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A Contribution to the Study of the Action of Currents of High Potential upon the Human Organism.

BY

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ACCIDENTS FROM THE ELECTRIC CURRENT.[1]

A Contribution to the Study of the Action of Currents of High Potential upon the Human Organism.

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Within the last fifty years, since man has made use of the electrical current, certain diseases have been recognized by the physician as due to the various contrivances by which electricity has been rendered capable of service. Telegrapher's cramp, the telephone ear, and photo-electric ophthalmia are all due to the mechanisms employed in the use of electricity, or to the effects obtained from them, but none of them are caused by the action of the electric current itself. Only in one class of diseases can electricity itself be said to play an important part, and its part here is in the influence which it has upon the delusions of the insane.

Constant familiarity with the wonders wrought by electricity — the telephone, the telegraph, and the electric motor — has, until recently, produced in the ordinary mind a certain degree of indifference. It is by no means uncommon, however, for the paranoiac to seize upon these wonderful powers and to twist them into the fabric of his delusions. Angels and devils rarely enter our asylums to-day, but, instead, the asylum walls are filled with wires which carry the thoughts of the paranoiac to his persecutors, and their threats to him, and which bring mysterious electrical

[1] Read before the Boston Society for Medical Improvement, February 24, 1890.

influences to torture and enfeeble him. This influence which electricity has upon the imagination is not, however, confined wholly to the insane. I have mentioned the paranoiac's delusions because we must bear this influence in mind in considering the action of electricity upon the healthy organism.

Within the last few years the employment of electricity in the service of man has undergone a complete change. Instead of the feeble currents of a few volts which suffice for the telephone or the telegraph, powerful currents of hundreds and thousands of volts are employed for the electric lights and electric motors. The arc light, which ten years ago was hardly more than a curiosity of the physical laboratory, now illuminates villages which never knew the vagaries of a gas meter, and electrical trains whir at the rate of fifteen or twenty miles an hour through the streets of town and city, and even along our country roads.

With this increased frequency in the use of strong electric currents, new problems are presented to the physician. Not only are the men employed in caring for the wires and in other electrical work exposed to accidents, but the ordinary citizen is not exempt. An electrical company gets permission to put up its wires — a matter usually of no great difficulty — and then it puts them up securely or insecurely as it pleases, no supervision is exercised by the city in regard to the erection of the wires, and no conditions of construction are demanded. The wires are put up hurriedly with our customary American carelessness, and, when they are once up, there is never any subsequent official inspection. The company may, if it chooses, look after them for a time, or the company may go out of existence and its wires are left in the air ownerless and uncared for. What happens? Some day one of these wires, never properly insulated and with

what insulation it had worn off, breaks away from its support or is dragged down by ice and snow. It may convey no current itself, but, in falling, it crosses an electric light wire, and makes a short circuit with the earth. In falling, too, it strikes a man or a horse and brings him into the circuit with fatal results. It may cross a telephone or a telegraph wire. Then it conveys this deadly current into our houses, killing or injuring the user of the telephone or setting fire to the house, as in the Bedford Street fire of last Thanksgiving Day. Of course no one is to blame, but in other countries where stringent regulations are made as to the erection and supervision of wires, accidents are less common, and electrical progress less rapid.

Our knowledge of the effects of electric currents of high potential on the human organism is still very meagre, and the altercations which have arisen in New York have unfortunately tended to obscure what little knowledge we have. It will be well, therefore, to consider very briefly some of the effects of electricity as manifested in the form of lightning before studying the effects of these artificial currents.

Lightning is more closely akin to static electricity than to voltaic, and as static electricity expends much of its influence upon the surface of objects with which it comes in contact we need not be surprised to find that the surface markings on the bodies of those struck by lightning have long been noted. Deposits on the skin, capillary injections, ecchymoses, discolorations, curious figures, such as arborization, the figures of Lichtenberg, or electrographic designs of neighboring objects (?), punctiform or ray-formed lesions, and burns of every degree have been reported by more or less trustworthy observers. These curious markings, which have been viewed almost in a superstitious light, have not been observed after injuries from the artificial current.

Death from lightning is usually instantaneous, but it may not occur until a fortnight after the shock. That it may occur not even the New York electrical experts will deny. In Massachusetts there have been thirty-two deaths in ten years (1879–1888). After death no constant lesions have been noted. Burns and various external injuries are common. It was once held that in the bodies of those killed by lightning rigor mortis was absent, the blood was abnormally fluid, and decomposition was rapid, but numerous exceptions to these rules have been reported. Punctate hæmorrhages in various organs are common, and even meningeal and intra-cerebral hæmorrhages of considerable size have been noted.[2]

In the non-fatal cases the victim seldom sees the flash or hears the thunder. There is often a period of unconsciousness; after which there may be mental depression or excitement; the respiration is feeble, the pulse small and slow, the skin cool, and the muscular strength diminished; there may be suppression of urine, nausea, loss of appetite, or diarrhœa. The menses may be suppressed. Vision is often affected. In some cases there are various symptoms due to the hæmorrhages or to inflammation of the internal organs, but the effect is not usually permanent.[3]

The nervous symptoms following lightning-shock are varied. Nothnagel found anæsthesia and paresis in definite regions, not corresponding to the nerve distribution, in animals which had received shocks. Pain in the affected region is common. It usually increases in severity for a day or two, and then subsides. It is occasionally most marked in the distribution of certain nerves, and may also be accompanied with diminished sensibility and paresis, due, perhaps, to hæmorrhage

[2] Sestier: De la Foudre, etc., Paris, 1866.
[3] Stricker: Arch. f. Path. Anat., xx, 45, 1861.

into the sheaths of the peripheral nerves or to neuritis. The cases of Knapp [4] and Putnam [5] are examples of this type. Eulenberg [6] reports a case of hemiplegia, due probably to an intra-cerebral lesion, and Barnes [7] found intra-cerebral hæmorrhage after death. Sestier [8] says that Tricou found softening of the cord, but he gives no history of the case. He also cites a questionable case of chronic dementia following lightning-stroke. Charcot [9] has recently reported a case of traumatic hysteria following lightning-stroke, and Nothnagel's case and the case of Gastillier which Sestier quotes [10] must also be regarded as hysterical. The paralysis following lightning is often of short duration, but it may be permanent. A certain number of victims of lightning after recovery seem peculiarly susceptible to thunder-storms and to electricity.

Turning from the effects of lightning to the effect of currents of high potential as used in the arts, we enter upon an arena where controversy is at its height and where scientific observation is replaced by personal abuse and ill-temper. Electrical experts assure us most confidently that the electric current is not and cannot be fatal, and contend that it is impossible to execute criminals by electricity, at least, if the dynamo furnished by their particular company is used. Their praise of their own dynamos, and their abuse of those made by other companies, is most convincing, yet the ordinary mind is somewhat at a loss to understand how the accidents which the newspapers report can have happened. Data as to the fatality of electricity in Massachusetts are wanting. The Registration

[4] J. H. Knapp : Arch. f. Path. Anat., xv, 378, 1858.
[5] J. J. Putnam : Boston Medical and Surgical Journal, Jan. 13, 1876.
[6] Eulenberg : Berlin klin. Wochen., April 26, 1875.
[7] Barnes : Medical Times and Gazette, June 20, 1868.
[8] Sestier : Op. cit., ii, 212.
[9] Charcot : Leçons du Mardi, ii, No. 19,
[10] Sestier : Op. cit., ii, 115.

Report for 1888 cites one fatal case in Lynn, but the other cases have probably not been put under a special heading; at least, I learn from Dr. Draper that he has seen two cases at the City Hospital morgue. Within a few months a horse and a dog have been killed in this vicinity. Brown[11] gives a partial list of ninety-one cases up to May, 1889, chiefly in this country, but he thinks this list contains less than half the cases. A good many cases have appeared in the newspapers since his book was published.

