Key Concepts in Electrotherapy

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The Changing Nature of Electrotherapy

Much as electrotherapy has been a component of physiotherapy practice since the early days, its delivery has changed remarkably and continues to do so. The most popular modalities used these days are in many respects quite dissimilar to those of 60 or more years ago though of course they are based on the same principles. Modern electrotherapy practice needs to be **evidence based** and used appropriately. Used at the right place, at the right time for the right reason, it has a phenomenal capacity to be effective. Used unwisely, it will either do no good at all or possibly make matters worse – as would be true for any other therapy. The skill of the practitioner using electrotherapy is to make the appropriate clinical decision as to which modality to use and when, and to use the best available evidence when making that decision.

The evidence base to support the use of electrotherapy modalities as a component of practice is extensive, despite popular claims that these 'agents' lack evidence. There are very few occasions where an electrotherapy modality employed in isolation is the most effective intervention. Used as a part of a package of care, the evidence is strong and supportive.

The term "Electrotherapy" in this context is used in the widest sense. Strictly speaking some modalities (Ultrasound and Laser for example) do not strictly fall into an 'electrotherapy' grouping (in that they do not deliver an electric current), which is why some authorities prefer the term 'Electro Physical Agents' (EPA's) which would encompass a wider range. The terms 'Electrotherapy' and Electro Physical Agents (EPA's) will both be used in this documentation, but it is expected that a transition to the term Electro Physical Agents is both proper and inevitable (Watson, 2010).

The Classification of Electrotherapy (Electro Physical Agents – EPA's)

One could write pages and pages on this issue, but I will confine this to a couple of paragraphs. Essentially, whichever way you divide up the various EPA modalities, there will be a conflict somewhere in the result. I have suggested (diagram below) that one way that you could divide up the various modalities is into a fairly simple ('**electrical stimulation modalities**'; '**thermal agents**' and the more tricky one '**non-thermal agents**'. Whether you use the term agent or modality is not a critical issue to me, though I have heard protracted debates on the topic. The last of the three groups – the non-thermal agents is valid from my perspective – it includes modalities that are in the thermal group – like ultrasound, pulsed shortwave and laser for example, but the point is that IF you apply them at higher doses, there is no doubt that they will bring about a thermal change. If however they are applied at a lower dose (micro thermal, sub thermal or non thermal in therapy language), they still generate a physiological effect and hence have therapeutic potential, but one that is not dependent on a heating effect in the tissues.

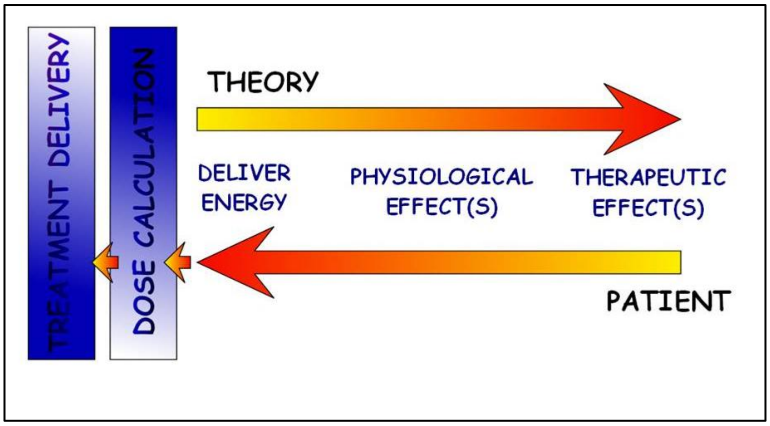
By way of example then, if you apply therapeutic ultrasound at relatively high dose, there will be a heating effect in the tissues – and this is absolutely fine if it is what was intended. The same energy, applied at a much lower dose will bring about changes which are relevant to tissue repair by means predominantly chemically mediated cascades. Recent evidence supports the use of ultrasound at even lower doses - Low Intensity Pulsed Ultrasound or LIPUS - for fracture healing - an example of low energy application being even more effective than higher dose interventions. The summary diagram below gives some idea of how the proposed 3 way classification might look.

