cerebro-spinal tract). This interruption of central control releases the activity of the myotatic stretch reflex, which becomes hyperactive. Since this stretch reflex is responsible for muscular tonus, hypertonia develops affecting mainly the antagonistic muscles (extensions of the lower limbs and flexors of the upper) since these are richer in neuromuscular spindles than their antagonists.

In time, spasticity leads to contracture, with shortening of muscle-tendon structures and a reduction in the range of articular movement.

B - Use of neuromuscular electrical stimulation (NMES)

Starting in the neuromuscular bundles are afferent proprioceptive nerve fibres, which are directly associated with the α motor neurons of the same muscle and indirectly associated (via interneurons) with the α motor neurons of the antagonist muscle. Stretching a muscle thus stimulates the afferent proprioceptive nerve fibres of the neuromuscular bundles and they will monosynaptically activate the α motor neurons of the muscle being stretched [myotatic stretch reflex] and inhibit, via an interneuron, the α motor neurons of the antagonist muscle [reciprocal inhibition reflex].

NMES of a muscle excites not only the α motor neurons of that muscle but also and even more readily the afferent proprioceptive nerve fibres with a lower stimulation threshold. The nerve stimulation of the latter will activate the α motor neurons of this muscle and inhibit the α motor neurons of the antagonist muscle [reciprocal inhibition reflex]. It is this last action that is exploited by NMES in the treatment of spasticity. NMES of a muscle antagonist to a spastic muscle makes it possible to reduce the spasticity by inhibition of the α motor neurons of the spastic muscle via the reciprocal inhibition reflex.

This phenomenon of inhibition of α motor neurons by NMES of the antagonist is clearly demonstrated by electromyography. In fact, Hoffman’s reflex in a muscle, produced by a stimulus, is reduced in amplitude when the motor nerve of the antagonist is stimulated.

NMES is an effective technique in the treatment of spasticity, not only because it reduces hypertonia, but also because it allows strengthening of the antagonist muscle as well as preventive or curative stretching of the retraction of spastic muscles, this is much more effective than the conventional passive means.

However, care must be taken in the treatment of spasticity to ensure that NMES is used correctly, to produce a positive effect. It is necessary to avoid any direct stimulation of a spastic muscle as well as any indirect stimulation by diffusion when the electrical energy is too high. It is also necessary, as set out in the standard programme, to use very gradual electrically-induced contractions in order to prevent any stretching reflex on the spastic muscle.

Spasticity mainly affects the antagonistic muscles but of these, the muscles most affected and the severity of spasticity varies greatly, depending on the type of disorder of the cerebro-spinal tract (hemiplegia, tetraplegia, paraplegia or multiple sclerosis). Moreover, for the same type of disorder of the cerebro-spinal tract, the severity of spasticity and the muscles in which it is most apparent varies from one patient to another. For these reasons, each case has to be considered individually, it is therefore the task of the therapist to carry out a clinical evaluation of each patient, so that the muscles on which treatment is to concentrate can be selected.

In general, spasticity mainly affects the following muscles:

- In the lower limb: triceps surae - quadriceps - adductors - gluteus maximus
- In the shoulder: pectoralis major - latissimus dorsi
- In the upper limb: biceps brachii - flexors of the fingers and wrist

NMES in the treatment of spasticity is applied to one or more of the following muscles, depending on the patient, tibialis anterior, extensor of the toes, lateral peroneal, posterior thigh muscles, tensor fascia lata, suraspinatus, triceps brachii, extensors of the fingers and wrist.

Treatment of spasticity

- Protocol

Spasticity: duration of treatment to be adjusted depending on progress.

1 - Treatment frequency

One to two 20 to 30-minute sessions daily.

3 - Electrode position

Place the electrodes on the antagonist to the spastic muscle to be treated. The stimulation acts not on the spastic muscle but on its antagonist.

4 - Patient position

The patient and the body part treated are positioned in such a way as to allow the maximum range of motion. Indeed, unlike the conventional rules for using NMES, it is worthwhile for these treatments to allow for isometric contraction of the antagonist muscle, causing movement to the maximum range of motion, thus causing...
maximum stretching of the spastic muscle.