Judging from the newspaper accounts of the cases of death from currents of high potential, the victim either dies at once, or dies in a few minutes with signs of extreme pain, marked tetanic spasm of the muscles, and deep burning of the flesh. Recorded autopsies are few. Sheild and Delépine[12] report a case where rigor mortis was well-marked; the blood was not abnormal but extremely fluid; the heart was not contracted and contained no clots. The muscles were firm, the skin congested. The median nerve was unchanged. There was a blister on the finger which was examined with very great care, and they thought that the appearances in the skin differed from those of an ordinary blister. Grange[13] gives a report of the autopsy on two men who took hold of a Brush-light wire in climbing a wall. The first man had slight burns, and cadaveric rigidity. The blood was fluid and arterial; there were ecchymoses in the viscera; and the meninges of the brain were adherent to the convolutions. The second man had burns of the hands; the left ventricle of the heart was contracted; the lungs and brain were much congested. In animals killed by electricity, Grange found adhesions of the

[11] Harold P. Brown: The comparative Danger to Life of the Alternating and Continuous Electrical Currents, third edition, 1889.
[12] Shield and Delépine: British Medical Journal, March 14, 1885.
[13] Grange: Annales d'hygiene publique, January and April, 1885.

cerebral meninges, capillary hæmorrhages, especially in the pons and medulla, the heart relaxed, the blood fluid, and respiration suspended. Biggs[14] in four autopsies, found dark fluid blood, rigor mortis, congestion of the viscera, and small hæmorrhages in the serous membranes. Richardson,[15] in animals killed by a gigantic induction coil, found the vessels of the brain distended, the heart filled with blood on the right side, the viscera congested, and the blood fluid. Peterson,[16] in animals killed by the electric current, found the blood dark and fluid, the viscera congested but without extravasations, and the nerve sheaths occasionally gorged with blood and showing capillary extravasations. He thinks there are no pathognomonic signs of death by electricity, but that it divides and disarranges the fine molecular structure of the body. Tatum[17] believes that there is no lesion after death which can be ascribed to electricity. The black, fluid blood, which is most constant, is due to the fact that the molecular life of the tissues persists after the cessation of circulation and respiration. He found, by experiments on dogs, that electricity did not impair the functions of muscles or nerves, that it caused no appreciable change in the blood, and that its fatal action was due to the arrest of the heart's action; the arrest being caused by the action on the heart itself, and not, probably, by the action on the medulla or the nerve supply.

In some cases the shock itself does not prove fatal, but the burns are extensive, and slough, and the patient may finally succumb. The following case was admitted to the service of Dr. M. F. Gavin, at the Boston City Hospital, and he has kindly permitted me to cite it here.

[14] Biggs: New York Medical Record, November 2, 1889.
[15] Richardson: Medical Times and Gazette, May 15, June 5, and August 14, 1869.
[16] Harold P. Brown: Op. cit., p. 50.
[17] Tatum. New York Medical Journal, February 22, 1890.

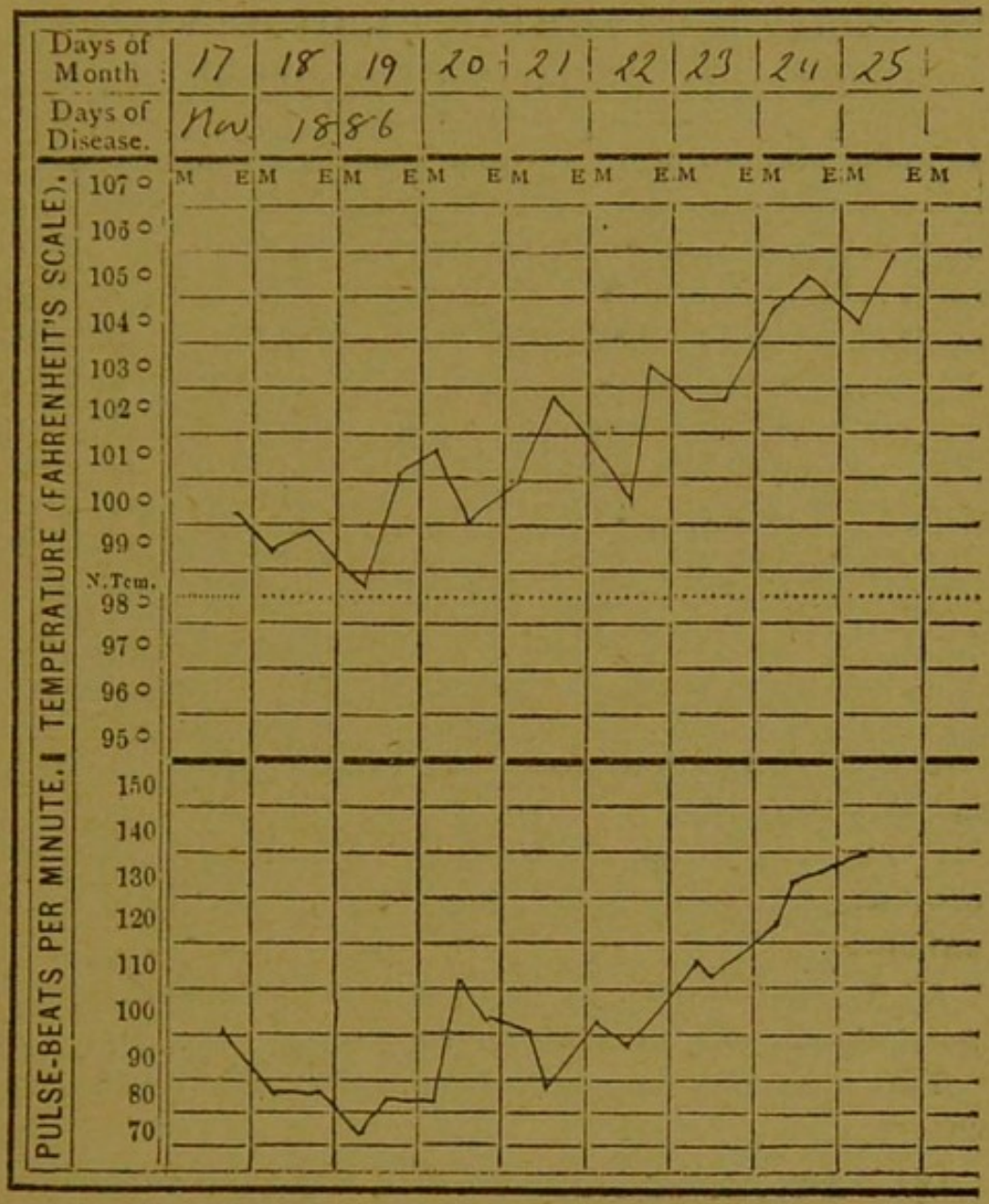
Case I. Electric shock. Fall from pole. Severe burns from electric light wire. Sloughing of burns, gradual failure, and death.

Peter K., nineteen, single, born in Ireland, a lineman. Some alcohol, denies syphilis. At 2 P. M., on November 17, 1886, while on a pole trimming an electric light was severely burned, and fell about twenty feet. Has no recollection of the fall, or how he struck. Considerable shock. Well developed and nourished. Right wrist burned superficially over a space about three inches each way. Right thenar eminence burned through to the muscles, and adductor pollicis laid bare over a space the size of a quarter of a dollar. Middle finger burned to the bone over a space about two inches long, beginning at tip of finger and on the back of it. Third finger burned over a space about one inch long on the back. Little finger burned the same as the third. Two middle toes on right foot burned a little. Poultices to burns. Two wounds of forehead over right eye, each about three-quarters of an inch long, and one of them just over the border of the orbit. Large subconjunctival hæmorrhage in left eye. Both wounds stitched with catgut, and sealed up with absorbent cotton and compound tincture of benzoin, after being powdered with iodoform. Brandy ℥xxv, and Magendie's solution ℥v, subcutaneously; heaters.

November 19th. On dangerous list. Poultice has made burns much less painful. Little finger of left hand, which had a brass ring on it, was slightly burned underneath the ring.

November 22d. Little finger of left hand has turned completely black. Sloughs on right hand are deeper, and are separating out. Arm swelled to elbow. To-night he feels miserably, and says he felt a repetition of the shock of the electricity, at 4 o'clock this afternoon, the time of the accident, or very near it. Still on the dangerous list.

November 25th. Has been delirious for some days. Pulse and temperature up. Very sick to-day, and failing fast. This afternoon, was constantly muttering



to himself. Pulse getting weaker and weaker. Takes brandy, a teaspoonful at a time. Sloughs on right hand very deep, and foul smelling. Little finger of left hand entirely dead. Died at 4.45 P. M.

There was, unfortunately, no autopsy, but it seems probable that the patient died of exhaustion from the sloughing burns. The symptom complained of, on the 22d, deserves notice. At the time there were three patients in the ward (Cases I, III and V) victims of electrical accidents, the other two nearly opposite this man. He and one of the men opposite him (Case III) complained, of their own accord, at almost precisely the same time, of feeling a shock like that of their original injury. Case V was up and about the ward, nearly well, and no inquiry was made as to whether he had a similar sensation. As the suggestion has been made that the alleged increased susceptibility to thunder-storms was due to an increased susceptibility to dampness, I inquired at the Signal Service office into the state of the weather on this day, and found that the day was clear and cloudless, the wind north-west, the barometer 30.081, the temperature 46° F., the dew-point 22.8, and the humidity 40, with no electrical disturbance in the atmosphere. I am, therefore, unable to account for this curious symptom.

