ELECTROLYSIS IN SURGERY

BY THE SAME AUTHOR

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THE USES

OF

ELECTROLYSIS IN SURGERY

BY

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IN CHARGE OF THE ELECTRICAL DEPARTMENT AT ST BARTHOLOMEW'S HOSPITAL; PHYSICIAN TO THE GROSVENOR HOSPITAL FOR WOMEN AND CHILDREN ; LATE HOUSE SURGEON TO ST BARTHOLOMEW'S HOSPITAL, AND TO THE HOSPITAL FOR SICK CHILDREN, GREAT ORMOND STREET

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PREFACE

It is difficult to draw a hard and fast line, or to define accurately in what cases the beneficial effects of galvanism are due to its electrolytic action, and those in which its stimulating properties, or influence as a nerve tonic, are of the greatest value. In all instances, no doubt, the electrolytic power is brought more or less into play, but this manual is devoted to those affections in which electricity is used as a remedial agent solely on account of its electrolytic properties, and in which it is, under certain circumstances, a useful mode of treatment.

No caustics or cauterising agents used in surgery can be so accurately measured or so limited in their action, so quickly applied or so entirely under the control of the operator, as Electrolysis and Galvano-Cautery; and yet for many purposes for which they are peculiarly adapted they are seldom or never employed.

The technical knowledge required, both of the apparatus and the manner of using it; the cost of the batteries and accessories; their number and diversity; the difficulty of keeping them constantly in order; and, above all, the amount of time required for their successful use, make it certain that electricity can never become one of the ordinary means of treatment to be employed in general practice; but there is no reason why the advantages claimed for it should not be made known, and those who have time to spare and wish to employ it should not have the means afforded them of learning how it is to be used to the greatest advantage.

Should this small work on Electrolysis prove to be useful in the way I have suggested, I hope that at some future time I may be able to deal with the other applications of electricity.

Mr L. Mark, of St Bartholomew's Hospital, has kindly executed some of the drawings for me, and I have to acknowledge the loan of several of the woodcuts from various instrument makers, viz. Messrs Coxeter and Son, Messrs Krohne and Sesemann, Messrs Lindsey and Pratt, Messrs Maw, Son, and Thompson, and Mr K. Schall. On this account I am aware of one disadvantage connected with the illustrations; that is, they are not all drawn to the same scale, and therefore may be somewhat misleading to those not acquainted with the instruments.

Some repetition also takes place in discussing the process of Electrolysis when applied to the different affections for which it is employed. This is due partly to the endeavour to make each description complete in itself, and partly to the fact that the work is to a great extent a collection of papers written and published at different times.

London;
November, 1889.

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ELECTROLYSIS

Electrolysis is the name given by Faraday to the property that electricity possesses of splitting up all chemical compounds, that are conductors, into their constituent elements or radicals. The chemical compound must be in a more or less liquid condition and is called the *electrolyte.* The points or surfaces at which the decomposition becomes manifest are called *electrodes.* The electrode connected with the positive pole of the battery is called the *anode* (or way up) and that attached to the negative pole is the *cathode* (or way down). The molecules of the electrolyte split up into elements or radicals and are called *ions;* those which appear at the anode are called *anions,* and those which appear at the cathode are called *cations.* The ions may be single atoms of an element or molecules which act chemically as radicals. "There is no direct attraction between the electrodes and the ions themselves, but the relation depends simply upon the temporary polarity they assume in the circuit."* When

* 'Electricity,' by John T. Sprague. London: E. and F. N. Spon.

bodies composed of two elements are decomposed, one element turns towards the positive and the other towards the negative pole. The elements which separate at the positive pole are called *electro-negative;* they are the acid radicals, such as oxygen chlorine, SO_4 (sulphion[1]), &c.; while those which separate at the negative pole are called *electro-positive,* or basic radicals, as hydrogen and metals.

All the elementary substances have been arranged in an *electro-chemical series:*

Electro-negative.	*Electro-positive.*
*Oxygen.	*Hydrogen.
*Sulphur.	Gold.
*Nitrogen.	Iridium.
*Fluorine.	Platinum (the least oxidisable metal).
*Chlorine.	Mercury.
Bromine.	Silver.
Iodine.	Copper.
Selenium.	Bismuth.
*Phosphorus.	Tin.
Arsenic.	Lead.
Chromium.	Cadmium.
Boron.	Cobalt.
*Carbon	Nickel.
Antimony.	*Iron.

[1] Ganot's 'Physics,' p. 751.

Electro-negative.	*Electro-positive.*
*Silicon.	Zinc.
	*Manganese.
	Cerium.
	Aluminium.
	*Magnesium.
	*Calcium.
	Strontium.
	Barium.
	Lithium.
	*Sodium.
	*Potassium (the most readily oxidisable metal).

Each element in the series is electro-negative to the one following it, but electro-positive to the one which precedes it. The first and last of the series, viz. oxygen and potassium, are the two between which the greatest difference of electrical potential can exist.

A compound of any two of these elements when decomposed by a current of electricity splits up into the same proportions as those in which the elements combined; viz. their chemical equivalents, not into the proportions of their atomic weights. Thus in the electrolysis of water, there will not be one atom of hydrogen liberated at the negative pole for every sixteen of oxygen at the positive, but there will be two atoms of hydrogen to every sixteen of oxygen, that is, in proportion to their chemical quantivalency. In the decomposition of a solution of iodide of potassium, the iodine is liberated at the positive pole and the potassium at the negative. The potassium immediately decomposes the water, and hydrogen is evolved at the negative pole. The presence of free iodine at the positive pole can be demonstrated by moistening some bibulous paper, previously steeped in starch, with a solution of iodide of potassium, and then applying both electrodes from a battery to the paper, on closing the circuit the action of the liberated iodine on the starch can be immediately seen at the positive electrode.

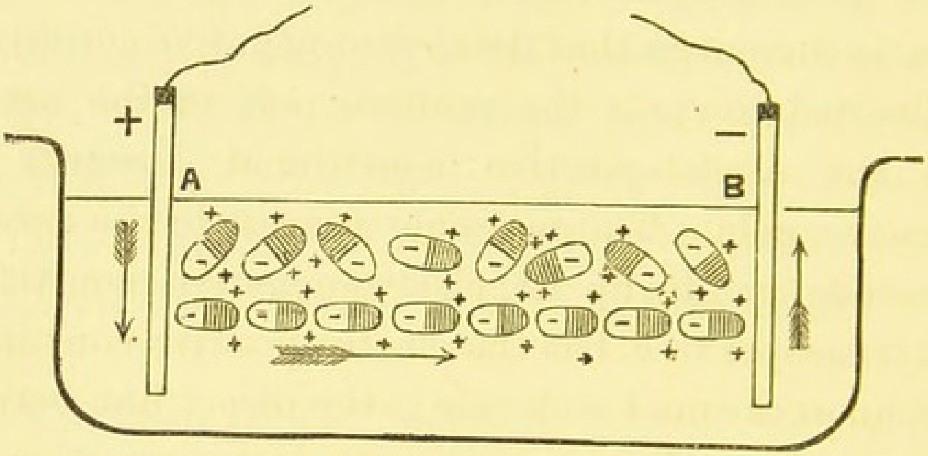
It has been pointed out that electrolysis splits up chemical compounds into the proportions in which their constituents have combined. Therefore, for every 127 parts of iodine liberated at the positive pole there would be 39 parts of potassium liberated at the negative pole; both elements being monads. In the decomposition of oxide of lead there will be 207 parts of lead liberated at the negative pole to every 16 parts of oxygen at the positive; while in the decomposition of chloride of tin there will be 118 parts of tin to $(2 \times 35 \cdot 5)$ 71 parts of chlorine. Tin in this compound being a dyad. And further, in each cell of the battery employed it will be found that 65 parts of zinc have been dissolved. This is the case whatever number of cells are employed; therefore, whenever a sufficient number of cells has been employed to overcome the resistance of the electrolyte any additional cells only accelerate the process, they do not increase the relative amount of decomposition that is taking place.

The theory advanced to explain the action of electrolysis is that the molecules of the substance electrolysed turn themselves, under the influence of an electric current, so that the electro-negative constituent is directed towards the positive pole of the battery and the electro-positive constituent towards the negative pole. The molecule nearest to the positive electrode yields up its electro-negative constituent and it escapes free, but the electro-positive constituent acts upon the next molecule in the direct line between the two electrodes, attracting its electro-negative constituent and again repelling the electro-positive atom or atoms. This action continues on in each contiguous molecule and forms a direct chain of decompositions and re-combinations across the substance being electrolysed until the negative pole or electrode is reached, and then the last molecule of the chain having yielded up its electro-negative constituent in the direction towards the positive pole, and there remaining no further molecules for the electro-positive element to split up, it is therefore discharged free at the negative pole. Such is the theory of Grotthüss propounded in 1805, and, as applied to water, is explained by the accompanying diagram :

A is the positive electrode and B the negative one.

In the upper line the molecules are seen arranging themselves so that the electro-negative element, the oxygen, is turned towards the positive electrode (A). In the lower line the molecules are arranged in a

Fig. 1.



chain across the liquid. The atom of oxygen nearest the positive electrode is then liberated as free gas, and the two atoms of hydrogen combine with the atom of oxygen directed to it in the next molecule and form a new molecule. This action extends throughout the chain, and ultimately the two atoms of hydrogen of the last molecule, having no further molecules to split up, are liberated as free hydrogen gas at the negative pole (B). Therefore the volume of gas liberated at the negative pole is double that liberated at the positive. No appreciable action or change can be seen or detected at any point across the fluid; the gases are liberated only at the points of contact with the electrodes. A similar diagram would explain the electrolysis of hydrochloric acid, only for the oxygen (the electro-negative atom) would have to be substituted one atom of chlorine and for the two atoms of hydrogen only one would be liberated by the decomposition of each molecule, because chlorine and hydrogen combine in equal volumes to form hydrochloric acid gas.

The primary effect of passing an electric current through an electrolyte is to split it up, the acid constituent passing towards the positive pole and the base or metal towards the negative pole. In this way Sir Humphrey Davy discovered sodium and potassium very soon after it was found that electricity would split up water into its two constituent elements. Potash and soda were up to the time of Davy supposed to be elementary substances but were then found to be oxides of the hitherto undiscovered metals sodium and potassium. The oxygen was liberated at the positive pole and the metal at the negative.

In very complex substances such as those of which the human body is composed, double decompositions take place. The tendency of the galvanic current is to split up the tissues into their most simple elements, but some of these elements when in a nascent state seize readily upon any other element in their immediate neighbourhood with which they can easily combine. This makes the subject of electrolysis when applied to the human body such a difficult one. It is impossible in the present state of our knowledge to say how many decompositions, and fresh chemical combinations take place at either electrode. Animal tissue itself is such a complex substance, and the combinations of elements are so various, and in so many different proportions, that it is almost impossible to make a correct analysis; decompositions and re-combinations must vary with every description of tissue experimented on. Tissues that we call by the same name vary in their composition in different parts of the body, the same elements combining in different proportions in different situations. For instance in the case of fat: stearic and palmitic acid are present in greater proportions in one kind of fat than in another. Therefore any attempt to explain the exact decompositions and re-combinations which take place would fail, and if correct for one tissue would not hold good when applied to any other or to the same tissue in another situation. The main facts of electrolysis only can be stated.

By the investigations of Althaus and others it has been shown that at the negative electrode the potassium and sodium contained in animal tissue are liberated, as they would be in any solution of an inorganic compound that might contain them when subjected to a current of electricity. The freed potassium and sodium while in a nascent state seize upon the oxygen in the watery constituents of the body, and form caustic potash and soda liberating hydrogen, which appears as bubbles of gas. The bubbles of hydrogen are said also to act mechanically, and by insinuating themselves between the cells or fibres of the tissue being electrolysed, split them apart, and thus accelerate their disintegration. The caustic potash and soda which are formed combine with any fatty or other constituent of the tissues with which they can form soap and a deliquescent eschar is the result which gives an alkaline reaction to test paper. The action around the negative pole extends farther into the surrounding tissues than that around the positive pole, and therefore, if the current is continued for a long time a slough is produced as it would be produced by the action of caustic potash or soda. No doubt other and numerous chemical changes take place at the negative pole, and to these other decompositions are due the better results which follow the treatment of unhealthy and ulcerated surfaces by electrolysis than when treated by simple caustic alkalies.

At the positive pole oxygen and chlorine are liberated and the reaction to test paper is acid. The tissues become oxidised, are deprived of their moisture, and are more or less charred, as after cauterisation with a strong acid such as sulphuric acid or nitric acid. Metals are decomposed, and by the theory of Grotthüss have a tendency to pass over and be deposited at the negative pole. The composition of the needles or electrodes employed in electrolysis is therefore a matter of consequence. The negative pole has no action upon metals, therefore an electrode attached to it remains as clean and bright after as before an operation. This is not the case with the positive needle or electrode, for the metal itself suffers decomposition during the process of electrolysis. This action of the positive pole is useful under certain circumstances. For instance, when electrolysis is used to destroy the fungoid growth or ulcerated surface of a cancer of the uterus, then if the electrodes be made of zinc, chloride of zinc is formed at the positive pole, and exercises its own peculiar cauterising effect in addition to the oxidising action of the electric current on the tissues. In the electrolysis of aneurysms additional advantage is obtained by the needles being composed of steel, for a chloride of iron is formed if the needles be made positive, and in addition to the coagulating effect of the positive pole we have the coagulating influence of the chloride of iron. Should the electrode applied to the part to be electrolysed be plated, then if the electrode be made positive all the plating will be removed at once and deposited in the tissues. This is important; and when the additional action of a metallic salt is not required, it is best to use the negative pole in electrolysis, especially in parts difficult of access, such as the os uteri, nasal duct, urethra, or œsophagus; and also where it is desired to use a caustic, the action of which is somewhat analogous to that produced by the caustic alkalies. This can only be obtained by the use of the negative pole. When it is essential to use the positive pole, and the action of a metal is not required, it is best to employ an electrode made of platinum, for of all metals it is the most difficult to oxidise, and therefore affected less by the action of the current.

Other changes take place in animal tissue subject for some time to the passage of an electric current. The chemical constitution of some of the cells is so altered as to render them capable of reabsorption. This is one of the reasons why fibroid tumours and the gristly thickening about strictures are found to gradually decrease for several days after the application of electrolysis. Some of the constituent parts of these adventitious growths are so changed that they can be again absorbed; and during the passage of an electric current, if not afterwards, ordinary osmotic action is increased in the direction from the positive to the negative pole. This would also to some extent account for the more ready reabsorption of any matter in a condition for being so disposed of.

Writing on this subject in a former work the following sentences occur.* "It is probable that changes are induced in the ultimate tissue cells of a part ex-

* 'Electricity, and its Manner of Working in the Treatment of Disease,' a thesis for the M.D. degree of the University of Cambridge, by W. E. Steavenson, pp. 24, 25: J. and A. Churchill, London, 1884.

posed to a constant current of electricity, analogous to the chemical action produced in the electrolysis of water. If the current is weak the process does not go so far as splitting up the watery parts of the cell into oxygen and hydrogen, but produces some sort of activity in the cell not present there before. It increases or alters the character of the secretion of the cells composing secreting glands, as evidenced by the increase of saliva, and metallic taste in the mouth produced by the application of a continuous current of electricity anywhere in the neighbourhood of the salivary glands. This probable increased cellular activity (the quickening of the building up and destruction of cells never-ceasingly going on in the living body) is sufficient to account for the increased demand of blood required for these changes, and the resulting increased supply afforded by the dilatation of the capillaries. The capillaries do not dilate by any power possessed by the constant current to cause muscular relaxation, but secondarily through nervous influence excited by the demand produced in the cells for more blood. The action of the constant current upon muscular tissue, if anything beyond, besides inducing these probable changes in the ultimate muscular elements leading to increased activity in the ultimate cells, increased nutrition and therefore increased tone (as it is called), is probably to induce contraction rather than relaxation."

"In considering these changes in the cellular elements of the body and in the blood supply, the osmotic power of electricity must not be forgotten. It has been found that if two fluids of different densities be divided by a porous diaphragm and an electric current be made to pass through them, osmosis takes place in the direction of the curreut. If the current passes from the lighter to the denser fluid the natural osmotic action is increased; but if the current passes in the reverse direction the osmotic action is reversed, the denser fluid passing through the diaphragm into the less dense. The osmotic power of electricity probably explains the influence of galvanism in causing the absorption of fluid effused into joints or serous cavities when applied in such cases."

The theory of Grotthüss, in which the electrolyte must be fluid, and in which no action takes place along the course of the current, but only at the surface of the electrodes, is not quite applicable to animal tissue. In fact, the action of electricity applied to the human body is not primary electrolysis but a combination of primary and secondary electrolysis.* The several compounds forming the tissues acquire different polarities, and act and react upon each other. It was shown by Dr. Stone in his recent lectures before the Royal College of Physicians,† that the human

* See Sprague on 'Mixed Electrolytes,' op. cit. p. 374.

† Lumleian Lectures ('Brit. Med. Journ.,' vol. i, 1886, pp. 728, 812, 863).

body, after the passage of a continuous current of electricity for some time, becomes to a certain extent a kind of secondary battery, and gives off a current for some hours that is capable of deflecting the needle of a galvanometer, in fact, a certain amount of electricity becomes stored up in the animal tissues by polarisation taking place in the cells of which the several structures of the body are composed, and which are traversed by the current.

The human body contains about fifteen elements (marked with an asterisk in the list of elements which appears on page 2) combined in different proportions to form the several tissues. Each of these elements preserves its polarity to the next marked element in the series; being more markedly electro-positive or electro-negative according to the number of intervening elements that appear in the original list. In the electrolysis of animal tissue the electro-negative elements are freed or appear at the positive electrode, forming at once new chemical compounds, and the electro-positive elements are liberated or undergo similar re-combinations at the negative electrode.

It would require a most accomplished analytical chemist to decide what actual changes take place at the relative poles, but what we know is that oxygen and chlorine are liberated at the positive pole and give an acid reaction; and that potash and soda are formed, and hydrogen liberated at the negative pole. Some of the most likely bodies to be found in animal tissue are: albumen, which contains C.H.N.S.O.; mucin (C 52·2, H 7·0, N 12·6, O 28·2 per cent.); gelatine (C 50·4, H 6·8, N 18·3, S + O 24·5 per cent.); keratin (C 50·3—52·5, H 6·4—7·0, N 16·2—17·7, S 0·7—5·0, O 20·7—25·0 per cent.) (Hermann's 'Physiology'), and the saline solutions of the body containing potassium and sodium phosphates. In these compounds "the molecules of the simpler bodies, as OH, CH_3, NH_2, C_6H_5, occur in the most varied and intricate combination." "Of these complex substances," which occur in the human body, "only a few can be obtained in a pure condition; the remainder cannot, either because they are too unstable, or because they are not crystallisable; with regard to the majority, we do not therefore know even their composition by weight, much less their constitution. The greater the number of atoms which combine to form a compound, the greater becomes the complexity of its composition, so that elementary analyses are insufficient clearly to indicate its formula. The formulæ of the substances are for this reason unknown to us" (Hermann's 'Physiology'). All we can say with regard to the electrolysis of these bodies is that the oxygen and sulphur have a tendency to be liberated at the positive pole and the hydrogen and potassium would traverse the space between the two electrodes, and appear upon the surface of the negative electrode.

This is the case with a simple compound and constitutes primary electrolysis. When the compound is more complex, what is called secondary electrolysis takes place. This would be the case in a solution of sodium sulphate, Na_2SO_4. We should obtain at the anode, from the splitting up of the water, an equivalent of oxygen, O, and an equivalent of free sulphuric acid, $H_2\,SO_4$, while at the cathode we do not obtain sodium, Na, but we have instead of it hydrogen, H, and in the solution we have also caustic soda, NaHO. This results also from the secondary splitting up of the water (Sprague, 'Electricity,' 1884). When we are dealing with mixed electrolytes, such as the substances composing animal tissue, the decompositions which take place are still more complicated.

It is difficult in the present state of our knowledge to say how many secondary electrolyses take place in the passage of the current through the body. That it meets several elements presenting different states of polarity towards each other is certain, but whether chemical change takes place at the points of junction of each of these heterogeneous bodies it is at present impossible to determine. As a rule, electrolysis does take place between any two substances of different electro-chemical polarity, at the point where they touch one another, if they are capable of conducting electricity. If in the treatment of a uterine fibroid we use an external potter's clay electrode, a water rheostat to regulate the current, and an intra-uterine electrode, we know that electrolysis takes place at four points : (1) in the cells of the battery; (2) in the water in the rheostat; (3) between the clay and the skin of the patient; and (4) at the point where the internal electrode touches the mucous membrane of the uterus.

That electrolysis does take place in the tissues is probable from the fact that storage of electricity takes place in a patient subjected to electrolytic treatment. The patient becomes a secondary battery, and is capable of giving off a current in an opposite direction to the one used from the primary battery. This can be demonstrated by disconnecting the rheophores from the battery immediately after an application of electricity has ceased and uniting them to each other, still keeping them connected to the electrodes in contact with the patient; a reverse current will immediately be shown on the galvanometer, at first about twelve milliampères, but rapidly decreasing to eight and four. No storage of electricity could take place unless some decomposition of the fluids contained in the tissues electrolysed had taken place. The liquids bathing the cell elements of the tissues must become split up, and their constituents accumulated on the opposite surfaces of contiguous tissue cells. It is this only that could produce a polarising current. Becquercl and Faraday have shown that polarisation results from the depositions caused by the passage of the current.

In the recent discussions on the electrolysis of fibroid tumours it has been asked: If the passage of an electric current has an effect upon the tumour, how is it that the normal structures, such as the bladder, muscles, skin, adipose tissue, &c., which are included between the two electrodes, are not also affected? It is quite possible that they are affected; that in them the normal tissue changes always in progress are accelerated, and that assimilation or "progressive metamorphosis" is encouraged. This from analogy would appear to be the case; for when a galvanic current is applied frequently to an atrophied and palsied muscle very often its nutrition is improved and its bulk increased; and Dr Apostoli has drawn attention to the extraordinary increase of subcutaneous adipose tissue which takes place in the abdominal walls of patients subjected to the electrolytic treatment.

The theory suggested by Dr Inglis Parsons, that the electric current has a modifying influence on the cells of a tumour which from their lower vitality could not recuperate themselves so well as the normal cells of the body, is also not altogether improbable. In fact, it may be that in the tumours subjected to a current of electricity a "retrograde metamorphosis" is set up.

Electrolysis must be distinguished from galvano-cautery. In galvano-cautery we use the power that a larger quantity of electricity has of heating a platinum wire to redness, white heat, or even to the fusing point, and its action on the tissues is exactly the same as the actual cautery. The tissues are really burnt—destroyed without any relationship to their chemical composition. But with electrolysis the chemical action of electricity is used. We employ an electric current of "high tension," as it is called, that is, possessing a great current strength, which, when a great external resistance has to be overcome as in the decomposition of water or the human body, depends upon a high electro-motive force. Chemical combination and decomposition is always accompanied by a rise of temperature, slight in some combinations, greater in others. The heat evolved in electrolysis is the same as heat evolved in other chemical processes, such as that which is familiar to us in the combination of sulphuric acid with water. But no greater heat is evolved in electrolysis than is dependent upon the activity of the chemical decomposition. In the electrolysis of water the heat produced is inappreciable, except with the most delicate tests, and in the decomposition of nævi appreciable heat is only evolved when the action is very rapid. Electrolysis is really a chemical decomposition by means of electricity, while destruction of a tissue by galvano-cautery is accomplished by actual heat, without any regard to the chemical composition of the parts destroyed. This much is necessary to clear up a very common error that prevails, viz. confounding the two processes of electrolysis and the use which is made of the heating power of electricity which is called galvano-cautery.

The battery required for electrolysis is very different to that employed for galvano-cautery. For electrolysis it is necessary to have a battery of high electro-motive force, for the purpose of overcoming the great resistance which is offered by all substances to their chemical decomposition by electricity.

The *electro-motive force* of a cell is the difference of potential between the positive element and the negative, and depends upon the composition of the elements and the nature of the exciting fluid in which they are bathed, and which acts chemically on one or both of them. The difference of potential thus established between the elements of a cell produces electromotive force, and electro-motive force is that force which tends to move electricity in a circuit, when the circuit is closed. The *volt* is the standard of electromotive force, and is very nearly the electro-motive force produced in one Daniell's cell.

The unit of *resistance* is *the ohm*. An ohm is the amount of resistance offered by 48½ mètres of copper wire of one millimètre diameter. Dr Stone, of St Thomas's Hospital, has shown* that the human body

* Lumleian Lectures, before the Royal College of Physicians of London ('Brit. Med. Journ.,' vol. i, 1886, pp. 728, 812, 863.)

offers a resistance of from 900 to 1000 ohms. This is when two large surface electrodes are both applied to the skin. If the electrodes are small the resistance of the body will appear greater. And if one large surface electrode is applied to the skin, and another electrode to some internal mucous membrane, the resistance will be very much less. If both electrodes are introduced beneath the skin the resistance will be still further diminished.

The *ampère* is the unit of *current strength* and is produced by one volt through the resistance of one ohm. In medicine one thousandth part of an ampère or a milliampère is the unit used. The current strength produced by a battery is determined by the accumulated electro-motive force of the cells divided by the resistance. This is what is called *Ohm's law*, and is expressed by the following formula:

$$C.\ S. = \frac{E.}{R.}$$

The current strength (C. S.) equals the electro-motive force (E.) divided by the resistance (R.). The resistance (R.) opposed to chemical decomposition is very great, and therefore the numerator (E.) of the fraction has to be proportionately greater, so that the current of electricity may be of sufficient strength to overcome it. To insure this a large number of cells have to be coupled together "in series," that is, the positive element (zinc) of one cell coupled to the negative element in the next cell, and so on, leaving a negative and positive pole at either end of the series of cells to which to attach the *rheophores*. The rheophores are the conducting cords leading from the battery to the electrodes. In this way the electromotive force of each cell is added to that of the next, and with a large number of cells we thus insure a high current strength. It is therefore necessary to have a battery composed of a large number of cells; and small cells are as efficacious as large ones as regards their electro-motive force, but they become more quickly *polarised*.

If there is more resistance in the circuit only a smaller amount of electricity can get along it in the same time, and therefore there is less chemical action in the cells. The chemical activity in a cell depends upon the strength of the current of electricity, and the strength of the current depends upon the facility with which it can get round the circuit, *i.e.* upon the resistance offered to its progress; therefore if the resistance is great the chemical activity in the cell is reduced. Beyond a certain limit large cells (containing large elements) are of no advantage. The internal resistance is so small as compared with the external resistance that it may be ignored, but if the external resistance is also very low, then any slight reduction in the internal resistance materially influences the strength of current. A cell composed of certain elements is only capable of a certain electro-motive force, no matter under how favorable circumstances it is placed. The difference of potential produced in each cell of a battery composed of the same elements, when joined "in series" is the same, therefore if one large cell be interposed among a dozen small ones the chemical action taking place in it when the circuit is closed will not be greater than that taking place in the other smaller cells.

