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The body electric: a long view of electrical therapy for functional neurological disorders

Laura McWhirter,1 Alan Carson2 and Jon Stone3

1 Department of Psychological Medicine, Edinburgh Royal Infirmary, Little France Crescent, Edinburgh EH16 4SA, UK
2 Departments of Rehabilitation Medicine and of Clinical Neurosciences and University Department of Psychiatry, Royal Edinburgh Hospital, Tipperlinn Road, Edinburgh EH10 5HF, UK
3 Department of Clinical Neurosciences, Western General Hospital, Crewe Rd, Edinburgh EH4 2XU, UK

The phrase ‘The body electric’ is derived from the poem ‘I sing the body electric’ in Walt Whitman’s ‘Leaves of Grass’ published in 1855.

Correspondence to: Dr Jon Stone, Dept Clinical Neurosciences, Western General Hospital, Edinburgh EH4 2XU UK; E-mail: Jon.Stone@ed.ac.uk

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Abbreviation: TMS = transcranial magnetic stimulation

Introduction

Functional disorders are common in neurology clinics. These disorders—also called psychogenic, or non-organic—encompass symptoms such as paralysis, tremor and seizures. The current approach to functional disorders involves a clear diagnosis based on positive physical signs, educating patients, and offering therapies including cognitive behavioural therapy or physiotherapy, but in recent years, small trials of electrical peripheral nerve stimulation and transcranial magnetic stimulation (TMS) have produced very promising results (Pollak et al., 2014). This use of electricity looks at first sight like a surprising new turn. Yet, little is as new as it looks; electricity has been used medically since early history.

Others have reviewed the history of medical electricity and its disputes (Steinberg, 2011). Our aim is to illustrate the history of electricity in the treatment of what are now considered to be functional neurological disorders and to consider what might be learned from the past; a perspective missing from previous longitudinal reviews. Our paper seeks to shed light on current clinical issues, and our intended audience are clinicians interested in the modern use of electrical treatments including TMS.

Our review is based on analysis of primary sources and historically contemporaneous commentaries on these sources. We have clinically examined historical cases studies for case descriptions of the use of electrical treatment in neurological disorders and neurologically interpreted the described symptom clusters, in accordance with modern classification, for a reasonable likelihood that the diagnosis was a functional disorder. Our unit of study, therefore, is functional disorders (specifically, functional motor disorders and non-epileptic seizures) as they are now understood; we do not intend to examine in detail how the symptoms were understood at the time. We use this deliberately anachronistic approach to draw lessons from the past.
18th Century

The term ‘electricus’ first appears in William Gilbert’s *De Magnete* in 1600, denoting the attractant properties of substances like amber. Initial experiments with static charge involved glass globes, cylinders, brass and silk threads; but the invention of the Leyden Jar in 1745–46 provided a portable and consistent electrical device and appears to have brought a period of flourishing inquiry into the medical possibilities of electricity.

Johann Kruger, professor of medicine and philosophy in Halle, Germany, was among the first to suggest that electricity might be useful in medicine, stating in a 1743 lecture (published in 1744 as *Zuschrit an Seine Zuhörer*) that the best effect might be found in paralysed limbs, but his pupil Kratzenstein was first to actually use it, describing in his 1745 *Abhandlung von dem nutzen der electricity in der arzneyweissenschaft* how he had ‘cured a woman of a contracted little finger in a quarter of an hour’ and in another case ‘so far relieved a person who had two lame fingers, by once electrifying them, that he could play upon the harpsichord, which he had before been disabled from doing’ (as translated in Priestley’s 1767 *History and present state of electricity*, p. 472). In Vienna in 1755, Dutch physician de Haen in *Ratio Medendi* recommended gentle shocks from the Leyden jar over half an hour for paralysis: reporting some patients were cured of paralysis of 1, 3, 6, 9, 12 years, and even longer (p. 234).