The cases which do not result fatally may be divided into two classes:

I. Cases in which the electric current gives rise to no protracted symptoms, except burns and their consequences.

II. Cases followed by more of less protracted symptoms, chiefly of a nervous character.

This first class may be further subdivided into three classes:

(*a*) Cases in which the electric current apparently produces no lasting symptoms of any kind.

(*b*) Cases in which the electric current itself apparently produces no symptoms, but gives rise to a fall which may cause more or less severe symptoms.

(*c*) Cases in which the electric current produces

more or less severe burns, but apparently no other symptoms referrible to electricity.

I (a). Cases in which the electric current apparently produces no lasting symptoms of any kind.

Case II. Shock from a 1,000-volt alternating current, without injury.

Mr. F. is an electrician, about twenty-five years of age, who has written out for me a very clear account of his accident, which is of peculiar interest, and is rather remarkable considering the known strength and the character of the current.

Boston, Mass., December 27, 1889.

My Dear Sir: — In accordance with your request, I write you, with great pleasure, an account of the shock of electricity that I received last spring. The shock received was caused by contact with wires carrying the 1,000-volt alternating current.

The current was furnished by a 500-light Thomson-Houston alternating machine, situated about 250 feet from the point where the shock was received, and running at a somewhat greater potential than is used in commercial lighting.

I was at work on my thesis work, which was the Efficiency of the Transformer, and received the shock at the primary wires which I was attaching to the converter or transformer. At this point the potential was 1,000 volts, determinations having been made a great number of times in various ways; the transformer was run under commercial conditions, and the wires leading to it, therefore, carried the potential always employed in commercial work. I had very carelessly neglected to switch off the current before handling the wires.

The two wires, with 1,000 volts pressure between them, were hanging loose from the ceiling when I took one of them in my hand, put it in a common brass connector attached to the transformer wire and was making it fast,

holding the connector firmly in my hand, and thus making a very good connection to the "live" wire, when the other wire swung and hit the back of my other hand, thus sending a current of electricity up one arm, through the body, and out at the other.

A very painful wrench of my arm was the result, I was thrown back against a table about three feet away, and saw at the instant a very brilliant light, probably caused by the action of the electricity on the optic nerve. There was absolutely no burning connected with the shock.

I recovered myself instantly, and felt slightly dizzy and my senses slightly benumbed; this was accompanied by weakness and unsteadiness of my legs, and slight trembling of arms and hands. I sat down in a chair about three or four minutes, and then resumed my work, feeling perfectly well, except a little fatigued.

I thought little about it at the time, and after that day have never been able to discover the slightest ill effect from the shock. I should say that the shock was no greater than I have several times experienced with a direct current at a pressure of 500 volts. This and a thousand similar cases occurring constantly, illustrate the fact that the pressure alone, at the points of contact, is not necessarily a measure of the effect on the body, but that the degree of perfection of that contact and all the existing conditions must be taken into account before any truthful estimate of the result can be made.

BOSTON, MASS., January 1, 1890.

MY DEAR SIR: — Your note of thanks and inquiry was received, and I am pleased to reply.

I cannot notice any difference in my susceptibility to electricity since my severe 1,000-volt shock last spring, although since that time I have spent several months around electrical apparatus, and have numerous times taken shocks at a pressure ranging from 110 to 600 volts, direct current. These, none of them, not even one which I took at 500 volts where I firmly grasped the brushes of a motor with both hands, have proved more than intensely unpleasant at the time; none of them having left any permanent effect behind them. This is contrary to the testimony of some

other people who have taken severe shocks, I know, yet, nevertheless, it has been strictly my experience.

In regard to thunderstorms, I can not recall any unpleasant feelings experienced during any storms we had last summer.

Mr. F. also informs me that a student of his acquaintance met with a precisely similar accident, without any bad result, but I was unable to get any account of it. The contact made by the wire simply striking the hand must, of course, have been very imperfect. As an offset to this, however, another gentleman told me recently, that when he received a shock from a 120-volt alternating current, he was used up for the rest of the day, and had a feeling of prostration for several days after.

I(b). Cases in which the electric current itself apparently produces no lasting symptoms, but gives rise to a fall which may cause more or less severe symptoms.

These cases, of course, are most apt to occur in linemen, who, while at the top of a pole, receive a shock which either throws them from their position or causes so much discomfort that they unwittingly start and lose their hold of the pole in the effort to escape. Dana[18] cites the case of a lineman, whose skull was fractured at the base from such a fall. In the two following cases the symptoms seem to be almost wholly referrible to the fall, and not to the electric shock.

Case III. Electric shock. Fall from pole. Scalp wound, but no burns. Ecchymoses. Pain in back and chest, with temporary respiratory disturbance.

George M., thirty-two, married, electric light trimmer, born in New Brunswick. Typhoid fever when young. Some alcohol. While on an electric light pole, November 17, 1886, he received a shock and fell

[18] Dana: New York Medical Record, November 2, 1889.

to the ground, a distance, he thinks, of twenty-five feet. He was brought to the Boston City Hospital, and admitted to the service of Dr. D. W. Cheever, who has kindly permitted me to make use of the records of the case. Brought in at once in a condition of shock; pulse full, but exceedingly soft; somewhat irregular, but afterwards became regular. Breathing short, gasping. Livid. Ecchymosis of tissue about right eye with extensive subconjunctival ecchymosis, especially of outer portion of eye. He hadal so a scalp wound, which was sutured.

November 18th. More ecchymosis about right eye, the skin being bulging outward and dark, eye closed. The cornea is clear, mind active. Can move limbs. Pain in back and side. Pulse not so weak and soft.

November 19th. Passes urine naturally. No further pains. Ecchymosis not more extensive. Breathing easier.

November 21st. Gaining in general condition. The subconjunctival ecchymosis is clearing up. Mind clear.

November 22d. At 4 P. M. feels as though having another shock of electricity. At the same time, a patient on the opposite side of the ward (Case I), who received a like injury from the electric current, was telling the nurse that he had a similar feeling. Lameness going.

November 26th. Can move about. No more bloody sputa. Eats well. Ecchymosis fading. Good spirits. No head symptoms.

November 29th. Looks better daily. The ecchymoses are clearing. Has very little pain. Functions all normal.

December 1st. Remains in excellent condition. No pain.

December 4th. The ecchymosis is rapidly going.

Has a slight facial paralysis of the right side, noticeable when he laughs or attempts to draw the angle of the mouth to one side. Head clear. Can breathe well. No pain.

December 7th. Sits up daily. No pain. Ecchymosis nearly gone. Looks bright.

December 10th. In every way looking well. The ecchymosis in eye has nearly disappeared. The wound on head is a granulating surface, about as large as a cent. No difficulty whatever in breathing. Functions normal. Discharged, relieved. The pulse never rose above 100, and the temperature rose above 100° only once, on the 21st.

I have made an effort to find this man to inquire into his subsequent condition, but he has apparently left the city.

Case IV. Shock from trolley wire. Fall from a pole. Fracture of spine. Profound surgical shock. Pain in back. Weakness and paræsthesia of legs.

John C., forty, single, painter, was admitted to the Boston City Hospital, September 17, 1889, in the service of Dr. H. L. Burrell. Previous history negative. While painting some telegraph poles, says he received a shock, fell to the ground, probably striking on head. Well developed and nourished. Can hardly speak. Extremities cold; pale; pupils contracted; skin damp; trembling; pulse very weak and compressible. Suffers pain in the head. Condition of extreme shock. Ammon. carbonat. gr. iiss and tinct. digitalis ♏xv, subcutaneously. Heaters; head raised at foot; not disturbed. From this condition he rallied in about an hour. An hour later had secondary shock worse than the first, from which he almost died. Brandy and digitalis subcutaneous revived him.

September 18th. Condition improved. Talks quite rationally, still somewhat wandering. Calomel, gr. x,

had no effect; repeated to-night. Right knee swollen, ecchymosed, very tender. Numbness in right foot.

September 19th. This evening pulse very slow and feeble; much weaker. Rejects brandy and food, wants ice-water all the time. Given enemata of brandy ℥i, and peptonized milk ℥iii, every four hours; ♏iv of laudanum in first enema. Sulfonal gr. xv, and tinct. digitalis ♏xv, every four hours, unless vomiting.

September 20th. Much weaker. Vomits everything. Tympanites. Right leg paretic. Nystagmus. Mind clouded. Pain in back. Magendie's solution ♏iv, every three hours, for sleep.