The requirements of a battery to be used for electrolysis are: that it shall be fairly portable; that the individual cells shall be made of such materials and in such a way as to possess a high electro-motive force; that there shall be some provision when the battery is in action to prevent as much as possible *polarisation* taking place; and that there shall be some arrangement for bringing the cells consecutively into the circuit without any make or break of the current.

Polarisation is a term used to designate a condition which is induced, more or less, in all batteries when in action. This condition is the tendency to the formation of a gaseous film on the surface of the elements produced by the chemical changes that take place in the battery. This film, besides increasing the internal resistance of the cell, produces a slight electro-motive force in the opposite direction to that produced by the battery, and acts in antagonism to it. The more violent the action in the cell, that is, the greater the strength of the current that is passing through it, the more rapidly does this polarisation tend to take place. A film of hydrogen is deposited on the negative element and a film of oxygen on the positive. The hydrogen is electro-positive to the oxygen, and therefore sets up a backward electro-motive force. To prevent this polarising action different devices are employed in different cells. One of the commonest in sulphuric acid cells, wherein an excess of hydrogen is liberated on the formation of sulphate of zinc, is to add bichromate of potash ($K_2Cr_2O_7$). The oxygen is liberated, and forms water with the hydrogen which is displaced.

Many operators prefer to use all the cells of their battery at once, for the purpose of lessening the chance of giving a patient a shock by any interruption of the current that might take place when the cells are added one by one to the circuit. The strength of the current is then regulated by a *rheostat.* Another advantage in employing a battery in this way is that all the cells get an equal amount of work. A current is obtained of high electro-motive force but not of great quantity, so that the action in each individual cell is not very great. When a strong current is obtained from a few cells those cells perform a relatively greater amount of work and sooner become exhausted.

Rheostats are made in different ways. They are simply arrangements by which an additional amount of resistance can be introduced into the circuit, and this resistance can be gradually reduced, with the result of a corresponding increase in the current strength. The best form of rheostat is made with bobbins of german silver wire, each bobbin having a known resistance in ohms. By including a greater or less number of these bobbins in the circuit the resistance can be increased or diminished. Another form of rheostat is made by including in the circuit a certain length of badly-conducting composition, and an arrangement exists for including a greater or less length of this composition in the circuit. One objection to this form of rheostat is that the actual amount of resistance at any time in the circuit cannot be accurately and readily determined. A third form of rheostat is used which consists of a column of water enclosed in a glass tube, through the cover of which a metallic rod connected to the battery can be raised or lowered so as to approach or recede from a piece of metal at the bottom of the tube which is in connection with the electrode; the current, therefore, has to traverse the water. The amount of resistance is directly proportionate to the distance of the metal rod from the metallic base of the tube (Fig. 2).

An objection to the employment of a rheostat to regulate the current in performing electrolysis is that an additional instrument is introduced, and therefore an additional point at which some difficulty may occur through the instrument not working properly; and a

FIG. 2.

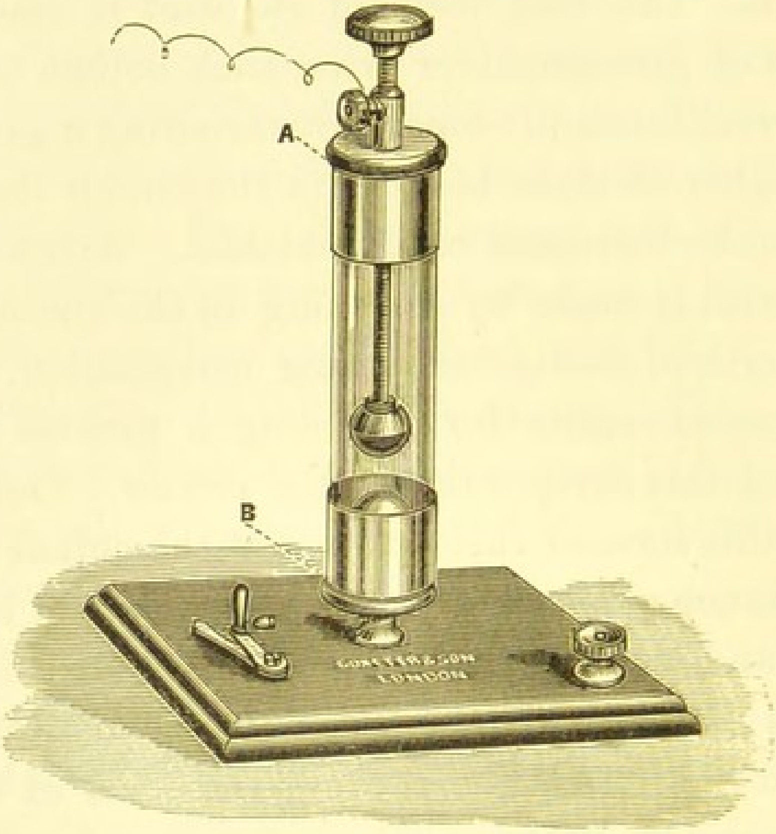
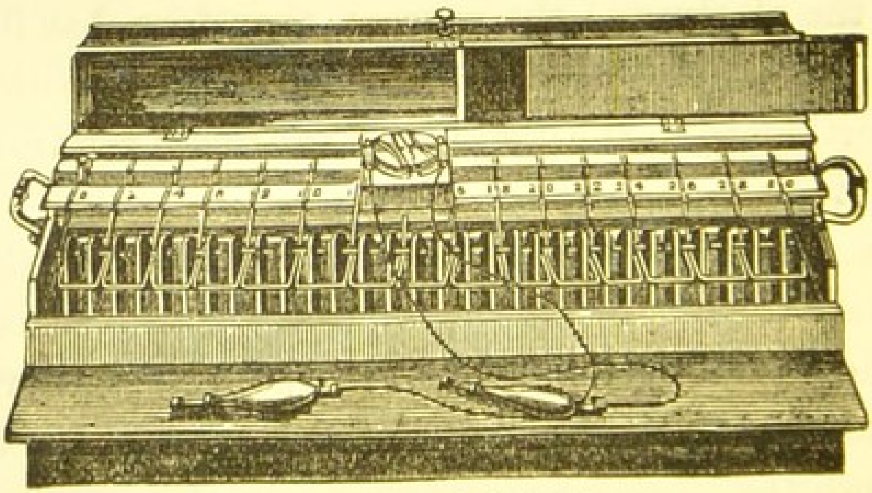


FIG. 3.



Stohrer's Hospital Battery.

water rheostat offers such a very high resistance that with all the cells of a thirty-cell battery in use we sometimes cannot obtain as high a current as we require, and therefore have to employ batteries of such power and size that they cease to be portable.

The batteries most commonly used in medicine and surgery are:

Daniell's,	electro-motive force,	. 1·079	volts.
Smee's	,, ,,	. 1·62	,,
Leclanché's	,, ,,	. 1·5	,,
Chloride of silver	,,	. ·915	,,
Stöhrer's	,, ,,	. 1·825	,,
Grove's	,, ,,	. 1·956	,,
Bunsen's	,, ,,	. 1·964	,,
Bichromate of potash	,,	. 2·000	,,

The Leclanché and Stöhrer batteries are the best for electrolysis.

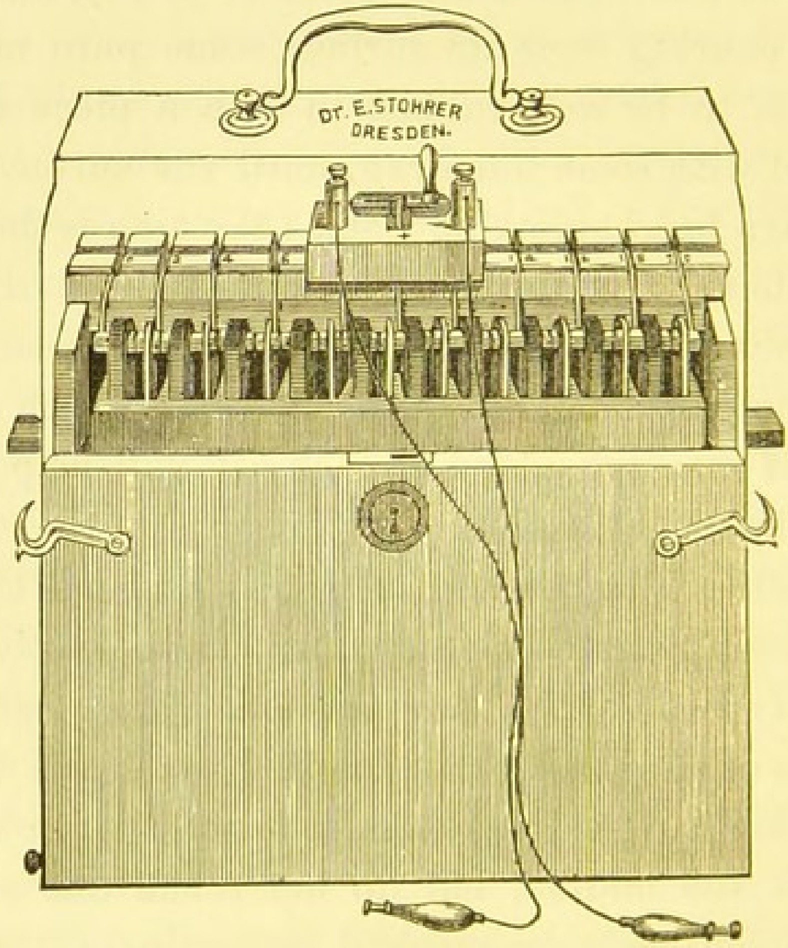
The Stöhrer's battery is the best for hospital practice as it lasts longer, its electro-motive force is greater, and it less frequently gets out of order. The Leclanché battery is perhaps more suitable for the consulting-room and for carrying to patients' houses, as it is more portable than the Stöhrer's, but the electro-motive force of each cell is not so great, and they more quickly become polarised.

A Stöhrer's battery is composed of "single fluid" cells, and is a modification of the Smee battery. The negative elements of the latter (platinised silver) are replaced by plates of carbon. The elements are immersed in a solution of sulphuric acid and water, and to diminish polarisation some bichromate of potash may be added. This form of battery possesses a high electro-motive force, it is fairly constant, and not quickly destroyed by being "short circuited," as is the case with the Leclanché. The fluid and zinc elements can be easily replaced when exhausted. The fluid consists of one part of sulphuric acid to ten parts of water; to this one tenth part of a saturated solution of bichromate of potash may be added. The elements are coupled "in series," that is, the zinc of one cell is connected with the carbon of the next. The cells are brought into the circuit two at a time by a travelling commutator, which can be pushed along a wooden frame, to which all the elements are attached. The cells, made of glass, which should be about two thirds filled with the exciting fluid, are arranged in a tray which can be raised to the elements when it is wished to put the current in motion.

Theoretically, no action ought to take place when the elements are immersed until the circuit is closed, but practically chemical action does take place on account of impurities in the zinc; and if the tray is not lowered after the battery has been used, these local circuits destroy its action by consuming the zinc and "killing" the exciting fluid by reducing it to a solution of sulphate of zinc. This tendency to local action in the cells is lessened by the zinc being *amalgamated,* that is, its surface covered over with a layer of mercury. Amalgamated zinc is also more positive than ordinary zinc, and therefore renders it a better source of electricity. Amalgamation is performed by cleaning the surface of the zinc, then dipping it in a solution of sulphuric acid and water (1 in 10), and afterwards pouring over its surface some pure mercury, which is to be well rubbed in with a piece of wood covered with some linen rag, until the surface of the zinc has a bright metallic lustre; the zinc is then to be set aside to allow the superfluous mercury to drain off. The zincs of a battery, when constantly in use, should be frequently amalgamated. A small pinch of sulphate of mercury added to each cell will help to preserve the amalgamation.

A Stöhrer's battery, when freshly charged, and with newly amalgamated zincs, has an electro-motive force of nearly two volts (1·825) per cell. The commutator consists of a cylinder of ebonised wood, the ends of which are covered by metal sheaths, which overlap towards the middle, but do not touch one another. These metal ends are marked respectively + and −, to indicate the poles. The cylinder can be half rotated by a small handle, and the metal ends are thus alternately made to touch one or other of two side springs, which communicate with two side brass rails underneath the travelling platform on which the cylinder is placed. By this means the poles can be reversed. The side brass rails, when the platform is moved, traverse a groove in the frame to which the elements are attached, and touch successively each pair of thick brass wires that support the elements. These metal

FIG. 4.



rails are long enough to touch two pairs of brass element holders at the same time, so that when slid along the groove a fresh pair of brass wires are touched before the previous ones cease to be in contact. By this means the strength of the current can be increased gradually without causing a make and break. It is of great importance to be able to recognise the poles of the battery. It will not do to trust alone to the + and – signs on the commutator. Occasionally, when the battery has been sent away for repair, it will be returned with the travelling commutator reversed, and then the signs will indicate the opposite to what is correct. The error can always be rectified by remembering that in each cell the direction of the current is from the zinc to the carbon, and, outside the battery, from the carbon to the zinc. Therefore the zinc although the positive element will give the negative pole. By tracing up the brass wire which conducts the current from the zinc to the commutator, the negative pole can always be determined, and if this does not correspond to the sign on the commutator, the commutator should be taken off, turned round, and then replaced. I have often known an accident to occur by the commutator being placed the wrong way, such as the decomposing of the plating on a meta electrode in the urethra, by the positive pole being substituted for the negative, or a large slough produced on the face, when destroying a mole, through the negative pole having been used instead of the positive.

There are many other sources of accident in the use of these batteries. The connection of the rheophores to the battery may not be secure, or the rheophores themselves may be imperfect in some part of their length or where attached to the electrodes. Oxidation may have taken place between the side springs and the cylinder of the commutator, or the side springs may have become bent so as not to touch the commutator. The same may be the case with the side rails underneath the commutator, so that they do not touch each pair of wires bearing the elements, or not be capable of touching two pairs at the same time. The carbons and zincs may not have been properly screwed together. One of the carbons may have been broken in moving the battery, and when the travelling commutator reaches it an interruption of the current will take place and the patient receive a severe shock. The same would occur if one cell had not received sufficient fluid or had been left altogether empty. A zinc or carbon may become inserted in an adjoining cell to the right one. Under any of these circumstances a patient may receive an unpleasant and sometimes a dangerous shock. All these faults have been known to occur in batteries, it therefore behoves the operator to examine his battery carefully before using it and to know where errors may exist and to be capable of rectifying them. The use of a water rheostat will prevent many of these accidents, but it is subject to the objections already mentioned. Leclanché batteries are also used for electrolysis, but more cells are required on account of their lower electro-motive force and greater internal resistance, and the number of cells has to be gradually increased to keep up the required current strength on account of the rapid increase of the internal resistance due to polarisation. A Leclanché battery is more portable than a Stöhrer's and therefore can be more easily taken to a patient's house.

For those who frequently employ electrolysis, and who attempt to keep their own batteries in order, a *voltmeter* is necessary for the purpose of taking the electro-motive force of the cells. It often happens that a battery when in use very rapidly loses its strength, and a battery that has been used for some time will often be found to have deteriorated. It is very annoying after the application of the current to a patient has commenced to find that the battery will not give the required current strength. The knowledge also of the electro-motive force of the battery enables us to calculate the resistance offered by the patient. A voltmeter is really a galvanometer possessing coils with a resistance of several thousand ohms, in comparison with which the internal resistance of a battery may be neglected, therefore the current strength sent through it will represent very closely the electro-motive force of the cells of the battery employed and can be shown on the instrument if it is properly graduated. A voltmeter graduated to show from one to twenty volts is the most useful for medical batteries.

It was discovered by Oersted in 1819 that a current of electricity passed along a wire in the vicinity of a suspended magnetic needle caused the needle to alter its position. If the current was passed above the needle from north to south the needle was deflected to the left, and *vice versâ*. This phenomenon has been utilised for the purpose of constructing an instrument called a *galvanometer*, with which the strength of a current can be measured. A needle is suspended by a cocon fibre or silken thread, or is balanced on a sharp point, in the centre of a coil of wire. When at rest the needle is parallel to the coil and in the magnetic meridian of the locality in which the instrument is used. If an electric current is passed through the coil the needle is deflected to the right or left according to the direction and strength of the current. By allowing the needle to swing over a graduated scale the strength of the current can be read off. Each galvanometer has to be separately calibrated by comparison with a standard galvanometer. "Equal deflections on the same galvanometer always indicate currents of the same strength. But it must be carefully kept in mind, 1st, that the angle of deflection is not proportional to the current, and 2nd, that it differs for the same current strength from galvanometer to galvanometer, depending on the length or number of turns of the wire, and upon the position of the coil with reference to the needle."* "When the deflections are *small* (*i.e.* less than 10° or 15°), they are very nearly proportional to the strength of the currents that produce them. Thus, if a current produces a deflection of 6° it is known to be approximately three times as strong as a current which only turns the needle through 2°. But this approximate proportion ceases to be true if the deflection is more than 15° or 20°, for then the needle is not acted upon so advantageously by the current, since the poles are no longer within the coil, but are protruding at the sides, and, moreover, the needle being oblique to the force acting on it, part only of the force is turning it against the directive force of the fibre; the other part of the force is uselessly pulling or pushing the needle along its length. It is, however, possible to '*calibrate*' the galvanometer,—that is, to ascertain by special measurements, or by comparison with a standard instrument, to what strengths of current particular amounts of deflection correspond. Thus, suppose it once known that a deflection of 32° on a particular galvanometer is produced by a current of $\frac{1}{100}$ of an ampère, then a current of that strength will *always* produce on that instrument the same deflection, unless from any accident the torsion force or the intensity of the magnetic field is altered."† The magnetism of the earth has

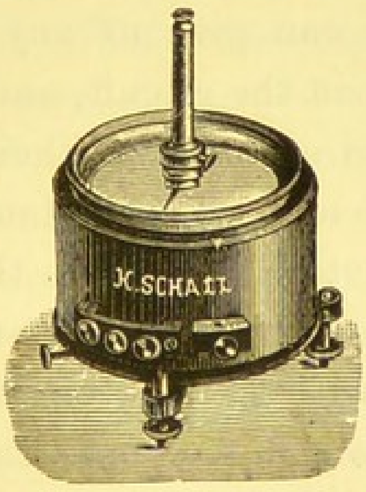
* De Watteville, 'Medical Electricity,' p. 25.

† 'Electricity and Magnetism,' by Silvanus P. Thompson, p. 163.

an influence upon a horizontal galvanometer which has to be taken into consideration when it is calibrated. A galvanometer which is graduated to read correctly in Paris will not do so in London. When calibrated to a scale of milliampères in the former place the error would amount to about 4 in every 198 milliampères in the latter. Therefore horizontal galvanometers have to be calibrated for the locality in which they are to be used. These details are arranged by the instrument makers. A vertical galvanometer is free from this source of error, for if the magnetisation of the needle remains uniform a given current will deflect it to the same extent at whatever part of the globe it may be used. The needle of a vertical galvanometer also settles more readily when influenced by a current, and can be more easily read from a distance. But the magnetisation of the needle is not constant, it gradually becomes demagnetised, and is therefore not so readily influenced, and after it has been used for some time will indicate a weaker current than is actually passing. It is therefore necessary from time to time to remagnetise the needle of a vertical galvanometer.

To Dr de Watteville we are indebted for the introduction of the milliampère as the unit of current strength for medical purposes. It is the most useful that could have been adopted, for it represents very appropriately the strength of the current usually used in medicine and surgery. The human body under various circumstances offers a resistance of from a few ohms up to several thousands, according to the description of electrodes used and to the part to which, and the mode in which, they are applied. In some cases we want to register single milliampères and in others several hundred; it is therefore necessary to have two or three galvanometers, one calibrated to a low scale for weak currents, and another graduated higher for stronger currents, or some arrangement in the galvanometer for allowing the current to pass through shorter coils of wire, and therefore deflecting

Fig. 5.



Edelmann's galvanometer.

the needle less, for stronger currents. Such a galvanometer is Edelmann's, supplied by Mr Schall, of Wigmore Street (Fig. 5). It is particularly useful for electrolysis, for it will register from 4 milliampères, the strength of the current used for the electrolysis of the Eustachian tube and lachrymal canals, up to the 250 milliampères used for the electrolysis of fibroids, or the four or five hundred sometimes used in the destruction of nævi when needles attached to both poles are introduced beneath the skin. "The enormous variations in the resistance offered by the human body to the current, according to the individual and the details of the application, make even an approximate estimation of the current strength by the number of cells used, impossible. The electromotive force of the cells themselves, and their internal resistance, differ from battery to battery, and from time to time in the same battery. The deviation of the needle alone can give us any information as to what is going on in the circuit, and allows us to compare the currents and ensure their uniformity when required."* The adoption of a standard measurement "enables us to not only compare the results obtained by ourselves on the same galvanometer with one another, but also with those obtained by other observers on galvanometers of any construction, but graduated in absolute units."†

By means of the galvanometer we can also approximately estimate the resistance offered by the human body or that part of it included in the circuit.

* De Watteville's 'Medical Electricity,' p. 31.

† Ibid., p. 29.

One volt through one ohm gives one ampère.

By Ohm's law the—

$$\frac{\text{Electro-motive force}}{\text{Current strength}} = \text{Resistance.}$$

Therefore if the electro-motive force of the battery is known (as taken by a voltmeter), and the current strength known as registered by the galvanometer, we can calculate the resistance in the circuit.

If twenty Leclanché cells (E. M. F. 30 volts) gives a current strength of 10 milliampères—

$$\frac{30 \text{ volts}}{0{\cdot}010 \text{ ampère}} = 3000 \text{ ohms.}$$

If we deduct the resistance of the battery (about 90 ohms) and the galvanometer, we have the resistance of the body. The resistance offered by the galvanometer is generally stamped upon it.

With the help of a resistance coil, the resistance of which is known, say one of 500 or 1000 ohms, we can by the galvanometer also ascertain the electro-motive force of a battery. For this purpose we must take Ohm's law thus :

Current strength × resistance = electro-motive force.

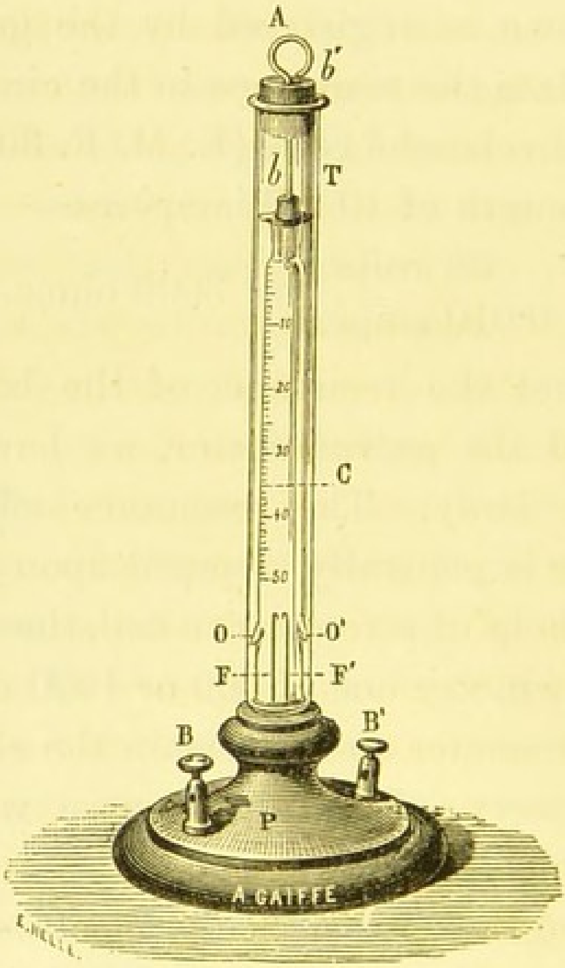
For instance, if the current strength is 10 milliampères, and the resistance of our coil and galvanometer 1050 ohms, then the electro-motive force would be—

$${\cdot}010 \text{ ampères} \times 1050 \text{ ohms} = 10\tfrac{1}{2} \text{ volts.}$$

The readings of a galvanometer can be verified by a very simple water voltameter made by Gaiffe, of

Paris (Fig. 6). It consists of two glass tubes, the inner one graduated so that each small division represents 50 cubic millimetres. Both tubes are filled with water; the outer one serves as a reservoir. The

Fig. 6.



inner tube has two openings at *o o* by which it can be replenished. Inside the inner tube at the bottom are two platinum wires, separated from each other by a piece of glass, and connected respectively with the two binding screws on the base of the instrument.

These screws can be connected respectively by rheophores with the positive and negative poles of a battery. When the circuit is closed oxygen is given off from the platinum wire connected with the positive pole, and hydrogen is given off from that connected with the negative pole through the decomposition of the water. The gases accumulate at the upper end of the inner tube, and the level of the water sinks. When an observation is completed fresh water can be admitted into the inner tube through the apertures, *o o*, by raising the cork at the top which is attached to a brass wire that passes through the cork in the larger tube. The inner cork can thereby be raised without removing the larger one.

A current strength of one ampère liberates in the electrolysis of water 114·6 cubic millimetres of hydrogen and 57·3 cubic millimetres of oxygen per second, or 171·9 cubic millimetres of mixed gases; say 172 cubic millimetres per second, or 10,320 cubic millimetres per minute. Therefore one milliampère will set free $\frac{10320}{1000}$ cubic millimetres per minute, or 10·3 cubic millimetres.

Each small division on the inner tube of the voltameter represents 50 cubic millimetres, therefore, if one of these small divisions is filled with mixed gases per minute, the current strength employed would be 5 milliampères. We have therefore to divide the number of cubic millimetres of mixed gases produced per minute by ten to obtain our current strength in milliampères.

In the same way as with the galvanometer, knowing the current strength produced and the electro-motive force of a battery, we can with the voltameter calculate the amount of resistance in the circuit, and knowing the amount of resistance by the use of resistance coils of a known number of ohms, and the current strength calculated by the voltameter, we can ascertain the electro-motive force of any battery that we may use.

One Daniell's cell will not accomplish the electrolysis of water. The resistance of water to the passage of electricity is so great that if a circuit between the two poles of a Daniell's cell be completed by its intervention no current will pass at all. It is only when by the combination of two or more cells we obtain a sufficient electro-motive force to overcome the resistance of the water that the needle of a galvanometer will be deflected. I tried a short time ago with some Leclanché cells which had been used, and it required four before the slightest deflection of the galvanometer needle could be detected, and that showed barely a current strength of a quarter of a milliampère, and the very smallest bubbles of hydrogen gas could be seen escaping at the negative pole. It will, therefore, be seen that for the efficient accomplishment of electrolysis in the human subject, which offers nearly as much resistance as water, a battery composed of a fair number of cells is required, and these cells, if few in number, should have been recently charged.