In 18th century Britain clergies John Wesley and Richard Lovett independently became enthusiastic practitioners of medical electricity, reporting success in hysterical disorders including those with symptoms suggestive of modern functional disorders. Lovett’s 1756 *The subtil medium prov’d* framed his efforts with medical electricity in a theological context, including description of treatment of a woman with a ‘low-spirited hysterical disorder’ and 10 years of fits. The semiology suggests non-epileptic seizures, which were ‘so violent, and appear’d so active’ that they were ‘rather inclin’d to mimic St Vitus’s Dance.’ She was cured after less than a fortnight of daily electrical treatments: ‘Drawing off Sparks’ and ‘simply Electrifying’—having her ‘Standing on the electrical cake [insulating resin] only, and Breathing the celestial Fire [accumulating static charge]... for the greatest Part of Half an Hour’ (p. 88).

In John Wesley’s 1759 *Desideratum: or electricity made plain and useful by a lover of mankind and of common sense* he describes another case of treatment of probable non-epileptic seizures; a 22-year-old female with ‘so violent Fits, that five or six Men were scarce able to hold her’. During one such fit an apothecary administered electricity from a Leyden jar with rapid effect: ‘On the first Shock her struggling ceased, and she lay still. At the Second her Senses returned. After two or three more, she rose in good Health. Some Months after she relapsed, and was electrifyed again, and again entirely cured. Last Easter she fell into a Fit again, thro’ a Fright: But by a few Shocks was cured and restored to Health.’ (p. 51)

Wesley’s book contains other brief descriptions of cases where response to treatment has been so immediate and impressive that the diagnosis of functional disorder is most likely. For example: ‘One at Stockholm, who had used Crutchets [sic] for seven Years, could walk without them in thirteen days’ (p. 57), ‘A Citizen of Upsal, who was thoroughly Paralytic, was perfectly cured only by drawing Sparks’ (p. 62).

Like Lovett, Wesley reflected on the metaphysical implications of electricity, describing it as ‘etherial fire’. He also speculated that it served some tonic influence on the body: ‘It communicates activity and motion to fluids in general, and particularly accelerates the Motion of Blood in a human Body’ (p. 42). In Wesley’s time some believed that the nerves were fine tubes through which mysterious fluid flowed; Wesley suggested ‘what if the electric ether is the only fluid in the universe fine enough to flow through them?’ (p. 4).

But regardless of physical or metaphysical mechanism, and despite his general enthusiasm, Wesley noted limitations to electrical treatments. He had little success with longstanding paralysis: ‘Many Paralytics have been helped: But, I think, scarce any Palsy of a Year standing has been cured’ (p. 63). He also noted a characteristic inconsistency in the response to treatment, resonant now as a typical placebo response:

‘there is something peculiarly unaccountable, with regard to its Operation... in some Experiments, it helps at the very first, and promises a speedy Cure: But presently the good Effect ceases, and the Patient is as he was before.’ (p. 3) (Fig. 1)

A similar mix of optimism and inconsistency can be seen in Benjamin Franklin’s experiences with medical electricity. In 1757 an account was published of Franklin’s (1754) treatment of a 24-year-old female with a 10-year history of hysterical symptoms, chiefly ‘cramps in different parts of the body’ and ‘general convulsions of the extremities’ (Evans, 1776, p. 83). After limited responses to ‘bleeding, blisters, anodyne and nervous medicines’ she travelled to Philadelphia to undertake electrical treatment. The patient’s account of her treatment follows:

