THE

NATURE OF ANÆSTHESIA

AN APPENDED NOTE

BY

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The Nature of Anæsthesia: An Appended Note.

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Introductory.

To understand the true nature of anæsthesia has proved a difficult problem to many. To explain it is no mere academic exercise, for given such an explanation, it must influence us alike in the methods we adopt in handling the various anæsthetics and the means we adopt to prevent inherent dangers or to avert accidental perils. For example, in days when nitrous oxide was deemed to be an asphyxiant it was the practice to give it rigidly excluding all air. Now we recognise it has a true anæsthetic action, and so give it, as we exhibit other general anæsthetics, with air or oxygen to avoid the occurrence of asphyxial symptoms as unnecessary as they are undesirable. Nor should we be justified in employing substances as powerful as are anæsthetics, unless we could accurately appreciate their physiological behaviour. It is to inquire what we know about anæsthesia that this note is written.

Paths of Anæsthesia.—(a) Nerve Endings; (b) sensory nerves; (c) ganglionic centres; (d) perceptive mechanism.

Anæsthesia occurs under various conditions. All are familiar with the disorders of sensation which occur in various forms of nervous disease, and give rise to hyperæsthesia on the one hand, and anæsthesia upon the other. (*a*) Variations in the interrelations of the end-organs of the skin or mucous membrane; (*b*) of the sensory nerve, or nerve of conveyance; (*c*) of the ganglionic nerve centres which translate the sensory stimulus into a feeling; and (*d*) the consciousness which perceives the feeling as pain or pleasure, may under morbid conditions of the organism give rise to true anæsthesia. Artificially we are able to bring about the same state of things producing a transient anæsthesia. Thus, by the use of cocaine we act upon the nerve ends in skin and mucous membranes, and prevent conveyance of sensory stimuli passing along the nerves. In the same manner carbolic acid or chloroform when applied to mucous membrane or even skin, will, by coagulating the albuminous materials with which they are brought in contact, cause anæsthesia. General anæsthetics even in a very early stage will act upon (*c*) the ganglionic nerve tissues and prevent painful sensations being recognised. A few inspirations of ether or chloroform will without paralysing motion or dulling the conductivity of the nerves, remove sense of pain even though the patient may struggle, fight, or express in no measured terms, his views on what is passing through his mind. He is in the land of dreams, and his talk and his actions have relation with phantom forms and illusory communications peopling that teeming waste. The curtain has dropped betwixt him and earth. In hypnotism we possess an example of a state in which pain is felt, but perceived as pleasure. It is, after all, a fact that life is not; only what it seems. The curious in such matters will find from Moll's book many examples of unquestionable instances of absolute anæsthesia, although there was every reason to believe that both the end organs in the skin, the sensory tracts and the ganglionic nerve tissue were intact and capable of producing and conveying sense stimuli; nevertheless the perception arrived at was not that of pain. The perceptive mechanism was blocked. In the days of Moore, anæsthesia was attempted by compression of the nerve trunks, and nerve sensations were in this way blocked at the point of pressure. Thus every link in the chain between skin which initiates the sense stimulus and the nerve centre which initiates the perception of pain, has been tested in the endeavour to achieve surgical anæsthesia.

Peripheral Sense Organ Anæsthesia.—Local anæsthesia, the blocking of the sense stimulus at the skin or mucous membrane is, of course, of little value for any save the most trivial operations. The agents employed and the elaborate plans suggested to produce it have not proved themselves safe or sufficient. Bichât, whose ever delightful book on "Life and Death" deserves more study than it gets now-a-days, taught the duality of life, a life of mere functional existence, and one of relativity. In anæsthesia produced by agents such as nitrous oxide, ether, chloroform, the life of relativity falls into abeyance, while the functional life or existence persists. But just as it is found impossible to limit the activity of a local anæsthetic to a regional area, so is it impossible to draw a hard and fast line between the influence of a general anæsthetic upon the cerebral centres and its overflow to the vital centres.