- Lower limb: leg; patient seated, thigh: ventral decubitus
- Pelvic girdle: dorsal decubitus
- Shoulder girdle: patient sitting, arm at 30° abduction to the body, elbow resting on an armrest.
- Upper limbs: patient seated.
- Triceps: elbow in supination. Extensions of the fingers and wrist: wrist in pronation.

5 - Stimulation energy

Always work with a low enough energy that will not produce muscle fibre stimulation in the spastic muscles. The stimulation energy must nevertheless be adjusted manually so that the isotonic contraction of the antagonist muscle causes movement to the maximum range of motion, thus causing maximum stretch of the spastic muscle.

This action cannot be achieved if the agonist-antagonist imbalance is too marked; this is the case when spasticity of the agonist-antagonist imbalance is too marked.

The stimulation energy must nevertheless be adjusted so as to obtain extension of the fingers first of all and then extension of the wrist. Extension of the wrist alone with flexion of the proximal and distal interphalangeal joints will not produce the optimum result. Extension of the interphalangeal joints is therefore the first objective.

4 - Patient position

The patient is seated beside a table. The elbow and the forearm rest on the table. The shoulder is in a functional position, the elbow is bent and the hand is pronated.

5 - Stimulation energy

Always operate at an energy below the level that will produce diffusion of stimulation to the flexors of the fingers and wrist.

Ideally, the stimulation energy should be adjusted so that contraction of the extensors extends the fingers and wrist to the maximum range of motion of extension.

The complete movement cannot be achieved if the spasticity of the flexor muscles exceeds the strength of contraction of the atrophied antagonist. Stimulation then only allows for more or less reduced movement or no movement at all. However, even in this situation, the treatment must be carried out, because stimulation, even subliminal, has a beneficial effect on the reduction of spasticity.

6 - Manual activation of stimulation

When the electrode is used [recommended], the stimulation session automatically begins with a measurement of the Chronaxy (\(m^{-3}\)). This short test lasting around ten seconds allows for adjustment of the optimal duration of the stimulation pulse, ensuring maximum comfort. If the electrode is not used, it is necessary to select the treatment zone beforehand. You must then gradually decrease the current, causing the first contraction of the antagonist muscle.

Then, each contraction is followed by a five-minute rest time. Once this rest time has passed, it is necessary to press the “+” key of any channel in order to trigger the next contraction. In this way, the start of each contraction is triggered and therefore controlled by means of a manual action.

This technique is of clear psychological benefit to the patient and allows this treatment to be synchronized with associated movements.

7 - Associated acts

- Passive motion: When contraction of the extensors is insufficient to mobilize the fingers and wrist to their maximum range, the movement should be completed by passive extension. The electrically-induced contraction is allowed to develop until the maximum extension it can produce is obtained. The movement is then completed by the application of gentle and gradual pressure.

3) The hemiplegic hand

In hemiplegic patients, the hand and wrist show paresis or paralysis with more or less pronounced spasticity of the flexor muscles and atrophy of the extensors. This highly debilitating situation leads to contracture, retraction and stiffening in abnormal posture if muscular maintenance treatment is not initiated.

As in dorsiflexion of the hemiplegic foot, we offer a specific approach to this problem relating to the treatment of spasticity.

METHOD

1 - Protocol

Spasticity

One to two 20-minute sessions daily.

3 - Electrode position

A single channel is sufficient to stimulate the extensor muscles of the fingers and wrist (epicondylosis). The positive electrode (small) is placed on the fleshy part of the epicondylar muscles around two fingers’ breadths below the epicondylo.

The negative electrode (small) is placed on the dorsal aspect of the forearm, where the lower and middle thirds meet.

The position of these electrodes must be adjusted as to obtain extension of the fingers first of all and then extension of the wrist. Extension of the wrist alone with flexion of the proximal and distal interphalangeal joints will not produce the optimum result. Extension of the interphalangeal joints is therefore the first objective.

4 - Patient position

The patient is seated beside a table. The elbow and the forearm rest on the table. The shoulder is in a functional position, the elbow is bent and the hand is pronated.

5 - Stimulation energy

Always operate at an energy below the level that will produce diffusion of stimulation to the flexors of the fingers and wrist.

Ideally, the stimulation energy should be adjusted so that contraction of the extensors extends the fingers and wrist to the maximum range of motion of extension.