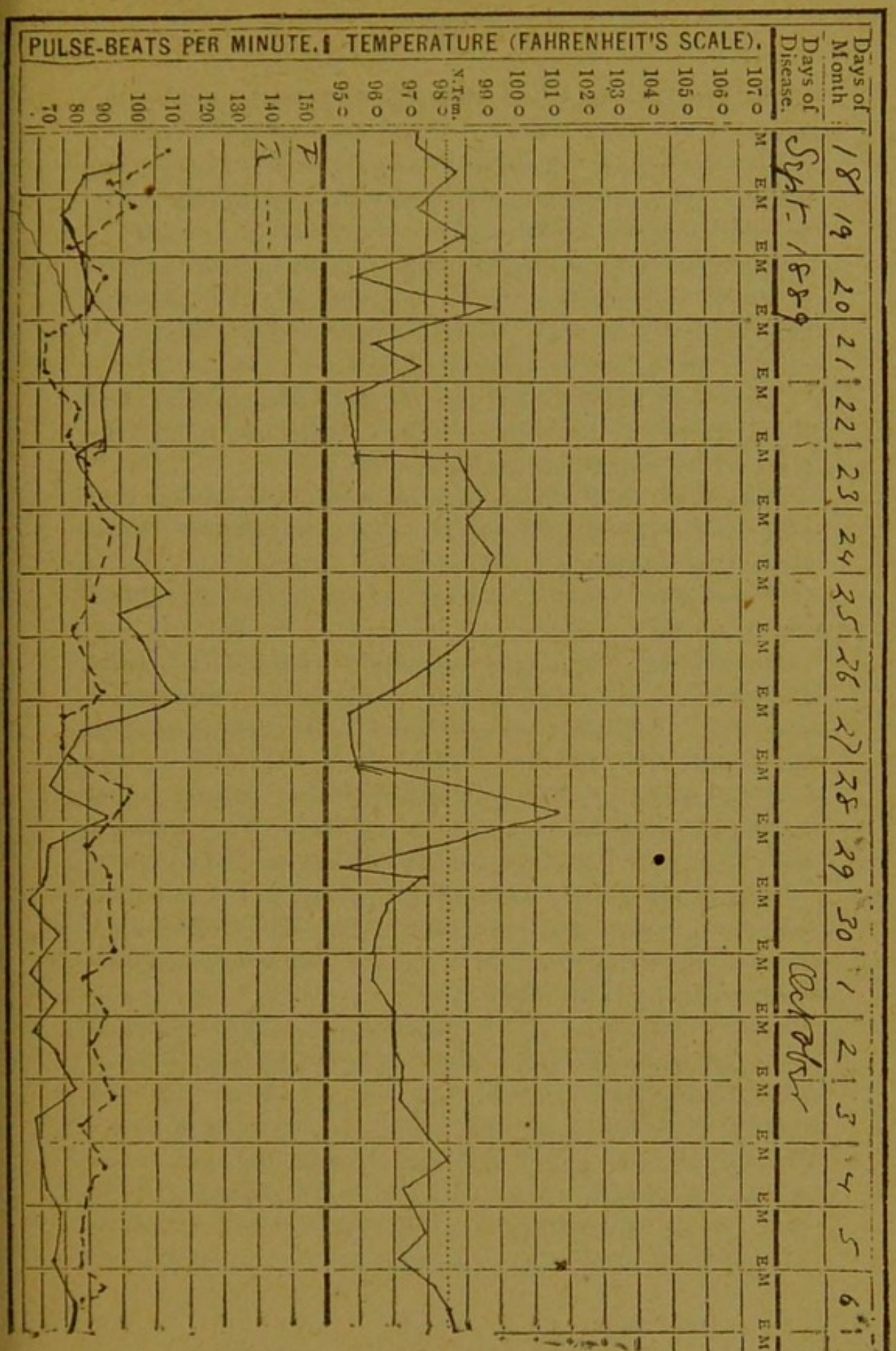
September 21st. To have stimulants if he can take them. Very weak. Considerable pain in back. Vomiting all the time. Vomitus black and slimy. Wants ice-water and nothing else. Contusion over right mastoid process.

September 23d. Wants to drink water all the time, but vomits it at once as he does everything else which he takes. Tympanites increased. Numbness in legs increased. Enemata are now partially rejected. Mind not very clear. There is a depression in the upper dorsal region behind over the spine. No priapism present. Sensation and motion of lower limbs good.

September 25th. Improves slightly. Takes a little food now. Sensation of numbness still present, but no loss of sensation. Motions of limbs are normal. Tympanites still present.

September 29th. The enemata are to be omitted as far as possible and food given by mouth; he takes it quite readily now. Last night he had an involuntary dejection of fæces, soiling the bed. He has a small carbuncle in the right occipital region, an inch and a half in diameter. Incised by the house-officer without ether, and pus discharged. Phenyl poultice. Brandy, ℥vi, per diem.

In the chart the figures for the respiratory curve are omitted. The line of 70 for the pulse stands for 15 for the respiration, 80 for 20, 90 for 25, etc.



September 30th. Improves daily. Digitalis, ♏ x, t. i. d.

October 5th. Does very well. No pain. Eats well. Moves legs about freely. Is perfectly conscious. Seems about to recover.

October 8th. Crucial incision made in the carbuncle to-night. Considerable pus evacuated. Phenyl poultice. Digitalis four times a day. Ferri et quinin. citrat., gr. v, four times a day.

October 17th. Can move legs about with ease. Tympanites diminishing. Can't sit up owing to a vertigo which seizes him when he does so.

October 27th. Has been up in a chair several days, and to-day sat up without feeling dizzy for six hours. Strength returning. No pain.

November 8th. Patient much relieved. Walks about without trouble. Has no pains. Sensation good everywhere. Appetite excellent. Still has a slight degree of vertigo, but nothing remarkable. Discharged, relieved. After October 6th the pulse and temperature were normal.

February, 1890. This patient was referred to me at the out patient department of the City Hospital by Dr. Burrell. He states that he was painting an iron guy-pole with a wooden cap for the trolley wires of the electric railway and got a shock in his right hand which threw him from the pole. He got a shock through the wet brush in his right hand, which was painting the wooden cap, the left hand having hold of the pole. He put his hand to the back of his head to save himself, and struck on the back, "fracturing his spine." For two weeks while at the hospital did not know what happened, although they called him conscious. For three weeks he says he could not hold his urine or fæces. For a time he had headache at night, but this has now disappeared; he still has vertigo on stooping. He

still has pain in the back, and any jar makes his bowels shake. He cannot lie on either side, and hence cannot sleep very well. He is not more nervous than usual, and has noted no change of disposition. He has had no trouble of any sort in his arms, and has had no burn or disagreeable sensation from his electric shock. His breathing is rather short. Lumps come in his belly from cramps if he sits still long. He is very hungry at breakfast time, but has no appetite afterwards. If he takes much food in the afternoon it distresses him, causing pain in the left side. Bowels rather costive. No trouble with micturition. He says the right thigh is now an inch smaller round than the left. From above the knee down the right leg feels "as your arm does when you hit your crazy-bone." The left foot from the ankle down feels the same way. The right knee is rather stiff, the right leg weak, and it tires him to stand or to sit up straight. No girdle sensation.

Cannot smell on right (camphor and oil of peppermint) smells a little on left. Movements of eye good, pupil of moderate size, reacts normally. Left eye disorganized and turned outwards from an injury received in childhood; can move it in all directions. Face and tongue move normally; sensation good. Does not taste with tip of tongue, does with back (salt, saccharin). Movements of arms strong and well co-ordinated. Sharp, but small knuckle in spine about tenth dorsal vertebra, about half-a-dozen of the vertebræ above that seem to arch backwards in a slight convexity. Tender over upper dorsal spines and below the knuckle, especially over the lumbar vertebræ. Tender over the erector spinæ muscles on the left, and over the lower two or three ribs, the tenderness extending round into the flank. Movements of legs good, well co-ordinated, and of good strength, but he favors the right leg in walking, and has to use a cane, Right thigh half an inch

smaller, seven and four inches above the upper border of the patella. Sensibility in the legs to pain, touch, pressure, localization, heat, cold, and muscular sensibility good. No delay of sensation. Abdominal, cremaster, and plantar reflexes alike and normal. Knee-jerks exaggerated on right. No ankle clonus. Vastus internus requires a very slightly stronger faradic current on right to make it react; KaSZ with $\frac{4}{10}$ ma. on each side (Barrett galvanometer) AnSZ a little quicker on right.

February 17th. Less pain in back after using static electricity. Says that the spark feels like the original shock. Is not especially sensitive to electricity.