Aim of Anæsthesia.—The problem before us is to discover how best to produce anæsthesia without allowing the ordinary processes of life to be trenched upon. We have advanced some distance along the road leading to this discovery, but we still have very much to learn, and what is more, very much more to unlearn. Whatever personal satisfaction may be the result of a frame of mind which leads its owner to believe he knows all there is to be known about anæsthetics and anæsthesia, it is one which, sooner or later, will not be shared by the friends of some of his patients.

Study of the Action of Anæsthetics.[1]—In the course of a very able paper on anæsthesia Lauder Brunton suggests alcohol as one of the best substances to study to arrive at an idea of the way in which the general anæsthetics act. He adds that carbonic anhydride is the most widely distributed body having claims to the title of anæsthetic.

Definition of Anæsthesia.—It may be useful in this place to ask what definition of anæsthetic is to be adopted. Of course I use the word in its colloquial acceptation, the one first suggested by Dr. Oliver Wendell Holmes. It seems to be now generally admitted that although many things may produce loss of sensation through abeyance of the faculty whereby we feel pain,

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[1] *Lancet*, 1895, vol. i., pp. 49, 80 and 143.

yet none should be regarded as anæsthetics unless they exert some definite influence upon the tissues of the body, rendering them indifferent to pain and that quite irrespective of their preventing due access to the tissues of some vital constituent. An ox pole-axed is rendered anæsthetic; a man poisoned by a charcoal stove grows anæsthetic after inhaling the fumes of carbonic oxide gas until he is practically at the verge of death; an indifferent gas such as nitrogen, can by excluding oxygen, produce asphyxia, in the advanced stage of which, perception to pain grows deadened or lost. In these cases the stunning, the carbonic oxide poisoning, the oxygen starvation due to the indifferent gas, act by virtue of interference with necessary vital processes but possess in themselves no anæsthetic properties, and are not anæsthetic. It is true that carbonic anhydride has been employed both as a general and a local anæsthetic, that nitrogen has also had its vogue; but as yet pole-axing has met with but scant favour save for the lower animals.

True and false Anæsthesia.—Brown Séquard[1] has pointed out that when carbonic anhydride, chloroform and other vapours are allowed to impinge upon the mucous membrane of the

[1] *Compt. rendus de l'Académie de Science, vol. C,* June, 1885, p. 1366.

larynx, trachea, or even upon certain skin areas, while they are prevented from entering the lungs, they produce unconsciousness of pain although the animal is awake and alert. Brown Séquard's theory that stimulation of the area supplied by the superior laryngeal branch of the vagus produced a sort of reflex inhibition of the brain's power of perception does not concern us at present. Carbonic anhydride has been also used as a general anæsthetic. Ozanam[1] employed a mixture of 75 carbonic anhydride to 25 of air. He rendered a young man unconscious while an abscess was opened. It has also been suggested that ether is rendered more effectual by combining its use with that of carbonic anhydride and even nitrous oxide has been used in combination with the expired air of patients, thus producing a mixed anæsthesia due to these two agents. Waller[2] has further shown that carbonic anhydride produced a brief abolition or diminution followed by prolonged augmentation of electrical excitability in the isolated nerve of frogs. This, however, is influenced by the amount of carbonic anhydride used. Expired air produces augmentation of

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1 Lyman's "Artificial Anæsthesia," p. 327.

2 Proceedings of Physiological Society, November, 1895, published in *Journal of Physiology*, vol. xviii., "Action of Anæsthetics on Isolated Nerve."

excitability, while a large quantity of carbonic anhydride gives the result stated above, viz., primary abolition and secondary augmentation. The use of carbonic anhydride as a local anæsthetic, takes us back to the days of Pliny. But experiments have been undertaken which prove that carbonic anhydride possesses the power of producing unconsciousness only so long as the oxygen tension in the blood remains below a certain level. Gréhant[1] employed mixtures of common air and carbonic anhydride, and found that when the animals experimented upon were completely narcotised, the gas of the blood contained 95·4 per cent. of carbonic anhydride as against the normal 34·3 per cent. (Pflüger)[2]. Gréhant's results had been obtained by Lallemand and Perrin as early as in 1860 ("Rôle de l'alcool et des anæsthetiques dans l'organisme," p. 405). This state of unconsciousness, however, is not one of anæsthesia and is only obtained at the expense of grave peril to the individual. The bodies commonly employed as anæsthetics—nitrous oxide, ether, chloroform—must then, differ in their action from carbonic anhydride. That this is so our present knowledge permits us to say, but compels us to admit

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[1] *Comptes rendus Soc. Biolog.*, 1887.