The complete movement cannot be achieved if the spasticity of the flexor muscles exceeds the strength of contraction of the atrophied antagonist. Stimulation then only allows for more or less reduced movement or no movement at all. However, even in this situation, the treatment must be carried out, because stimulation, even subliminal, has a beneficial effect on the reduction of spasticity. To complete the extension, passive stretching will also be necessary. Combined treatment of stimulation and passive motion is therefore given.

6 - Manual activation of stimulation

When the electrode is used [recommended], the stimulation session automatically begins with a measurement of the Chronaxy (\(m^{-3}\)). This short test lasting around ten seconds allows for adjustment of the optimum duration of the stimulation pulse, ensuring maximum comfort. If the electrode is not used, it is necessary to select the treatment zone (forearm and hand) beforehand. You must then gradually increase the current, causing the first contraction of the antagonist muscle.

Then, each contraction is followed by a five-minute rest period. At the end of this rest period, press the “+” key of any channel in order to start the next contraction. In this way, the start of each contraction is triggered and therefore controlled by means of a manual action.

This technique is of clear psychological benefit to the patient and allows this treatment to be synchronized with associated movements.

7 - Associated acts

- Passive motion: When contraction of the extensors is insufficient to mobilize the fingers and wrist to their maximum range, the movement should be completed by passive extension. The electrically-induced contraction is allowed to develop until the maximum extension it can produce is obtained. The movement is then completed by the application of gentle and gradual pressure.
B - Use of neuromuscular electrical stimulation (NMES)

NMES of the abductor muscles of the arm (deltoid and supraspinatus muscles) may be used in the prevention or treatment of atrophy and reduction of spasticity in the latisimus dorsi and pectoralis major muscles. This technique is indicated in the prevention and treatment of subdislocation of the shoulder in the hemiplegic patient. Radiological investigations show evidence of re-centring of the humeral head in relation to the glenoid cavity.

Moreover, the pain in the shoulder and arm often associated with subdislocation is effectively reduced by this type of treatment. The analgesic action, in the event of pain radiating into the arm, can be potentiated by the use of TENS [gate control], which is programmed on channel 4.

In the shoulder-hand syndrome, apart from shoulder pain, which is itself a secondary event of pain radiating into the arm, can be treated using the programmes and methods described in RSD should be treated using the a programme active on the third and the fourth channels. For each channel used, two large neutral electrodes are positioned to cover the painful area or irradiation.

4 - Patient position

The patient is seated beside a table, with his elbow and forearm resting on a cushion on the table.

5 - Stimulation energy

The energy is gradually increased for each contraction until the maximum tolerable energy level is reached. The therapist plays a fundamental role in encouraging and reassuring the patient, enabling him/her to tolerate currents that produce powerful contractions.

If the TENS programme is used on channels 3 and 4, the energy level will be adjusted on these channels so that the patient clearly feels tingling. However, care must be taken to ensure that the energy is low enough to avoid any muscle contraction.

**TENS**

If pain is radiating towards the hand and forearm, the NLMS should be used. The TENS programme is active on the third and the fourth channels. For each channel used, two large neutral electrodes are used, positioned to cover the painful area or irradiation.

4 - Patient position

The patient is seated beside a table, with his elbow and forearm resting on a cushion on the table.

5 - Stimulation energy

The energy is gradually increased for each contraction until the maximum tolerable energy level is reached. The therapist plays a fundamental role in encouraging and reassuring the patient, enabling him/her to tolerate currents that produce powerful contractions.

If the TENS programme is used on channels 3 and 4, the energy level will be adjusted on these channels so that the patient clearly feels tingling. However, care must be taken to ensure that the energy is low enough to avoid any muscle contraction.

**METHOD**

1 - Protocol

**Shoulder subluxation**

2 - Treatment frequency

One 25-minute session daily, five days a week for 4 weeks.

3 - Electrode position

Channels 1 and 2 are used for stimulation of the abductor muscles of the arm, one channel for the deltoid and the other for the supraspinatus muscle. A small, positive electrode is placed on the lateral aspect of the shoulder, in the middle of the deltoid another small, positive electrode is placed at the level of the outer part of the supraspinous fossa. The negative electrode of both channels is connected to a large electrode that is placed like an epaulette on the acromion.