A certain combination of elements, such as compose the cells of any particular battery, is only capable of producing a current of a certain electro-motive force, The electro-motive force produced depends upon the constitution of the cell, not on its size. Sulphuric acid will attack or decompose zinc only at a certain rate, sixty-five grains of zinc replacing every two grains of hydrogen in the sulphuric acid. However large the cells may be, this scale of interchange goes on, and anywhere else in the circuit where a chemical compound has to be traversed it is split up exactly in the same ratio; thus, if water should be the compound, directly a current strong enough to overcome the resistance of chemical affinity is used, sixteen grains of oxygen and two grains of hydrogen are liberated in the water for every sixty-five grains of zinc consumed in the battery. Therefore a sufficient number of cells have to be used to overcome the resistance. We all know that by Ohm's law current strength equals the electro-motive force divided by the resistance. In the Daniell's cell the electro-motive force (E. M. F.) = 1 volt; and one volt through the resistance of one ohm gives a current strength of one ampère, and would take a second to pass. If we take water as offering a resistance of 1000 ohms (it must be remembered that the resistance of water varies very much according to its temperature), then one volt passed through water would give the current strength of a milliampère, and would take 1000 seconds to produce the same amount of mixed gas as one ampère would produce in one second. If the resistance is very great the current strength is very small, and the chemical action going on in the battery cell takes place very slowly. When electrolysis is applied to animal tissue chemical changes take place in it which theoretically exactly counterbalance the chemical changes which are taking place in the battery. When sixty-five grains of zinc are decomposed in the battery a corresponding number of grains according to their chemical quantivalency are decomposed among the elements which form the substance electrolysed.

By the recognition of these facts we can determine the current strength that it is advisable to use according to the result it is wished to accomplish. If we wish simply to destroy an unhealthy surface we use a weak current, if we wish to dissolve a gristly stricture we use a slightly stronger current, or a weak current for a longer time; and if we wish to produce profound tissue changes in a uterine fibroid we use a very strong current.

The exact current strength employed cannot be accurately gauged by the number of cells that are included in the circuit. To obtain this information it is necessary to use a galvanometer or a voltameter.

The galvanometer is the more handy instrument, as it has already been graduated, and it is only necessary to read off the number of milliampères that are being used. With the voltameter some calculation is necessary before a knowledge of the current strength can be arrived at. The pole to which an electrode is attached, and the metal of which it is composed, is of some consequence, and varies in medical practice according to the diseased condition for which electrolysis is employed, and the effect it is wished to produce. Unless the action of the metal itself is also required, it is necessary when using the positive pole to have the electrode made of platinum, because platinum of all metals is the least oxidisable, and therefore does not itself enter into the new combination of elements formed around the positive pole.

ANEURYSM

Electrolysis has been occasionally used now for many years in the treatment of aneurysm. The results up to the present time appear to have been very uncertain, but the operation has proved successful in rather less than one third of the cases in which it has been tried. It must be borne in mind that it has as a rule been tried only in inter-thoracic or abdominal aneurysms, which would no doubt be the most difficult to treat by compression or ligature even if such procedures could in these regions be effectively accomplished.

The operation has been performed in various ways, by needles attached to both poles of the battery, or by needles attached to the negative or positive pole only. Sometimes weak currents have been used and sometimes very strong ones. The duration of the operation has also varied in different cases. Sometimes insulated needles have been employed and sometimes the reverse.

Galvanism was first used for aneurysms by Phillips in 1832, but was unavailing until Pétrequin (1845) and Ciniselli improved the apparatus and methods of employing it. It is also used only for aneurysms that cannot be successfully treated by other means, such as internal aneurysms, thoracic and abdominal, or those situated at the root of the neck. Varicose and cirsoid aneurysms can also be often more successfully treated by galvano-puncture than by any other method. Mr Holmes says an internal aneurysm is best adapted for this treatment when it is pressing on the parietes, but has not absolutely perforated them. Again, the sacculated condition of the aneurysm and the relative smallness of the opening are essential conditions for a case which is to be looked on as really favourable." Aneurysms of this kind generally (but not always) have a distinct bruit, which may be looked upon as a symptom favourable for electro-puncture.* Ciniselli says that when large vessels issue from an aneurysmal sac galvano-puncture is useless. Ciniselli measured the current he used by a voltameter, that is by the amount of gases liberated in the electrolysis of water in a given time (see Fig. 6, p. 40). The current strength would equal by our present mode of measurement about 40 or 50 milli-ampères; and that would be a very suitable current to employ. The time occupied by each operation has

* Poore, 'Electricity in Medicine and Surgery,' p. 247.

greatly varied in the hands of different surgeons, and has ranged from ten to thirty minutes to an hour or longer.

From the physical laws of electrolysis which have been previously given, and from the experience already obtained, it would seem that it would be best to employ needles attached only to the positive pole of the battery, for it is with this pole that we obtain a more dense and hard coagulum. The needles should be insulated to within a short distance of their points and inserted so that all the uninsulated part is within the aneurysm. A weak current should be used at first and gradually increased without any break, so as to avoid as much as possible a shock being given to the heart. Internal aneurysms are sufficiently near the heart for that organ to be powerfully influenced by any current that may be passed through them.

It is an advantage that the needles should be made of steel, for, in addition to the coagulating effect of the positive pole, the needles themselves become dissolved, and we have the additional coagulating effect of the oxide and chloride of iron.

It would seem advisable that the first operation should not be prolonged for more than twenty minutes, and if the patient bore it well subsequent applications might last from half an hour to an hour. Intervals of six or eight days should be allowed between each application of the current. When the needles are used attached only to the positive pole a large surface electrode attached to the negative pole should be placed on some indifferent part of the body, a current strength sufficient to decompose the steel needles can then be obtained without any injury to the skin. The author has employed an external electrode moistened in warm salt water, measuring nine inches by twelve.

If needles attached to both poles are thrust into the aneurysm a sufficient current strength can be obtained with a very much smaller number of cells. Of all the constituents of the human body blood is the best conductor of electricity. It has been estimated that blood in an aneurysmal sac offers a resistance of about 8 ohms (Bartholow).

With needles in an aneurysm attached to both poles the resistance is thereby very greatly reduced, a double clot is formed, and coagulation takes place much more rapidly. This method of procedure is therefore often adopted. Great care should be taken that needles attached to opposite poles do not touch, otherwise the current would be short circuited. The insulating substance on the negative needles is often partially destroyed by the alkalies set free at that pole. The number of needles to be used depends on the aneurysm. It is generally sufficient to have two or three connected with each pole.

In the case of cirsoid aneurysms three or four needles can be used, each one in a different convolu-

4

tion of the enlarged vessel and all attached to the positive pole.

Coagulation takes place round the needles in the shape of a cone; around the positive needles the base of the clot is about half an inch in diameter, and around the negative needle about three quarters of an inch. The negative clot is frothy and alkaline; the positive clot smaller, firmer, darker in colour, and has an acid reaction. Albumen, fibrin, fat, acids, and chlorine are separated at the positive pole; watery and alcoholic extracts, alkaline and earthy bases, iron and colouring matter appear at the negative pole (Heidenreich). The gas which is produced in the electrolysis of aneurysms is in too small bubbles to be troublesome. No occurrence of embolism has ever been reported as following the operation. The removal of the needles requires some care, as those connected to the positive pole become fixed in the clot formed around them. An attempt should be made to gradually disengage and withdraw them by employing a semi-rotatory movement; should this not be successful the current should be reduced to zero, and then the commutator reversed and the current increased again and allowed to flow for a few minutes with the positive needles made negative. This soon causes their disengagement from the clot and facilitates their withdrawal, at the same time it lessens the chances of hæmorrhage from those needles which, during the course of the operation, have been negative by making them positive for the last few minutes, and thus coagulating more firmly the blood in the neighbourhood of their points of exit. Bleeding is more likely to follow the removal of the negative needles, or the positive needles if suddenly pulled out. Should any hæmorrhage occur it is only necessary to cover the orifices of exit by small pieces of lint or cotton-wool with or without collodion.

It has not been found necessary by most operators to anæsthetise their patients, such a necessity would materially add to the difficulties of the operation if the current was employed for an hour at a time. To allay apprehension a hypodermic injection of a quarter of a grain of morphia has been used a short time before the operation; and to reduce the sensitiveness of the skin to the pain caused by the puncture of the needles it has been previously frozen by ether spray or by the application of ice. With some patients and with some aneurysms, especially cirsoid aneurysms, an anæsthetic is always found necessary

The performance of electrolysis often gives great relief to pain and reduces the pulsation and thrill; it sometimes also retards the bursting of the aneurysm. Dr Ralfe, of the London Hospital, reported a case of aneurysm, treated by electrolysis, before the Pathological Society in November of last year (1888), in which these results were obtained. The relief experienced by the patient was so great that he asked for a repetition of the operation. In all it was performed thirteen times, and the man died subsequently from exhaustion from the gradual oozing of blood through one of the punctures. Sudden rupture was avoided by the increased thickness of the walls of the aneurysm caused by the electrolysis.

The advantages of the electrolysis of aneurysms may be summed up as follows: it relieves symptoms, checks the growth of the tumour, prolongs life, and sometimes ends in cure.

The introduction of soft iron wire into the sac of an aneurysm would probably be a great additional advantage to the ordinary treatment by galvano-puncture. The author has suggested* such a modification of Moore's method of treating aneurysms which consists of passing a large quantity of steel wire into the aneurysmal sac and by this means producing coagulation. In the modified operation it is suggested 'that the wire used should be of soft iron instead of steel, of No. 29 gauge according to the Birmingham scale. That the introduction should be accomplished by means of a perforated needle fitted to a handle in a similar way to that used by Mr T. Smith in the operation of staphyloraphy. That the wire should not, as in the latter instance, be previously wound upon a reel or bobbin, but should be paid out from a

* 'Lancet,' June 11, 1887, p. 1182.

tolerably large coil or skein so as to reduce the chance of kinking. The amount of wire to be used would vary in accordance with the size of the aneurysm. That the perforated needle should be a straight one made of ivory (or vulcanite)* and much longer than those ordinarily employed for cleft palate. That the needle should be introduced to such a depth that the point would be well within the aneurysm. When sufficient wire has been introduced, it should be cut off near the hank or coil from which it was paid out, the handle detached from the needle, and the needle left in the aneurysm with the end of wire protruding from it. That the wire should then be connected with the *positive* pole of a strong galvanic battery, a sponge, or tin and amadou plate electrode, moistened in salt and water, should be attached to the negative pole and placed on some indifferent part of the body. That the circuit should be closed and a current of from fifteen to twenty milliampères passed through the aneurysm until it became consolidated; or for thirty minutes. The pad connected with the negative pole should be moved to different parts of the body when found necessary, so as to avoid any particular spot becoming blistered or sore. That at the conclusion of the operation the remaining piece of iron wire protruding from the needle should, if not already

* Such a needle has been made for the author by Messrs. Coxeter and Son, of Grafton Street, W.C.

detached by the decomposition which had taken place in the sac, be pushed through the perforated needle by a blunt trocar into the aneurysm, and the small puncture hole closed by a piece of strapping. By the wire being attached to the positive pole of a battery coagulation would be encouraged within the aneurysm and the wire itself would undergo decomposition with the formation of chloride and oxide of iron, which would in addition exercise their own specific coagulating properties.

The clot resulting from electrolysis is distinctly softer than an ordinary clot. This is no doubt partly due to its rapid formation, and it would probably shrink and consolidate and possibly become as firm as any other clot when of a similar age. In the suggested operation the clot produced by electrolysis would have a long and extensive origin and be entangled at innumerable points by the coils of the iron wire. Another probable reason why the coagulum formed by electrolysis "appears very frequently not to be stable, but to be liable to melt down again into the blood stream,"* is because needles attached to both poles, or to the negative pole only, have been used. Around the negative pole the blood is coagulated into a yellow friable alkaline mass composed to a great extent of gas bubbles, which very quickly

* 'Lectures on the Surgical Treatment of Aneurysm,' by Timothy Holmes, M.A., F.R.C.S., 'Lancet,' Sep. 7, 1872, p. 326.

breaks down. It would seem probable that a combination of Moore's treatment of aneurysm with that by galvano-puncture, as here sketched out, would offer a very fair chance of a successful result.

CIRSOID ANEURYSM, ETC.

For some forms of aneurysm electrolysis is perhaps the most applicable mode of treatment. I allude to cirsoid aneurysms, aneurysms by anastomosis, those large tumours composed of cavernous tissue fed by large arteries and emptying themselves into dilated veins, and traumatic arterio-venous aneurysms.

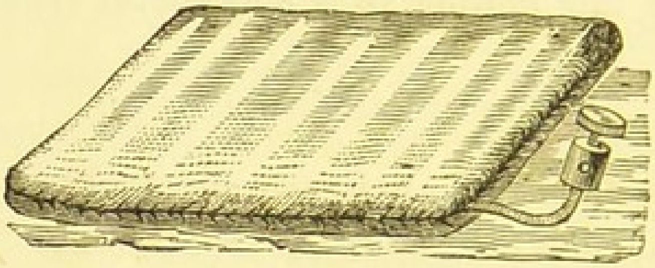
In a recent paper 'On the Value of Electrolysis in Angioma and Goitre,'* Dr John Duncan, of Edinburgh, writes:—"I have no hesitation in saying that the only justifiable method of treatment for cirsoid aneurysm is electrolysis. Its perfect safety and reliability ought to determine its use, even though the tumour be not enlarged."

In the case of a cirsoid aneurysm of the left temporal artery operated upon by the author, the patient was made to lie upon a large surface electrode, measuring twelve inches by nine (Fig. 7), covering the greater part of the back between the shoulders. This electrode was attached to the negative pole of a Stöhrer's battery. The patient was placed under the influence of an anæsthetic and four insulated needles

* 'Brit. Med. Journal,' Nov. 3, 1888, p. 985.

attached to the positive pole were thrust into different convolutions of the diseased vessel. The uninsulated

Fig. 7.



part of the needles was buried in the artery. A strong current of from 150 to 220 milliampères was passed for fifteen minutes. The needles were greatly corroded, and on one occasion the destruction of the metal was so great that about a quarter of an inch of one of the needles was left in the aneurysm. The operation was repeated three times, when the aneurysm was found to be consolidated. Some of the large trunks forming the aneurysm had been previously ligatured, but this had not succeeded in arresting the pulsation.

VARICOSE VEINS

Electrolysis can also be used for the occlusion of varicose veins. Needles attached to the positive pole only should be inserted, because the clots formed by them are firmer, and embolism less likely to follow.

Varicocele may also be treated in the same way. The mode of procedure in both cases is the same as that described for the treatment of aneurysm.

NÆVI*

ONE of the most frequent applications of electricity to surgery is in the treatment of nævi. Nævi are treated in many different ways, such as subcutaneous ligature, setons, injection of perchloride of iron, caustics, the actual cautery, excision, and electrolysis. Nearly every surgeon has his own method, which he prefers, but the employment of electrolysis is becoming more and more prevalent. In some situations no doubt electrolysis gives the best results, especially where it is desirable that the subsequent scarring shall be as little noticeable as possible, but it also possesses certain other advantages over most of the modes of treatment. Except in very vascular nævi, electrolysis can be performed without causing bleeding. The action of the current can be better and more easily localised than that of acids or caustic alkalies, because the action ceases directly the current is broken, and no

* This article on "Nævi" appeared in the 'Provincial Medical Journal' for Dec., 1888.

caustic material is left behind to consume the tissues until it is neutralised. The cauterisation produced by electrolysis is only proportionate to the strength of the current, and is in consequence of the current. Twenty-three parts of nascent sodium are produced at the negative pole for every sixty-five parts of zinc consumed in the battery; and sixteen parts of oxygen are produced at the positive pole. The sodium at once forms caustic soda at the negative pole, which combines with the tissues, and hydrogen is liberated. The oxygen oxydises an amount of tissue in proportion to the quantity that is disengaged, therefore the caustic effects of the battery can be limited at will, which is not the case with more or less fluid chemical caustics. Electrolysis is not so prone to cause constitutional disturbance as the seton and ligature, and it is less painful, the pain ceasing immediately the current is broken. This is a most remarkable fact, and is no doubt due to the destruction of the ends of the nerves, which is not the case when a nævus is excised. This freedom from after pain would alone recommend the operation by electrolysis to mothers who have to nurse their children afterwards; and as a rule less scarring is left after the use of electricity than after any other method, but the treatment by electrolysis is more tedious, requires more skill, and is more expensive to the operator; therefore, in parts where a scar is of very little importance, ablation may be performed, and is much more expeditious and less troublesome to the surgeon, though causing more after pain to the patient.

Nævi may be divided into three classes :—Cutaneous, subcutaneous, and mixed. Some will remain stationary or may disappear spontaneously, while others have a tendency to grow. John Duncan, of Edinburgh, recommends that nævi the size of a pin's head on the face should be destroyed, as they are very persistent, and will sometimes grow. When small they can be removed with the least appreciable amount of pain, and in about the space of half a minute, leaving no mark. Those larger nævi, which persist after puberty, are not likely to disappear spontaneously. Every growing nævus should be attacked at once, as the difficulty of dealing with them increases with their size. It is only possible to destroy nævi by galvano-cautery or electrolysis without leaving a scar when they are entirely subcutaneous. When this is the case the nævoid tissue can be coagulated, and gradually absorbed and obliterated without injury to the superficial skin. Subcutaneous nævi of the cheek or lips, and in other favourable situations, can be attacked through the mucous membrane from the inside. Nævi of the mixed variety, cutaneous nævi, and port-wine stains cannot be removed without leaving some scar, for the discoloured and diseased skin has to be destroyed.

Needles may be made of steel, platinum, or gold, but it must be remembered that when attached to the positive pole the metal itself is also decomposed. This may be an advantage in very vascular nævi if steel needles are used, for a chloride of iron is formed which assists in the coagulating process. Gold needles used under these circumstances only become permanently discoloured; it is best, therefore, to reserve them for use with the negative pole. Platinum of all metals is the least affected by electricity, and needles made of this metal are therefore most usually employed. The action of the current appears to extend for a greater distance around platinum needles, and they do not become so tightly fixed in the tissues as the steel needles do. Steel takes the best point, and the needles made of this metal are very frequently spear-shaped (Fig. 8). The trocar-pointed needle is the easiest to insert, and is usually the shape in which the gold needles are made. Of all three metals platinum takes the worst point, and these needles are usually made with a sharp rounded point, like a pin (Fig. 9 *a*).

Dr Althaus has suggested the use of several fine gilt needles fixed together like the prongs of a fork (Fig. 10, No. 3) and these are sometimes employed; but most frequently separate needles are used. If more than one are used with either pole, they are attached to it by a *serres-fines* conductor (Fig. 10, Nos. 11, 13, &c.), which is a rheophore containing several strands of wire, united at the battery end, but divided usually into six tails at the other end, to which the needles are attached by small clamps or wire holders (Figs. 11 and 12). The needles are bare at the end connected to the rheophore, but insulated in their stems up to within a variable distance of their points. When a nævus has to be treated, needles are chosen with uninsulated points of a length to correspond with its size. The uninsulated ends must be completely buried in the nævus, especially with the subcutaneous variety, otherwise the skin will be destroyed around the point of entrance of each needle. Different materials are used for insulation, such as shellac, gum elastic, and vulcanite. An operator can coat his own needles with shellac, but it very quickly comes off. The number of needles to be used, and the pole to which they should be attached, depends upon the size and situation of the nævus. As a rule, platinum needles should be used with the positive pole, except in the case of very vascular nævi before alluded to; but it does not matter of what material the needles are made when used with the negative pole; gold needles are often employed to distinguish them from those which have been made positive. If the nævus is situated on a conspicuous part of the body, such as the face, where the smallest possible amount of scarring is desirable, it is best to use

FIG. 8.

FIG. 9 (*a*).

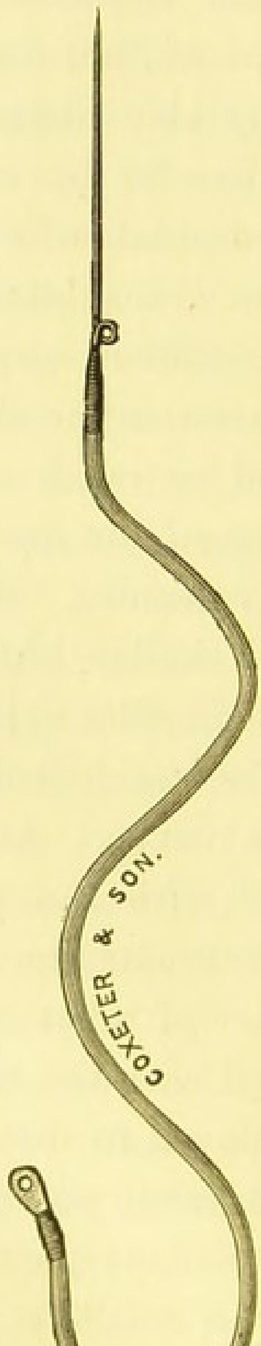


FIG. 9 (*b*).

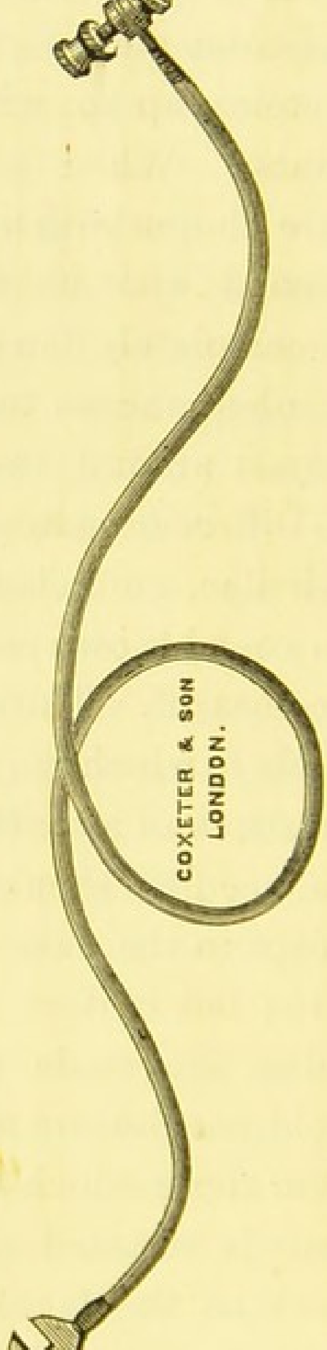
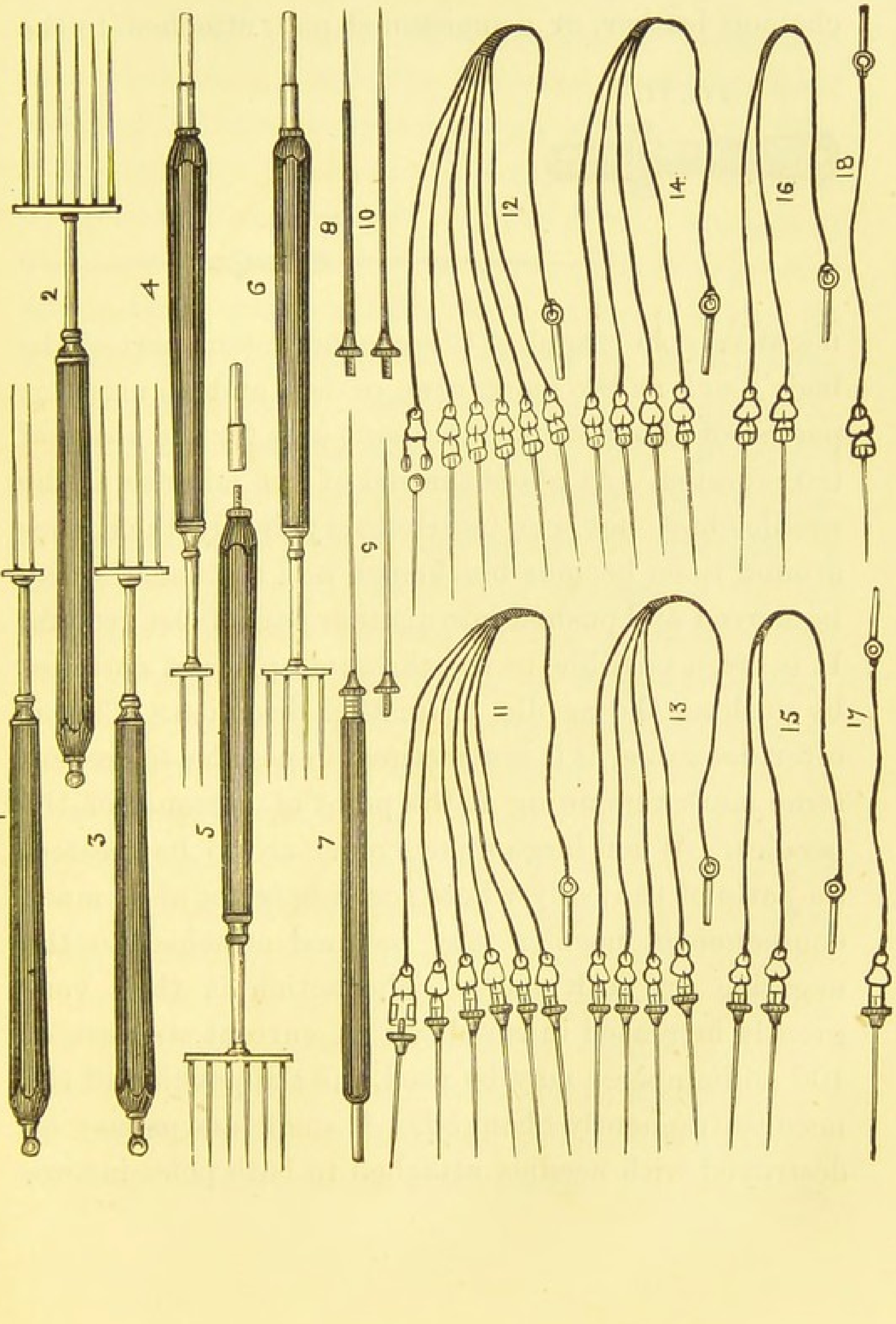


FIG. 10.



platinum needles attached only to the positive pole. A moistened sponge or carbon electrode covered with chamois leather, or a moistened pad, attached to the

Fig. 11.

