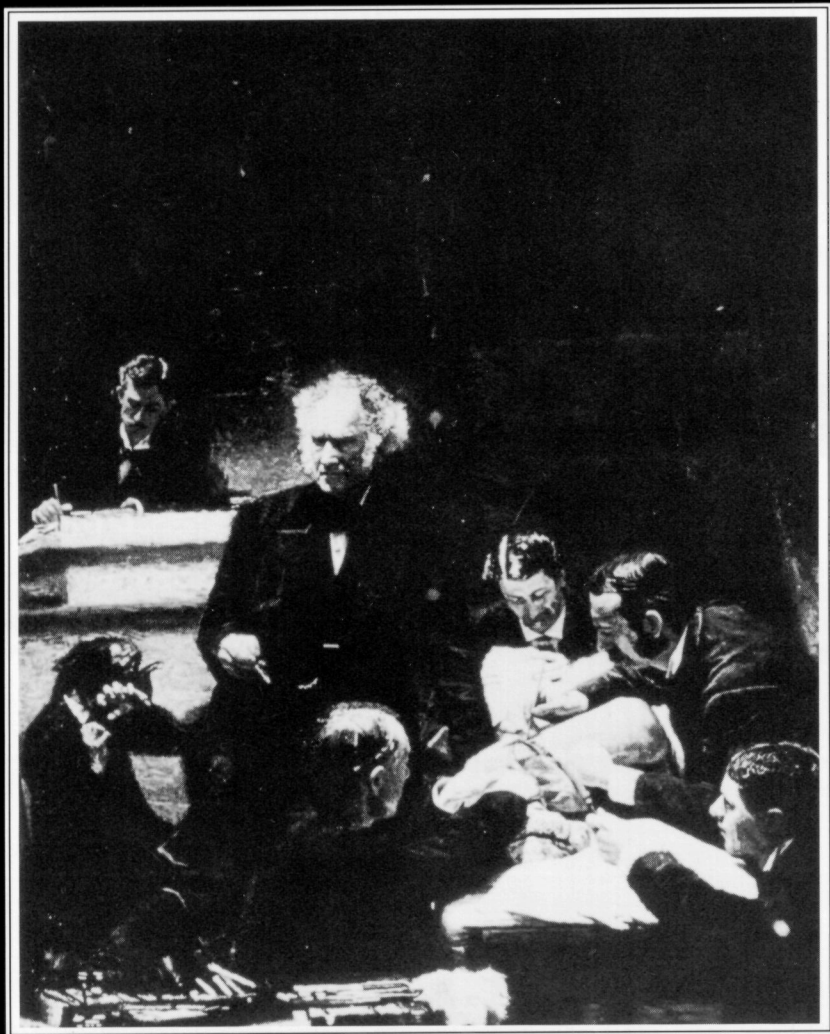


# The History of Anesthesiology

Reprint Series: Part Twenty

## Surgeons and their Contributions to Anesthesia



**The Gross Clinic, 1875**

A painting by Thomas Eakins — highlighting the dominating role of surgeons in that era as typified by Samuel Gross of Jefferson Medical College in Philadelphia. Joseph W. Hearn is the anesthetizer.

# THE HISTORY OF ANESTHESIOLOGY

Reprint Series: Part Twenty

1990

## Surgeons and their Contributions to Anesthesia

It may seem paradoxical to speak of Surgeons and their Contributions to the Development of Anesthesia, when, with the exception of Great Britain, surgeons were mainly responsible for the growth of the specialty well into the 20th century. Many were their clinical, pharmacological and technological innovations. Consequently, in this collection of memorable articles which range in time from the 1860s to the 1940s, only a small sample can be offered. Moreover, one should not overlook another kind of benign surgical influence and that is the early perception on the part of some prominent American surgeons of the need for professional anesthesia. Two of America's pioneering anesthetists, John S. Lundy and Ralph M. Waters owed their entry into academic anesthesia to the blandishments of W. J. Mayo at Rochester and Erwin R. Schmidt at Wisconsin, respectively.