[2] *Archiv für die gesammte Physiologie*, i., 1858, p. 285.

that so far as many of our methods are concerned, anæsthesia is as Dastre[1] has said, the first step in a general poisoning of the organism. It is the realisation of the truth of this dictum which compels us at once to recognise the necessity of understanding the precise range of safety limiting artificial toxæmia, and to appreciate the responsibility falling upon those who undertake the control of producing and limiting it.

Theories of Anæsthesia.—In the early days of chloroform two very careful observers, Flourens[2] and Longet[3] were led by their researches to advance a reasonable enough theory. They asserted that the anæsthetics possessed a selective action upon the nervous tissues. Thus, if an anæsthetic was taken, it at once found its way to the nerve cells and produced unconsciousness. Other observers have believed that because *post-mortem* examination of the tissues of those dead after taking anæsthetics revealed the fact that the nerve tissues contained a somewhat larger proportion of the anæsthetic employed than other tissues, therefore this selective power was a reality. We now know the theory to be false and the reason-

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[1] "Les Anesthetiques, Physiologie et Applications Chirurgicales," p. 34.

[2] *Comptes rendus de l'Academie des Science,* vol. xxiv., 1847.

[3] *Archives Générales de Med.,* 1847.

ing fallacious, as the nervous tissues do not actually take up more of the anæsthetic, but retain more of it.

Mode of Action of Anæsthetics.—It then becomes a matter of very serious moment to ascertain in what way the anæsthetic enters the organism, what paths it takes, and by what means it is thrown off. Knowledge upon these points will enable us to ascertain how far anæsthesia trenches upon the vital processes of the organism. The lungs, the heart, and the brain have been called the tripod of life. Death, we know, must occur when the lungs or the heart cease to perform their function, but of the cerebro-spinal axis only the lower ganglionic centres are, even in mammals, essential to the existence of the animal. Hughlings Jackson[1] in his lectures on the Evolution and Dissolution of the Nervous System, after pointing out that the evolution of the nervous centres is the "putting together of the nervous system," and involves a correlation of the most automatic with the most voluntary—the most automatic being through the necessity of the existence of the creature the most stable, and hence most highly organised, the most volun-

[1] Croonian Lectures, 1884, in *Lancet*, March 29, p. 556; see also Lauder Brunton, who quotes Dr. Jackson, and applies his reasoning to the question of anæsthesia (*Lancet*, July, 1895, p. 84).

tary being open to constant change to meet environing necessities, and hence most unstable and less organised—goes on to show how dissolution is the reverse of this evolution, is, in point of fact, unpicking the lock of life. He adds: " In uniform dissolution the whole nervous system is under the same conditions or evil influence—the evolution of the whole nervous system is comparatively evenly reversed. In these cases the whole nervous system is 'reduced,' but the different centres are not equally affected.

" An injurious agency, say alcohol, taken into the system flows to all parts of it, but the highest centres being the least organised, give out first and most; the middle centres being more organised, resist longer, and the lowest centres being most organised, resist longest. Did not the lowest centres for respiration and circulation resist more than the highest do, death by alcohol would be a very common thing." If we replace the word alcohol by alcoholic anæsthetic in Dr. Jackson's remarks, we arrive at the pith of our subject.

It is, then, the sum and aim of the scientific use of anæsthetics to act upon the higher and more unstable centres of the nervous system without affecting the lower or automatic centres. But the problem cannot be narrowed down to this easily appreciated theorem. The inter-relations of the higher with the lower centres, in highly differentiated animals, are many and intimate. Dangers appear in every zone of narcosis, lest impulses become initiated which involve the stable centres through the unstable ones.