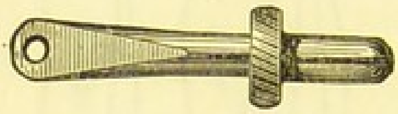


Fig. 12.

negative pole is applied to some indifferent part of the body, such as the back, arm, or leg, and a current is passed of about seventy milliampères for the space of ten minutes. At about the end of five minutes, if the needles have not been inserted very deeply, the tissues around them become blackened, and the needles may be moved and pushed into another part of the growth. It is often possible to use the same place of entrance by pushing the needle in another direction. This is often desirable, as it is sometimes impossible to prevent some mark remaining at the point of entrance of the needles. When large mixed nævi are to be treated, on parts of the body where scarring is not of so much consequence, needles may be used attached to the negative or both poles. The action is then very greatly increased in rapidity. A current strength of 100 milliampères may be used, and the position of the needles frequently changed. A small nævus may be destroyed with needles attached to both poles in two, three, or five minutes, according to its size. If the current strength is increased to 200 milliampères, great heat is evolved from the rapid chemical decomposition that takes place, and if the negative needles be kept too long in the same spot a slough is produced. The effects are not due to the development of heat, but to chemical decomposition. If the needles are moved at the proper time a dry blackened surface is present where the positive needles have been used, and an emphysematous discoloured swelling at the negative needles, with the surrounding skin greatly congested. If a needle slips out some bleeding may sometimes occur. This may usually be arrested by inserting the needle again, and increasing the strength of the current; the negative pole appears to be as efficacious for this purpose as the positive. The growth of a nævus may often be more thoroughly arrested by passing the needles into some of the larger vessels or blood spaces, but of course the liability to hæmorrhage is increased. A small compress of lint may be placed over the point of the needle as it is withdrawn, and kept pressed to the puncture by another compress and bandage, until all likelihood of bleeding has ceased. The circulation through a nævus is often thus materially obstructed and its vitality impaired. Needles attached to the positive pole sometimes stick, and are with difficulty removed, so that on withdrawal bleeding takes place, but if the needles are previously loosened by twisting them round, and then quietly and slowly removed, this chance of hæmorrhage is reduced unless the tumour is very vascular.

The electrolysis of a nævus should be stopped when every bright red or morbid part has changed colour. It may be that some few vessels escape destruction, and after the greater part of the destroyed surface has healed these veins may recommence growing, and require another operation. No untoward circumstances as a rule accompany the electrolysis of nævi, except perhaps the destruction of more tissue than is necessary by the current being used too strong or for too long a time. It is very difficult to estimate the amount of action necessary, so that the blood in the vessels may be obstructed, and the viability of the nævus destroyed, and that the whole mass may not slough. It is wonderful how nature will repair parts that appear to have been thoroughly destroyed. Often, if the first scab is knocked off too soon, a deep excavated sore will be seen, which sometimes greatly alarms the child's parents. I have seen the scalp destroyed to the bone over an area the size of a sixpence, and yet for it to fill up and skin over, so that a very small visible scar was left. The whole septum or tip of the nose has appeared sometimes to be destroyed, but nature has replaced them accurately. The tip of the nose is a very common place for a nævus to occur, and it is difficult to treat. It is better to do too little than too much. The operation can be repeated, but a part may be destroyed beyond repair. Often, after part of a nævus has been destroyed, other vessels which have escaped may become strangled and obliterated by the contraction which takes place during the process of healing.

An anæsthetic is necessary for a nævus of any size, for the operation while it lasts is acutely painful, and is sometimes prolonged for eight or ten minutes. Alarming pallor may occur during the electrolysis of nævi on the head. This is much aggravated when the child is under the influence of chloroform. Therefore the current has to be put on very gradually. This collapse and faintness is produced directly the circuit is completed, and is possibly due to the patient not being sufficiently under the influence of the anæsthetic, and therefore suffers from shock; but I should not advocate, in view of this theory being probably correct, that a patient should be profoundly anæsthetised, for if the current still produced its characteristic effect under these circumstances, the result might be fatal. It is best to increase the strength of the current gradually, and at the same time, as prudence dictates, to push the anæsthetic. The younger the infant the more grave the symptoms. The pulse can be felt immediately as influenced, and sometimes becomes almost imperceptible. The breath, which before the circuit is closed was normal, becomes crowing and shallow, showing that the pneumogastric, and especially its recurrent laryngeal branch, is profoundly affected. A very favourite place for nævi is at the vertex, just over the anterior fontanelle. The current is therefore passed direct through the brain. When a nævus is in that situation, it is also essential not to get suppuration, on account of the underlying meninges; therefore, it is always preferable to use needles attached only to the positive pole. This greatly prolongs the operation, and often necessitates a second, and even a third, application of the electricity, which also increases the risk. A nævus, therefore, over the anterior fontanelle is not treated by electrolysis without some danger. The same may be said of any other form of treatment that may be adopted.

With large nævi the operation by electrolysis is extremely tedious and troublesome, but with perseverance and patience the largest and worst may in time be cured, with more or less resulting scar, according to the skill of the operator. For some pendulous nævi, or for certain parts of nævi, galvano-cautery is sometimes preferable to electrolysis. The number of times it is necessary to operate depends upon the size of the nævus, and the effect produced by each operation. A month or six weeks may intervene between one application of the current and the next, except in the case of very large nævi, in which a distant part may be attacked after the lapse of a fortnight, so as to let the part first operated upon continue the process of healing undisturbed.

Nævi situated on the dorsum of the tongue can best be removed by galvano-cautery. One or two curved needles are thrust through the base of the nævus so that their ends extrude on either side of the growth. The platinum wire of the galvano-cautery instrument is placed beneath the ends of the needles and so as to include the whole growth, and, when raised to a dull red heat, is gradually drawn through the tissue of the tongue just beneath the growth and the transfixing needles so as to remove them both together. A seared dry surface is left on the tongue ,which does not bleed if the operation has not been performed too rapidly ; and this burnt surface gradually heals.

Port wine stains and superficial moles can also be treated by destroying a small portion of them at a time, when the mark is not small enough for the whole to be attacked at one sitting. Some port wine stains have little nodular excrescences upon them which can be previously removed by the galvano-cautery. I have thus removed two or three little prominent points on a port wine stain at the same sitting. When healed, these spots are covered by small islets of healthy skin. For the flat part of the port wine stain or mole I use electrodes suggested to me by Mr. R. W. Parker, Surgeon to the Grosvenor Hospital for Women and

Children. They consist of metal plates of various sizes, covered with platinum foil. The different sizes are used so as to fit on to different portions of the un-

FIG. 13.

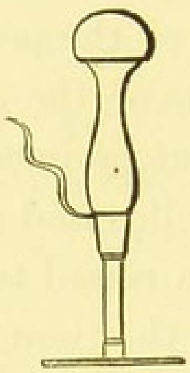
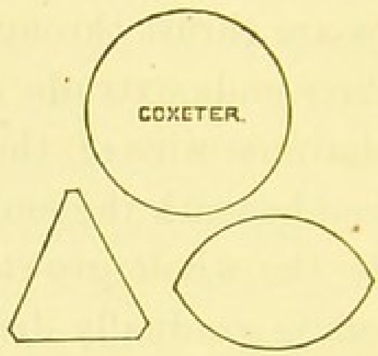


FIG. 14.



destroyed discoloured skin (Fig. 14). No part of the metal plate is allowed to touch healthy skin. They are used with the negative pole of the battery, a pad attached to the opposite pole being placed on some indifferent part of the body. The surface of the port wine stain beneath the metal plate is moistened with salt water, and a current of about forty to fifty milliampères allowed to pass until the skin is destroyed to a sufficient depth. The patient must be under chloroform. A frothy, slimy *débris* soon collects under the metal plate, and if attention is not paid to the electrode it is likely to slip off the part being operated upon, and more or less destroy neighbouring skin. The part of the stain that has been destroyed subsequently becomes a dry scab, and comes off, leaving beneath it a layer of more or less healthy skin. The process can then be repeated, usually after an interval of two or three weeks, on a fresh part of the stain. I have treated *hairy moles* in this way, and when the skin has been destroyed to the depth of the follicles from which the hairs grow, all the hairs will come out with the greatest ease. If, after the scab has separated, a few hairs still remain, they can be removed by the process about to be described.

THE REMOVAL OF SUPERFLUOUS HAIR

The removal of superfluous hair from the face, and sometimes from other parts, or of little hairy warts, and other disfiguring marks, is often of the greatest importance to ladies. Many are the nostrums that have been sold for the purpose of effecting this desirable object, and much time has been fruitlessly wasted, sometimes every day, in removing by the tweezers these obstinate and ever-returning hairs; each time they grow again stiffer and longer than before. The only effectual way of permanently removing these hairs and marks is by electrolysis.* It is best that the patient should be lying down in a good light. A pad soaked in salt water, and connected with the positive pole of a battery, is placed beneath the collar. Each hair as it is to be extracted is seized by a depilatory forceps, and a needle usually

* *Vide* 'British Medical Journal,' November 14th, 1885, p. 943.

made of platinum (Fig. 15), mounted on a suitable handle, is thrust down in the follicle beside the hair, as far as the papilla from which the hair grows. The depth of the follicle depends upon the hair, and is deeper for large hairs than for small ones. It will be found generally necessary to insert the needle from one sixteenth to an eighth of an inch. The circuit is then closed; this can best be done by an arrangement on the handle holding the needle (Fig. 17), and a current of about five milliampères is passed for twenty or thirty seconds. The hair all the time is held just tight by the forceps. When the papilla is dissolved away the hair will slowly slip out without any extra force being used. The exact time occupied by the process depends upon whether the needle is close to the papilla or not. During the time the current is passing, a small amount of froth is seen to rise up by the side of the hair. A slight bump, like a flea-bite, remains at the spot from which the hair has been removed for about two hours, and sometimes a little speck will remain for a week or ten days; this then falls off, and no mark remains. It is best only to remove the longest and darkest hairs, and those chosen should not be too close together. About twenty or thirty hairs are sufficient to remove from a lady's face at each sitting. The operation may be repeated at the end of every ten days or a fortnight until all the hairs have been removed that cause disfigurement.

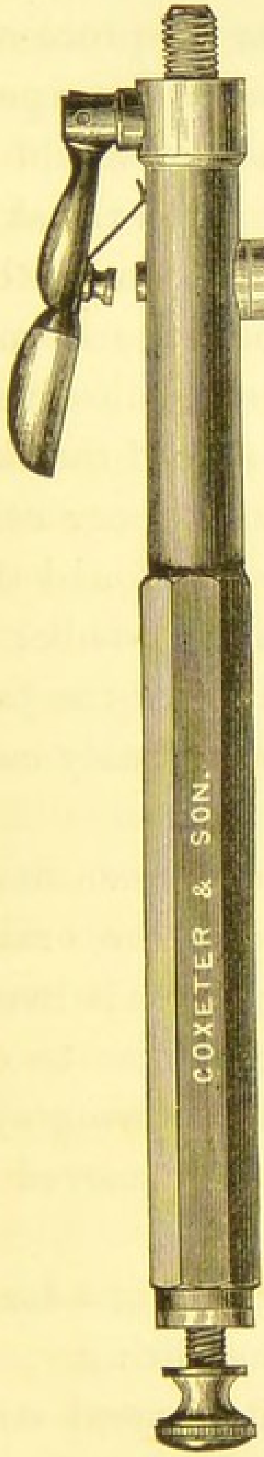


FIG. 17.

FIG. 15.

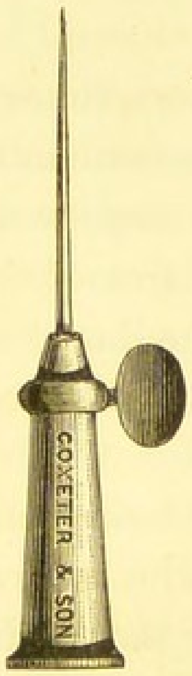


FIG. 16.

FIG. 18.

Platinum needle for electrolysis in ivory handle, with cap, suitable for the waistcoat pocket.

The number of times that it is necessary to perform the operation depends upon the abundance of the growth. No anæsthetic is required, as the process is not a very painful one. A slight twinge is experienced at the removal of each hair, such as would be caused by a spark from the fire alighting on the skin. With the greatest amount of care it will be found that one or two hairs escape total destruction, and may return; but these can be removed on a subsequent occasion. It is said that the sensitiveness of the skin may be reduced by painting it over with a 5 per cent. solution of cocaine. I have never really found this necessary. I have operated on a large number of ladies, and none of them have complained of the pain being more than trifling. It ceases immediately each hair is removed.

The operation is sometimes required in men to remove the hair that occasionally grows on the bridge of the nose, or there may be a bushy growth between the eyebrows, with hairs of such a length as to occasionally get into the line of sight. In-growing eyelashes (*trichiasis*) can also be effectually removed by this method.

A wart, or a *small hairy tuft or mole,* having a dozen or sixteen hairs, can be removed at one sitting.

Keloid scars after the healing of suppurated strumous glands or *cicatricial tissue* about the junction of healed wounds following the removal of the breast, &c.,

have been removed by electrolysis. A needle connected with the negative pole has been thrust into the nodular mass and a current of about 50 to 70 milliampères allowed to flow for two or three minutes or until the hardened mass has softened down. Several of these keloid masses, or as many as exist, can be attacked on the same day.

Small tumours and growths can be treated in the same way. More than one needle may be required, according to the size of the tumour. When several needles are used they are thrust into the base of the tumour in a radiate form. Where the sloughing out of the tumour is not objectionable some of the needles may be attached to either pole. In the case of a small tumour, for instance, on the upper lip, where as little disfigurement as possible is desired, needles should be used attached only to the positive pole. When this is the case the operation will take a much longer time. The current should be arrested when an obvious change has taken place in the tumour. An anæsthetic in these cases would always be necessary.

Sebaceous cysts of the head and *cystic tumours of the eyelid* may be attacked in this way.

Lupoid ulcerations of the face, and *serpiginous ulcerations* on the hand or other parts, may be destroyed by electrolysis and a healthy base to the sore produced which will ultimately heal.

STRICTURES

The same electrical action has been used in the treatment of abnormally narrowed and strictured passages of the body, such as stricture of the urethra, rectum and œsophagus, stenosis of the os uteri, obstruction of the lachrymal canals and of the Eustachian tube.

STRICTURE OF THE URETHRA

In 1839 Crussel began his investigations on the use of electrolysis in surgery and appears to have been the first who suggested its use in the treatment of stricture of the urethra. The method was revived in 1867 by Mallez and Tripier in Paris, and about the same time by Althaus in this country. During the last decade it has been developed and improved by Dr Robert Newman, of New York, to such an extent that it has now become one of the recognised modes of treatment of stricture.

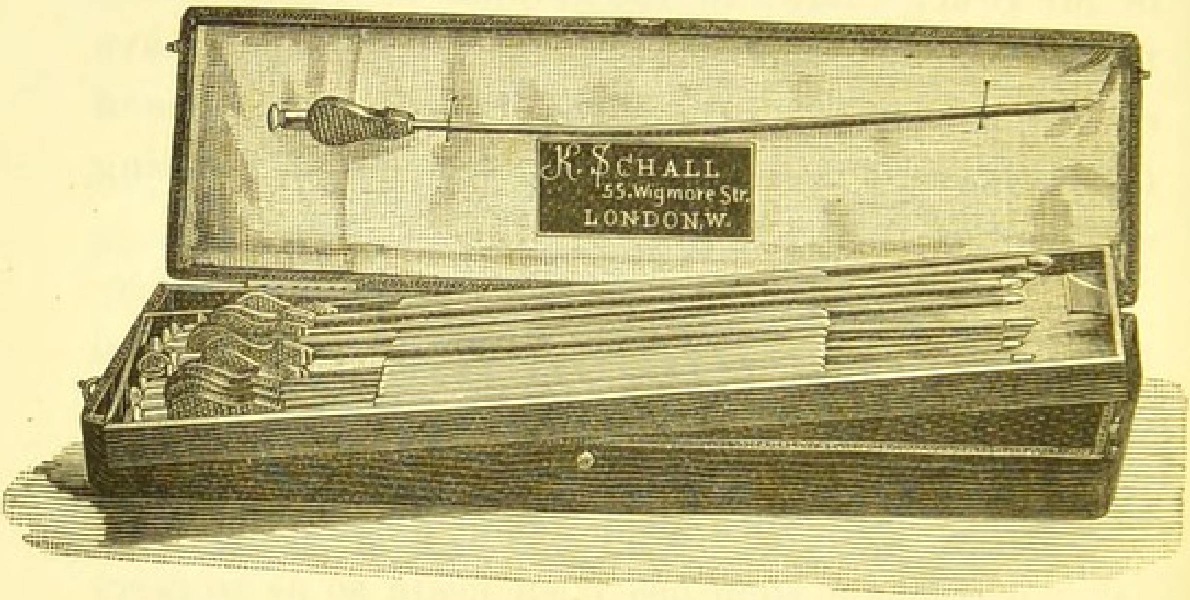
Soon after my appointment to the Electrical Department at St Bartholomew's Hospital in 1882, my attention was called by Dr Shelly, of Hertford, to the success achieved in America by this mode of treatment. I then had electrodes made for the purpose of carrying out the treatment, but had no patients to try them on until I obtained the assistance of Mr Bruce Clarke in the autumn of 1885. Since then we have had numerous cases which have established beyond a doubt that electrolysis is one of the most efficient and satisfactory modes of treating stricture of the urethra.

In the treatment of stricture of the urethra by electrolysis* the best form of electrode is a catheter-shaped gum-elastic bougie, having an olivary-shaped metal end (see Fig. 20, B) connected by a copper wire (seen at C) with a Brodie's handle, on which is a binding screw (A). A common stem has been made so as to carry different sized olivary ends, as seen in the diagram. These electrodes, consisting of an insulated copper wire, are as flexible as ordinary gum-elastic catheters, and can be bent to any curve that will suit the operator; but a set of firm electrodes are also made, which can be directed as accurately as a silver catheter, these latter are pictured in the bottom figure of the diagram.

* This account of the treatment of stricture of the urethra by electrolysis appeared in 'The Provincial Medical Journal' for July, 1888.

The olivary ends in all these electrodes are nickel-plated, there is no necessity to employ platinum, as they are always used attached to the negative pole of the battery, and therefore not affected by the current. In one or two cases so little sensation was produced in the patient by the passage of the current that it was

Fig. 19.



Case of Urethral Electrodes.

difficult for him to believe that any decomposition of his stricture was taking place. The current was therefore once or twice reversed, by means of a commutator, with the result of immediately removing the plating from the electrodes. The shock of making and breaking the current soon satisfied the patient that some uncommon force was present in his urethra.

An electrode attached to the positive pole is placed under the patient's back, or on some other indifferent part of the body. The best electrode for the purpose is one made of tin, on to which is stitched some

FIG. 20.

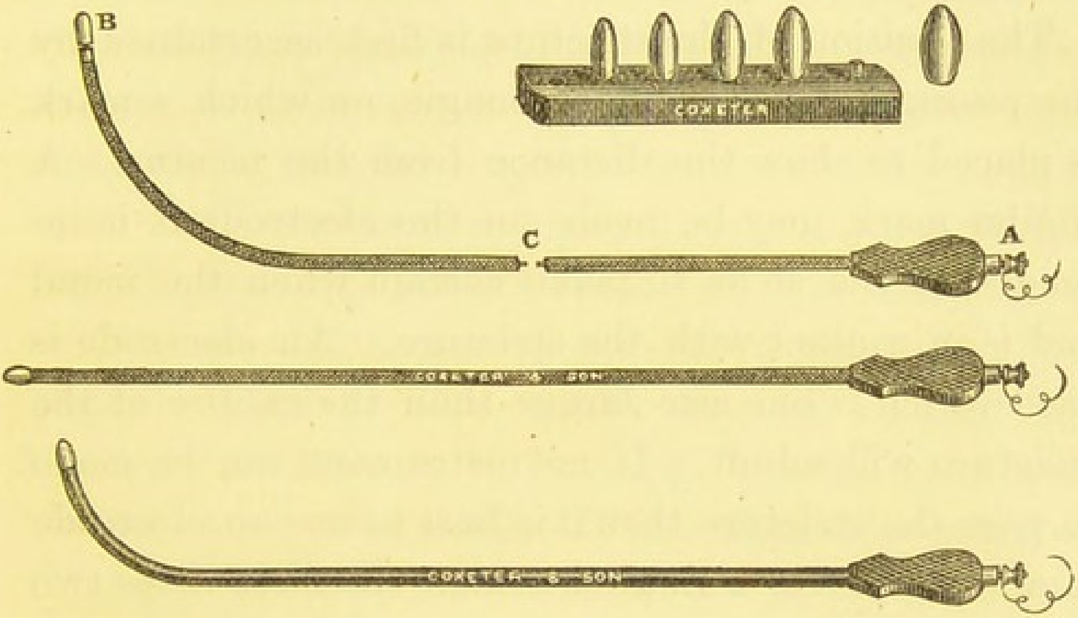
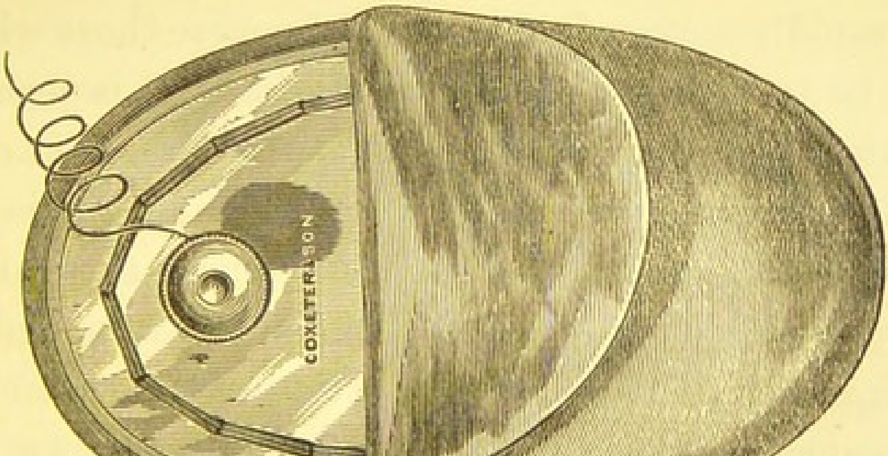


FIG. 21.



amadou or house flannel, for the purpose of retaining moisture (Fig. 21). This pad is moistened in salt and water, and then placed in a cover, one side of which is made of waterproof, so as to protect the bed-clothes or couch. It is best to have the patient lying on his back.

The position of the stricture is first ascertained by the passage of an ordinary bougie, on which a mark is placed to show the distance from the meatus. A similar mark may be made on the electrode it is intended to use so as to make certain when the metal end is in contact with the stricture. An electrode is used which is one size larger than the calibre of the stricture will admit. If no instrument can be made to pass the stricture then it is best to use an electrode of about No. 5 or 6 English scale. In these cases two or three applications of the current may be necessary before the electrode will pass the stricture. The most rapidly successful cases are of course those which could be treated by ordinary dilatation. It is perhaps an unfairly severe trial of the method to select only those cases which resist all other forms of treatment. They are also of course the most difficult to treat by electrolysis. When the electrode, it is intended to use, is in position against the stricture it is attached to the negative pole of the battery by a wire from the screw (A) on the handle. The circuit is then closed and the strength of the current gradually increased to five or six milliampères. A current of greater strength will produce pain. To ascertain the strength of the current it is necessary to include a galvanometer in the circuit either between the negative pole and the bougie electrode or between the positive pole and the pad on the back. Sufficient accuracy cannot be attained by simply considering the number of cells employed, as cells vary in strength according to their composition and the length of time they have been in use. No anæsthetic is required; in fact, it is an advantage that the patient should be conscious so that he can say if the current appears to be too strong. The electrode is kept gently pressed against the stricture, no force is to be used, but the electricity allowed to do the work. If the electrode is forced through the stricture the operation amounts to little more than ordinary rapid dilatation. The attention must be kept continually on the electrode so as to guide it in the right direction, otherwise a false passage may be dissolved into the side of the urethra. Immediately the electrode passes the stricture the current should be turned off and the bougie withdrawn. The time occupied in dissolving the stricture varies according to its density and length, but is usually from ten to five-and-twenty minutes. If the electrode has not passed the stricture before the expiration of twenty-five minutes it is best to turn the current off and continue the treatment at some later period. Even if the electrode has not passed, great benefit is often derived from the use of the current; the difficulty in passing the water is relieved and the size of the stream enlarged. When the electrode is withdrawn the patient is left undisturbed for a week or ten days, sometimes for a fortnight. It is then found that a bougie larger than the electrode which passed on the last occasion will now pass the stricture. If the French scale is used, two sizes larger will often be found to pass; taking the English scale, about one size larger can be used each time. The operation is then repeated with the larger-sized electrode. The number of times it is necessary to perform the operation depends greatly on the calibre of the stricture when the treatment was commenced. The great success achieved by Dr. Newman, of New York, is mainly due to the employment of weak currents and the frequent repetition of the operation. There is no comparision between the treatment of stricture of the urethra by the ordinary methods and its treatment by electrolysis. Should the permanency of the good results prove to be as a rule not so great as those recorded, still the calibre of the stricture remains enlarged for a longer space of time than after any other form of treatment.

In the 'New England Medical Monthly' for December last an editorial article was published under the heading "What is the present status of Electrolysis in the treatment of Urethral Stricture?" The article says "Not long ago physicians and surgeons of repute flouted the treatment of urethral strictures by electrolysis. Now it is so generally and successfully practised that scarcely anyone opposes it.

"This change of opinion is undoubtedly due, first, to the better understanding of the electrolytic treatment as distinguished from the 'galvano-caustique;' secondly, to the successful treatment, without relapse, of a large number of cases (fully reported) by many physicians of high repute.

"It is undeniable that the method now adopted was first grasped and put forward by Dr. Robert Newman, of New York, who, despite the misrepresentations and abuse of the ignorant, has zealously laboured for eighteen years to perfect the instruments used and the technique of the operation, until by extraordinary success the most sceptical are convinced.

"Experiments in the treatment of stricture with electricity have been made since 1847, and until 1872, without any method, except such as destroyed tissues by too strong currents. Mallez and Tripier called their method 'galvano-caustique,' showing that they used a current with caustic, not electrolytic action, and therefore they naturally failed.

"The present method is electrolysis, with weak currents applied at long intervals, resulting in galvano chemical absorption, known and recognised as Newman's method. Newman not only introduced and perfected the electrolytic method, but also invented and perfected instruments for use in the operations, so that failure in the operation is hardly possible.

"In England eminent surgeons so fully comprehend and acknowledge the great value of this method, that it is taught at the medical schools as one of the ways of treatment of urethral strictures. In St. Bartholomew's Hospital an additional department has been established for treatment in this way,* and many successful cases have been reported by Dr. W. E. Steavenson and Mr. W. Bruce Clarke.

"The following bibliography of articles, reports, and lectures which have been published, will prove of value to the student and practitioner who is interested in this subject—and who is not?

"By Dr. Newman.

"Treatment of Strictures of the Urethra by Galvanism.—'Medical Record,' March, 1867.

"Electrolysis in the Treatment of Stricture of the Urethra.—'Transact. Med. Soc.,' State of N. Y., 1874.

"Ten Years' Experience in the Treatment of Stric-

* The Electrical Department at St. Bartholomew's has not been established solely for the treatment of strictures.—W. E. S.

ture of the Urethra by Electrolysis.—'Med. Record,' N. Y., August 12th and 19th, 1882.