February 19th. His habitual gait is with the legs well apart and the body bent a little forward He can bend forward quite readily and without much pain, but the effort to straighten the spine causes great pain. No special stiffness of right knee to passive motion. Reaction of muscles of thigh apparently normal. Vasti externi react alike to faradism. KaSZ $\frac{4.5}{10}$ ma. left, $\frac{4}{10}$ ma. right. AnSZ $\frac{7}{10}$ right, $\frac{9}{10}$ left. Edelmann galvanometer. Subsequent examination showed the reactions of the tibialis anticus and gastrocnemius normal. He has improved somewhat under galvanism.

I (c). Cases in which the electric current produces more or less severe burns, but apparently no other symptoms referrible to electricity.

These cases are perhaps the commonest thus far reported. The burns, of course, take place at the point of contact of the wire or other channel for the electric current, and are thought by Dana to be more intense when the skin is dry. "With a wet skin and good connections," he says, "there is little burning and more serious internal effect." With this opinion I am not disposed entirely to agree, for serious nervous com-

plications may arise with severe burns. It is questionable whether the severity of the burning is much, if any, indication of the severity of the shock, any more than it is with lightning. Electrical burns are apt to do rather badly, and the skin sloughs over a much larger region than appears burned at first. As a rule, there is no excessive amount of surgical shock in these cases.

I am again indebted to Dr. Cheever for permission to report the following case.

Case V. Electric shock. Fall. Severe burn of left hand, requiring amputation of thumb. Fracture of ribs. Scalp-wound. Recovery.

George M. H., thirty-three years, married. Electric light patrolman, born in Maine. Does not drink. Pneumonia at the age of seventeen, otherwise always well. While at work upon an electric lamp-post last night (November 2, 1886), as he was preparing to strap himself to the cross-bar, a slight shock passed through the top of his head, through some careless move. This made him jump, and he put his left hand against a rod to save himself in such a way as to get a shock; through the body he says; at any rate he was thrown forcibly to the ground. Does not know how much he struck on the way down.

Physical examination: Well developed and nourished. Burn over the proximal phalanx of the left thumb, on the inner and posterior aspect, running from the radial side forwards in a curved line nearly to the median line in front, the wound being nearly an inch wide and going down so as to expose the bone over fully one-half its circumference. The wound is entirely sealed up, the bone showing hard and dry, and the edges being somewhat everted. Tissues about wound dry and bright red. No sensation in thumb and no power to use it. No pain. On the proximal phalanx

of the index finger is a burn, commencing at the junction of the posterior and radial aspects and running diagonally forwards and downwards half an inch. Its width is half an inch and the bone is exposed over a small area at the bottom of the wound. Finger warm. On the proximal phalanx of the second finger is a burn passing through the skin, three-quarters of an inch long and half an inch wide. On the dorsum of the third finger, at the junction of the first and second phalanges is a burn half an inch in diameter. No hæmorrhage from any of these wounds and the parts are not sensitive.

Wound in scalp one inch in length, directly above the ear, three inches above the meatus, running in an antero-posterior direction. Fracture of eighth and ninth ribs in posterior axillary line on right side. Considerable pain on taking a long breath. Pressure below the ribs on the left side causes much pain and there seems to be a fulness there. No fracture found. Soda wash dressing on finger. Swathe about chest. Rather dazed when brought in.

November 4th. The thumb entirely cold. More fulness on left side in lumbar region. Not much pain. Functions normal.

November 5th. Catheterized once. Thumb turning dark. Burns suppurating. In afternoon much pain in the abdomen.

November 8th. Can pass water himself part of the time, but occasionally requires the catheter. Less pain. Nail of thumb came off this morning. Considerable suppuration. Redness near limit of burn. Remains on back all the time on account of pain in left side of pelvis when he moves. Mental condition much better than before.

November 10th. Suppuration taking place. Excellent condition.

November 12th. Suppuration well marked; thumb all gangrenous. Ether operation by Dr. Cheever. Tissues divided and scraped away about the line of separation and the head of the first metacarpal bone sawn off. Opening irrigated. One stitch taken to bring parts together, and an iodoform gauze dressing applied. Urine normal, reaction acid, specific gravity 1014, faint trace of albumen. No blood or casts, few clumps of pus and bladder cells.

November 13th. Very easy after the operation. Took ether very well.

November 14th. The part is healthy, and shows vigorous granulations.

November 15th. Seems to have recovered entirely from the electric shock. A new swathe affords relief, although his breathing is not very difficult without it. Looks well.

November 19th. General condition good. Breathing easy. Thumb doing well. No pain. Less tenderness in pelvis. Looks well.

November 23d. The opening at the thumb is clean and covered with bright granulations; the finger is also granulating, although the bone seems quite dead. Straight palmar splint applied to straighten finger.

November 27th. The surfaces are granulating in a healthy way. Moderate discharge from the thumb stump. The bone on the posterior surface of the index finger seems to be covering over rapidly. General condition excellent. No more pain in the region of the pelvis. Discharged, relieved. The pulse and temperature were not remarkable. An effort to find this patient lately, proved unsuccessful, so I can say nothing of his subsequent condition.

Moyer[19] reports the case of a man who received a shock from an arc light and fell grasping the side wires

[19] Moyer: Chicago Medical Journal and Examiner, November, 1886.

of the light with his hands, grounding the current with his knee against an iron rail. There was a punched-out opening over the knee, and an eschar on the posterior aspect of the thigh, leaving a deep fistulous track which was slow to heal. There was no other trouble.

Hummel[20] reports two cases. One was a man who got a shock from a 3,000-volt Brush-light wire, running fifty 2,000-candle lights. He got also an extra current from cutting the wire. He hung by his hands from the wire for three minutes, and then was able to come down a ladder without help. The hands were burned, but he had no other trouble sufficient to confine him to the house. There was some slight loss of motion and sensation in the forearms for a time. The second man received a shunt current, of unknown strength, from a Brush-light wire for five minutes. He was senseless for a time, but soon rallied. The thumb and two fingers of one hand were so badly burned as to require amputation. The pulse never got above 86, nor the temperature above 101° F., nor the respiration above 24. There was a similar transitory diminution of motion and sensation in the arms.

Buchanan[21] reports a case where a man received a shock from a Brush-light wire. He was stunned, his sight was dimmed, his hands were burned and his face and neck blistered, and there was slight shock. All the symptoms passed off in twenty-four hours, except that the burns sloughed and required six weeks for recovery.

Terry[22] reports the case of a man who received a shock from an electric light wire, and hung by the legs with his head down for an hour before he could be removed. He had no memory of the shock, and no surgical shock at any time. The hands were burned, and

[20] Hummel: Philadelphia Medical Bulletin, April, 1885.
[21] Buchanan: Lancet, February 13, 1886.
[22] Terry: North American Journal of Homœopathy, December, 1888.

there was a burn over the inner aspect of the thighs and the end of the penis, taking off a congenital phimosis. The burns sloughed, but finally healed. The man made a satisfactory recovery.

Dana reports the case of a young man who was struck by a live arc-light wire. He grasped it with his left hand and instantly fell. The current passed through his arm and body for several moments. He remembered only feeling a sudden blow on the head which knocked him down and made him partially unconscious. He heard voices about him, saw a glimmering light, felt intense pain, expected death, and at last lost consciousness. The left hand was so badly burned as to require amputation, but the arm was not in the least paralyzed or anæsthetic, and the effect on the general bodily functions was *nil.*

The subsequent history of these cases, however, is not always obtainable. It is possible that some of them, later, exhibited nervous symptoms of the types of which I shall now speak.

II. Cases followed by more or less protracted symptoms, chiefly of a nervous character.

The cases already reported show the remarkable tolerance of the human organism to currents of high potential. I have already spoken of the influence which the wonders of electricity exert on the diseased imagination of the paranoiac. It would be strange if, when the newspaper reports of electrical accidents have produced a feeling of panic in many minds, the actual victims of such accidents should not develop many nervous symptoms which often have a distinctly psychical origin. Such symptoms might naturally be expected to be most common in nervous persons, unfamiliar with the action of electricity. It would be going too far, however, to assume that the nervous symptoms which

follow an electrical shock were purely psychical, or were to be found only in persons of the class mentioned, as the following cases will show.

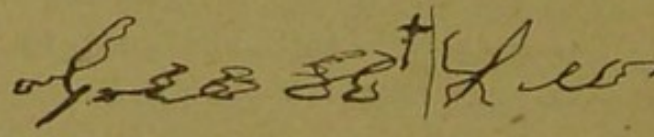
Case VI. Probably imaginary shock. Marked tremor, nervousness and general shattering of the nervous system. Recovery.