‘I received four shocks morning and evening; they were what they call 200 strokes of the wheel, which fills an eight gallon bottle, and indeed they were very severe. On receiving the first shock, I felt the fit very strong, but the second effectually carried it off; and thus is was every time I went through the operation; yet the symptoms gradually decreased, till at length they entirely [sic] left me... I now enjoy such a state of health, as I would have given all the world for, this time two years, if it had been in my power, and I have great reason to hope it will continue.’ (p. 85–6)
However, like Wesley, Franklin had less success with electricity in the treatment of paralysed limbs. In his 1757 Account of the effects of electricity in paralytic cases he described drawing sparks from the paralysed limb three times per day, observing that minor improvements in strength did not continue beyond the fifth day: ‘how far the apparent temporary advantage might arise from the exercise in the patients journey, and coming daily to my house, or from the spirits given by the hope of success, enabling them to exert more strength in moving their limbs, I will not pretend to say.’ (p. 481)

Other physicians around this time recognized the importance of hope or expectation of success in response to physical treatments, describing what we might now call placebo effects. In his 1765 text Observations on the nature, causes, and cure of those disorders which have been commonly called nervous, hypochondriac, or hysterical, Edinburgh physician Robert Whytt noticed that a piece of brimstone placed in the patient’s hand could treat hysterical spasms, the effectiveness lying entirely in expectation and belief: ‘brimstone cures spasms not by any medical virtue... its effects are to be ascribed to the patient’s attention and faith’ (p. 467).

These ideas remained alongside others. The 1784 Medical cases of another Edinburgh physician, Andrew Duncan, include the 1777 treatment of a 24-year-old amenorrhoeic female with electric shocks to the lower abdomen, daily, for several weeks, after which a ‘paralytic affliction of the lower extremities’ was entirely cured (p. 197). Although this description suggests that Duncan believed the paralytic symptoms originated in the female reproductive system, the target of treatment, he also speculated that electricity might ‘affect the state of the nervous fluid, as every stimulus, applied to the extremity of the nerves... may alter the state of action in the brain in general’ (p. 136) (Fig. 2).

### 19th Century

The early 19th century saw a flurry of technological developments and by the mid-19th century many large hospitals had electrical departments, with static apparatus, Leyden jars, rudimentary batteries, as developed by Galvani and Volta between 1791 and 1800, and soon after Faraday’s discovery in 1831, electromagnetic induction machines (Fig. 3). New technology was very quickly put into action: in 1800 for example, Grappengiesser reported the cure of a young female with a 4-year history of hysterical aphonia using Galvanic current applied to blisters on the throat over a period of 5 days (Grappengiesser, 1802, p. 250–52).

In 1836–37 Golding Bird established the Department of Electricity and Galvanism at Guy’s Hospital in London under the supervision of Thomas Addison. In a Report on the value of Electricity as a remedial agent in the treatment of diseases published in Guy’s Hospital Reports in 1841, Bird reported treating 36 cases of chorea, most caused by ‘fright’ or ‘terror’ and some of which might have represented functional movement disorders. Treatment consisted of drawing sparks from the spine daily or on alternate days for 5 min. Duration of treatment is not reported, but all cases but two (one of whom ‘left in alarm’) were either relieved or cured (p. 88–89). In Bird’s Lectures on electricity and galvanism, delivered at the Royal College of Physicians in 1847 and published in 1854, he stated that electricity was effective in both hysterical (functional) and feigned paralysis, although via different proposed mechanisms:

‘If the patient simulates paralysis... she can seldom resist the pain and surprise of the shock, and the previously rigid limb will generally instantly move... in hysterical paralysis, where the affection, however excited at first is now uninfluenced by the patient’s will, there are few curative remedies so important as the electro-magnetic current’ (p. 164).

Other 19th century practitioners also found hysteria particularly responsive to electrical treatment. Althaus working at King’s College Hospital in London commented in his 1859 Treatise on electricity:

‘Cases of hysterical paralysis not infrequently require only a few applications of electricity. Thus I have cured a case of hysterical...
aphonia and two cases of amenorrhea by only one séance each’ (p. 260).

Sarlandiere in France combined Eastern techniques of acupuncture with electricity to make electro-acupuncture, used in gout, rheumatism and nervous afflictions. He related success to aetiology, with functional disorders being most responsive to treatment:

‘Paralyses, epilepsy, and the different types of manias have been quite resistant to electricity when these disorders resulted from an organic lesion of the brain or the spinal marrow; when they are merely functional, however, unhoped-for success can be achieved’ (Sarlandiere, 1986, p. 81).