"Answers to Correspondents about the Electrolytic Treatment of Urethral Strictures, with a few Selected Cases.—'New England Med. Monthly, June, 1883.

"Electrolysis in Surgery.—'Jour. Am. Med. Ass.,' April 25th, 1885.

"Tabulated Statistics of 100 cases of Urethral Strictures treated by Electrolysis without relapse.—'New Eng. Med. Mon.,' August 1885.

"Progress of Electrolysis in Surgery.—'Gallard's Med. Journ.,' December, 1885.

"Causes of Failure in the Treatment of Urethral Strictures by Electrolysis.—'Transactions N. Y. State Med. Ass.,' 1885.

"Is Electrolysis a Failure in the Treatment of Urethral Strictures?—'N. Y. Med. Record,' September 25th, 1886.

"The Armamentarium for the Treatment of Urethral Strictures by Electrolysis.—'New England Med. Monthly,' March, 1887.

"A Lecture on Electrolysis.—'New Eng. Med. Monthly,' August, 1887.

"Synopsis, of the Second 100 cases of Urethral Stricture treated by Electrolysis, with cases.—'Journ. Am. Med. Ass.,' September 24th and October 1st, 1887.

" By other Operators.

" David Price, M.D., Jacksonville, Ill.—'Transactions Ill. State Medical Association,' April, 1873.

" J. F. Frank, M.D.,—Multiple Strictures of the Urethra treated by Electrolysis.—'Med. Record,' February 2nd, 1874.

" John Butler, M.D., New York,—'Am. Journ. of Electrology,' October, 1879, and Three Cases of Stricture of the Urethra cured by Electrolysis after all other methods had failed.—'N. Y. Med. Times,' November, 1882.

" J. H. Glass, M.D., of Utica, N. Y.—Report of Nine Cases.—'N. Y. Med. Record,' May 12th, 1883.

" W. H. Dickerman, M.D., of Olean, N. Y.—Impermeable Strictures successfully Treated.—'N. Y. Med. Record,' June 25th, 1883.

" T. Belfield, M.D., Chicago.—Nine Cases of Impermeable Urethral Strictures.—'Journ. Am. Med. Ass.,' April 24th, 1886.

" W. E. Steavenson, M.D., and W. Bruce Clarke, F.R.C.S., London, England.—'Lond. Med. Record,' May 25th, 1886.

" T. J. Hayes, M.D.—Report to the Academy of Ireland.—'British Med. Journ.,' July 17th, 1886.

" Geo. C. Pitzer, M.D., of St. Louis, in his work on Electricity in Medicine and Surgery, St. Louis, 1884.

"C. A. Bryce, M.D., Richmond, Va.—Reports successful cases in 'Southern Clinic,' July, 1886.

"W. E. Steavenson, M.D., London, England.—The Employment of Electricity in the Treatment of Diseases of the Urinary Organs.—'British Med. Journ.,' November 27th, 1886.

"Robert Bartholow, M.D., Philadelphia, Penn.—Lecture, December 18th, 1882.

"W. F. Hutchinson, M.D., of Providence, R. I.—Urethral Electrolysis.—'New Eng. Med. Monthly,' December, 1886.

"G. W. Overall, M.D., Memphis, Tenn.—'Miss. Valley Med. Monthly.'

"W. T. Belfield, M.D.—Reports thirty-seven cases in 'Med. Age.'

"L. Wolff, M.D., Philadelphia, Penn.—'N. Y. Medizinische Presse, 1887.'

"W. Bruce Clarke, F.R.C.S.—The Treatment of Stricture of the Urethra by Electrolysis.

"Edwin Morton, M.D., London.—Treatment of Stricture.—'British Med. Journ.,' October 1st, 1887."

And recently the paper by F. Swinford Edwards.—Electrolysis in the Treatment of Resilient or Non-Dilatable Stricture of the Urethra.—'Med. Press and Circular,' April 11th, 1888.

And numerous other reported cases of successful treatment by various medical men.

STRICTURE OF THE RECTUM

Stricture of the rectum can, like all other strictures, be treated by electricity. The amount of success achieved by this means depends upon the nature of the obstruction. In some cases cure can be effected, in others relief only can be obtained; but in these latter cases, where the stricture is due to cancer, life can be prolonged for a variable period, and made more endurable by the relief of pain; and that last and terrible expedient of colotomy can be postponed and perhaps dispensed with altogether.

The steps of the operation for the electrolysis of stricture of the rectum are as follows* :—A galvanic battery of from 20 to 30 cells is required. The number of cells to be employed depends upon the composition of the battery, and the length of time it has been in use. The current strength that it is most advantageous to maintain is one of five milliampères, which can be gauged by means of a galvanometer. A pad moistened in salt and water is connected by a conducting wire with the positive pole of the battery, and placed on some indifferent part of the body, and a specially

* This account of the treatment of stricture of the rectum by electrolysis appeared in Mr. Alfred Cooper's work on 'Diseases of the Rectum,' H. K. Lewis, London, 1887.

made bougie electrode (Fig. 22) is connected with the negative pole, and held against the stricture.

Fig. 22.

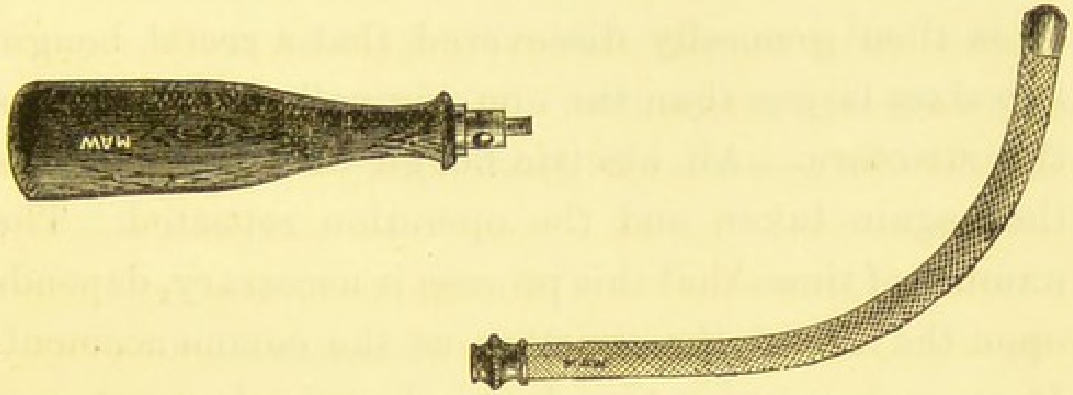
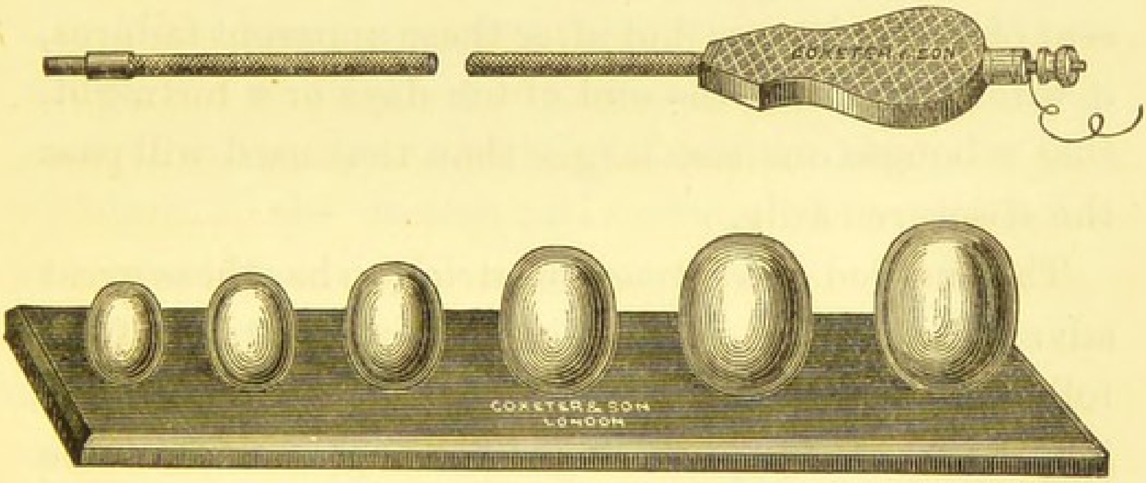


Fig. 23.



The bougie electrodes are made in sizes corresponding to the ordinary rectal bougies (Fig. 23). It is first necessary to ascertain, by means of an ordinary bougie, what is the calibre of the stricture. An electrode bougie of one size larger is then taken and attached to the battery as already described, and held against the stricture until it has dissolved away enough to enable it to pass. The circuit is then broken and the bougie withdrawn. The patient is left ten days or a fortnight before any further examination is made. It is then generally discovered that a rectal bougie two sizes larger than the one originally used will pass the stricture. An electric bougie of a larger size is then again taken and the operation repeated. The number of times that this process is necessary, depends upon the size of the stricture at the commencement. If on each occasion the electric bougie does not pass in about twenty minutes or half an hour, it is best to desist, as too large a slough may be produced at the seat of the stricture; but after these apparent failures, it will be found, at the end of ten days or a fortnight, that a bougie one size larger than that used will pass the stricture easily.

This method of treatment of stricture has these great advantages. The patient is not incapacitated from following his ordinary occupation, provided his general health in other respects is good enongh for him to be about. No anaesthetic is required; the pain is very trifling, and the strength of the current is regulated to a great extent by the feelings of the patient. It is therefore necessary that he should be conscious. There is usually no bleeding, if the operation be properly performed, and no necessity for any antiseptic precautions, as the procedure itself is aseptic.

In the majority of cases there is no contraction or return of the stricture; but if due to cancer, a fresh growth of diseased tissue is very likely to take place, necessitating a recourse to the treatment. Successive applications of electricity are far better than the *dernier ressort* of colotomy, and may keep the intestine patent as long as the disease allows the patient to live.

STRICTURE OF THE ŒSOPHAGUS

Stricture of the œsophagus has also been treated by electrolysis with success. A long flexible electrode, like an ordinary œsophageal bougie, is required, to which can be attached olivary metal ends of various sizes as in the case of some of the electrodes used for stricture of the urethra and rectum. The electrode is connected with the negative pole of the battery, that connected with the positive pole being placed on some indifferent part of the body. A current strength of five milliampères is generally employed, and the current allowed to flow for fifteen or twenty minutes unless the electrode passes the obstruction in a shorter time. It will be found, as in the case of strictures in other parts, that recontraction does not take place so rapidly as after dilatation, and that usually after a week's interval a bougie one size larger can be passed than that used on the former occasion. A perforated electrode has been used which will pass over a celluloid guide so as to diminish the risk of its passing into a pouch by the side of the œsophagus, or of its decomposing laterally too much of the cancerous tissue of a malignant stricture and by this means making an opening into the posterior mediastinum. The guide is sufficiently small to pass through the stricture and thus direct the passage of the electrode. As with other forms of treatment of œsophageal stricture, electrolysis gives more prospect of success with the fibrous variety than with the malignant.

LACHRYMAL OBSTRUCTION*

The great difficulty of effecting anything like a cure for obstinate cases of epiphora due to obstruction in the lachrymal passsges is known to all. The usual treatment by astringents, probes, styles, and slitting up the canaliculi are all open to grave objections, and often of little benefit to the patient. Mr Power, in his lectures at the Royal College of Surgeons of London, drew special attention to the anatomical conformation of the lachrymal passages and the great harm that might be generally done to them by the passage of the large probe so often used.

The treatment of obstruction of the puncta and the

* The following appeared in an article by the author and Mr W. H. Jessop on "Electrolysis in the Treatment of Lachrymal Obstruction," published in the 'Lancet,' Dec. 24th, 1887, p. 1371.

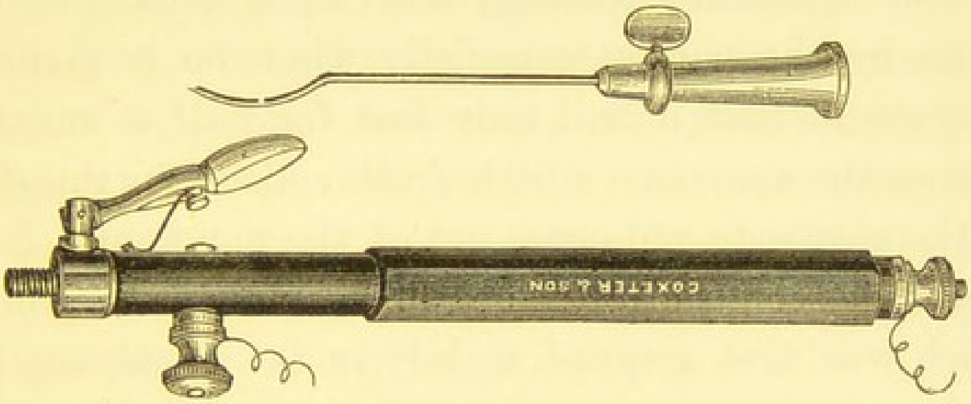
lachrymal canals by electrolysis is only another example of the great advantages that the employment of electrolysis possesses in the treatment of stenosis, and other affections occurring in parts difficult of access. The smaller the passage the greater the difficulty of performing an operation. The application of caustic alkalies in the treatment of stricture of the urethra has been used and abandoned on account of the difficulty experienced in limiting the action of the caustic to the part it is wished to destroy. This objection does not exist in the application of electrolysis, because its action is entirely under the control and direction of the operator. The site of its influence can be limited to the smallest point. The duration and extent of its cauterising action is also absolutely at the command of the operator, and depends on the strength of the current employed and the time it is allowed to flow.

For the removal by electrolysis of organic material of any description which has caused an obstruction or stricture in any of the passages of the human body, the negative pole is used because the obstructing material is by its means as it were melted down and dissolved and the passage thus made larger. The electrode which is used, if in the first place it is not very much too large, is enabled to pass the obstruction and be removed again with ease. If an electrode connected with the positive pole is used it becomes glued to the surface of the passage and cannot be removed without some difficulty. The negative pole has no effect upon the metal of which the electrode is made, and when the electrode is withdrawn it is as bright as when introduced, but at the positive pole the metal is dissolved as well as the tissues, and enters into the new combinations which take place ; this, in the case of stenosis or stricture, is undesirable.

The material to be decomposed by electrolysis in stenosis of the lachrymal canals is not very dense and does not offer such a very great resistance, and therefore a battery composed of a comparitively smaller number of cells is sufficient. A galvanometer should be introduced into the circuit for the purpose of measuring the current, for different batteries are possessed of different electro-motive force ; a difference also exists in cells which have been recently charged, or which have been in use for a long time. Two to four milliampères will be found a sufficiently strong current to enlarge any narrowed lachrymal canal. Some patients offer very much more resistance than others ; whereas in one patient three or four cells will give the required current strength, in another it will require six or eight cells. This difference in resistance is what is so little understood, but it is the factor which plays, perhaps, the most important part in electro-therapeutics. No reliable information can really be derived from reports of cases in which the number of cells only is given, so much depends upon the resistance of the patient and the strength of the cells.

For stenosis of the lachrymal canals a probe small enough to be inserted into the punctum is introduced and passed along the canal to the nasal duct. The probe is fitted into a socket which is screwed on to a

Fig. 24.



handle (Fig. 24), and is attached to the negative pole of a battery. A flat plate electrode (Fig. 21) covered with some substance which will retain moisture is connected with the positive pole, and generally placed on the back of the neck beneath the collar, having been first moistened with salt and water. The handle of the negative electrode possesses a mechanical arrangement for completing the circuit. Four cells of a Stohrer's battery will usually be found sufficient with the resistance they have to overcome, to give a current strength of four milliampères. A Leclanché battery will do equally as well for such a small operation, but perhaps one or two more cells would have to be used. With a current strength of four milliampères the enlargement of the caniculus takes about thirty seconds. A lower current strength would accomplish the object desired, but then the electrode would have to be held in the canal for a longer space of time. No anæsthetic is necessary. A sharp burning sensation is produced in the canal during the time the current is actually passing, but this is usually easily borne by the patient especially when he is assured beforehand that it will only last for half a minute. During the operation a little froth collects by the side of the electrode and oozes out of the punctum. In a very few seconds after the circuit is closed, the probe, which was first gripped tightly in the canal, can be made to move backwards and forwards along the passage with great ease. The neighbourhood of the punctum, the inner canthus, and the surrounding integument to about an inch in circumference, remain slightly congested and suffused for about two hours after the operation. Care must be taken in all cases in which electricity is applied to the head owing to its often producing faintness in the patient. The probes used should never be greater than 1·5 mm. During the operation great care must be taken to keep the patient's head fixed, as sudden pain is felt at making and breaking the circuit; the probe must also be kept away from the eyeball.

The advantages attending this treatment by electrolysis are chiefly due to the fact that so little displacement or alteration of the normal channels is effected, and by it we have the means of increasing the lumen of the puncta and canaliculi without any excessive stretching, which must necessarily alter the conditions of the surrounding muscular and other structures.

Nasal duct.—The same mode of treatment has been tried for closure of the nasal duct. The probe must be insulated nearly to its end, and connected with the negative pole of the battery. A weak current of from about two to four milliampères only should be used. Tripier is said to have operated by electrolysis with success in this affection.

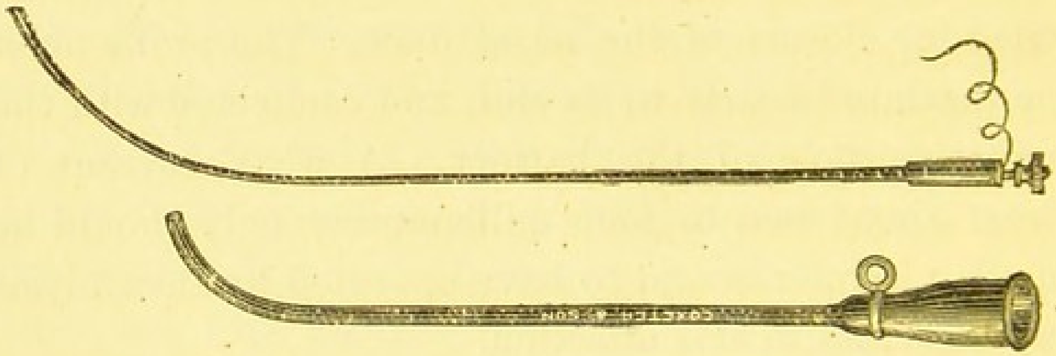
Anterior hypertrophies on the inferior turbinated bones have also been treated by electrolysis; two or three negative needles are thrust into the hypertrophied tissue. *Posterior hypertrophies* (or adenoid growths) about the orifice of the Eustachian tube are better treated by galvano-cautery, but they can also be removed by electrolysis.

OBSTRUCTION OF THE EUSTACHIAN TUBE

The great success which followed the treatment of stricture of the urethra and other mucous passages by electrolysis suggested the idea that an obstructed

Eustachian tube might be opened up by the same means. At the latter part of 1887 the author had several bougie electrodes made with the object of carrying this idea into practice*. The instrument which was found most suitable consists of a vulcanite Eustachian catheter and an electrical bougie (Fig. 25). The bougie is made of a number of fine copper wires

Fig. 25.



about seven or eight inches long, insulated by vulcanite to within an eighth of an inch of their ends. The ends of the wires are soldered into a small nickel-plated metal cap. The bougie is small enough to pass along the catheter and exceeds it in length by about one inch. The handle end of the bougie is provided with a binding screw, to which the insulated copper wires are also attached, for the purpose of connecting a rheophore from the battery. On this end of the bougie an inch is marked off divided into eighths. Each eighth of the inch passes into the catheter as one

* Published in the 'Lancet,' by Mr. A. E. Cumberbatch and the author, Nov. 24th, 1888, p. 1014.

eighth protrudes at the other end. It is therefore possible to tell, when the catheter is in the orifice of the Eustachian tube, how much of the bougie is in the canal. On the catheter there is a metal ring, or some other mark, as on all catheters, to indicate the position of its end when it is being inserted.

Electrolysis of the Eustachian tube is performed in much the same way as the electrolysis of the other mucous passages which has previously been described. A pad connected with the positive pole of a battery is moistened and placed at the back of the patient's neck. The Eustachian catheter is then passed along the nostril and guided into the tube; the bougie, already attached to the negative pole of the battery, is passed along the catheter and Eustachian canal as far as it will go, until it meets an obstruction. The current is then closed. A galvanometer should be included in some part of the circuit, and the strength of the current increased until a strength of four milliampères is obtained. A frizzling noise will be heard by the patient in his head, usually likened to the frying of fish; and the operator, by approaching his ear to the catheter, can often hear the crackling produced by the frequent breaking of minute bubbles of gas. The electrolysis is kept up for four minutes, and usually before the expiration of that time, if it is possible that the obstruction can be removed, it will be found that the bougie can be pushed on for a small distance, sometimes for its full length. Generally on the first occasion the Eustachian tube is rather sensitive, but it seems to acquire toleration for the process, and at no time is so much discomfort experienced as might be expected from setting up chemical decomposition in the middle of the head. The operation has now been performed a large number of times without any unpleasant experiences, nor has the treatment caused anything more than very temporary discomfort to the patients. In those cases in which the deafness has been due to a simple obstruction of the Eustachian tube the results have been most encouraging. Mr Cumberbatch, the Aural Surgeon to St Bartholomew's Hospital, has written the following concerning the operation :—" Our experience is at present too limited to be able to say what cases of chronic catarrh of the middle ear are most likely to be benefited by this new method of treatment. That strictures of the Eustachian tube, which do not yield to the ordinary methods, can be cured by the use of the electric bougie we have proved. In many cases of chronic catarrh with obstruction of the Eustachian tube, there is no actual ankylosis of the ossicular joints; and in such case restoring the patency of the tube, and thus relieving the pressure on the membrana tympani and the chain of ossicles, must act beneficially on the hearing. In cases also where catarrh has spread to the labyrinth, the distressing tinnitus, when due to circulatory disturbance rather than to any lesions of the nervous elements, is likely to be removed. When auditory vertigo is caused by undue pressure on the labyrinth owing to strong retraction of the membrana tympani, it is possible to relieve it (of course by restoring the patency of the Eustachian tube) by means of the continuous current, as has been proved by several cases which have been thus treated. In conclusion, I may add that, if after three or four trials a patient experiences no benefit, the probability is that further treatment by this method will be useless."

DISEASES OF THE URINARY ORGANS

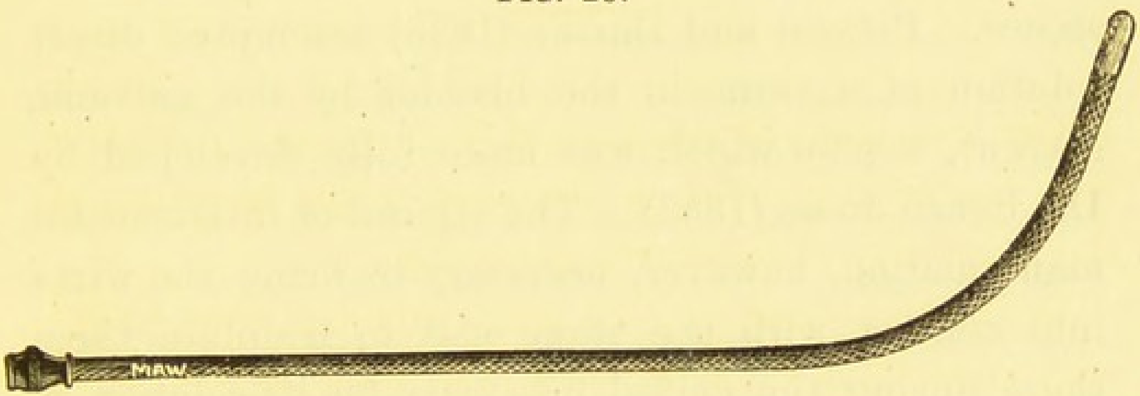
The treatment of stricture of the urethra by electrolysis has been previously discussed when speaking of the treatment of strictures generally.

In the treatment of *gleet* electricity has been found very successful.* It is used somewhat in the same way as medicated bougies. The metal part of a vesical electrode, or electrical bougie (Fig. 26) such as is used in the treatment of stricture, is held against the sore unhealed surface which keeps up the discharge and which is frequently to be found on the bladder side of a stricture. The electrode is made negative and is moved slowly backwards and forwards over the sore surface for about two or three minutes with a current strength of five milliampères. The electrode connected with the positive pole is placed on some indifferent part of the body, but by preference over the lumbar enlargement of the cord, as possibly the

* 'Provincial Medical Journal,' May, 1888, p. 204.

effect of the electricity upon the nervous supply of the urethra may be beneficial. In the treatment of gleet no doubt the electrolytic property of the current is the chief agent at work. The unhealthy ulcerated surface on which the gleet depends is decomposed or altered in such a way as to put it into a condition in which it will heal.

FIG. 26.



VESICAL CALCULUS

For the last eighty years attempts have been made from time to time to dissolve vesical calculi by electrolysis. Experimentally it was found that all calculi could be dissolved by a galvanic current in a concentrated solution of nitrate of potash. Platinum electrodes were applied on either side of a calculus immersed in this solution, chemical decomposition of the nitrate of potash followed, nitric acid appeared at the positive pole, and caustic potash was formed at the negative. The phosphatic stones were dissolved by the nitric acid; and the uric acid, and urate of ammonia calculi were dissolved by the caustic potash. Dr Bence Jones also found that oxalate of lime calculi could be dissolved by the same means; but these attempts have never been successful in the human bladder.

Sir Henry Thompson says,* "I must not omit to name the agency of electricity which has also been locally employed, both for uric acid and for phosphatic stones. Prévost and Dumas (1823) attempted direct solution of a stone in the bladder by the galvanic current, a plan which was more fully developed by Dr. Bence Jones (1852). The amount of instrumental manipulation, however, necessary to bring the wires into contact with the stone and to maintain them there during the period necessary for its solution, is considerably greater than that required to crush the stone by the modern method of lithotrity, and must therefore be regarded at present as inapplicable."

Sir Geo. H. B. Macleod in his Address in Surgery before the British Medical Association at Glasgow in August, 1888, said, "When chemistry had demonstrated the composition of urinary calculi, it was hoped that their solution within the body would be shortly accomplished with the same ease as it was attained in the laboratory. After many and varied attempts in different countries, this has been abandoned, as has also the use of galvanism alone or with

* 'Diseases of the Urinary Organs,' 8th ed. p. 364.

chemical solvents. At present this hopeful field of research may be said to remain barren of results."