I was asked by Dr. D. W. Cheever, to see George L., forty-two, married, a coachman, who was said to be suffering from an electric shock. I saw him on April 14, 1889, and obtained the following history of his accident. He had always been well and strong, although slightly hypochondrical, had used alcohol pretty regularly, although never to excess. He had been in one or two serious runaway accidents, and had conducted himself with marked coolness, judgment, and courage. Five days ago, on the 9th, a wet day, he was driving a span of horses attached to a coupé, and about 10.30 A. M., one or both of the horses stepped on the conduit of the West End Street Railway, which, from some defect in construction, had become charged with the electric current used in running the cars, claimed to be 500 volts, but probably greater. The horses got a shock, dropped, and lay squealing and struggling for a moment. As they fell, the driver, who was sitting on the box holding the reins, says that his hands felt numb and queer, and prickled and tickled. He jumped down, and thinks he stepped on the conduit; at any rate he felt a shock and a prickling sensation like needles in his legs, which was worse than in his arms, but neither shock was painful. He wore ordinary sewed single-soled shoes, with iron nails only in the heels. He thought he did not touch the conduit with his hands, but he may have touched the tire of the wheels, although he felt no further shock; he cannot say whether he knelt on the conduit. He saw no sparks before his eyes, and had no queer taste in his mouth. He sprang

to the coupé, after alighting, and got the horses loose, and they started and ran to the stable. A friend who helped him move the carriage felt a slight shock, which was not painful. L. was very much excited and felt that he could not go after the horses. He did go to a house some two blocks away to tell his employer of the accident. In doing so he had to take a friend's arm, as he had severe pain in the knees, especially in the knee-caps. He then returned to the scene of the accident, where he met the stable-keeper, who had come in a buggy to see what the matter was. L. got into the buggy, helped take the coupé to the stable, and then went home. Since that time he has stayed in the house most of the time, being unable to do anything. He has been extremely nervous and apprehensive, and for two days had the feeling of pins and needles in his feet, and cramps in the calves of his legs at night, with occasional pain in the knees; but he has had no pain in the knees since the 12th. He has occasionally an aching pain in the back. He has a general shivery feeling, but does not feel cold or sick. He had a little headache on the 9th and the 13th, but not enough to amount to anything. He feels a little dizzy on stretching. There is no trouble with vision. Sleep has been very poor until last night, when he slept pretty well under thirty grains of bromide. He has been kept awake by a nervous feeling, and when he did fall asleep would start. Night before last he shook all night. To-day he has a slight pain across the epigastrium. He has had no sexual desire since the accident. Since his accident he has had a constant trêmor, most marked in the hands; this is rather better to-day. When he came home he could not put his toes down to the floor very well. The calves now feel a little stiff.

L. is stout, ruddy, and the picture of vigorous health. He is very nervous, apprehensive and restless, con-

stantly rubbing his hands together. He fears that he will never be able to work again, or to be the man he was before. There is a tremor of the head and limbs, most marked in the hands; this tremor is slightly increased in the arms on intended movements. The grip is not very strong, but there is no ataxia or Romberg's symptom, and he walks well. The tactile sensibility seems a trifle blunted all over the body, possibly more on the left side of the face than on the right, but there is no distinct line of division, and no true hemianæsthesia to touch. The field of vision as tested by fingers seemed slightly contracted on the right. All movements were well performed. There was slight tenderness over the calves and the fourth dorsal vertebra, and rather more tenderness over the upper lumbar vertebræ. The knee-jerks were exaggerated, there was front tap contraction, and a tendency to a patellar clonus. There was no real clonus either at the patella or ankle, but a tap caused several contractions and a general muscular spasm. Examination of chest, negative; pulse, 106. No electrical tests were made. His handwriting is here given.



Handwriting of G. L. At the point + the wrist was held, and the writing thus became steadier.

April 16th. Sleeping better; tremor almost gone. Complains of soreness in the back. Goes out a little, but is unable to do any work.

May 30th. Getting on well. Still has a slight tremor in the right hand. Knee-jerks normal. Says he is not the same man, and is rather despondent and anxious. Nervous; gets out of breath easily; arms give out on carrying anything.

Soon after he went with his employer to the seashore, and resumed his work. His employer states

that he complained more or less of his back until July, and was somewhat hypochondriacal; but that since then he has apparently been all right. During the winter, however, he has indulged in alcohol much more freely, carrying it to excess, thereby losing his situation.

In this case the symptoms seem to have been due purely to the imagination, for I cannot see how any current to amount to anything could have passed through his body. An unusual accident so terrified him as to shatter his nerves completely.

I inquired into the condition of the horses, who did receive a shock and I learned that the accident had no effect on them. One had pneumonia a month later, but neither of them was rendered more skittish, or lost anything in strength or speed.

It was apparently different with another pair of horses who were the victims of an electrical accident. I will quote the account of the accident from the *Boston Post*, of December 10, 1889.

> A couple of horses attached to a cart were driven against a trolley wire of the West End Company's electric system, at the corner of Boylston and Dartmouth Streets, yesterday forenoon at about eleven o'clock, and were thrown to the ground. The wire, it is said, had been torn from its fastenings on the overhead cross-wire by a pile-driver loaded on a team, and had sagged down to within a few feet of the ground. The driver of the cart drove on without noticing the wire, with the result above stated. The horses were on the ground several minutes, but were finally unharnessed and pulled out, apparently not much injured, but trembling in every limb.

On February 15, 1890, I was told by a man employed at the stable that the horses had been sick and good-for-nothing ever since; being stupid, weak, and unfit for any work.

A similar accident happened on February 25th, at Lynn: A telephone wire at the corner of Hanover

and Washington Streets fell on the trolley wire of the Myrtle Street electric line. A Peabody horse-car came along, the horses ran against the wire, and were instantly knocked down. There was considerable excitement on the car. The horses were severely cut and burned, but were finally rescued. I was unable to get any information from the company as to the subsequent condition of these horses.

Case VII. Shock from trolley-wire current through the telephone. Pain, lameness, swelling and weakness of affected arm. Increased nervous irritability.

Mrs. B., forty-eight years, married, housewife, examined August 8, 1889. Was always quick and nervous. "Inflammation of the bowels" some years ago, which has prevented her from running. Health otherwise fair, but not very strong and rather nervous. Menopause a year ago. About 7 P. M., December, 1888, the first day the electric cars ran near their house, her husband saw a ball of fire in the telephone, which was burned out. A wire passed from the telephone into the cellar and was grounded on the gas-pipe between the meter and the street main. There was a burner connected with this gas-pipe near the furnace in the cellar, and the gas-pipe then crossed the water-pipe, touching it in crossing. The telephone company stated subsequently that the trolley wire fell and crossed their wire, which grounded the trolley current. Mrs. B. went to the cellar, after the telephone took fire and started to light the gas. As she took hold of the cock with her left hand she felt something like the stinging of bees and could not hold on. She persevered, however, and lit the gas. When she had done so she found the cellar "full of electricity," the air filled with something like feathers floating about, and the water-pipe burned off. In considerable alarm she shut off the gas, receiving another shock,

and hurried up stairs. As their own telephone was useless she hurried to the nearest drug-store to telephone for assistance. She felt that she could not put on her clothes, she had no control of her limbs, she could not stop, her feet seemed to go without her control, and she ran all the way to the drug-store, a distance she had not run for years. Her husband, meanwhile, cut the telephone wire. He got a slight shock himself in taking hold of some part of the furnace. Later in the evening, about 10 P. M., Mrs. B. sat down with her feet on the register and felt a shock through a pair of ordinary single-soled shoes. Since that time the left arm has been lame, weak and swollen, so that for three or four months she could not get on a ring that had been large enough before. For months she had constant pain and aching in the arm, and still has it to a lesser degree. The arm is still not as strong as the other. She has numb and prickly feelings in the hand, and the grip is poor. She cannot hold the telephone to her ear with that hand, as it gives rise to an aching and a prickly sensation, although she does not get this same sensation from doing anything else. The right hand is perfectly well. The left hand always used to be stronger. Now the whole left side has been weaker, especially during thunder-showers. She improved until a heavy shower in May, but that disturbed her very much. She has much more pain during a shower, and feels very nervous and prostrated, and her head feels light. She did not sleep well for a long time, but sleeps well now. Ordinarily she can now attend to her housework except for her hand. For some weeks she was unable to hold her sewing in that hand. She is not especially nervous now, except when tired or during showers. Has old aural trouble in right ear, and is occasionally subject to vertigo which has been worse since her accident. More easily excitable and more

depressed since her accident. Has no trouble in chest, back, digestion, or micturition. No change in vision or hearing. The pain is worse in the hand, but extends to the shoulder; lately the hand seems different and flabbier. The legs are now all right. For a time she had a general "shaken-up" feeling.