Later 19th century practitioners suggested that electrotherapy should be reserved for difficult-to-treat functional disorders. In the second edition of Robert Todd’s Clinical lectures on paralysis published in 1856 he recommended what would be viewed currently as a modern, rehabilitative approach to the treatment of hysteria, emphasizing that ‘attention should be diverted as much as possible from the paralysed limb or part, and the exercise of the latter promoted by indirect means’ (p. 21). He reserved galvanism for more difficult cases of hysterical paralysis, advising mild shocks from the galvanic trough or coil machine to the paralysed limb two or three times per day with gradually increasing intensity (p. 22); although Todd clearly found the treatment valuable, its use alongside rehabilitative treatments over months means the contribution of the electrical treatment to any symptom recovery is unclear. Gowers, in

Figure 2 George Adams, instrument maker to King George III, demonstrates an electrical machine. From G. Adams, ‘Essay on Medical Electricity.’ London, 1784 (Wellcome Images).

Figure 3 Electromagnetic machine designed by Duchenne, circa 1848. (Wellcome Images).
his 1886 *A manual of diseases of the nervous system* reserved faradism for difficult cases of hysterical aphonia but found it most effective for hysterical paralysis; the efficacy, in his opinion, lying in the generation of movement in the muscles and the pain produced, but also in expectation: ‘It is important that the patient should expect the gain in power which will follow its use’ (p. 1027). Similarly, he suggested that hysterical seizures could be removed by ‘an agent which produces a strong sensory and moral impression, such as faradism, or static electricity’ (p. 1030).

Although William Erb, in his 1883 *Handbook of electrotherapeutics*, proposed both local and generalized electrical treatments as beneficial in neurological disorders including hysteria, he also commented on the striking but inconsistent pattern that we now associate with a placebo response:

‘The therapeutic results in the hysterical form are sometimes... extraordinarily prompt and indeed magical, at other times they are the very reverse, so that long-continued treatment is necessary before recovery occurs’ (p. 294).

In Rockwell’s 1896 *The Medical and surgical use of electricity* local treatment of specific hysterical symptoms is dismissed as ‘unphilosophical and usually unsuccessful’ except in hysterical aphonia, where ‘any form of irritation, external or internal, electric or otherwise, may cause instantaneous cure’ (p. 478). For hysterical paralysis Rockwell advocated the general application of electricity to the whole body; although observing like many others that the response could be ‘capricious and inconsistent’, commenting ‘In many instances general faradization promotes rapid recovery; other cases are very rebellious and only improve up to a certain point’ (p. 399) (Fig. 4).

20th Century

The late 19th and early 20th century was a time of intense interest in the causes of hysterical disorders and the role of suggestion. Charcot believed that hysteria was in part an inherited neurological condition, and that in individuals with a hereditary disposition to hysteria an incident or circumstance, an ‘agent provocateur’, could trigger symptoms. Charcot, and later Babinski, used static baths, sparks and faradization in both diagnosis and treatment of hysterical paralysis and ‘hystero-epilepsy’.

Janet was more transparent that electrical treatment was a form of suggestion. Lecturing at Harvard University in 1906 (lectures published the following year as *Major symptoms of hysteria*) he described treating a patient with hysterical paraplegia and ‘total anaesthesia’ using electricity to the legs, producing strong muscular contractions at each contact of the electrode: ‘when all at once we saw that the two wires which fastened the plugs to the apparatus had dropped. For a long time we had thus been applying electricity with mere pieces of wood.’ (p. 169).

Freud too used electricity early in his career, but later dismissed it altogether stating (as translated in the 1963 edition of *An autobiographical study*):

‘I put my electrical apparatus aside, even before Moebius had saved the situation by explaining that the successes of electric treatment in nervous disorders (in so far as there were any) were the effect of suggestion on the part of the physician’ (p. 27).