ENLARGED PROSTATE

The treatment of enlarged prostate by the means usually employed has on the whole yielded most unsatisfactry results. Palliative measures frequently prove useless and operative measures disastrous. Mr. Harrison, late of Liverpool, in writing on enlargement of the prostate has said* "how slight is the prostatic barrier in some of these instances, but yet how complete is the obstruction which is thus occasioned both relatively to the act of spontaneous micturition and to the introduction of an instrument to relieve it. When we consider how extremely limited physically is the nature of the obstruction in many of these cases, it is not difficult to understand how readily this state may be remedied by the timely adoption of mechanical means. How easily the mere outlet of the bladder may be improved in some instances of obstruction by a large prostate is shown by the undoubted success which frequently followed the practice of Mercier in making a linear incision through the prostatic bar, and more recently by the means advocated by Gouley, where no more than a small portion of the obstruction is punched out by an ingenious

* 'Lancet,' January 16th, 1888, p. 101.

instrument contrived for this purpose." He also says that often in persons with large prostates "the regular expulsion of urine from within outwards is capable of preventing obstruction by the formation of grooves or channels in the hypertrophied mass."*

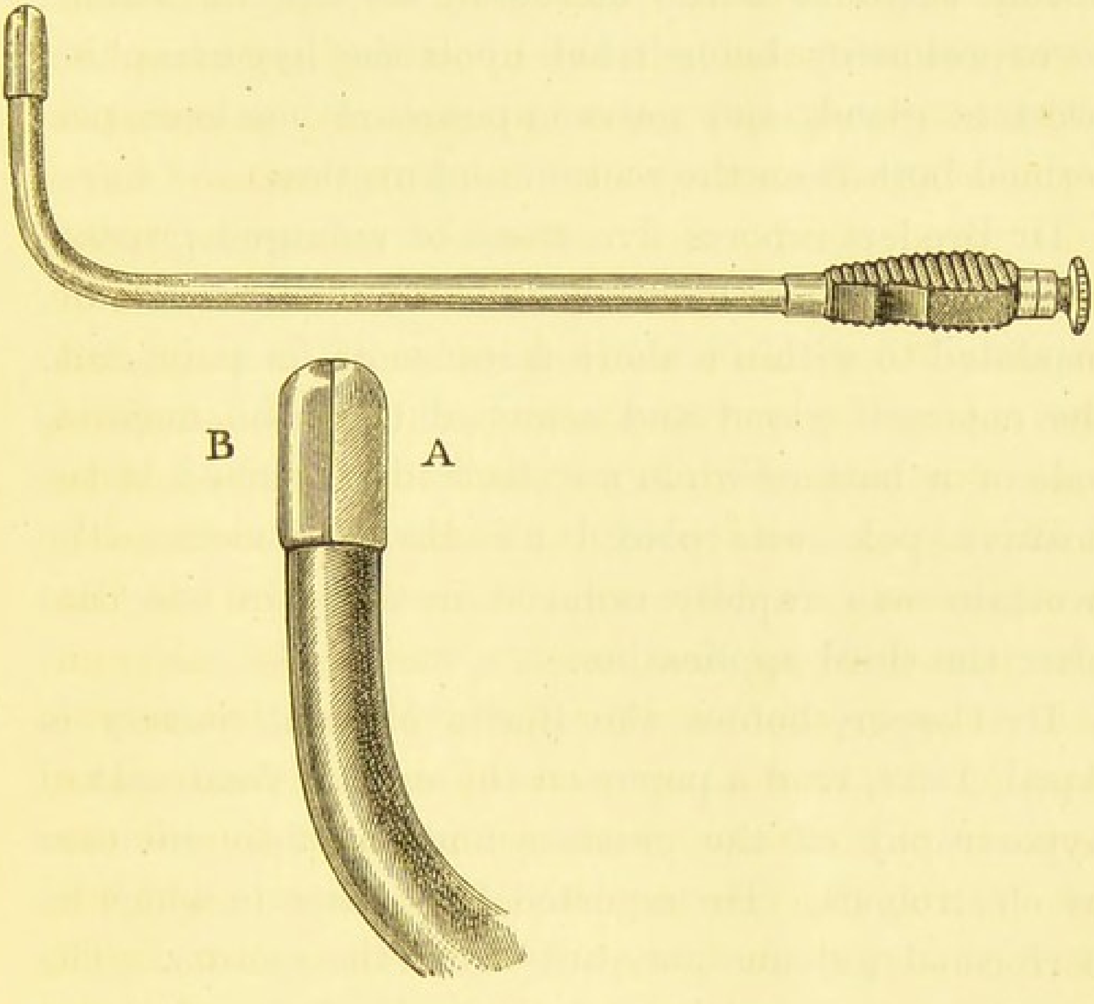
This conservative process I propose may be imitated by the means of electrolysis. For this purpose I have had some electrodes made after the manner of those used for the electrolysis of stricture, but instead of the ends being made entirely of metal I have had them made of ivory with phalanges of metal embedded in one side (see B, Fig. 27), so that the metal would be on the convex surface of the ends of the electrodes. By this means we insure that when the electrode has been passed along the urethra the metal phlange shall come in contact with the prostatic bar or obstructing hypertrophied part of the prostate. The electrode is connected with the negative pole of the battery, the positive pole being placed on some indifferent part of the body. The circuit is then closed and a weak current of five milliampères is employed; by this means a furrow or groove is made on the surface of the enlarged prostate by the action of the current.

I have only had an opportunity for using these instruments in one or two instances, and these not very bad cases, but the results have been such as to en-

* 'Lancet,' January 16th, 1888, p. 101.

courage the hope that this may prove a very useful form of treatment. The operation should not be pro-

FIG. 27.



longed for more than twenty minutes and on the first few occasions for about half that time unless the electrode passes into the bladder sooner. Should this be the case I would advise that all further attempts be suspended for at least a week, and then repeated if no indication to the contrary had arisen.

The mode of treatment by electrolysis above described is a much less serious procedure than that which has been more frequently tried. The success, such as it is, which has attended the treatment of fibroid tumours of the uterus by electrolysis has led to experiments being tried upon the hypertrophied prostate gland, and galvano-puncture has been performed both from the rectum and urethra.

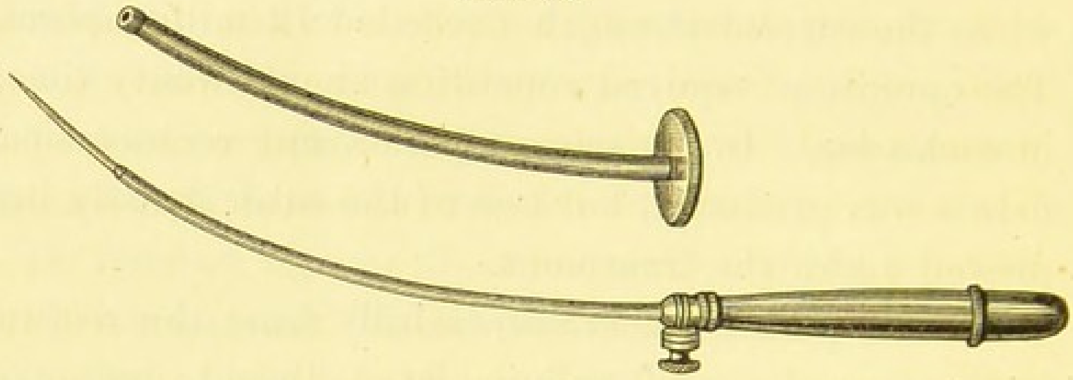
Dr Bredert reports five cases of enlarged prostate in which he used electrolysis. He thrust a needle, insulated to within a short distance of its point, into the enlarged gland and attached it to the negative pole of a battery while an electrode attached to the positive pole was placed on the abdomen. The prostate was rapidly reduced in size; in one case after the third application.

Dr Casper, before the Berlin Medical Society in April, 1888, read a paper on the radical treatment of hypertrophy of the prostate and prostatic tumours by electrolysis. He reported four cases in which he performed galvano-puncture from the rectum. The bowel was on each occasion previously washed out with a one per cent. solution of sublimate. After the insulated needle had been thrust into the prostate, at the end of five minutes it was partly withdrawn and then thrust into the gland in another direction, but no fresh hole was made through the rectum. This change in the direction of the needle was made again at the end of the second five minutes. The whole operation lasting fifteen minutes. The current strength used was from 10 to 25 milliampères. A slight burning and pricking was felt in the *glans penis* when the current strength exceeded 12 milliampères. The operation required repetition about twenty times in each case. In one case a permanent recto-vesical fistula was produced, but two of the cases greatly improved under the treatment.

I have operated most successfully from the rectum in the case of a small pedunculated fibroid tumour of the uterus attached to its posterior wall. *Per vaginam* it felt like a retroverted uterus. The tumour caused obstruction to defæcation. The patient could feel it fall back and obstruct the gut when she moved from the prone to the erect position, and also when straining at stool. It became impossible to pass any natural motion and it was necessary to continually take medicine to keep the dejections liquid. Under these circumstances, as life became almost a burden to the woman, I consented to perform galvano-puncture from the rectum. Every antiseptic precaution was employed. The rectum was syringed out with carbolic solution (1 to 80) before each operation; the instruments were immersed in carbolic acid solution, and after each operation of galvano-puncture the rectum was again washed out with the antiseptic fluid. The washings out were repeated every day for a week. The operation was performed three times. A trocar (Fig.

28), protected to within about an inch of its end, was passed into the rectum guided by the left fore-finger,

Fig. 28.



and the trocar was thrust into the most prominent and hard part of the tumour, any pulsating vessel having been previously sought for and avoided. A current strength of 20 to 30 milliampères was employed for seven minutes on each occasion. The trocar was made negative and the positive pole was applied to the abdomen through the intervention of a potter's clay electrode (see p. 128). Each operation was accompanied by some pain and throbbing, but not sufficiently severe to require an anæsthetic. A week after the first operation a puckered nodule could be felt on the tumour where no doubt the trocar had entered. Ten days later, at the date of the third operation, it was difficult to reach the tumour with the finger, it had become adherent to the wall of the rectum and had been raised higher up in the pelvis. An uneven surface could be detected at the site of the punctures. The peduncle of the tumour could still be felt from the vagina, but there was no feeling then as of a retroverted uterus. There had been no rise of temperature after any of the operations.

A month later the patient reported herself as quite well. There was no difficulty in passing the motions and the bowels acted regularly every day. The tumour could be felt diminished in size with its rounded surface flattened and the mucous membrane of the intestine adherent. This had produced the desired result—although the tumour had not much diminished in size it had altered in position and become adherent to the rectum, and the obstruction to defæcation had been removed.

Some such result might be hoped for in treating enlargement of the prostate from the rectum by electrolysis. With a current less severe than that which would produce suppuration in the gland we might set up adhesive inflammation sufficient to make the prostate become adherent to the bowel and by this means its position might be so altered as not to obstruct the orifice of the urethra. Such an operation is certainly worthy of trial, for with careful antiseptic precautions it does not appear that the patient runs any great risk.

Dr Robert Newman, of New York, who has treated stricture of the urethra so successfully by electrolysis does not employ it in the treatment of enlarged prostate but uses in preference the galvano-cautery.

DISEASES OF WOMEN*

The number of caustics and agents used for cauterisation in gynæcological practice is extremely numerous, but no decision has been arrived at as to their relative values. No doubt physicians and surgeons have their own reasons for preferring one agent rather than another, but there appears to be no detailed account of the actual effect which each agent has upon animal tissue.

What are the relative values of nitric acid, chromic acid, nitrate of silver, potassa fusa, potassa fusa cum calce, and other caustics that we use? For what reasons do we decide to use the actual cautery, Paquelin's thermo-cautery, or the galvano-cautery? Mr Robert Ellis, in a paper read before the Obstetrical Society in 1861, said that "cauterising agents have a different ultimate value, and that sufficient regard had not been

* A large portion of the matter contained in this section was written for a paper "On the Use of Electrolysis in Gynæcological Practice," read before the Obstetrical Society of London, June 6th, 1888. *Vide* 'Obstetrical Society's Transactions,' vol. xxx, p. 229.

paid to that fact in determining the nature of the caustic selected by the obstetrician." He goes on to say, "Some caustic substances are found to produce a sore of greater, and some of less vitality, a result by no means explicable simply by referring to the different chemical nature of these substances. The character impressed by the cauterising agent on the living tissue differs to a greater or less extent in each case. That resulting from the actual cautery" shows a "very remarkable contractility in the process of healing and afterwards. The cicatrix of a burn, built up of cells of feeble vitality, shows a singular inaptitude for extension, and after a time contracts in a very remarkable manner. It might be conjectured that this result—observed in no other instance to the same degree—is due to the nervous shock communicated to the living structures by the burning substance, and ultimately affecting the nutrition of the newly-formed parts." The nutritive changes are no doubt really due to the destruction of the ends of the nerves; this also accounts for the smaller amount of pain which follows operations performed by the galvano-cautery when compared with those performed by the knife.

It has often been stated that caustic potash produces a less contractile scar than any other caustic, but I cannot find any authoritative grounds for the assertion; I do not deny that such is the case, but I cannot find that the fact has been proved. It may be said that the opinion rests upon clinical observation. Dr Matthews Duncan says that there are no grounds whatever for saying that the scars produced by caustic potash are less retractile than any others, but I believe most gynæcologists prefer in practice caustic potash or potassa cum calce, although it is not determined on what grounds that preference is based. Dr Galabin says that the best potential cautery is the potassa fusa cum calce because it is less superficial than nitric or chromic acid, while its action is more easily limited than the potassa fusa or chloride of zinc. All the good effects of the caustic alkalies can be obtained by the use of an electrode connected with the negative pole of a continuous current battery without any danger to the surrounding parts, and with the extent of its action absolutely under the control of the operator.

I can remember a controversy some ten or twelve years ago on the value of nitric acid so extensively used by Dr Lombe Atthill, of Dublin, in gynæcological practice. An objection was raised against its use on the ground that it produced a hard, dense, and contracted cicatrix. Dr Duncan says that the opponents to the use of nitric acid as employed by Dr Atthill had no grounds for saying that it produced more contraction,—they could not ascertain that fact, as the acid was applied to the internal surface of the uterus for endometritis.

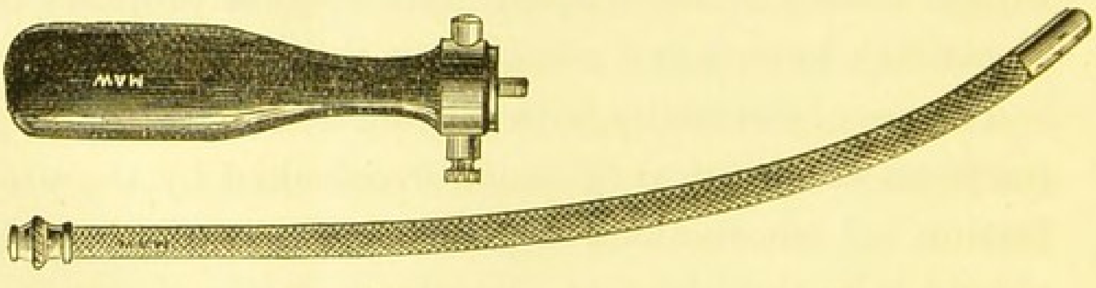
Paquelin's cautery, galvano-cautery, and cautery irons, require the presence of an assistant, and therefore cannot be well used at all times in the consulting room; and they all produce the disagreeable smell of burnt flesh, which is an objection when the operation takes place in a private house. The Paquelin's cautery and cautery irons have to be kept hot, and when used are introduced hot into the vagina. The heat cannot be diminished and raised at pleasure as with the galvano-cautery. If a wire loop is used with a galvano-cautery battery it can be placed *in situ* around a growth or other substance it is wished to remove before the circuit is closed. The amount of heat can be regulated, and its action commenced and arrested at the will of the operator. These details are under his control in a more thorough and complete manner than with any other form of cautery known to surgery.

The use of galvano-cautery in uterine surgery is an extensive enough subject to deserve a paper entirely devoted to its discussion. I have here to restrict myself mainly to the employment of that property of electricity known as "electrolysis."

The use of electricity both for caustic and cauterising purposes has been very much overlooked by the profession. I am inclined to advocate that electrolysis should take the place of all other caustics in gynæcological practice for the same reasons that galvano-cautery should take the place of all other cauteries. Electrolysis finds its widest field for usefulness in internal parts—situations that are difficult of access, and where it is wished to apply caustics or other local applications. Hence its frequent employment in the treatment of stricture in various regions, and in those diseases of women in which local applications are necessary. It is a more efficient and elegant way of applying caustics than any other that we possess. It can be most accurately localised at the part that it is wished to affect ; the amount used and the extent of tissue to be destroyed can be regulated to a nicety; and its action can be arrested at any moment at the will of the operator, the slight pain ceasing immediately the current is cut off.

Stricture of the Urethra.—For stricture of the female urethra, as in the male, a bougie electrode is used of a size larger than the largest one that can be passed. It is of no consequence of what the metallic end of the bougie is made, for it is used with the negative pole

Fig. 29.



of the battery, and when withdrawn from the urethra is as bright as when introduced. A flat electrode connected with the positive pole is placed on some indifferent part of the body. The bougie electrode is passed until arrested by the stricture, against which it is held without any appreciable pressure, but sufficient to enable it to pass into the bladder when the obstruction has melted away from before it. When the bougie-electrode is in its place against the stricture the circuit is closed, and a current of the strength of about five milliampères is allowed to pass for five, ten, or fifteen minutes, or until the obstruction is overcome. No anæsthetic is necessary, as a patient's own feelings are a guide to some extent as to the strength of the current to be used. If five milliampères cause pain the strength of the curreut can be reduced by taking one or two cells out of the circuit. Directly the bougie electrode has passed into the bladder the current must be broken, and the electrode removed. No further interference with the urethra should take place for ten days or a fortnight, and then most probably, instead of there being recontraction, as is usually the case when strictures are treated by dilatation, it will be found that bougies two sizes larger than the electric one at first used will pass easily into the bladder. If the urethra is still of a smaller size than it naturally should be, the operation has to be repeated commencing with a bougie electrode one size larger than the improved calibre of the passage will then admit.

In the same way stenosis of the os uteri or cervical canal can be treated by electrolysis for the relief of dysmenorrhœa and sterility instead of incisions or by the tents and dilators now usually employed. The treatment by electrolysis takes a much shorter time, requires less frequent visits of the patient, and the result is more permanent.

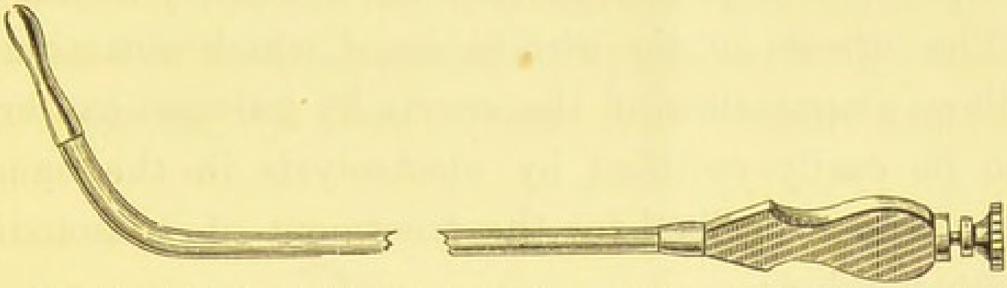
I will not enter into the question as to whether or not stenosis is the cause of the painful menstruation, but a common mode of treating the affection even by the opponents of the obstructive theory, is to dilate the os uteri. With electrolysis no previous dilatation is necessary and therefore the operation can be done much more easily and comparatively without the slightest pain. No doubt after the operation the cervical canal is larger from the chemical action which takes place around the electrode.*

A uterine sound adapted for connection with a battery is used with the negative pole, a pad being placed on the back or thigh as in cases of stricture of the urethra. The sound must be encased in some insulating substance to within an inch or an inch and a half of the extremity, and can then be used without a speculum and without injuring the walls of the vagina

* 'Lancet,' Sept. 18th, 1886, p. 559.

or the vulva. It is usually only necessary to apply the electrode to the uterine canal for about two or three

FIG. 30.



Uterine Electrode for Electrolysis, used in the treatment of chronic cervical catarrh, dysmenorrhœa and sterility, &c., in place of caustics, tents, and dilators usually employed.

minutes, and the gain in calibre remains permanent. Different sized sounds, of course, are necessary according to the size of the os when the operation is commenced. About five milliampères will usually be found a current of sufficient strength, although stronger currents can be borne without pain in this situation than in the urethra. For the membranous variety a stronger current has to be used and if possible the whole of the internal mucuos membrane of the uterus touched with the electrode. This is therefore not such a simple operation as for spasmodic dysmenorrhœa. The patient has to be more or less undressed so that a large surface electrode may be placed upon the abdomen. The current strength used should approach as nearly as possible to 100 milliampères, and the time occupied by the application should be prolonged by a minute or two.

In most other forms of treatment that have been adopted it is necessary to previously dilate the os uteri. This is not necessary in treatment by electrolysis and an operation requiring chloroform is thereby avoided.

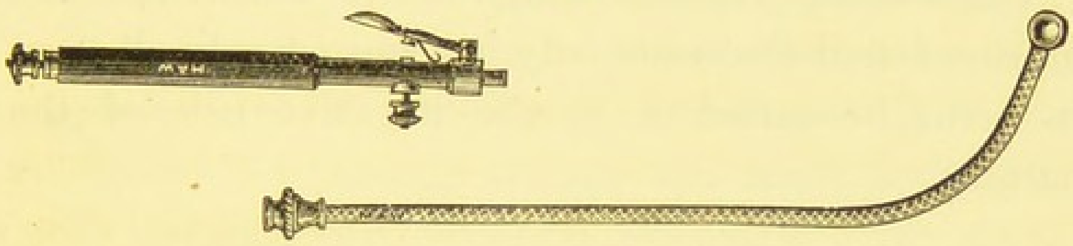
The *atresia of the uterine canal* which sometimes follows amputation of the cervix by galvano-cautery can be easily rectified by electrolysis in the same manner as described for the treatment of spasmodic dysmenorrhœa.

Menorrhagia :—Menorrhagia can be treated most successfully by intra-uterine electrolysis in the same way as membranous dysmenorrhœa, but the electrode used internally must be made positive. The current strength to be used should be about 100 milliampères and the applications are made every four to seven days. Good results are obtained in the relief of this symptom in the treatment of fibroid tumours by Apostoli's method which will be described later on.

ABRASION OF THE OS UTERI

Perhaps the most common affections for which gynæcologists resort to the use of caustics, and caustics of all sorts and descriptions, are abrasions of the cervix uteri, chronic cervical catarrh, and leucorrhœa. When one caustic does not succeed another is tried. As I have said before, electrolysis is a more elegant and efficient way of applying caustic to internal parts than any other we possess. It destroys unhealthy surfaces and promotes healing in a more reliable manner, and its action can be more easily regulated. For abrasion of the cervix I have used an electrode with a rounded end similar to that used for faradising the vocal cords. This electrode is at-

Fig. 31.



tached to the negative pole of the battery; the pad connected with the positive pole having been previously moistened in salt and water is placed on some indifferent part of the body. A speculum having been introduced, and the abraded surface brought fully into view, the metallic knob of the negative electrode is lightly moved over the unhealthy surface with a current strength passing of about five milliampères. A white froth resembling fine soapsuds is formed wherever the electrode touches. This froth is alkaline to test paper. All the unhealthy surface will usually be sufficiently destroyed in about two or three minutes. The electrode is then withdrawn, and all chemical action and the slight tingling produced ceases at once. There is no after-pain. If the erosion appears to extend up the cervical canal then a uterine sound electrode (Fig. 30) as already described is passed into the canal for about a minute or a minute and a half. Two or three applications of the battery in this way will often make an abraded surface heal which has for months, or sometimes years, resisted all other modes of treatment.

For *chronic cervical catarrh* and *leucorrhœa* the uterine sound electrode only is required. In all cases it is to be attached to the negative pole of the battery.

UTERINE FIBROIDS*

The treatment of fibroid tumours of the uterus by electrolysis was practised before 1878 by Dr Ephraim Cutter, of New York, and the results reported to the American Medical Association. A *résumé* of the cases can be found in the 'London Medical Record' of August 15th, 1878. Other cases were reported in the same year by Dr J. M. Freeman, and this mode of treatment has since been attempted from time to time by other surgeons in America, on the Continent, and in our own country, but has never been widely adopted. Recently this mode of treatment has again

* This section on the "Treatment of Uterine Fibroids by Electrolysis" was published in advance in the autumn of 1887.

been revived by Dr Apostoli, of Paris, who has modified and improved the manner of performing the operation. He has devised a large surface electrode, made of potters' clay, which is placed over the abdomen of the patient and adapts itself closely to the skin; by this means a stronger current can be employed than was formerly the case, except when needles attached to both poles were thrust into the tumour. Needles or trocars are now only used when it is found to be impossible to introduce the internal electrode into the uterus through the cervical canal, and experience has gradually led to the punctures being made less frequently, less deep, and the duration of the flow of the current much shorter than used formerly to be the case. The current that is used is also weaker than when needles attached to both poles were employed. From all these causes the operation is much less frequently disastrous. By the means at present adopted an amount of success has been achieved which has caused the treatment of fibroids of the uterus by electrolysis to be well recognised, and led to its adoption by many physicians and surgeons. The technical knowledge required and the expense of the batteries and apparatus will no doubt limit its employment to a great extent to those who make electricity a more especial study, and to patients who are in a position to pay for a costly and elaborate operation which, of necessity, has to be frequently repeated. But it has been demonstrated that electrolysis when properly performed is the most successful way of dealing with fibroid tumours short of their actual removal by abdominal section. The tumour seldom entirely disappears, but the diminution in size is sufficient, and the relief of distressing symptoms is so marked that few would be willing to subject themselves to the risk of an abdominal section for the removal of a tumour when so much benefit can be derived from a comparatively safe and almost painless operation.

By the theory of Grotthüs electrolysis consists of a series of decompositions and re-combinations transmitted from one molecule to the next as if by a chain across the electrolyte, no appreciable change taking place except at the incidence of the respective poles; the electro-positive elements are liberated at the negative pole and the electro-negative at the positive pole. This may be true of simple compounds, but in a complex material such as that of which the human body or a fibroid tumour is composed, it is hard to believe that no change whatever takes place through the intervening tissue when a current of electricity is passed, but only at the surface of the electrodes. It would seem from clinical observation that by the passage of an electric current adventitious tissues which have been deposited are changed into a condition which allows of their being re-absorbed. This re-absorption will continue for several days after a strong current has been used.

The denser the structure traversed by the current the less capable of re-absorption is it rendered. It must be borne in mind that during the passage of a current of electricity there is no doubt that the ordinary osmotic action which is continually going on in living animal tissue is accelerated in the direction from the positive to the negative pole.*

A Stöhrer's battery (see p. 30) is the best to use for the electrolysis of fibroids, because the electro-motive force is high and the internal resistance low, and polarization does not take place to such an extent as in many other forms of battery. A battery of thirty cells will be found sufficient, and when the cells have been freshly charged and the plates newly amalgamated it will seldom be necessary to bring more than eighteen or twenty-two cells into the circuit to give a current strength of 100 milliampères when the external large surface electrode of potter's clay is used for covering the abdomen.