Electrical Stimulation Agents / Modalities	**Thermal Agents / Modalities**	**Non Thermal Agents / Modalities**
Transcutaneous Electrical Nerve Stimulation (TENS)	Infra Red Irradiation (IRR)	[Pulsed] Ultrasound
Interferential Therapy (IFT)	Shortwave Diathermy (SWD)	Low Intensity Pulsed Ultrasound (LIPUS)
Neuromuscular Electrical Stimulation (NMES)	Microwave Diathermy (MWD)	[Pulsed] Shortwave Therapy (PSWT)
Functional Electrical Stimulation (FES)	Other RF Therapies	[Pulsed] Laser Therapy (LLLT / LILT)
Faradic Stimulation	Hydrocollator Packs	[Pulsed] Microwave Therapy
Iontophoresis	Wax Therapy	Low Intensity RF Applications
High Voltage Pulsed Galvanic Stimulation (HVPGS)	Balneotherapy (inc spa/whirlpool)	Pulsed Electromagnetic Fields (PEMF's)
Low Intensity Direct Current (LIDC) and Pulsed LIDC	Fluidotherapy	Microcurrent Therapies
Twin Peak Monophasic Stimulation	Therapeutic Ultrasound	**MAGNETIC THERAPIES**
Diadynamic Therapy	Laser Therapy	Pulsed Magnetic Therapy
H Wave Therapy ; Action Potential System (APS)		Static Magnetic Therapy
Russian Stimulation : Medium Frequency Stimulation	Cryotherapy / Cold Therapy / Ice / Immersion Therapy	Microcurrent Therapy
Rebox Therapy; Scenar Therapy		
Microcurrent Therapy (MCT)		

Some modalities – e.g. magnetic therapy only appear in this (non-thermal) list as they are not widely employed in therapy as a heating agent. Microcurrent therapy sits comfortably in the non thermal group (in that it is able to stimulate repair) but also can be seen to sit in the electrical stimulation group – which is technically correct in that the applied energy is in the form of an electric current, but they are not classic electrical stimulation in that they are not intended to result in nerve stimulation. I am currently working on a more detailed analysis of EPA groups and the theoretical construct behind the structure, though whether it ever gets as far as publication is a different issue!

Basic Model of Electrotherapy (Electro Physical Agents) Intervention

A simple, but effective clinical decision making model (represented in the diagram) can be utilised. All electrotherapy modalities (with the exception of biofeedback) involve the introduction of some **physical energy** into a biologic system. This energy brings about one or more **physiological changes**, which are used for **therapeutic benefit**. Clinically, it is probably more useful to work the model in reverse - determine first the nature of the problem to be addressed. Then establish the physiological changes that need to take place in order to achieve these effects. Lastly, the modality which is most able to bring about the changes in the tissue(s) concerned should be a relatively straightforward decision (Watson, 2008; 2010).



In the clinical environment, there are two additional 'jobs' to do : firstly to select the most appropriate '**dose' of the therapy** and then lastly to **apply the treatment**. Generally speaking, the delivery of the therapy is relatively straightforward. The dose selection however is critical in that not only are the effects of the treatment **modality dependent**, but they appear to be **dose dependent** as well. In other words, it is important to select the most appropriate modality based on the available evidence, but also to deliver it at the optimal dose. There are many research publications that have identified a lack of effect of intervention X, yet other researchers have shown it to work at a different dose. This appears strange at face value, but when dose and treatment parameters are taken into consideration, it becomes clear that there is a dose dependency, and the evidence for this is getting stronger the more that gets published. This issue is considered further (briefly) in the next section.