Under normal conditions the purely vital functions of life are controlled by the lower centres, and indeed, in more humble animals, are incapable of being influenced by higher centres. In man the cerebro-spinal axis can, and does, influence the processes of life in obedience to impulses from without which require some modification of the routine of life. The diver, for example, can control the automatism of his breathing; while under the influence of pain, of shock, or of subjective fear of pain, the heart's action may be inhibited. Such interference, however, is seldom excited without voluntary connivance. The simple reflexes of life are controlled when the higher centres are working in health. As soon, however, as any disturbance of these centres occurs through, it may be, an "injurious agent," as Dr. Jackson calls it, there is a danger, and a very real danger, lest simple stimuli from without cause the most widespread reflex actions. Even those protective of the vital processes become, when unrestrained by limiting nervous control, inco-ordinated and make for the destruction of those very processes of life which it is their function to preserve. And further, the due performance of the vital processes depends upon not only nerve impulses and viscera and muscles. It requires that these shall be in such a condition of vitality that they can perform their physiological duties. It pre-supposes also that these shall be able to meet unusual calls made upon them; if, for example, the "injurious agent" at work, be an anæsthetic which produces a sudden fall of blood pressure, for safety, the controlling centres of the organism must be equal to some re-adjustment by which this vascular depression may be counterbalanced. It also necessitates that throughout the whole time of the action of the injurious agent the tissues of the body shall receive their due quota of nourishment. This last essential implies that the blood stream shall be maintained pure in sufficient circulation, and capable of removing the products of tissue metabolism. A circulation capable of at once feeding and depurating tissues can only be one which passes through the lungs, and there becomes subject to those gaseous exchanges which occur in physiological life. Nor is the problem as yet clearly before us. Elimination of the injurious agent is at least as essential as the due control of those safeguarding vital processes against which it militates. Take chloroform, for example. In persons whose chests are, through pulmonary emphysema, in a state of constant inspiration, the expiratory effects are so ineffectual that the heavy vapour readily drops into the ever patent air cells, and there accumulates, until it reaches a tension which interferes with and threatens the mechanism of life. In the same way heart failure may occur in spite of a normally acting system of safeguards in the nervous system. If, in response to demands made upon the heart by impulses from the nerve centres, that organ, through disease, is unable to execute the work required of it, fatal syncope arises.

All anæsthetics in common use enter the blood stream through the lungs. The inhaled vapour in passing over the pulmonary mucous membrane produces changes in its epithelium which according to McKendrick, Newman, and Coats[1] is inflammatory in character, "The capillaries are contracted, their walls become less distinct, and the blood corpuscles in them become partially dissolved. These changes are, however, rendered less and less as the vapour employed is diluted more and more. It is probable that these effects are the result of an irritant as far as the epithelial cells and capillaries are con-

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[1] Glasgow Commission on Chloroform, quoted by Lauder Brunton, *op. cit.*, p. 85.

cerned. The influence upon the corpuscles is, however, different, and furthermore, varies in the case of different anæsthetics. In every case blood removed from the body and shaken with an anæsthetic shows destruction of the corpuscles, and reduction, with pouring out, of the hæmoglobin. It would appear also that a similar if a less marked phenomenon occurs in the body. Da Costa[1] has demonstrated that "Etherisation produces a marked diminution in the hæmoglobin of the blood." He finds also that with destruction of the red discs, a change in the character of the leucocytes becomes apparent. I am at present investigating this point, and have up to the present time found that a decided diminution in the corpuscles takes place under nitrous oxide, ether and chloroform. It is, however, not improbable that factors other than the anæsthetics may be found at work in bringing about the result.

The combination or association between the gaseous anæsthetics or vapours and the constituents of the blood must be a loose one, since in their presence oxygen is displaced. Were they to form combinations as stable as those which carbonic oxide establishes, not only would the

[1] "The Blood Alterations of Ether Anæsthesia," by Dr. J. C. Da Costa, *Medical News*, March 2, 1895, p. 225.

anæsthetic displace, but would render impossible the re-formation of, oxy-hæmoglobin. Hence death must result. Whether or not, in certain conditions, the corpuscles have less power of again taking oxygen after prolonged anæsthetisation it is impossible to say. It seems that probably such is the case. Deoxydation of the tissues[1] at one time was thought to be the explanation of anæsthesia; we now recognise this is not so, for among other reasons we can produce profound anæsthesia with hyper-oxygenation, and many deoxidating bodies have no anæsthetic properties.