Leclanché batteries are also used for this operation, but more cells are required, on account of their lower electro-motive force and greater internal resistance, and the number has to be gradually increased to keep up the required current strength, on account of the rapid increase of the internal resistance which takes

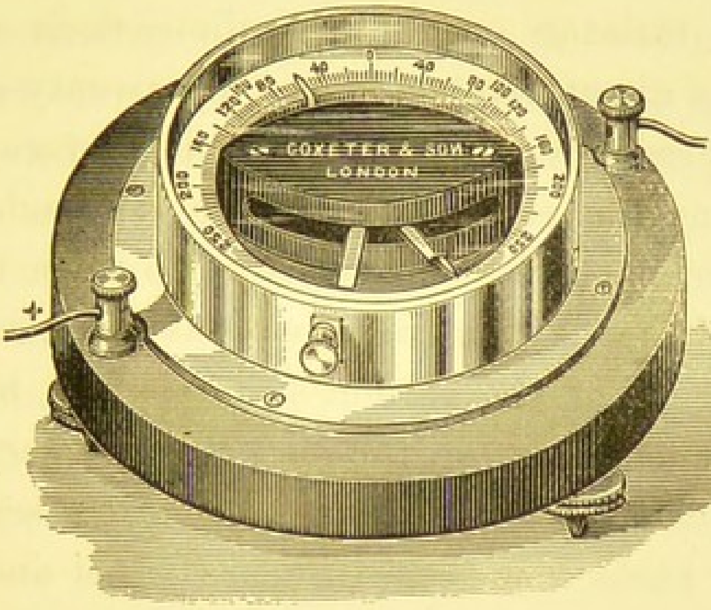
* See 'Electricity and its Manner of Working in the Treatment of Disease,' a thesis for the degree of M.D., by W. E. Steavenson, pp. 24 and 25: J. & A. Churchill, London, 1884.

place in consequence of polarization. A Leclanché battery is more portable than a Stöhrer's, and therefore can be more easily taken to a patient's house.

The *current strength* is regulated by a galvanometer. The one used by Dr Apostoli is horizontal, and graduated so as to indicate at least 250 milliampères. A vertical galvanometer, as made by Dr. Stöhrer, can also be used, and will register a current strength of 1000 milliampères (or one ampère). A Stöhrer's galvanometer possesses a marked binding screw, which must always be connected with the positive pole of the battery, and then, by lifting the right-hand peg, a resistance of about 100 ohms is introduced into the circuit, and the needle swings to the left and will register up to 40 milliampères. If the middle peg is removed as well as the right-hand one, a resistance of nearly 1000 ohms is introduced into the circuit, and much smaller currents can be easily registered. To detect strong currents, such as are used in the electrolysis of fibroids, it is necessary to keep the middle and right-hand pegs in their proper holes and to remove the left-hand peg, the needle then swings to the right; the graduated spaces each indicate 100 milliampères, and extend up to 1000.

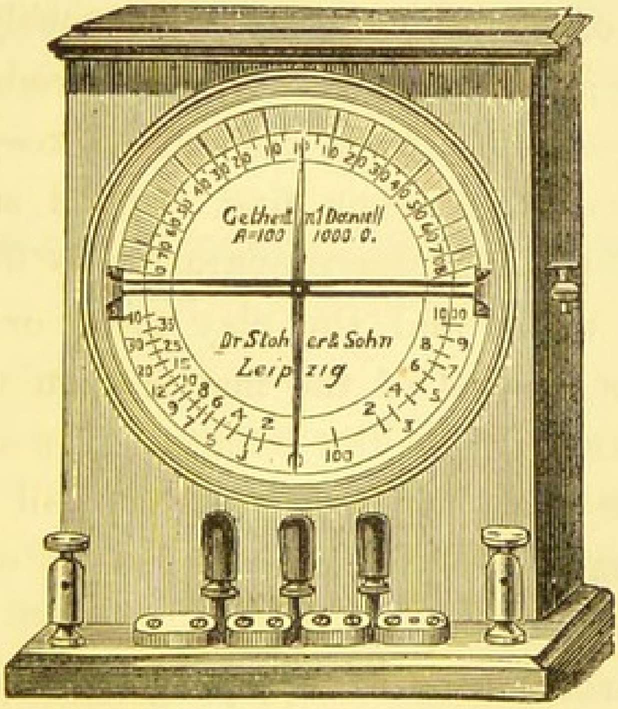
The potter's clay electrode introduced by Dr Apostoli, and which is used as the external electrode for covering the abdomen of the patient, is prepared by moistening the clay to the consistency of soft

FIG. 32.



Gaiffe's Galvanometer.

FIG. 33.



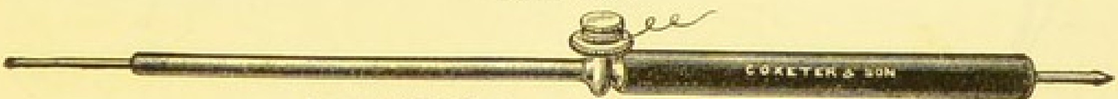
Dr Stöhrer's Galvanometer.

putty and spreading it out half an inch thick on a piece of tarlatan or net, the dimensions of which should be about twelve inches by twenty-six. The clay is spread over about half this surface, that is, about nine inches by twelve, the remainder of the tarlatan or net is folded over so as to cover the upper surface of the clay, and to prevent as much as possible the smearing of the patient's clothes. A hole is cut in the upper layer of the net, and a piece of soft metal, such as tin, possessing a binding screw upon its upper surface, is passed under the net and allowed to rest on the surface of the clay. To the binding screw is attached one of the rheophores leading from the battery. No more convenient electrode has as yet been devised that will adapt itself so closely to the inequalities of an abdomen often enormously distended by a tumour; but the potters' clay electrode has many disadvantages—it is very difficult to keep it warm, and therefore often when first applied strikes very cold to the patient; its preparation is disagreeable and messy work, and the clay more or less oozes through the meshes of the material on which it is spread, and adheres to the patient's skin and clothes. Some better form of electrode that will diffuse the current equally over a large surface is much to be desired.

The electrodes used for applying the current internally are of different patterns, according to the description of tumour that is to be dealt with, and whether or not a sound can be passed into the uterus through the os and cervical canal. In the former methods of treating fibroid tumours by electrolysis, galvano-puncture was practised much more frequently than is now the case. Many of the punctures were made through the abdominal walls, and careful directions were given, in descriptions of the operation, as to how the needles were to be introduced and removed. The former operations were from this cause much more serious and risky, and on the whole, even when no unfavorable symptoms occurred, were not so satisfactory in their results as these operations are at the present day.

When it is possible to pass a sound into the uterus Dr Apostoli uses a platinum rod about a foot long, blunt at one end and pointed as a trocar at the other.

Fig. 34.

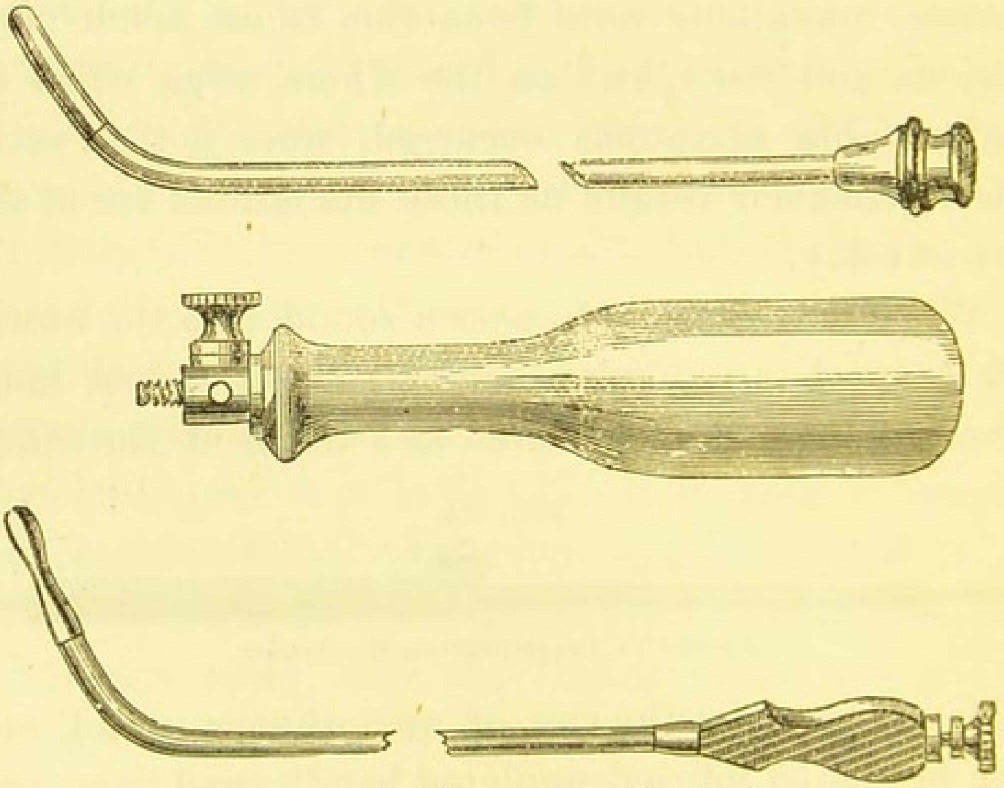


Apostoli's Intra-uterine Electrode.

This rod is about the size of an ordinary sound, and can be passed into a cannulated handle, and fixed by a screw swivel on its side. Either end can be thus fixed according to the requirements of the operation. At first the whole rod was made of platinum, but now the trocar half is made of steel, as steel takes a better point, is not so expensive, and can be used equally as well as platinum with the negative pole—the pole always employed when galvano-puncture is practised. A vulcanite or celluloid sheath is used to protect that part of the sound electrode that is in the vagina or against the vulva.

The electrode used by the author is much more flexible. It consists of a copper wire insulated by a No. 5 or 6 English gum elastic catheter. The last

Fig. 35.



Steavenson's Intra-uterine Electrodes.

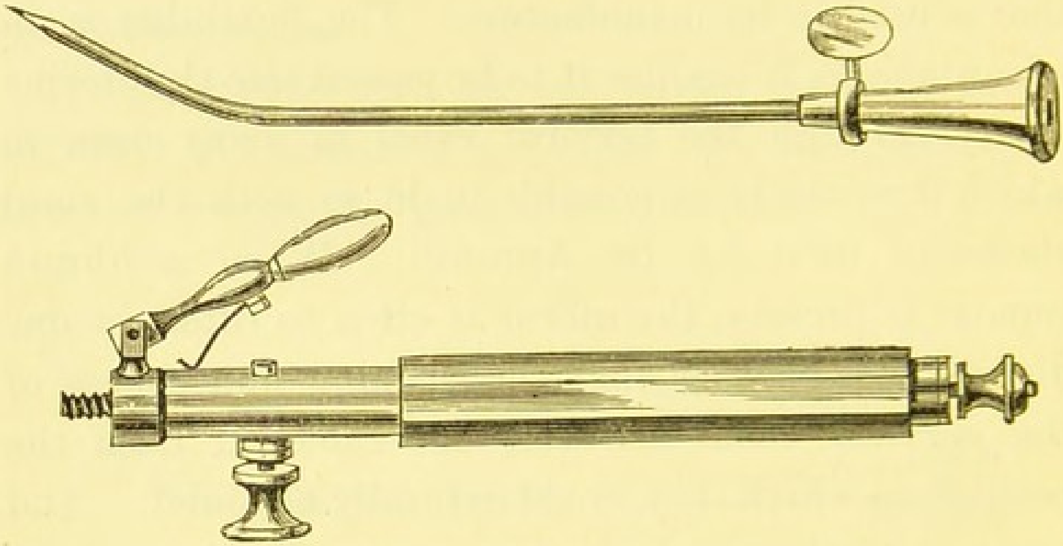
inch consists of a piece of platinum of the same size as the catheter, welded on to the end of the copper wire. The electrodes are made so that they can be used with an ordinary handle, or are provided with a

Brodie's handle possessing a binding screw, to which can be attached the other rheophore leading from the battery. This form of electrode is very much less expensive on account of the smaller amount of platinum that is used in its manufacture. The flexibility is an advantage, as it enables it to be passed into the uterine cavity through the cervical canal in many cases in which it would be impossible to do so with the rigid electrode used by Dr Apostoli. When a fibroid tumour is present, the uterus is often so tilted in one direction or another that the opening and course of the cervical canal are very far removed from the position in which they would naturally be found. And again, with the celluloid or vulcanite sheath used by Dr Apostoli it is almost impossible to shield that part of the platinum rod which is in contact with the cervical canal and os uteri. With the more flexible electrode it is quite easy to get the unprotected end of the platinum well within the uterine cavity; the gum elastic part of the stem only being in the cervical canal.

The needles for puncturing the tumours are made of platinum or steel of the shape shown in the diagram (Fig. 36), and are fitted on to a handle. They are intended to be used with a speculum, but might be used without if the greater part were insulated, leaving only about an inch of the metal bare at the end (see also Fig. 28, p. 110).

Before commencing an operation the size of the tumour should be accurately gauged and measured, so

FIG. 36.



that comparison can be made during the course of the treatment, or when sufficient relief has been obtained so as to render its continuance unnecessary. In this relationship it must be remembered that in the great majority of cases, and especially in women of about middle age, as the distressing symptoms are relieved and the general health improves, there almost invariably takes place a deposition of subcutaneous abdominal fat, which would seriously invalidate the measurements if not taken into consideration. The capacity of the uterus, as evidenced by the distance to which a sound can be introduced, is one of the best guides as to increased or diminished size. The other most important measurements to be taken are :

From the tip of the xiphoid cartilage to the centre of the umbilicus.

From the xiphoid cartilage to the symphysis pubis.

From the umbilicus to the symphysis.

Girth at umbilicus.

From one anterior superior spine to the other.

From the right anterior superior spine to the umbilicus.

From the left anterior superior spine to the umbilicus.

If the tumour is at all prominent, additional measurements may be made:

From the tip of the xiphoid cartilage to the highest part of the tumour.

Girth over the most prominent part of the tumour.

From the highest part of the tumour to the symphysis; and, if possible, the greatest width and length of the tumour taken with calipers.

After electrolysis has been performed several times, both the size and shape of the tumour will be found to be altered.

The Operation.—The vagina should be syringed out with an antiseptic solution, such as dilute carbolic acid (1 in 80), and the patient placed in the dorsal position on a couch or operating table, with the buttocks brought well down to the edge. If the table does not possess supports for the feet a couple of chairs should be placed on which the feet can rest. The abdomen of the patient should now be uncovered and sponged with warm salt and water, or a warm $2\frac{1}{2}$ per cent. solution of chloride of zinc. This helps to reduce the resistance of the skin. A large surface electrode of potters' clay should now be placed upon the abdomen and pressed gently with a towel so as to make it adapt itself perfectly to the skin. Should there be any scratch, abrasion, or acne spot on the abdomen it should be first covered with a small piece of oil-silk or plaster before the electrode of potters' clay is applied, as any such imperfection in the cuticle offers less resistance to the passage of the current, and, as the strength is increased, would cause great pain, so that the patient would not be able to bear such strong currents as she otherwise would.

The electrodes, needles, or trocar, intended for internal application, as well as the handles to be used with them, should be placed by the side of the operator in a porcelain dish containing an antiseptic solution. The operator should place himself between the thighs of the patient, and having rinsed his hands in the antiseptic solution, should introduce the forefinger of the left hand into the vagina and seek for the os uteri. Should he be able to reach it, the sound electrode (Fig. 35) is passed along the finger, already in the vagina, and its end tilted up so as to make it enter the cervical canal. If possible, the internal electrode should always be passed into the cavity of the uterus, but in some cases it is accomplished with great difficulty, and occasionally is altogether impracticable, on account of the uterus being tilted and displaced by the size and weight of the tumour; but every manœuvre should be practised by which a sound can be introduced. The os can sometimes be pulled down by a hook, or pressure on the tumour through the abdominal wall will so alter the direction of the uterus that an electrode can be passed into the canal. The employment of the more flexible electrode is in these cases a great advantage. With the index finger in the vagina, the end of the electrode, when it reaches the os, can very often be turned so that it enters the aperture.

In the majority of cases the internal electrode should be attached to the negative pole of the battery, for instance, when the tumour is of a dense and fibrous nature, accompanied by dysmenorrhœa, amenorrhœa, or the ordinary pressure and bearing-down symptoms due to its size and weight, or when reflex neurotic symptoms predominate. When the tumour is of a soft and more vascular nature, and inclined to be associated with menorrhagia, then the internal electrode should be attached to the positive pole on account of its hæmostatic action. When used with the positive pole the metal, intra-uterine portion, of the electrode should be made of platinum, because of all metals it is the least oxidisable. With the negative pole any metal may be employed, as the current does not then oxidise, and the electrode will be removed from the uterus with the metal portion as clean and bright as when introduced. When it is found necessary to puncture the tumour, for instance in those cases when a sound cannot be introduced, the needle or trocar is attached to the negative pole, and, as far as the current is concerned, may be made of any metal. Steel takes the best point, and is, therefore, the metal usually preferred.

The needles are most frequently employed with the object of making an artificial passage into the uterine substance, which is subsequently used for the introduction of the sound electrode; but sometimes punctures are made into dense hard tumours, when it would be quite possible to introduce an electrode through the cervical canal, so as to expedite the process of disintegration. Sometimes the punctures are used in conjunction with the intra-uterine application. All the punctures are made from the vagina, and into the most prominent part of the tumour, or into that part which will lead most readily to the uterine cavity, of course taking care that the needle does not injure any neighbouring parts, such as the bladder or Douglas's pouch, or enter into any large vessel which might be indicated by the presence of pulsation. The punctures are not made so deep as formerly, but now are usually only about half an inch in length. They may or may not communicate with the cervical canal or uterine cavity; if not, the channels made may be used for subsequent introductions of the electrode when the current is employed, or fresh punctures may be made from time to time on "suitably presenting parts of the tumour."* The punctures are made through a speculum when the needles are used; with Dr Apostoli's trocar (fig. 34) a speculum is not necessary. The needle or trocar is allowed to remain in the puncture for about five minutes, and 100 milliampères is the current strength which most patients can bear.

The actual cautery has not infrequently been used in the treatment of hypertrophied cervix, and by Dr Greenhalgh to favour the enucleation of fibroids; the puncture and production of a hole in the cervix uteri by electrolysis is in no way a more dangerous proceeding. The application of electrolysis is itself antiseptic, but in order that no precaution may be omitted, it is usual to have the vagina syringed out with some antiseptic solution both before and after the operation. When it is necessary to perform galvano-puncture this precaution is perhaps the more desirable.

When everything is ready and in position,—that is, the potters' clay electrode accurately adapted to the skin of the abdomen and connected with the positive or negative pole of the battery according to circumstances; the internal electrode selected and placed in

* Dr Apostoli's paper read at Dublin, Aug., 1887, 'Brit. Med. Journ.,' Oct. 1st, 1887.

position and connected with the other pole; and the galvanometer arranged so as to be included in the circuit,—the circuit is closed, and the current gradually increased in strength without any break. If when strong it gives rise to any complaint on the part of the patient, the strength must be gradually reduced again by eliminating one or two cells from the circuit, but the patient must be encouraged to bear as strong a current as she can. It will often be found that at the first application a current of more than 70 or 100 milliampères cannot be tolerated. On subsequent occasions the current can be borne stronger, and sometimes reaches as high as 250 or 300 milliampères. Anything over 100 may be considered quite strong enough to obtain results in cases of non-galvano-puncture. The time occupied by each application varies from five to eight or ten minutes. The current should be gradually reduced in strength, cell by cell, in the same way as it was increased, and the greatest care taken not to produce any shock which would be the result if the circuit were suddenly broken.

It is as well that the patient should remain in bed and quiet for twenty-four or forty-eight hours after the first application, and on subsequent occasions if there be any pain or tenderness of the abdomen; but generally a patient may, after an hour or two's rest, walk about, and on the following day pursue her usual occupation.

The resistance the patient offers to the current varies very much with the condition of the skin at the time of the application, and with the size and moisture of the external electrode. In one case, when a current strength of 140 milliampères was used, and given by 10 cells of a Stöhrer's battery, the resistance was calculated to be about 130 ohms. In another case, with a current strength of 120 milliampères from 16 cells, the resistance was about 225 ohms. In each case the electromotive force of the battery was taken by a voltmeter previously to the operation. In some American cases the resistance offered has been reported as low as 60 ohms; this seems almost incredible, but is probably true if the current used in any way approached in strength those recorded, viz. 500 to 1000 milliampères.

The number of applications of the current that are necessary will vary with the character of the tumour. For bleeding fibroids four or five applications are sometimes sufficient to obtain relief, although the majority require ten or twelve. Hard, dense fibroid tumours diminish in size very slowly, and may require as many as thirty applications of intra-uterine electrolysis. It is difficult to fix any exact time at which the applications should be discontinued as the tumours seldom disappear entirely. When the patient has been relieved of all distressing symptoms and the tumour is reduced sufficiently in size to cease to be an annoyance through its bulk and weight, the applications may be reasonably stopped, or only had recourse to occasionally, should any symptom return to justify it.

The frequency with which the applications should be made is also a matter which depends upon various circumstances, such as the nature of the tumour, convenience, menstruation, the effects produced, and other conditions. In some cases the applications may be made as often as twice a week, or every four days, in others intervals of ten days or a fortnight may be necessary.

The great danger inseparable from abdominal section and the uselessness of all medicinal treatment for the removal of uterine fibroids, makes this mode of treatment by electrolysis the more acceptable and of greater importance. There are few fibroid tumours which do not cause some inconvenience, and more or less distressing symptoms. In some cases they render life almost intolerable;—the ever constant weight and dragging pain; the interference with digestion, defæcation, and sometimes with micturition; the reflex neurotic symptoms and depression; the ever constant ill-health with exacerbations at the ordinary monthly periods, sometimes with downright acute pain or profuse hæmorrhage, which incapacitates the patient for several days or a week; the drain on the vital powers produced by this incessant pain and sometimes constant loss of blood; all these call for some relief beyond the usual exhortation to wait for the menopause or a useless visit to Kreuznach or Horncastle. Enucleation is often impracticable, and is never unattended with danger. In electrolysis we have a means of relief, the application of which is not difficult to those who understand the medical and surgical uses of electricity. It is not unduly painful. It is, if properly applied, practically free from danger. If the tumour is not much reduced in size the distressing symptoms are almost invariably relieved, and the patient's health improved, and she is not in a worse condition for more heroic measures, should they be deemed advisable, than before the application of electricity. The treatment is spread over rather a lengthened period of time, but after the first or second application no enforced confinement to bed is necessary or imposed upon the patient.

In the St Bartholomew's Hospital Reports for 1888 I have given the details of "thirty cases of Fibro-myomata of the Uterus treated by Electrolysis." Twenty-three of these cases were benefited by the treatment. In eight the result may be described as very good; the patients having greatly improved and the tumours diminished in size. Fifteen may be said to have improved, the symptoms being relieved. In one of these cases the tumour was larger at the end of a year, but the distressing and exhausting symptom of loss of blood, for which treatment was primarily sought, was relieved and has not recurred. In one case the tumour was extruded from the os and removed by the écraseur. In one case the occurrence of pneumonia cut short the treatment. Two cases of the fifteen were improved at the time they left the Hospital, but have not been heard of since. In four cases no improvement took place. Two improved while under treatment, but relapsed. One case ended fatally by ulceration taking place into a large vessel. Such a catastrophe could hardly be anticipated or guarded against, but the possibility of its occurrence must be taken into account when weighing the relative value of this mode of treatment. Uterine fibroids resent interference. In more than one case already reported, enucleation has been induced by the application of electrolysis—not altogether an unfortunate occurrence if the patient makes a good recovery; should the reverse be the result, the electricity has to bear all the blame of the misfortune. The tumours do not disappear so rapidly or so completely as we have been led to expect, or perhaps as British gynæcologists supposed would be the case. I do not think that the electrolytic treatment will supplant the necessity for abdominal section or removal of the uterine appendages in such cases as those in which these operations would be appropriate, but I do think that in the use of electricity we have a means of treating fibroid tumours which is superior to any we have formerly employed, short of their entire removal. I have treated a large number of cases, and in nearly all the symptoms have been relieved, in many the tumours have decreased in size, and in some the decrease has been considerable. The hæmorrhage has usually been arrested; the dysmenorrhœa has been relieved; the pain and discomfort have decreased; the rectal and bladder troubles have also been lessened, and the patients are able to get about and walk with much less difficulty. All these favorable symptoms are probably due to the relief from pressure caused by a slight diminution in the size of the tumour. Nearly all the patients I have operated upon have expressed themselves as feeling better—better in health and better in spirits. In those whose tumours were accompanied by menorrhagia no doubt the improvement in health was greatly due to the arrest of the hæmorrhage. That adventitious tissue does decrease and get reabsorbed under the electrolytic treatment I feel sure, and have been able to observe it in several cases of stricture of the urethra.

Hypertrophy of the Cervix.—This affection has often been treated successfully by electrolysis, and sometimes when other means have failed. One or two needles connected with the negative pole are thrust for about half an inch into the hypertrophied tissue and a current strength of eight to ten milliampères used for five to eight minutes. The positive pole is placed on the abdomen, or, if the patient is on her side, on some indifferent part of the body. This operation can be performed twice between each menstrual period, not fixing an operation too near them, and allowing ten days or a fortnight to elapse between the applications of electricity.

Fungoid growths may also be destroyed by electrolysis by employing the galvano-puncture.

Attempts have also been made to encourage re-absorption in *Ovarian cysts* by means of galvano-puncture, but the results collected and published by Dr Paul F. Mundé, of New York, are not very encouraging.* The deaths following the employment of electrolysis were 17·6 per cent., and the cures only 55 per cent.

Electrolysis has also been used to reduce the thickening which sometimes remains after inflammation of the cellular tissue included in the pelvic folds of the peritoneum (*pelvic cellulitis*). Interference by electricity in the acute stage is to be deprecated, although it has been advised by some authors.

Negative galvano-puncture is performed sometimes into the thickened mass and sometimes into the enlarged uterus or hypertrophied cervix. Chloroform is not as a rule necessary. A previous injection of morphia may be employed to allay apprehension and

* "The Value of Electrolysis in the Treatment of Ovarian Tumours," by Paul F. Mundé, M.D., New York, 'Gynæcological Trans.,' 1878.

quieten the patient. The strength of the current used must be regulated by the feelings of the patient, and may vary from 50 milliampères even up to 250. The higher currents cannot as a rule be used without an anæsthetic. The time occupied at each application of electricity should be from five to eight minutes; and the applications should be made midway between the menstrual periods. The number of applications necessary depends upon the case. The punctures should be made by preference into the posterior part of the uterus, avoiding all pulsating vessels, but choosing as far as possible the most prominent part of the enlarged organ. The punctures should not be deep (a quarter to half an inch.) Antiseptic precautions should be employed. The vagina should be syringed out both before and after the operation by some antiseptic solution such as carbolic acid solution 1 in 80. The instruments to be used should also previously be immersed in a similar fluid. After the puncture a tampon of iodine and glycerine may be used.