Electrotherapeutic Windows

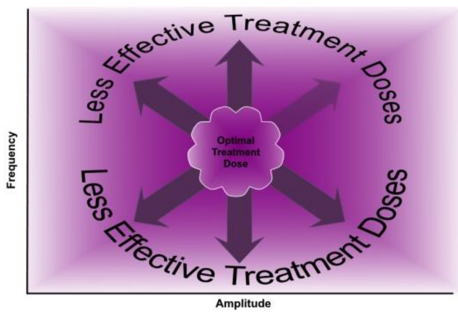
Windows of opportunity are topical in many areas of medical practice and are not a new phenomenon at all. It has long been recognised that the '**amount**' of a treatment is a critical parameter. This is no less true for electrotherapy than for other interventions. There are literally hundreds of research papers that illustrate that the same modality applied in the same circumstances, but at a different 'dose' will produce a different outcome. The illustrations used here are deliberately taken from a range of studies with various modalities to illustrate the breadth of the principle. Furthermore, the examples used are not intended to criticise the researchers reporting these results. Knowing where the window 'is not' is possibly as important as knowing where it is (Watson, 2007; 2008; 2010).

Given the research evidence, there appear to be several aspects to this issue. Using a very straightforward model, there is substantial evidence for example that there is an **'amplitude'** or **'strength' window**. An energy delivered at a particular amplitude has a beneficial effect whilst the same energy at a lower amplitude may have no demonstrable effect. Laser therapy provides a good example – one level will produce a distinct cellular response whilst a higher dose can be considered to be destructive. Karu (1987) demonstrated and reported these principles and research produced since has served to reinforce the concept (e.g. Vinck et al 2003).

There are many examples of **amplitude windows** in the electrotherapy related literature, and in some instances, the researchers have not set out to evaluate window effects, but have none the less demonstrated their existence. Papers by Larsen et al (2005) measuring ultrasound parameter manipulation in tendon healing, Aaron et al (1999) investigating electromagnetic field strengths, Goldman et al (1996) considering the effects of electrical stimulation in chronic wound healing, Rubin et al (1989) investigating electromagnetic field strength and osteoporosis, Hughes et al (2013) looking at TENS and pain relief and Cramp et al (2002) comparing different forms of TENS and its influence on local blood flow all provide evidence in this field.

Along similar lines, **'frequency windows'** are also apparent. A modality applied at a specific frequency (pulsing regime) might have a measurable benefit, whilst the same modality applied using a different pulsing profile may not appear to achieve equivalent results.

Electrical stimulation frequency windows have been proposed and there is clinical and laboratory evidence to suggest that there are frequency dependent responses in clinical practice. TENS applied at frequency X appears to have a different outcome to TENS applied at frequency Y in an equivalent patient population. Studies by Hughes et al (2013); Sluka et al (2005); Kararmaz et al (2004) and Han et al (1991) are amongst numerous studies that have demonstrated frequency dependent effects of TENS. There are also several authors who appear to have demonstrated that frequency parameters are possibly less critical, especially in clinical practice, and examples can be found in the literature on TENS and Interferential Therapy. Frequency windows are not confined to TENS treatments, and there are examples from other areas including electromagnetic fields (Blackman et al 1988), ultrasound (Schafer et al 2005; Conner Kerr 2012), microcurrent therapy (Poltawski et al 2012) and interferential (Noble et al 2000).

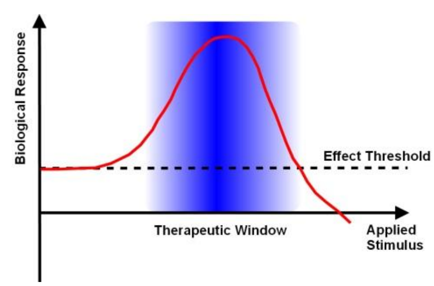


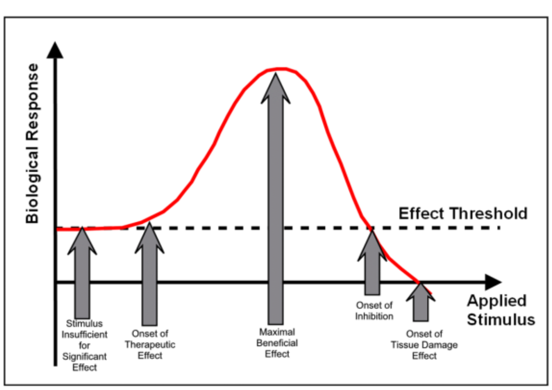
A simple therapeutic windows model is illustrated in the figure alongside, using amplitude and frequency as the critical parameters (Watson, 2010).