When it is remembered that the tissues are dependent upon the red corpuscles for their nutrition this question of their destruction by anæsthetics assumes a position of great importance. Hayem[2] has demonstrated that in anæmic and diseased states of the kidneys and liver the corpuscles are manifestly deficient in quantity and quality, and Haldane, working with Lorraine Smith,[3] has asserted that the corpuscles possess a different oxygen capacity. If, for example, one layer of these bodies can acquire and convey a certain amount of oxygen

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[1] "Practice of Artificial Anæsthesia," *Brit. Med. Jour.*, Sept. 19, 1885.

[2] "Du Sang," 1889.

[3] *Journal of Physiology*, vol. xvi., p. 468.

to the tissues, another will carry more or less as the case may be. We have yet to learn how far pathological conditions affect this oxygen capacity of blood corpuscles. It is not impossible that the behaviour of anæsthetics towards the corpuscles, which it has been shown they affect so profoundly, may be such as to modify in a material degree their capacity for conveying oxygen to the tissues. The behaviour of anæsthetics toward corpuscles also illustrates a further and important point in our present consideration. There is a common tendency to accredit the central nervous system with absolute control over the vagaries of anæsthetics, to believe that if the ganglionic centres are keeping pace with the requirements of the organism that no fear of danger need be entertained. Certainly in the case of chloroform this belief is delusive. That body is a virulent protoplasm poison. Ether and nitrous oxide also act upon undifferentiated protoplasm, and all anæsthetic agents are able to influence living tissue, even when devoid of nervous connections.[1] Pickering, working with the embryonic heart, has demonstrated that not only does chloroform act directly upon tissues out of nervous control, but so far differentiates between them as to affect

[1] *Journal of Physiology*, vol. xiv., p. 446.

them in various degrees. For while chloroform depresses the rhythm, causing diastolic stoppages of the auricle and ventricle, it proves itself much more toxic to the auricle than to the ventricle. Ether stimulates the embryonic heart, although very large doses will eventually stop it in diastole. The frog's heart, again, can be removed out of the control of the nervous system, and can be again and again stopped with chloroform or ether, and while it is often impossible to restore it in the former case, it is difficult to kill it when ether is perfused.

It must be then that these anæsthetics are able, quite independently of the central nervous system, to act upon corpuscular and muscular tissue. Thiem and Fischer's research indicates that chloroform can produce a change in the heart muscle, which appears identical with fatty degeneration; while MacWilliam[1] has proved that dilatation changes in the capacity of the heart as a whole, follow immediately on the inhalation of chloroform. These changes are also influenced largely by the actual quantity of chloroform contained in the blood as well as by the length of time it has had access to the tissues. It is further probable that the changes which we know take place as a result of alcohol, possess ana-

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[1] *Journ. Physiology*, vol. xiii., 1889, p. 860.

logues in those brought about by other anæsthetics, and so that the nervous tissue is also structurally affected by them. Waller and others have demonstrated the changes in isolated nervous tissue, but as yet no full research has been conducted upon the nervous elements as they occur in the body. An attempt was made in this direction by me in working out the physiological action of nitrous oxide[1] with results which, I think, proved the anæsthetic properties of that gas. It must then appear probable that the changes brought about in the blood elements react upon the more stable tissues by lessening their supply of oxygen, while the tissues themselves are brought under the influence of the anæsthetic which the blood stream conveys to them.

The next changes which are brought about by the anæsthetic are those connected with respiration, circulation, and nerve regulation. In obedience to stimuli conveyed from the lungs, diminution of the amount of oxygen or its excess leads to corresponding respiratory efforts. In association with these are the somewhat complicated series of changes in the blood-pressure, the cardiac rhythm, the dilatation and constriction of the capillary areas which go to form the

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[1] *Trans. Odont. Society*, 1887, pp. 90-131.