Well developed and nourished, rather active and nervous. Movements of eyes and pupils normal; field of vision to fingers good. Tactile sensibility and motion in the face and tongue normal. Smell slightly less on left. *Vod.* $\frac{5}{4}$ *vos* $\frac{5}{6}$. Watch heard *as*, 14 inches, *ad*, one inch (old middle ear disease *ad*). Tactile sensibility in left hand and arm good, distinguishes between sharp and blunt points readily. Slight tenderness over nerve-trunks in left arm. Makes all the movements with the left hand, but the grip is weaker. Elbows flexed with about equal strength. No vasomotor or trophic disturbances in left hand. Muscles of the left arm react slightly less well to faradism than the muscles of the right, but they react to a moderate current; the electricity seems to cause pain in that arm. Triceps reflex, present right, absent left. Knee-jerk slightly increased on left. Patella twitch present left, absent right. Walks well. No ataxia or Romberg. Pulse 84.

February 22, 1890. Says that she has been worse since the examination in August. The mild faradic current employed increased her pain. Ever since has had very severe pain in the arm and side, with tenderness along the nerves and on the left scapula in the intra-spinous region. This seems very sensitive to a slight touch and her husband says it is cold. No spinal tenderness. General health fairly good. She finds that she gets more relief from trying to work than by holding the hand still, although using the hand itself for even light work produces great pain. Cannot

lie on that side. Sleep poor, exhausted feeling in morning. Arm very weak, cannot pass a dish across the table without dropping it, if she has to hold it out for any length of time. Unusually nervous on the evening of the 18th before the thunder-storm. Cannot use the telephone without pain in the arm. Can ride one trip on the electric cars without much discomfort, but if she goes into town and comes out again on them she suffers for twenty-four hours.

Although in this case the psychical element was well-marked, and some of her statements are rendered doubtful by her excited condition (notably the statement that "The air was full of something like feathers," since the dynamo current is not likely to electrify surrounding objects in the way the static spark sometimes does) it seems to me that there is something more than a psychical affection here. We certainly have not a hysterical monoplegia, a "local traumatic neurosis," and it seems probable that there is some disturbance of the peripheral nerves in the arm (perhaps from hæmorrhages in their sheaths) combined with a general functional disturbance.

Case VIII. Shock from the arc-light current. Burns and fall. Insomnia and nervousness of four years' duration.

January 3, 1890. I had an opportunity for a brief conversation with G. H., but unfortunately I had no chance to make any elaborate inquiry into his symptoms, or to make any examination. He is twenty-four, unmarried, and is, at present, fireman for a stationary boiler. In November or December, 1885, he was an electric lineman, and one wet night he was on a wooden pole, with an iron step on which his right thigh rested, adjusting a T. and H. arc light. He held the carbon in his right hand, when a grounded wire made a circuit through his body and the wet pole, and he fell on

the top of a freight-car. It is uncertain whether he lost consciousness, but he was finally picked up by a brakeman and went home. For a week he tried to work, but finally he was obliged to give it up. He was very nervous, "all broke up," and slept none for three nights. He had a bad burn on the inside of the thigh, and a slight burn on the hand. For a year after his injury he had, at times, pain and a queer swelled feeling in the thigh. Since that time he has been very nervous and has had to give up electric light work; he used to tremble greatly while at work. Ever since his injury he has slept poorly and has been nervous and shattered, although he is slowly improving. Before his injury he was strong and well, and a good sleeper; he often took electric shocks, and never saw but one battery that he could not bear; now electricity breaks him up and he feels nervous and feels the electricity when going near a dynamo. Thunder-storms, however, have no effect.

Robert [23] reports the case of a man who received a shock in a telephone office from a blind wire. He had clonic muscular spasm, temperature 97° F., respiration 50, pulse very rapid. He had severe pain in left arm, and later convulsions of that arm and the right leg — a sort of jactitation, suppression of which caused severe pain. This continued three days, the fourth day it became a tremor, and the fifth day it ceased.

The manager of the Oakland Electric Light and Motor Company, was measuring the resistance of electric light circuits.[24] He took hold of two wires, which unknown to him were in a circuit, taking one firmly in each hand to pull them apart. He says, "My hands were paralyzed, my arms were as stiff as bars of iron,

[23] Robert: St. Louis Courier of Medicine, November, 1886.
[24] Occidental Medical Times, October, 1889, p. 562.

and the cords stood out in large bunches; my head was turned round in the direction of the current (to the right, the current entering by the left hand); my eyes bulged out with burning pressure and glazed over, then I lost my senses and fell to the floor." This broke the circuit which lasted about five seconds. The voltage was about 1,400, from two Weisse dynamos. He had no pain, and slight burns, but the shock to the nervous system was very severe, and two months later the effects were still evident.

Dana cites a case of Thompson's. A man of fifty saw a fatal electrical accident. Two weeks later he was struck by a dead wire carrying no current. He fell unconscious, and a few hours later was found to have typical traumatic hysteria, right hemiplegia and hemianæsthesia.

Peterson [25] gives two cases: An elevated railroad employee, twenty-five years of age, who had hitherto been a very strong and healthy man, on August 13, 1889, about 11 A. M., while at work, picked up a wire on the elevated railroad, which was probably dead, but enlivened by his moving it and bringing it into circuit with some other. He had a buzzing in his head, and instant muscular rigidity followed almost immediately by relaxation. He had evidently made a circuit by picking up the wire, and his tetanic spasm had broken it again. He felt momentarily unhurt, then fell in a heap, and was conveyed to the hospital. In the ambulance he recovered consciousness, but was so drowsy at the hospital that they forcibly kept him awake. He was burned but very slightly. He was able to walk home unassisted, at 6 P. M., the same day. For a week he had considerable muscular twitching, like chorea; suffered from insomnia, and when asleep would dream of touching the wire, getting a shock,

[25] Peterson: New York Medical Record, November 2, 1889.

and would then suddenly waken. There is no sign now of any organic disease about him. He is unable to work, however. He has pain in moving his eyes, but his eyes are normal. He walks in a stooping position, and says he cannot straighten up because of pain in his back. His muscles twitch occasionally, according to his account, and he has a slight tremor, and the knee-jerks and wrist-jerks are exaggerated. He is troubled with headache, and his face has a somewhat anxious look. He evidently has sustained a profound shock to his nervous system, and his mind is much absorbed in the contemplation of his morbid condition and symptoms. His state is more than one of neurasthenia, and less than hypochondriasis. It evidently corresponds to the traumatic neuroses due to other kinds of shock, like railway-brain, railway-spine, etc. He mentioned another case of a man in whom choreiform movements had developed after a severe shock from an electric wire.

In this second class of cases the symptoms are neither new nor strange. With the exception of the burns, there is little if anything showing a specific action of the electric current. They are similar to the symptoms which develop after severe shocks to the nervous system, such as falls, fright, or railway accidents. As Dana and Peterson both claim, these cases are practically identical with the cases of traumatic neuroses from other causes.

I said in the beginning of this paper that the diseased imagination of the paranoiac was readily influenced by the wonderful powers of the electric current, but these powers had ceased to excite wonder in the ordinary mind. The recent manifestations of these powers, under such frightful aspects have excited the entire community, and among some persons, at least, electricity is regarded with almost a panic terror. It

is not strange, therefore, that the old maxim, *omne ignotum pro magnifico*, here holds good, and that people ignorant of electricity are now disposed to ascribe all sorts of action to it. In such persons the psychical effect of a mild shock, or of an imagined shock, would be very great. The action of shocks from currents of high potential, however, cannot be wholly imaginary, for, as I have shown, serious nervous symptoms may arise in persons familiar with the actual working of electricity, and persons who have frequently subjected themselves to its action.

The important question that now arises is, What is the dangerous dose of electricity? This is the question which has been so bitterly discussed in the public press, by alleged experts whose scientific candor was far less than their zeal to support the pretensions of some special dynamo. It is a question, moreover, which at present admits of no definite answer. The cases thus far presented, however, and a reference to some of the facts of electro-physics may throw some light upon the subject.

The determination of the actual strength of current which passes through the human body depends upon Ohm's law, that the intensity varies directly with the electro-motive force, and inversely with the resistance: the well-known formula, $I = \frac{E}{R}$. The resistance of the human body is a very vague and uncertain factor. The researches of Gärtner,[26] which were subsequently confirmed by Jolly,[27] show that the resistance of the skin at the moment the current enters is very great, but that if the current continues to act it may fall to one-thirtieth of its original amount. The amount of the decline in resistance increases with the intensity of the current, and the length of time it passes. Gärtner

[26] Gärtner: Medizinische Jahrbücher, p. 519, 1882.