The 'ideal' treatment dose would be that combination of modality amplitude and frequency that focuses on the central effective zone. It can be suggested (from the evidence) that if the 'optimal' amplitude and frequency are applied at the same time, then the maximally beneficial effect will be achieved. Unfortunately, there are clearly more ways to get this combination 'wrong' than 'right'. A modality applied at a less than ideal dose will not achieve best results. Again, this does not mean that the modality is ineffective, but more likely, that the ideal window has been missed. The same principle can be applied across many, if not all areas of therapy.

The situation is complicated by the apparent capacity of the windows to 'move' with the patient condition. The position of the therapeutic window in the acute scenario appears to be different from the window position for the patient with a chronic version of the same problem. A treatment dose that might be very effective for an acute problem may fail to be beneficial with a chronic presentation.

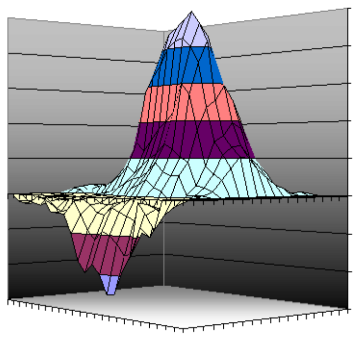
The 'therapeutic windows concept is illustrated in other ways by some authors – considering for example the **Arndt-Schulz** rule or law (commonly cited in connection with laser therapy, but actually relevant across the board in electrotherapy). If one were to superimpose the two, it can be easily seen how they are consistent in their concept (illustrated).





The ideal 'dose' would be that which hits the top of the curve. Deliver the energy at too low a dose, then the treatment will be less effective. Deliver at too high a dose, the benefits can be lost and if pushed too far, tissue destructive effects can be achieved. The tissue destructive approach is employed in medicine (e.g. laser ablation, ultrasound (HIFU) as a means to destroy tumours), though it is important to note that the applied doses in such instances are considerably higher than those used in 'therapy' applications.

Given the rapidly increasing complexity simply by using a two parameter model (amplitude and frequency) with two levels of condition (acute and chronic), it is easy to see how difficult the clinical reality might be. As the volume of published work continues to increase, new results can be included into the existing framework, and this helps to identify where the windows are (positive research outcomes) and where they are not (negative outcomes). If this methodology is pursued, it is interesting to note how the effective treatments cluster when plotted, adding weight to the therapeutic windows theory.



Assuming that there are likely to be more than two variables to the real world model, some complex further work needs to be invoked. There is almost certainly an energy or time based window (e.g. Hill et al 2002) and then another factor based on treatment frequency (number of sessions a week or treatment intervals). Work continues in our and other research units to identify the more and less critical parameters for each modality across a range of clinical presentations. The diagram left illustrates a 3D model of the Arndt-Schulz concept for doses in electrotherapy, and I am pursuing this concept in my current work on doses, dose treatment windows and associated phenomena.