If pain is radiating towards the hand and forearm, the TENS, which must be activated beforehand by pressing the “+” key on the second channel, will also be activated.

**Treatment of hyperhidrosis with iontophoresis**

Sweating is a physiological phenomenon intended to contribute to heat regulation in order to maintain a constant body temperature at 37°C. Hyperhidrosis [Hyperhidrosis (sweat)] occurs when sweating is excessive. Indeed the amount of sweat produced considerably exceeds the volume required for thermoregulation. The neurological control responsible for sweating is provided by the hypothalamus and the sympathetic system. In some cases, hyperhidrosis, in particular in its general form, constitutes only a symptom of the cause which must be found. Treatment with iontophoresis involves localized palmar or plantar (or mixed) forms, which are usually idiopathic, although a psychological cause is sometimes suspected. The problems caused are significant: difficulty in performing manual tasks, cutaneous symptoms, etc., and have social and professional repercussions. It is estimated that around 1% of the population is affected by localized hyperhidrosis. Treatment with iontophoresis (Hyperhidrosis programme) makes it possible to obtain lasting remission of hyperhidrosis after around ten sessions. The remission period can last up to six months, and the treatment can be started again when the signs reappear.

**METHOD**

USE CHANNEL 1 (other channels inactive for this programme)

1 - Protocol

**Hyperhidrosis**: The first session will be conducted with the electrical density automatically provided (by default) of 0.05 mA/cm². You must then increase this electrical density by 0.01 in each of the subsequent sessions.

- First session: D = 0.05 mA/cm²
- Second session: D = 0.06 mA/cm²
- Third session: D = 0.07 mA/cm²

2 - Treatment Frequency

Three sessions per week until remission of the symptoms, generally between 5 and 10 sessions.

3 - Electrode position

Use channel 1, connecting the “+” and “–” outputs to the large red iontophoresis electrodes, then place the electrodes in the bottom of a nonmetal basin two-thirds full of tap water.

4 - Patient position

The patient is seated with the feet or hands immersed in the basin, with the palms or soles resting on the electrodes.

5 - Stimulation intensities

For these programmes, the intensity increases automatically after validation (“+” or “–” key on the fourth channel) of the desired electrical density selection.

**Treatment of traumatic oedema**

This chapter addresses the electrotherapeutic treatment of traumatic oedema. The practical method presented has been developed on the basis of the following publications:

Bettany JA, Fish DR, Mendel FC
High-Voltage pulsed direct current: effect on oedema formation after hyperflexion injury
Arch Phys Med Rehabil 71 (3) : 877 – 81; 1990

Karnes JL, Mendel FC, Fish DR, Burton HH
High-voltage pulsed direct current: its influence on diameters of histamine-dilated arterioles in hamster cheek pouches
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Fish DR, Mendel FC, Schultz AM, Gottstein-Yerke LM
Effect of anodal high-voltage pulsed current on oedema formation in frog hind limbs
Phys Ther 71 (10) : 677 – 81; 1991
Specific indications

Taylor K, Fish DR, Mendel FC, Burton HW. Effect of a single 30-minute treatment of high voltage pulsed current on edema formation in frog hind limbs. Phys Ther. 72 [1]: 63 – 8; 1992

The use of interrupted direct current can reduce post-traumatic oedema in 3 to 4 days. Although Taylor has shown that a single 30-minute session can successfully reduce oedema, the effects are short-lived (lasting only about 6 hours). To achieve long-lasting results, other methods designed to reduce oedema formation (cold therapy, compression bandaging, elevation, etc.) should be used between sessions. The mechanisms by which interrupted direct currents act (consisting of monophasic pulses) are still unclear. Karnes has ruled out a vasoconstrictor mechanism and the most plausible hypothesis is that the currents reduce local protein substrate density by reducing vascular membrane permeability, also preventing the arrangement of protein molecules, or by combining both mechanisms.

METHOD

1 - Protocol

2 - Treatment Frequency

3 per day, or even up to one session every four hours.

3 - Position of the electrodes

The negative pole is the active pole. It is necessary to try to cover the oedematous region with negative electrodes. For example, for oedema caused by an ankle sprain, two stimulation channels will be used: two large negative electrodes will be placed on the mallotalar and perimalleolar region, and one of the two outputs of each electrode is not used. A large electrode is positioned above the patella, at the level of the quadricipital tendon, and will be connected to the positive poles of the two stimulation channels.