As suggestion came to be seen as a central in the response of hysteria to electrotherapy, emphasis was placed on the demeanour and attitude of the treating doctor. In the view of German neurologist Oppenheim, writing in *Diseases of the nervous system* in 1904, the success of electrotherapy and other physical treatments in hysteria depended largely on the ‘trust and faith of the patient’, stating that in general: ‘The basis of the treatment is psychotherapy. The physician must betray intense interest in his patient, and must gain his confidence without losing his authority’ (p. 740). London neurologist Wilfred Harris in his 1908 *Electrical treatment* shared the view that the positive effects of faradic current in hysteria occurred through ‘psychic sensory effect’ (p. 65) and stated ‘the personal efforts of the operator are therefore necessary, aided at the same time by continual encouragement to the patient as to recovery’ (p. 66). Harris noted greater improvements with
more impressive equipment: ‘better effects are often to be obtained with a large battery, because of its greater impressiveness, than with a small one’ (p. 66).

Lewis Yealland’s 1918 account of electrical therapy at Queen Square during World War I, *Hysterical disorders of warfare* represents the best known example of electrical treatment in a military context. Yealland used electricity as a powerful suggestive tool and made no claims for biological mechanisms. He treated functional paralysis by demonstrating the presence of movement in the affected limb by faradizing the skin over a motor nerve-point. Although Yealland professed to avoid ‘compulsion’, where the patient did not respond quickly ‘faradic stimulation was increased until his attention was obtained and movement voluntarily performed’ (p. 75). His readiness to progress to painful stimulation intensities was undoubtedly aversive, although a balanced view of Yealland’s achievements has been presented in a recent analysis (Linden et al., 2013). Others have discussed the painful use of electrotherapy by Vincent and Roussy in France at around the same time, nicknamed ‘torpillage’ because of torpedo-like impact on the body and criticized at the time in the public press (Tatu, 2010).

Reports of electrical treatment in the years following World War I diminish. In Oxford physician William Turrell’s 1922 manual *The principles of electrotherapy* he noted the effectiveness of electrotherapy for hysterical aphony and paralysis, primarily through suggestion, but noted that the treatment was tainted as it had been ‘frequently applied as almost a punitive treatment; this is exceedingly bad for the reputation of electrotherapy, and it is, moreover, as much calculated to harm as to benefit the patient’ (p. 193) (Fig. 5).

Late 20th century to present

Discussion of ‘hysteria’ in neurology textbooks steadily declined over the 20th century (Stone, 2008). Increasing recognition of psychological factors in hysterical disorders and especially psychodynamic models put the aetiology and treatment of patients out of reach of the average neurologist, most of whom seemed quite content that it was not their problem anymore. Reports of electrical treatment of hysteria also declined despite a corresponding rise in electro-convulsive therapy for psychiatric disorders and deep brain stimulation for movement disorders. Publications describing old-fashioned ‘faradization’ for functional disorders have since appeared only rarely and without reference to their historical roots. Transcutaneous electrical nerve stimulation (TENS), developed during the 1970s and primarily used for pain, is arguably a refined form of cutaneous faradization of an earlier era, and has been trialled with some promise in an uncontrolled series of 19 patients with functional movement disorders (Ferrara et al., 2011).

Although electromagnetism has its own history in the treatment of neurological disorders (Martens et al., 2013) the focus and power afforded by TMS, allowing practitioners to generate muscle movements by stimulating the motor cortex, can be considered a significant development. TMS has brought renewal of interest in the electrical treatment of functional neurological disorders especially in
combination with functional MRI and SPECT studies looking for neural correlates of symptoms.