blood circulation. Not only may these be thrown out of gear by impediment to the pulmonary circulation arising from asphyxia, the commonest danger of anæsthetics, but may be profoundly affected from without through skin or visceral stimuli, leading to disaster. Oliver[1] by means of his ingenious instrument, the arteriometer, is able to record changes in the size of the blood vessels under various circumstances. He very kindly assisted me in some observations made at University College Hospital, and we found that during various stages of anæsthesia, the pulling upon the intestines, the spermatic cord, etc., incident to various operations upon viscera, produced the most startling changes in the diameter of the radial artery. This must indicate a profound series of impressions upon the control system. To my mind, many disasters under anæsthetics are explicable by these observations. Under chloroform especially, the shock conveyed by the removal of a tooth would, if the anæsthesia were not deep, in a certain number of cases, produce reflex inhibition of the heart. That this reflex inhibition does occur, has been proved by many observers, but the results of Amrus and Gärtner[2] are conclusive. Even where the animal

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[1] "Pulse Gauging," 1895.

[2] *Wiener Med. Blätter*, No. 20.

is deeply anæsthetised, they found weak faradic currents applied to the vagus produced a very prolonged heart-stoppage. When the heart-pause had persisted for a certain time, respiration also failed, and slight spasms succeeded.

In the paper to which I have referred above, Lauder Brunton insists upon a form of death under anæsthetics, which is certainly a common one, and which, when recognised, must relieve anæsthetics of responsibility in very many fatalities. Adopting Caspar's views he attributes these deaths to neuroparesis.[1] Not only do circulation and respiration fail simultaneously, but all the nervous centres are instantly annihilated. The death is one of shock. It may follow surgical shock; it may and does result from pain felt during imperfect anæsthesia, or even before any appreciable amount of the anæsthetic has been taken. I think a study of the cases of fatalities published will convince you that a large number of examples of death result from neuroparesis.[2]

Anæsthetics are, however, not simply dangerous *per se*. They too frequently have to be given to those whose tissues are already in a diseased

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[1] "Neuroparesis," Lauder Brunton, *Lancet*, 1895, vol. ii., p. 23.

[2] See *British Journal of Dental Science* "On Nitrous Oxide Anæsthesia," Oct. 1 and 15, 1895; also "Clinical Report of Deaths under Chloroform," *Lancet*, 1893.

condition. Take anæmia, fatty degeneration, "renal inadequacy," various functional and organic diseases of the ganglionic centres—of the heart—and cyanosis, the result of obstructive pulmonary or cardiac diseases, as examples of the many pathological states which place a patient, even before taking an anæsthetic, in a condition which renders him especially liable to suffer from such phenomena—caused by anæsthetics—as destruction of corpuscles, irritative inflammatory changes in the epithelium of the lungs and kidneys, fatty changes in the heart, regular and uncontrolled nerve storms. All such people must take an anæsthetic. And until we are fully alive to the way in which the several anæsthetics act upon persons so diseased we can neither select with accuracy nor control with precision, but must content ourselves with empiricism.

What, then, are the practical lessons our present knowledge teaches us? In general we must conclude that the action of the anæsthetic should be restricted within those clearly defined limits which involve only the higher ganglionic centres; that under no circumstances should incomplete anæsthesia be deemed sufficient for even the most trivial operation.

Of methods, our present knowledge allows us to say much, but it is impossible for me to do more than indicate in the briefest way what rules should guide us. All methods involving asphyxial symptoms are open to grave censure. In the case of all anæsthetics it is possible to produce unconsciousness, and yet to avoid cyanosis. Nitrous oxide, once thought to be an asphyxiant, is now known to be a true anæsthetic, and to be capable of being given with oxygen or air, and of producing peaceful anæsthesia without any asphyxial phenomena. Of ether the same is true. Of chloroform it must be said that any association between it and asphyxia must lead in the healthy subject to grave peril, in the diseased to fatal results.

A word further. Close study of the behaviour of anæsthetics makes me certain that all methods which employ a large quantity of anæsthetic substances are faulty. The pneumonia, the renal catarrh, the cardiac asthenia following anæsthesia are due, in most cases, not so much to the anæsthetic as to the unwary way in which it is employed.

When anæsthesia is better understood, and those who employ anæsthetics recognise more the responsibility they incur; when the Examining Boards demand of their candidates at least a nodding acquaintance with anæsthetics and their uses, then will there be fewer fatalities and more common-sense practice of this branch of the healing art.