Metritis and *endo-metritis* are often treated by the chemical galvano-cauterisation of the mucous membrane of the uterus or the cervical canal, which is, in fact, the electrolysis of the mucous membrane. It is performed by passing an uterine electrode into the cervical canal or into the cavity of the uterus. Antiseptic precautions should be employed. In cases associated with much hæmorrhage, the positive pole is used internally and the uncovered metal part of the electrode within the uterus (see fig. 35) must be made of platinum. In other cases the internal electrode is made negative. It is not necessary to use a current that will cause pain. With nervous patients 40 or 50 milliampères will be sufficient. The current should always be increased slowly, 20 to 30, to 50 milliampères, by adding one or two cells of the battery at a time to the circuit. At the first application the current strength should not exceed 100 milliampères, but on subsequent occasions, if the patient bear the treatment well, 200 milliampères or even stronger currents may be used. Each application should occupy five to ten minutes, and the current strength reduced as gradually as it was increased. The electrode when passed into the uterus should be made as much as possible to touch every point of the mucous membrane by occasionally moving it from place to place. The application can be made once every week or twice as often if necessity requires. The number of applications necessary depends upon the case.

Dr. Bartholow says:—"A large and accumulating experience in this country and abroad, has conclusively demonstrated the power of galvanism to bring about the absorption of inflammatory exudations in the pelvic cavity. By Remak this function of galvanism was entitled *catalytic*, but at present the term most in vogue is *cataphoric*. As has been shown, galvanism lessens or removes congestion by an influence exerted on the vessels. When the faradic current can be directly applied to the affected part, as is feasible in uterine affections, strong contractions of the arterioles can be caused by it. Whether the result, in pelvic diseases, is effected by this action on the vessels, or by catalytic or cataphoric influence, may be a merely technical question; but the important practical fact is established that by galvanic, faradic, and galvano-faradic applications very serious maladies are cured more speedily, safely, and easily, than by the best directed use of medicines."

CANCER

The subject of the treatment of cancer by electrolysis has been again brought prominently before the profession by recent papers in one of the medical journals, and has excited some attention. The treatment of cancer by this agent has from time to time been revived and extensively employed to again fall into disuse. The chief reasons for the fluctuation in the prevalence of the use of electricity for this as for many other affections, is that immediately it is brought into prominence it is frequently employed in unsuitable cases, and therefore gives unsatisfactory results; or, the expense and trouble with the batteries, and the time necessarily involved in carrying out the details of the treatment are so great that medical men very soon are induced to abandon it for more expeditious and less troublesome methods. The latter in most cases of cancer are no doubt the more suitable. For instance, for the removal of a cancer of the breast, the knife is in most cases much to be preferred to the use of electricity as far as our present knowledge of its application enables us to employ it. But there may be cases that are beyond the hope of successful excision or in which the patient will not submit to a cutting operation, and then the treatment by electrolysis may be the most suitable of all other alternatives.

A tumour of the breast can be destroyed and allowed to slough out with as good a prospect of its not returning as when removed by the knife ; but the process by electrolysis takes a much longer time, is much more troublesome, and in the long run involves more pain.

The use of electricity for the destruction of small scirrhus masses is described by Dr. Golding Bird in his lectures on 'Electricity and Galvanism,' published in 1849 (p. 137) ; again by Dr. Althaus in 1867 in his paper "On the Electrolytic Treatment of Tumours and other Surgical Diseases." The plan advocated by Dr. Althaus was extensively tried by the late Mr. Callender in 1873 and 1874 in the wards of St. Bartholomew's, and also at the same date by the author when House Surgeon for Mr Luther Holden, but the results were not satisfactory. Large sloughing sores were left in the patient's breasts, with only a partial destruction of the cancer. The only benefit was some reduction of pain. Dr Althaus says, "It is a curious fact that the peculiar lancinating pains of cancer generally seem to disappear, or at least to diminish considerably, soon after the commencement of the electrolytic treatment, and long before the whole tumour has disappeared."

In nearly all the cases operated on at the date to which reference has been made, very strong currents were used. In those days there were no galvanometers graduated into milliampères, but from later experience it would seem that the current strengths employed were quite as high as those recently employed for uterine fibroids.

Drs Beard and Rockwell have described a system* of treating scirrhus tumours which they call "electrolysis of the base." It consists of passing needles connected with both poles of a galvanic battery into the normal tissue beneath the tumour, when that is possible, and thoroughly destroying the connection between the tumour and the subjacent structures. When the tumour is a large one they consider it best to remove it by the knife and then to thoroughly

* 'Medical and Surgical Uses of Electricity,' by Drs. Beard and Rockwell, 3rd ed., 1881, p. 668.

destroy the surface, from which the tumour has been removed, by electrolysis, so as to destroy any cancer cells that may be in the parts subjacent to the tumour. The advantages they claim for this method are that there is less liability to recurrence, less hæmorrhage, less liability to shock, more satisfactory healing, and less likelihood of septicæmia and pyæmia.

There are other cases such as *cancer of the uterus* in which the disease has spread to the vaginal walls, or where the cauliflower excrescences are so extensive and diffused that there is no prospect of removing them with the knife, the écraseur, or the galvano-cautery, in which electrolysis is of the greatest service in removing portions of the growth, arresting its increase, relieving pain, decreasing hæmorrhage, and prolonging life. For this purpose an electrode composed of

Fig. 37.

a broad piece of zinc is connected with the positive pole of a constant current battery, the negative pole being placed on some indifferent part of the body. When the circuit is closed decomposition of the diseased tissue takes place with a formation of chloride of zinc around the positive electrode. This has an advantage over destruction by ordinary chloride of zinc, or the actual cautery, inasmuch as the action can be localised and arrested at pleasure, and the destruction of the tissues can be regulated to the exact amount that is desired. Needles are also used for destroying portions of the growth, and may be attached to the negative pole, or to both poles. In the latter case the destruction takes place much more rapidly. The positive pole is used only when the additional action of the metal, of which the electrode is composed, is required.

A recent writer on the treatment of cancer by electricity has advocated the employment of shocks, given by the interruption and reversal of very strong galvanic currents. He advocates this mode of treatment on the theory that the low vitality of the cancer cells is extinguished by the sudden reversion of the current, and likens it to the process by which human life is destroyed by electricity. He denies the occurrence of any electrolytic action between the two poles in the ordinary method of treating fibroid tumours, and brings forward experiments to substantiate his contention. The author has before argued* that electricity probably does not kill by shocks when administered to lowly organised living material, but by the effects of shock upon highly organised living beings, acting through the inhibitory nerves, and interfering with the rhythm of the heart. It is probable that it

* 'St Barth. Hosp. Reports,' vol. xix, p. 40.

is more difficult to extinguish lowly organised vitality by shocks than highly specialised vitality, presided over by an elaborate and finely differentiated nervous system. The experiments also brought forward to prove that no change takes place between the poles when a current of electricity is applied to animal tissue, have been proved to be fallacious. The experiments referred to are as follows :*—"Three glasses were connected together with a stout lamp-wick. Into each of these a standard solution of iodide of potash was placed. A current was then passed through the solution, with an intensity of 200 milliampères, until the whole of the iodide of potash in the two outer glasses was decomposed. On testing the centre glass, it was found to contain as much iodide of potash as before, although in the two outer glasses it was all decomposed." "A second experiment was then tried with water in the outer glasses, and a solution of iodide of potash in the centre. The current was passed as before, but no decomposition took place in the centre glass. A third experiment was tried on the web of the frog's foot, and watched through the microscope. At the positive pole a coagulation took place, with exudation of blood from the capillaries. At the negative pole a collection of hydrogen bubbles could be seen. Between the poles no change could be observed, and the circulation went on as before. Finally, a strong

* *Vide* 'Brit. Med. Journal,' April 27th, 1889, p. 937.

current was passed through a fibroid tumour, soon after removal from the body, for a period of several hours. On making sections of the portion between the poles, no change could be detected. All these experiments demonstrated in a conclusive way that the passage of a constant current does not cause any decomposition between the poles, although there must of necessity be an exchange of atoms between the molecules."

In referring to these experiments before the Obstetrical Society of London, on June 21st, 1888, the author stated that he had repeated the experiments,* "substituting pieces of copper wire for the lamp-wick, as his connecting media. The copper wire, while being a very good conductor, was also decomposed by electricity. In this case the iodide of potassium was split up in each jar, free iodine appearing at the positive ends of the pieces of connecting wire, and a large quantity of gas (hydrogen) being liberated at the negative ends."

Some interesting experiments are also detailed in Golding Bird's 'Natural Philosophy,' to show that changes do take place at other points than the electrodes when a current of electricity is passed through several electrolytes.† "The statement that, in cases of electro-chemical decomposition, the changes which

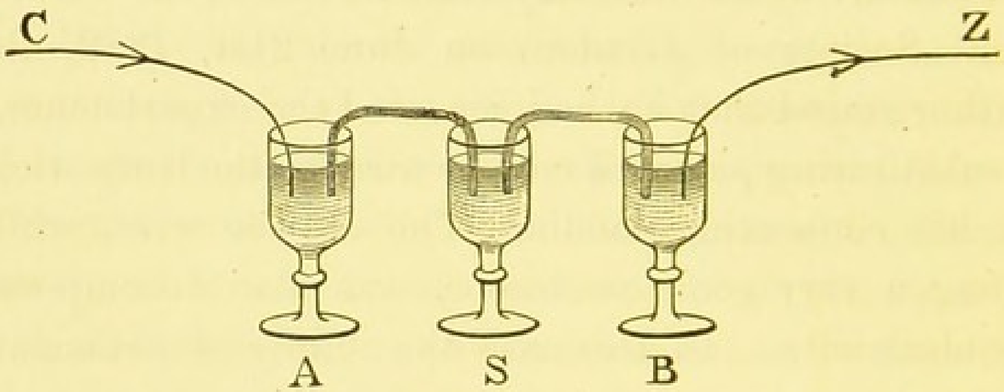
* 'Obstetrical Transactions,' vol. xxx, p. 291.

† Pp. 292, 293.

take place in the electrolyte are continuous through a line of molecules, and not limited to those in contact with the electrodes, meets with an interesting illustration in the well-known experiment in which an alkali appears to traverse an acid without combining with it; and which has been erroneously regarded as a case of suspension of the laws of chemical affinity.

"Let three cups, A, S, B, be placed side by side and

Fig. 38.



connected by means of pieces of lamp-cotton, moistened with a solution of sulphate of soda. Let A and B be filled with a solution of this salt, and the central cup, S, with dilute sulphuric acid. Let a platinum electrode, C, connected with the last copper cell of the battery, dip into A, and another, Z, from the last zinc plate, dip into B. The positive current will now enter the fluid in A, and escape from B through Z, traversing S in its course. Electrolysis of the sulphate of soda will take place, its acid with oxygen being set free in A, and the sodium will pass through the sulphuric acid in S and reach B, so that a quantity of free soda will soon be found in B; the sodium being oxidised at the expense of the water. It is evident that this alkaline body must have traversed the acid in S, with which, indeed, it for an instant combined, and the resulting sulphate of soda being decomposed by the current, the soda ultimately appears in B."

"That in experiments of this kind the base really combines with the acid it is made to traverse is proved by using a salt with the base of which the acid forms an insoluble combination. Under these circumstances it is removed from the influence of the current and does not reach the third cup. Place in A, B solutions of chloride of barium, and in S dilute sulphuric acid; on the current passing, the contents of A are decomposed, chlorine is evolved, and barium set free; this is conveyed in the manner before described to the middle cup, and here it is arrested in its course by the acid which, in combining with it, forms an absolutely insoluble salt, the sulphate of barytes, which falls to the bottom of the vessel, and then neither barium nor its oxide reaches the cup B. Hence the salt chosen for experiment must be one whose base forms a soluble combination with the acid in the middle cup."*

* The author has repeated the above experiment but has not been able to obtain the white precipitate mentioned by Dr Golding Bird; possibly from insufficient battery power.

Another experiment by Professor Daniell will show that changes take place at other points than at the surfaces of the electrodes in connection with the battery when the current has to traverse two or more electrolytes, and these changes are apparent where the electrolytes are in apposition :—

"A small bell glass, with an aperture at the top, had its mouth closed by tying a piece of membrane over it. It was half filled with a dilute solution of caustic potash, and suspended in a glass vessel containing a strong solution of neutral sulphate of copper, below the surface of which it just dipped. A platinum electrode connected with the last zinc rod of a large constant battery of twenty cells was placed in the solution of potash, and another connected with the copper of the first cell was placed in the sulphate of copper immediately under the diaphragm which separated the two solutions. The circuit conducted very readily, and the action was very energetic. Hydrogen was given off at the *cathode*, and oxygen at the *anode* in the sulphate of copper; a small quantity of gas was also seen to rise from the surface of the diaphragm. In about ten minutes the lower surface of the membrane was found beautifully coated with metallic copper, interspersed with black oxide of copper and light blue hydrated oxide.

"The explanation of these phenomena is this :—

"In the experimental cell we have two electrolytes, separated by a membrane, through both of which the current must pass to complete the circuit. The sulphate of copper ($CnSO_4$) is resolved into its compound *anion* (SO_4) and its *cathion* (Cn); the latter in its passage to the cathode is stopped at the surface of the second electrolyte, which may be regarded as water improved in conducting power by potash. The metal here finds nothing by combining with which it can complete its course, but, being forced to stop, yields up its charge to the hydrogen of the second electrolyte, which passes on to the *cathode* and is evolved. The corresponding oxygen stops also at the diaphragm, giving up its charge to the *anion* of the sulphate of copper. The copper and oxygen, thus meeting at the intermediate point, partly enter into combination, and form the black oxide, but from the rapidity of the action there is not time for the whole to combine, and a portion of the copper remains in the metallic state, and a portion of the gaseous oxygen escapes. The precipitation of blue hydratid oxide doubtless arose from mixing of a small portion of the two solutions."*

Other reasons for supposing that some change takes place in animal tissue when traversed by an electric current are given on pp. 16, 17, and 18.

Dr Neftel, who is a great authority on the treatment

* 'Electricity,' by H. M. Noad, revised by W. H. Preece, 1879, pp. 235, 236.

of cancer by electricity,* is inclined to believe that electrolysis produces remote constitutional effects, by altering the condition of the protoplasm of the cells in which the poison of the cancer is contained, and by the propagation of which the disease becomes constitutional. As soon as the protoplasm has, by the electrolytic process, lost its specific contagious qualities, the cancer is prevented from reproducing itself, and gradually disappears through the process of absorption."

The preceding lengthened reference to the treatment of cancer by the interruption and reversion of strong voltaic currents has been made because, in the author's opinion, the method is founded on unproven and probably fallacious theories, and is not free from danger to the patients. Electrolysis is no doubt sometimes very useful in cancer, not only to destroy portions of the growth and thus check the advance of the disease, but noticeably to diminish the pain so frequently attending it.

Small growths on the vulva, vascular pimples, warts, moles, or any slight permanent thickening of the epidermis, ought to be destroyed; and it can be best accomplished, as on the face, by electrolysis. There is no part in women so obnoxious to epithelioma as the vulva.

The inflamed and sensitive condition of the orifices

* *Vide* 'Medical Electricity,' by Dr. Althaus, p. 650.

of the vestibular glands and the surrounding parts which so frequently cause *dyspareunia* can often be successfully treated by electrolysis, but cocaine is seldom sufficient to render treatment tolerable. If an anæsthetic is indispensable, it would generally be better to destroy this unhealthily congested condition of the mucous membrane more thoroughly by galvano-cautery. But with galvano-cautery the presence of a second person is necessary, and one who understands well how to manage a galvano-cautery battery. The presence of an assistant is not necessary for treatment by electrolysis.

EXTRA-UTERINE FŒTATION

The Americans claim most satisfactory results from the treatment of extra-uterine pregnancy by electricity.* The chief forms employed are the faradic current and the continuous current, of some considerable strength, rapidly made and broken, and attempts have also been made to kill the fœtus by galvano-puncture. In my hands the treatment of extra-uterine fœtation by electrolysis has not been successful. I know of only one reported successful case,

* *Vide* Massey on 'Electricity in the Diseases of Women,' F. A. Davies, Philadelphia, 1889, p. 186, *et seq.*; and Bartholow, 'Medical Electricity,' Young J. Pentland, Edinburgh, 1887, p. 240, *et seq.* and p. 266.

that of Dr Petch of York.* In the case reported by Dr Duncan,† he says :—" The appearance of the fœtus *post-mortem* shows that the electrolysis had tremendous effect upon it, and its survival is most marvellous. The *post-mortem* was little more than two days after its death. The destruction of its tissues did not at all resemble that seen in the ordinary course of putrefaction—the bones extensively laid bare, the skin and great part of the tissues having been dissolved and having disappeared; and showing that this was due to the electrolysis, there were parts uninjured, the skin entire as in a fœtus only dead two or three days. Yet during most of this destruction the fœtal heart continued to beat, apparently undisturbed, except as to frequency of pulsation.

In the case reported by Dr Percy Boulton‡ it was not possible either to verify the diagnosis or see what effect the electrolysis had produced.

Dr Strahan in his Jenks Prize Essay on "The Diagnosis and Treatment of Extra-Uterine Pregnancy" (1889) denounces all forms of electrical treatment, especially that by electrolysis.

* 'Brit. Med. Journal,' Dec. 4, 1886, p. 1092.

† 'St. Barth. Hosp. Reports,' vol. xix, p. 44.

‡ 'Brit. Med. Journal,' April 30, 1887, p. 925.

FISTULÆ

Sinuous passages, such as those leading to the site of former abscesses in the breast and elsewhere, can be made to heal from the bottom by inserting a probe insulated to within a short distance of its end and connecting it with the negative pole of a battery. When the probe is in position at the bottom of the sinus the circuit is closed and electrolytic action takes place around its unprotected end. The current should be allowed to flow for about two minutes and the applications repeated about once every week until the sinus is completely obliterated. This is an improvement upon the old method of coating a probe with nitrate of silver and then thrusting it to the bottom of the sinus. In the latter case some of the nitrate of silver gets rubbed off, in its passage, by the walls of the sinus.

Fistula in ano can also be treated by electrolysis. A wire is inserted along the entire track of the fistula and connected with the positive pole of an ordinary galvanic battery, the negative pole being

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placed on some indifferent part of the body. The circuit is then closed, and the lining membrane of the fistula destroyed by chemical decomposition. If electricity is employed for this affection the galvano-cautery wire is perhaps to be preferred. It is passed through the fistula into the rectum and then brought down by the finger and the two ends are attached to handles connected with either pole of a galvano-cautery battery and the wire allowed to burn its way through the intervening tissue, so that the fistula, is opened into the bowel, as when the operation is performed by the knife.

Perineal, vesico-vaginal, and *salivary fistulæ,* are probably better treated by galvano-cautery than by electrolysis. A double platinum wire at a red heat is thrust into them and the edges of the fistula cauterised, but they can also be treated by electrolysis in the same way as anal fistulæ when no galvano-cautery battery is at hand.

PILES

Electrolysis has been used for the destruction of piles. When the piles have been brought well into view, needles attached to the negative pole have been thrust into them and the positive pole has been placed on some indifferent part of the body. A weak current of ten to fifteen milliampères is allowed to flow for ten or fifteen minutes. But if electricity is used for piles the loop of wire with the galvano-cautery battery is preferable and is perhaps the most efficient and satisfactory way of removing piles that we possess.

WOUNDS AND ULCERS

For *bedsores* a silver plate connected with the negative pole of a battery is placed over the sore; the positive electrode is placed on some indifferent part of the body. A current of from two to four milliampères is allowed to pass for five or ten minutes every day. Unhealthy granulating wounds may be treated in the same manner. Electricity is very effectual in stimulating granulations. The applications should not be painful.

A very interesting account of the treatment of ulcers by the electrolytic property of the galvanic current is given in a letter from Mr. T. Spencer Wells, R.N. (now Sir Spencer) to Dr Golding Bird, to be found as an appendix to the work 'Electricity and Galvanism' written by the latter in 1849.

GRANULAR LIDS

Granular lids have been treated successfully by electrolysis. The eyelid is everted and a small electrode connected with the negative pole is moved slowly over the unhealthy mucous membrane. The positive pole is placed at the nape of the neck. The electricity should be applied for several minutes and will require to be repeated six or eight times.

HYDATIDS

Galvano-puncture has been used in the treatment of hydatid cysts. Several cases have been reported by Mr Durham and the late Dr Hilton Fagge of Guy's Hospital. Needles attached to the negative pole were introduced into the tumours and the positive pole applied to the surface of the body. No suppuration is reported to have taken place and the cases progressed favorably. The good effects of the electricity in these cases has been questioned, as satisfactory results have followed simple puncture and aspiration of similar tumours.

HYDROCELE

Hydrocele has been treated in the same way, but needles attached to both poles have been passed into the sac, care being taken that they should not touch one another. By this means electrolysis of the fluid contained in the sac has been set up and said to have been followed by its absorption.

Dr. Rudolfi has reported several cases in which he first aspirated the hydrocele, and then passed a probe connected with the negative pole into the sac, thus setting up adhesive inflammation by the liberation of an alkaline caustic. These operations have been followed by fairly successful results.

EXOPHTHALMIC GOITRE

Goitre has been treated by electricity in various ways, but with very uncertain results. Some cases have been quickly cured, but on the other hand cases have been known suddenly to improve without any treatment whatever. Lately on the Continent and also by Duncan, of Edinburgh,* electrolysis has been tried. Needles attached to both poles of a galvanic battery have been thrust into the enlarged thyroid, and a current of 10 to 15 milliampères allowed to flow for four or five minutes. The galvano puncture has been repeated several times.

The pathology of exophthalmic goitre is a most interesting one, and as yet we are only on the threshold of our knowledge regarding it. That there is some connection between this diseased condition and the sympathetic nervous system is more than probable. The recent investigations into the nature of cretinism, myxœdema, and allied conditions, and the results of

* *Vide* 'Brit. Med. Journal,' Nov. 3rd, 1888, p. 986.

thyrodectomy, will doubtless throw much light upon the nature of goitre. Its probable relationship with the nervous system would seem to point it out as an affection most favorable for treatment by electricity; and probably it will ultimately prove to be so when we have been able to decide on some uniform plan of treatment, and have some reason and explanation for the plan we may adopt. Galvano-puncture, although it has proved successful in some cases, is purely empirical; and probably not performed without risk. The unfortunate contingency of sudden death occurring to patients suffering from exophthalmic goitre must always be borne in mind. What explanation there is for such deaths occurring is at present unknown, but should one happen during an operation by galvano-puncture the treatment by electricity would receive serious discouragement.

Treatment by electrolysis has been proposed and tried for numerous other affections, but with doubtful results.

THE ADVANTAGES OF ELECTROLYSIS

Electrolysis is a force that can be used with great advantage in the practice of surgery. There is no destructive agent employed by the surgeon at the same time so potent and so entirely under his control. It can in most cases be used without the loss of blood. It is a more effectual and elegant way of applying caustic than any other we possess. The pain caused by the application ceases immediately the current is broken, and when employed in painful affections, the pain by its means is often greatly relieved. It encourages absorption, and produces healthy granulations when applied to ulcerated surfaces. The chemical decomposition, short of producing a slough, is itself antiseptic. It can be applied to narrow passages of the body, and to other parts difficult of access, in a way and in cases that it would be impossible to apply any other agent. It can be most accurately localised at the part it is wished to affect. The amount used, and the extent of the tissue to be destroyed, can be regulated to a nicety; and its action can be commenced and arrested at any moment at the will of the operator.

Prof. Ogston, of Aberdeen, has written* "Many common mechanical instruments for studying and treating disease, such as the measuring line, the weighing machine, the concave reflecting mirror, and the speculum, are regularly employed by the majority of practitioners; *while electricity, despite its value* in the diagnosis and treatment of nervous diseases, as an unsurpassed illuminating agent, *as an electrolytic*

* 'Lancet,' April 30th, 1887, p. 67. The italics are by the author.

destroyer of diseased tissues, tumours, and nævi, as the most manageable cauterising agent, and as supplying the electro-magnet for extracting fragments of iron from the eyeball, *is superseded* for these purposes *by less efficient means.*"

For the purely surgical applications of electricity a technical knowledge of the subject and an intimate acquaintance with the manner of using the different forms of batteries is most essential. I know, from the numbers of applications I have had from members of the profession asking for details of the operation for the electrolysis of fibroids, the best batteries to use, &c. &c., that an indiscriminate application of this mode of treatment is being made by men without the slightest previous knowledge of electricity. The use of the wrong pole in electrical treatment may be followed by most disastrous results, and the chances of the wrong pole being used are very numerous, sometimes even escaping the vigilance of the most experienced. The commutator of the battery may have been arranged wrongly by the instrument maker, the galvanometer may have been inserted on the wrong side of the circuit, the current may have to be arrested during an operation and the commutator reversed by accident, or by the negligence or ignorance of an assistant. One operation may have required the use of the positive pole and the next of the negative, and the necessary alteration in the battery have escaped notice.

All these accidents have occurred within the knowledge of the author. I have seen part of the mucous membrane of the urethra torn off, and followed by profuse hæmorrhage, by the use of the positive pole in the treatment of stricture. I know of a case where the patient suffered from such extreme collapse after a similar operation that the surgeon for a time was fearful as to the result. The collapse was produced either from the current being used too strong, or when strong, suddenly broken. I have been upbraided by a surgeon for advocating the treatment of stricture of the urethra by electrolysis, because in two cases he had set up most intractable cystitis by not cutting off the current after his electrode had passed the stricture, but by passing it on and electrolysing the coats of the bladder; and yet, when properly performed, I believe electrolysis to be the best mode of treating stricture. I have seen a patient disfigured for life by the too energetic use of the wrong pole in treating a hairy mole on the face. In another case an abscess or slough was produced in the upper part of the pharynx, accompanied by the most intolerable earache, by the use of the wrong pole in an attempt to electrolyse the Eustachian tube. Most profound collapse has been caused by an assistant uncoupling one of the electrodes after the electrolysis of a uterine fibroid, and before the current had been gradually reduced in strength. Very painful and disagreeable shocks have been produced when treating the same affection by the battery having been sent home by the instrument maker with the zinc of one couple of elements placed in a wrong cell, and in another instance by the battery being sent home with the fluid omitted from one cell.

A case has been published where no doubt the woman's life was in jeopardy by the sloughing of a tumour produced by the use of a too strong current. I mentioned in my paper read at Dublin the difficulties, though not serious, which followed the use of the wrong pole in the treatment of lachrymal obstruction. I could greatly extend this list of the dangers and difficulties connected with electrical treatment, but I have said enough to show that it should not be undertaken without a thorough knowledge of the apparatus to be used and the mode of using it.

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