In the listed reprint, we learn that Edmund Andrews, Chicago surgeon, experimented in the 1860s with a mixture of free oxygen and nitrous oxide, so that surgical patients might be anesthetized for an indefinite period (in contrast to dental anesthesia) without the danger of asphyxiation. Even so it would be many decades before anesthetists would accept the truism that oxygen in the nitrous oxide molecule is not freed for metabolic needs. According to the second reprint, around 1879, William Macewen, pioneering neurosurgeon, as influenced by Pierre-Joseph Desault, began his investigations on the possibility of peroral intubation of the larynx. He had been involved in the care of many a patient with diphtheritic laryngitis. His reports reveal the successful outcome of his endeavors, antedating the first use by Samuel J. Meltzer of intratracheal ether anesthesia in 1910. Another fledgling neurosurgeon as revealed in reprint No. 3, Harvey Cushing, in 1902, (borrowing from George Crile's concept of anoci-association) anticipated current concerns with the autonomic nervous response to anesthetic and surgical stress. By employing cocaineization of large nerve trunks (regional anesthesia, he called this process) during general anesthesia for major amputations, Cushing was able to avoid the startling gyrations in blood pressure and pulse rate that would otherwise have occurred. Historians of anesthesia will also re-

call that Cushing (and fellow medical student E. A. Codman) were the first to keep anesthetic records, that Cushing was the first to advocate blood pressure measurement during anesthesia, and with his anesthetist S. G. Davis, the first to employ precordial stethoscope.

Regional anesthesia almost as we know it today was introduced and perfected by surgeons within the first two decades following the discovery by Koller of the topical anesthetic properties of cocaine. Among the leading proponents (as depicted in reprint No. 4), was Heinrich Braun, who was quick to utilize epinephrine in conjunction with cocaine to prolong local anesthetic action and diminish its toxicity. Braun's paper was written within a few years of John Jacob Abel's purification of the adrenally derived hormone. In no other respect have two classes of drugs since been so extensively linked and used over the years in clinical practice as have epinephrine and local anesthetics.

While we have already referenced Harvey Cushing's concern with anesthetic matters, it remains to be stated that perhaps his most prescient act was his recruitment of Walter M. Boothby as anesthetist to the newly opened Peter Bent Brigham Hospital in 1913. As revealed in reprint No. 5, Boothby, a surgeon, had had an interest of some standing in anesthesia, a manifestation of which was his perfection of an apparatus, with Frederic J. Cotton for the administration of nitrous oxide-oxygen, ether anesthesia. The new features approaching modern design were: (a) an absolutely regular flow of each gas at any rate desired without the necessity of frequent valve manipulation; (b) the flow of gases rendered visible so that their proportions could be approximately estimated at a glance; (c) an efficient method of adding ether vapor gradually yet rapidly up to any amount that even an extreme case would require; and, (d) a modified face piece, absolutely air tight and practically self retaining. There were other innovations as well.

In the final reprint of this series, we reproduce a classic article written by an obstetrician-gynecologist, Curtis L. Mendelson, whose description of the aspiration of gastric contents into the lungs has since earned the eponym, Mendelson's Syndrome. The clinical circumstances and pathophysiology of acid aspiration, so completely documented, has with consequent development led over subsequent years to the virtual disappearance, of this dire complication in obstetric anesthetic practice as well as in anesthesia at large.

Leroy D. Vandam, M.D.

## SURGEONS AND THEIR CONTRIBUTIONS TO ANESTHESIA

### SELECTED PAPERS

1. Andrews, E. The oxygen mixture, a new anaesthetic combination. *Chicago Medical Examiner* 1868; 9:656-661.
2. Macewen, W. Clinical observations on the introduction of tracheal tubes by the mouth, instead of performing tracheotomy or laryngotomy. *British Medical Journal* 1880; 2:122-124 (July 24); 163-165 (July 31).
3. Cushing, H. On the avoidance of shock in major amputations by cocainization of large nerve-trunks preliminary to their division. With observation of blood-pressure changes in surgical cases. *Annals of Surgery* 1902; 36:321-345.
4. Translation of an extract from Braun, H. The addition of epinephrine to cocaine for local anesthesia. *Archiv für klinische Chirurgie* 1903; 69:541-591.
5. Cotton, FJ, and Boothby, WM. Nitrous oxide-oxygen-ether anaesthesia: notes on administration; a perfected apparatus. *Surgery, Gynecology and obstetrics* 1912; 15:281-289.
6. Mendelson, CL. The aspiration of stomach contents into the lungs during obstetric anesthesia. *American Journal of Obstetrics and Gynecology* 1946; 52:191-205.





THE CHICAGO  
MEDICAL EXAMINER,

A MONTHLY JOURNAL DEVOTED TO THE  
EDUCATIONAL, SCIENTIFIC, AND PRACTICAL INTERESTS  
OF THE  
MEDICAL PROFESSION.

EDITED BY  
N. S. DAVIS, M.D.,  
PROFESSOR OF PRINCIPLES AND PRACTICE OF MEDICINE AND OF CLINICAL MEDICINE, IN THE  
CHICAGO MEDICAL COLLEGE, ETC., ETC.