A case report of a patient improving with TMS was first published in 1992, and subsequently several studies have investigated TMS as a treatment for functional motor disorders (Pollak et al., 2014). Chastan and Parain (2010) treated 70 patients with functional limb weakness with 15 min TMS with a remarkable success rate of 89%; although many of their patients were acute or younger cases who arguably may have improved anyway. Garcin et al. (2013) report that 75% of their 24 patients with functional movement disorders (median duration 2.8 years) had sustained benefit from TMS given in a rehabilitative context. Most authors acknowledge the role of suggestion or placebo, but none reference older electrical treatments, perhaps in part because of editorial or space limitations. Despite the treatments described being insufficient to induce after-effects in the brain, speculations about biological mechanisms are common: ‘rTMS may have the ability to restore an appropriate cerebral connectivity by activating a suppressed motor cortex’ (Chastan and Parain, 2010, p. 1504).

Initial excitement at the therapeutic potential of repetitive TMS for depression, pain, Parkinson’s disease and stroke has generally not matured into good evidence. This relatively short-lived arc of popularity is perhaps a testament to the randomized controlled trial even if most studies had trouble solving the issue of blinding the practitioner administering the therapy. Despite this, electrical therapies have never been in such good health. Transcranial direct current stimulation has provided renewed excitement for treatment of many disorders including neuropathic pain, migraine and tinnitus. With home ‘Do-It-Yourself’ transcranial direct current stimulation selling for $40 (www.tdcs-kit.com), transcranial electrotherapy could cross into the domestic arena in the same way that TENS presented a watered down domestic version of hospital-based peripheral faradization.

Summary and conclusion

The use of electricity in medical treatment has always been technology-driven, rather than aetiology-driven; as new techniques have appeared, clinicians have quickly looked to try them in the treatment of all sorts of conditions where existing treatment options are limited. Functional disorders—as identified anachronistically in our analysis—have been key contenders for emerging electrical treatments: with Leyden jars, with galvanic and electromagnetic machines, and more recently with TMS and TENS. Parallels can be drawn with the history of electrical treatments for migraine and headache (Koehler and Boes, 2010).

Regardless of the mode of delivery of electricity, stimulating a limb to produce movement has repeatedly been found to aid and assist recovery in functional motor disorders. This may also be true of non-electrical methods: we have found benefits using both therapeutic sedation and explanatory demonstration of a positive Hoover’s sign as therapeutic methods of demonstrating normal movement in functionally weak limbs (Stone et al., 2014).

Each surge in enthusiasm for new electrical treatments has been followed by questions about the nature of the disorder and validity of the treatment response. Physicians have tended to attribute therapeutic success initially to powerful biological or even metaphysical effects, but with time and experience these explanations have been replaced by views that the treatment works through suggestion and placebo. Discomfort with these conclusions has in the past discouraged ongoing development of electrical treatments, even if the end result for patients has been encouraging.

In Edwards’s Bayesian model, functional motor and sensory symptoms are hypothesized to arise when ‘pathologically precise prior beliefs’ mediated by attentional processes cause experience of symptoms via a hierarchy of false inferences (Edwards, 2012). It can be argued that use of TMS or peripheral stimulation to produce movement of a functionally weak limb has the specific potential to modulate pathological expectations. To reject these treatments as no more than placebo may mean missing an unusual opportunity to manipulate key elements in the mechanism of the disorder. However, changes to these ‘priors’ may also be dependent upon patient expectations, and as we see through history, this may only happen if the patient believes there is an actual neuromodulatory effect. This may give rise to significant ethical issues in that the treatment may well directly benefit patients but only if they are (mis)informed that there is an underlying biological rationale.

We conclude that modern trials of TMS in functional disorders are part of a repeating cycle of experimentation recurring since the mid-18th century. We suspect that emerging technology, including transcranial direct current stimulation, will follow a similar pattern of experimentation, speculation and marginalization. We suggest that considering our modern efforts in a historical context could aid our ability to further expand and maintain our use of electrical therapies that have proven helpful in the past for patients with functional disorders.

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