4 - Patient position

The patient will be placed in the most comfortable position for him or her, with the treated limb elevated. For example, for oedema of the ankle, the patient will be in the supine position, with the lower limbs elevated by about thirty centimetres relative to the plane of the table.

5 - Stimulation intensities

The oedema programme begins automatically with a short test in which the stimulation intensity increases automatically. The rehabilitation therapist, visually or by palpation, attempts to detect the start of muscular activity. As soon as the motor threshold is reached, the therapist presses one of the “+” or “-” keys on one of the channels used (MEMO symbol), and the oedema programme then beings with an intensity equal to 93% of that of the motor threshold.

4 - Patient position

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2) Situation 2

Partial denervation outside the time

Example: PARALYZED SCIATIC

Questioning the patient gives us the following information:

- The level of the injury: Radicular compression L4 - L5 following a discal hernia.
- The date of the injury: The patient has had a steppage gait for at least 3 years.

Question n° 1: Are we outside or within the re-innervation time?

The distance between the injury and the motor point of the deltoid can be assessed at 6/8 cm. The re-innervation time is therefore 3 months, or 6 months at most. As the injury is 9 months old, there is therefore no hope of re-innervation.

Question n° 2: Is the denervation total or partial?

Testing for total or partial denervation of the deltoid

1 - Protocol

Biase atrophy, level 1.

2 - Electrode position

Use two channels, one for the anterior fascicle and the other for the centre fascicle of the deltoid. A positive electrode is placed on the motor point of the medial part, a few centimetres below the outer edge of the acromion. Another positive electrode is centred on the fleshy body of the anterior fascicle. The two negative connections are connected to a large electrode positioned on the shoulder.

3 - Stimulation energy

The energy will be gradually increased until significant figures are reached (above 40 or 50 mA).

CONCLUSION

Our patient has paralysis of the axillaris nerve with total denervation of the deltoid, with no hope of re-innervation.

PRACTICAL THERAPEUTIC APPROACH

Electrostimulation of the deltoid, using Denervated programmes, is of very little value here. Whatever is done, a denervated muscle without any hope of re-innervation will always end up atrophying and sclerosing. Rehabilitation can then be solely palliative.

4 - Results

No muscular contraction of the deltoid is observed, either visually or by palpation. It can then be concluded that denervation is total.
Specific indications

CONCLUSION

Our patient has paralytic paresis of the sciatic nerve due to partial denervation of the muscles of the antero-external part of the leg. There is no hope of reinnervation for the denervated fibres.

PRACTICAL THERAPEUTIC APPROACH

Electrostimulation of the muscles of the antero-external part of the leg using Denervated programmes is of no value. Denervated fibres with no hope of reinnervation will always end up atrophying and sclerosing.

On the other hand, it might be worthwhile to work on the innervated part of the paretic muscles by means of neurostimulation with rectangular biphasic pulses in order to achieve hypertrophy of the innervated fibres to compensate for the denervated ones (compensating hypertrophy).

METHOD

1 - Protocol

Disuse atrophy, level 1

2 - Electrode position

Use one stimulation channel. The large, negative electrode (large) is placed crosswise at mid-height on the outside of the leg. It must cover the full width of the fleshy part of the epicondylus muscles, a small negative electrode is placed a few centimetres below on the dorsal side of the forearm.

3 - Treatment frequency

Three times a week for six to eight weeks. Then, maintenance of what has been achieved at a rate of one session every two weeks.

4 - Patient position

The patient, with bare feet, is placed in a standing position; his weight is on the inside of the foot to combat the movement caused by the electrically induced contraction.

5 - Duration and frequency

The treatment lasts for 8 minutes and must be repeated 5 times a week until possible reinnervation is achieved. It will be abandoned as soon as the reinnervation time has elapsed.

During rehabilitation, it is desirable to test the denervated muscles regularly with the Disuse atrophy programme in order to check for the possible start of reinnervation, in which case it is appropriate to choose triangular shaped pulses, i.e. the form of the pulse suitable for stimulation of partly denervated muscles (see Situation 4 below).

In the Denervated programme, we work in bipolar mode, i.e. the positive and negative poles are immaterial.