[27] Jolly: Untersuchungen über den elektrischen Leitungswiderstand des menschlichen Körpers, Strasburg, 1884.

measured the resistance by applying one moist unpolarizable electrode to the flexor surface of the forearm, the other to the extensor surface of the same arm. Weak currents as a rule (three to thirty volts) were employed for brief periods. The initial resistance was from 50,000 to 250,000 ohms, soon falling, however, to 5,000 to 9,000. This resistance is chiefly in the epidermis, for, on removing the epidermis from the arm of a cadaver, whose resistance had been from 30,000 to 80,000 ohms, Gärtner found it from 1,600 to 2,000 ohms.[28] With the skin more thoroughly wet, and the duration longer, the resistance of course is less. Grange found resistance of 6,000 to 17,000 ohms in frogs, and 6,000 to 90,000 in men. Professor Trowbridge informs me that in testing the resistance from hand to hand, the hands being immersed in a zinc sulphate solution, he found it 3,000 to 6,000 ohms. Brown[29] cites the experiments made by Edison as evidence which totally disproves the view that the resistance of the body may be great. As a matter of fact Edison's experiments are in close accord with Gärtner's. Gärtner, as I said, found a resistance of 1,600 to 2,000 ohms when the epidermis was removed; Edison soaked the epidermis in caustic potash, thus rendering it a comparatively good conductor, and found the resistance was 1,000 to 2,000 ohms. In ordinary accidents the conditions in Edison's experiments, or even in Gärtner's, do not obtain. The epidermis is dry, the contact imperfect, and perhaps of very short duration, and the resistance to the first passage of the current may be even greater than Gärtner found. The great electro-motive force of the current, however, will speedily lessen this resistance. We see, then, how

[28] Gärtner's figures are given in S units which equal 0.97 ohms. The figures in the text are given in round numbers and are somewhat below Gärtner's figures when reduced to ohms.

[29] Brown : North American Review, November, 1889.

Case II escaped from any bad effects from the electric shock, and we must admit that the resistance of the body may vary greatly. Another factor must be considered when man becomes a link in the circuit that grounds the current, and that is the resistance of his shoes, which must be considerable. Horses, with iron shoes, are perhaps more readily prostrated than men. That the current may be conveyed through the shoes seems evident by certain facts given me by Professor Trowbridge. He tells me that in the Jefferson Physical Laboratory at Cambridge, it is possible to get a perceptible spark by touching the insulated wire that carries a 120-volt alternating current, grounding it through the body. Here the grounding current must pass through the insulating material (the "underwriters'" insulated wire), the body, rubber-soled shoes, and several inches of concrete.

The problem of the electro-motive force is by no means so simple as it would appear from the ordinary statement that the current used was one of 500 or of 2,000 volts. In the early days of Faraday's researches he was asked why a shock was felt when a circuit containing an electro-magnet was broken, and why no shock was felt when the circuit contained neither electro-magnet nor wire coil. This led Faraday to study what he called extra currents, but which are now spoken of as currents of self-induction or inductance.[30] If the circuit contains a coil of wire, it is found that on closing the circuit a current of brief duration is induced in that wire, which runs in the opposite direction to the steady current. On opening the circuit another current, running in the same direction, is induced in the circuit. These extra currents, or currents of self-induction, were carefully studied by

[30] Fleming: The Alternate Current Transformer, p. 37, et seq. London, 1889.

Blaserna,[31] who found that the extra current of opening was of shorter duration, but much more intense than the extra current of closing. Now every dynamo current necessarily contains a coil in its circuit, and consequently must present the phenomena of inductance. Hence, when a person receives a shock from a dynamo-current, he must also get when the current is broken, a self-induced or extra current of opening, of great intensity, but short duration. The strength of this extra current depends on so many factors that it is not easy to calculate, but I understand that, with a current of 500 volts, it may reach 2,000 or 3,000 volts.

It follows, then, that where the factors in the problem are so variable, we cannot make any positive assertions, and say that because A received a shock from a 2,000-volt current, without harm, it must be harmless to B, when we known neither the body-resistance of A or B, nor what part of the current A received. As well say that, because A swallows ten grains of morphine and survives, ten grains is a safe dose to give to B.

Bearing all this in mind, we may note the very few data which we possess, in the hope of getting some little empirical knowledge.

The currents of high potential to which we are exposed are the continuous and the alternating: the former being the one now in use in Boston for the electric cars and the electric lights. The voltage of the trolley-current is claimed to be 500, although this is probably often exceeded. The voltage of the arc light is about 2,000 to 3,000.

As regards the trolley-current we have seen (Case VII) that it may produce serious injury. I learn that the horse recently killed by electricity in Cambridge made a ground circuit with a trolley-wire, and at

[31] Blaserna: Giornale di scienze naturali ed economiche, vi, 22, 1870.

Edison's laboratory a dog weighing 57½ pounds was killed by a continuous current of 400 volts. With imperfect contact and a high resistance of the body it is not likely to prove fatal, but with firm contact and lessened resistance it would be unwise to run much risk. We certainly are not justified in proclaiming that this current is harmless. The arc-light current, as we have seen, may be dangerous to life and health.

The chief bone of contention between electrical experts is the relative dangers of the continuous and the alternating currents, and examination of the discussions on this point gives us comparatively little scientific knowledge, but does increase our knowledge of invective. It is an admitted fact in electro-therapeutics, which any one can demonstrate to himself in two minutes, that shifting the pole-changer of an ordinary galvanic battery, thus alternating the current, will give a much more powerful stimulation — the most powerful, in fact, of which we make use in electro-therapeutics. We would naturally expect, *a priori*, that the alternating current of high potential would have a more profound effect upon the human organism. This *a priori* view seems to have some support from experiments on animals. Peterson, who followed the experiments at Edison's laboratory, confirms the results given by Brown, that dogs who withstood continuous currents of 1,000–1,400 volts were killed by alternating currents of 250–800 volts; and Edison himself states [32] that he has seen a large dog killed by an alternating current of 168 volts. The rapidity of alternation, according to Peterson,[33] makes a great difference. Dogs were killed by continuous currents of 400–1,000 volts, and by alternating currents of 140–800 volts. Brown, moreover, claims that the alternating current of high poten-

[32] Edison: North American Review, November, 1889.
[33] Peterson, etc.: Report of the Committee of the Medico-Legal Society on the Best Method of Execution of Criminals by Electricity.

tial has killed men who touched its insulated wires. Grange states, from experiments on animals, that, with equal electro-motive force, generators of alternating currents produce differences of potential double those of continuous currents, and that, while the dangerous effect of continuous currents exists only on making and breaking, the dangerous effect of alternating currents exists during the whole period of their passage; therefore, he concludes that the alternating current is incomparably more dangerous. He found that by alternating harmless currents he could produce death. D'Arsonval [34] states that the danger from continuous currents comes from sudden breakage; although he thinks a 500-volt current not dangerous in itself, there is danger from the extra current at 100 volts, which proved fatal to a guinea-pig. The alternating current is much more dangerous. In experiments on guinea-pigs he succeeded in killing them with alternating currents of 120 volts. D'Arsonval was appointed by the minister of the telegraph and postal service as a member of a commission to regulate the electric currents, and he, therefore, advised 500 volts as the maximum for the continuous current, and 60 volts as the maximum for the alternating current, which might be employed without special permission. Above this he considered that there was danger.

I have referred to these French observations at some length as they seem less tainted by controversy, and as this question of the relative safety of the two currents has recently been raised in Boston. The advocates of the alternating current [35] do not advance any experiments on animals to prove that their current is less dangerous, but they cite cases, like Case II, where persons have been uninjured from shocks from the cur-

[34] D'Arsonval: Comptes rendus hebd. des séances et memoires de la société de biologie. 8 ser. T iv, p. 95, 1887.

[35] Westinghouse: North American Review, December, 1889.

rent. I have already spoken of the fallacy connected with such arguments.

It is from the purpose of this paper, which has already reached too great a length, to speak of the measures to be adopted to avoid these accidents. In but one city, outside of America, England and Italy, are the wires carrying these high currents allowed to be above ground.[36] In France and Germany the number of accidents is very small. The number of accidents in this country is, of course, relatively very small, the risk being vastly less than from railways or other accidents, but most of these accidents are preventable, and it is our duty, as physicians, to urge that the most rigid control be exercised over these new uses of electricity. They cannot be abolished, but they can be controlled.

CONCLUSIONS.

(1) Currents of high potential may produce no permanent effect upon the human organism, or they may cause severe burns without other effects, or they may give rise to nervous symptoms of various kinds, similar to those seen after other injuries, — the so-called "traumatic neuroses."

(2) Currents of high potential may prove fatal immediately, or they may give rise to burns which later cause death.

(3) The limit of safety from death or injury from currents of high potential has not yet been determined, and is probably variable.

(4) The alternating current is probably more dangerous than a continuous current of equal electromotive force.

[36] Thomson: North American Review, February, 1890.