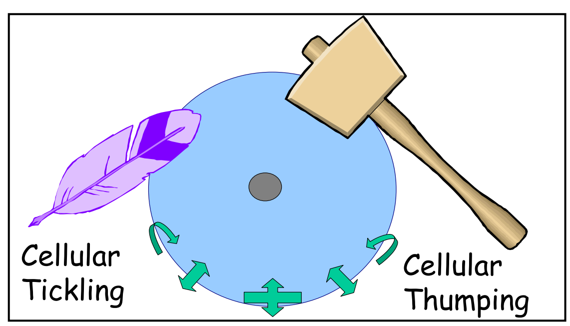
The Body Bioelectric

The electrical activity of the body has been used for a long time for both diagnostic and monitoring purposes in medicine, largely in connection with the ‘excitable’ tissues. Examples include ECG, EMG, EEG. More recent developments have begun to look at the tissues which were not regarded as excitable, but in which, endogenous electrical activity has been demonstrated. The **endogenous electrical activity** of the body arises from a variety of sources, some of which are well documented whilst others remain more obscure in their origins & control mechanisms. The relationship between endogenous electrical activity (not exclusively potentials), injury & healing have been researched in several areas of clinical practice and has been well documented in several publications, including Watson (2002, 2008).

The subject of endogenous bioelectricity is somewhat larger than can be detailed here, though there are important links between regular electrotherapy and endogenous bioelectrics which are discussed in numerous publications including Watson (2008, 2010); Kloth (2005); Poltawski and Watson (2010).

Approaches to Electrotherapy

Given the natural energy systems of the living cell, there are two approaches to the application of electrotherapy modalities. Firstly, one can deliver sufficient energy to overcome the energy of the membrane and thereby force it to change behaviour. Secondly, one can deliver much smaller energy levels, and instead of forcing the membrane to change behaviour, it can be ‘tickled’. Low energy membrane tickling produces membrane excitement, and membrane excitement in turn produces cellular excitement – or ‘up regulation’ to give it a more formal term. Excited cells do the same job as bored cells, but they do so at a rather harder and faster rate. It is the excited cells which do the work rather than the modality itself.



In addition to considering the endogenous potentials, there are several exciting aspects of this work which are of more direct relevance to therapists. Most obviously is the possible relationship between the endogenous bioelectric activity and the energy inputs (in a variety of forms) by means of electrotherapy treatments.

There has been a general trend over the last few years, for the energy levels applied in electrotherapy to be reduced. Ultrasound treatment doses are significantly lower (in terms of US intensity & pulse ratios) than previously thought to be effective. More recently still, the development of Low Intensity Pulsed Ultrasound – or LIPUS – has generated a very substantial evidence base in relation to fracture healing. The energy delivered with LIPS is considerably lower than would be delivered with a 'normal' therapy session dose. Pulsed Shortwave employs power levels which are several orders of magnitude lower than those applied during continuous shortwave therapy. Laser therapy is another such example of the clinical application of low energy levels to damaged, irritated or traumatised tissues. The refinement of microcurrent and magnetic therapies is adding to the evidence stacking up in favour of low energy interventions.

The over-riding principle of these interventions, is that the application of a low power/energy modality can enhance the natural ability of the body to stimulate, direct and control the healing and reparative processes. Instead of 'hitting the cells' with high energy levels, and thereby forcing them to respond, the low energy applications are aiming to tickle the cells, to stimulate them into some higher activity level and thus use the natural resources of the body to do the work.

This philosophy can be applied to many areas of therapy, not exclusively to electrotherapy - though it does marry well with the subject. One final area of interest is to potentially take the applied energy to really low levels (microcurrent type therapies) and deliver a current to the tissues that is remarkably similar to the endogenous currents that appear to be physiologically effective. Several machines are already available that work on this basis, and the research is picking up rapidly in this field.

Summary

Electrotherapy (Electro Physical Agents) has a place within clinical practice. When used appropriately, the evidence supports their effectiveness. The modalities can be applied in an ineffective way (clearly demonstrated by the evidence) and part of the skill of the practitioner is to be able to use the best evidence to make the best decision. When used in this way, EPA's can be powerful. Used badly, they are a waste of time – but then so would any other therapy used badly. The skill of the practitioner is in the decision making as well as in the delivery. EPA's (I would argue) are no better than say manual therapy or exercise therapy, but they are certainly no less effective when used properly.

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- (3) Electrical Properties of Tissues
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