After being coated with gel, the two electrodes will be positioned crosswise on the fleshy part of the muscle (thus avoiding the tendinous parts); the size of the electrodes will have been previously determined so that they cover the muscle fibres as much as possible; they must therefore cover the full width of the muscle.

3 - Stimulation intensities

The maximum tolerable intensity should always be used in order to obtain the greatest spatial recruitment possible. For safety reasons, in the Denervated programme, the maximum intensity strength is limited to 300 mA.

4 - Stimulation frequency

In automatic mode, the pulses are 100 ms wide and are repeated every two seconds [frequency 0.5 Hz]. The muscle fibres respond to each pulse with a single twitch.

5 - Duration and frequency

The treatment lasts for 8 minutes and must be repeated 5 times a week until possible reinnervation is achieved. It will be abandoned as soon as the reinnervation time has elapsed.

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During rehabilitation, it is desirable to test the denervated muscles regularly with the Disuse atrophy programme in order to check for the possible start of reinnervation, in which case it is appropriate to choose triangular shaped pulses, i.e. the form of the pulse suitable for stimulation of partly denervated muscles (see Situation 4 below).

In the Denervated programme, we work in bipolar mode, i.e. the positive and negative poles are immaterial.

After being coated with gel, the two electrodes will be positioned crosswise on the fleshy part of the muscle (thus avoiding the tendinous parts); the size of the electrodes will have been previously determined so that they cover the muscle fibres as much as possible; they must therefore cover the full width of the muscle.

3 - Stimulation intensities

The maximum tolerable intensity should always be used in order to obtain the greatest spatial recruitment possible. For safety reasons, in the Denervated programme, the maximum intensity strength is limited to 300 mA.

4 - Stimulation frequency

In automatic mode, the pulses are 100 ms wide and are repeated every two seconds [frequency 0.5 Hz]. The muscle fibres respond to each pulse with a single twitch.
4) Situation 4
Partial denervation within the time

Example:
PARALYSIS OF THE LATERAL POPLITEAL NERVE

Questioning the patient gives us the following information:
• The level of the injury: This is a complication of a total knee prosthesis.
• The date of the injury: The operation was carried out 45 days ago.

Question n°1: Are we outside or within the re-innervation time?
The distance between the injury and the re-innervation time will therefore be around 5 months. As the injury only goes back a month and a half, we are within the re-innervation time.

Question n°2: Is the denervation total or partial?

METHOD

1 - Protocol
Partial automatic or Partial manual.

2 - Electrode position
Use one stimulation channel. A small, positive electrode is placed under the head of peroneous where the lateral popliteal nerve passes through. The negative electrode (large) is placed crosswise at mid-height on the outside of the leg.

3 - Results
By gradually increasing the current, an incomplete dorsal flexing movement of the ankle is seen as well as a hint of an eversion movement of the foot.

CONCLUSION
Our patient has paresis of the lateral popliteal nerve with partial denervation of the muscles of the antero-external part of the leg, there is hope of re-innervation for the denervated fibres.

PRACTICAL THERAPEUTIC APPROACH
With a denervated muscle, several therapeutic choices are available to the rehabilitating physiotherapist. See Choice of pulse shape and parameters (Denervated muscles – Theory).

Depending on the clinical circumstances and the school we subscribe to, we can work on the innervated part of the muscle using the short duration rectangular biphasic pulses supplied by the Neurostimulation programmes.

However, it seems necessary to try to prevent atrophy and limit the phenomenon of sclerosis of denervated fibres. To do this, use the sloped pulses of the Partial automatic or Partial manual programmes.

4 - Stimulation intensities
The maximum tolerable intensity should always be used in order to obtain the greatest spatial recruitment possible. For safety reasons, in the Denervated programme, the maximum intensity is limited to 30 mA.

5 - Stimulation frequency
The triangular pulses are repeated every two seconds (frequency: 0.5 Hz). The muscle fibres respond to each pulse with a single twitch.

6 - Duration and frequency
The treatment lasts for 8 minutes and must be repeated 5 times a week until re-innervation is achieved. It will be abandoned as soon as the re-innervation time has elapsed. If re-innervation is only partial, once the time has elapsed, a disuse atrophy treatment on card 1 must be used in order to achieve compensating hypertrophy [see Situation 2].