VOLUME IX. 1868.

CHICAGO:  
ROBERT FERGUS' SONS, PRINTERS,  
12 & 14 CLARK STREET.  
1868.

## ARTICLE XLVI.

## THE OXYGEN MIXTURE, A NEW ANÆSTHETIC COMBINATION.

---

By E. ANDREWS, M.D., Prof. of Principles and Practice of Surgery,  
Chicago Medical College.

---

Every surgeon who has seen the prompt and pleasant anæsthetic action of the nitrous oxide gas, so much used by dentists, has wished that in some way it might be made available in general surgery. The patient usually goes under the influence in 30 or 40 seconds, and wakes with equal promptness, without vomiting or other unpleasant symptoms, all of which is in striking contrast with the slowness, the nausea, and the discomforts of chloroform and ether. There have been, however, great obstacles to the use of the gas, owing to its evanescent action. The oxygen contained in it is in a state of chemical combination, so that it is not available for oxygenation of the blood; hence if any attempt is made to continue its action, the patient becomes purple in the face, showing all the signs of asphyxia; subsultus tendinum then supervenes, and shortly after he almost ceases to breathe, and, if allowed nothing but pure nitrous oxide, would doubtless die in a few minutes.

I have for some time been experimenting, to see whether by the addition of free oxygen to the nitrous oxide, a mixture would not be obtained, by which a patient might be anæsthetized for an indefinite period without danger of asphyxia, and thus render gas available for the most prolonged operations of surgery. These experiments are not yet finished, but they have advanced far enough to show that the preparation, which I have named the Oxygen Mixture, is certainly available for a large part of our operations, and that for pleasantness, and probable safety, it is infinitely superior to chloroform, ether, or unmixed nitrous oxide. The following facts and experiments show the present state of our knowledge on the subject:—

In the first place, pure nitrous oxide, when given for brief operations, appears to be the safest anæsthetic known. Chlo-

reform, in American and European hospitals, kills one out of about every 3600 patients who take it; but the Colton Dental Association, a company with branches in all our principal cities, established for the sole purpose of extracting teeth, has on its books over sixty thousand cases of anæsthesia by nitrous oxide, without a single death caused by the anæsthetic.

Now, it cannot be supposed that the addition of a moderate amount of free oxygen, in mechanical mixture, to nitrous oxide can produce any new danger; on the contrary, by removing all possibility of asphyxia, it must be eminently an element of safety.

To test this question, the following experiments were performed:—

EXP. 1. A large rat was placed in a glass jar on a perforated floor, beneath which was a stratum of lime-water to absorb the carbonic acid produced by its breathing. To make more sure of this result, a jet of lime-water spray was thrown into the jar at frequent intervals during the experiment. I then turned on a small stream of pure nitrous oxide gas, which, being fifty per cent. heavier than atmospheric air, settled to the bottom, and expelled the atmospheric air by displacement. In two minutes the animal fell over upon its side, breathing slowly with deep-labored inspirations. The respirations continued to become slower, until, at the end of ten minutes, they ceased entirely, and life was found to be extinct. The death was doubtless from asphyxia.

EXP. 2. Another rat was placed in the jar under the same conditions, and exposed to an oxygen mixture consisting of about one-fourth of free oxygen to three-fourths of nitrous oxide. In two and a half minutes he was so completely anæsthetized that he could not be made to respond to pinching or pushing. There was no panting, or laboring for breath, as when pure nitrous oxide was used, but the respiration was rather slow, and very gentle. He was kept in the mixture half an hour, and then removed, still perfectly anæsthetized. In five minutes he began efforts at walking, and in ten seemed to be perfectly restored to his natural condition.

EXP. 3. A rat was placed in the jar and given the oxygen mixture, containing 25 per cent. pure oxygen. This being more than is contained in the atmosphere, diluted the nitrous oxide too much, which, together with the fact that the animal was less susceptible than the former, prevented full anæsthesia. He fell into a sort of intoxicated condition, without appearing to be fully unconscious, and continued thus throughout the experiment. At the end of 30 minutes the gas was shut off, and the animal shortly recovered his sobriety.

EXP. 4. The same animal was again exposed to the oxygen mixture for half an hour, with precisely the same results as before.

EXP. 5. To test the relative safety of the oxygen mixture as compared with ether, my friend Dr. Sherman took the same rat, after his recovery from experiment No. 4, and dropped into the jar a little sulphuric ether. In a short time he was unconscious, and in two minutes was dead.

EXP. 6. A lady had an anchylosed knee, to which I wished to restore motion by forcible flexion. Having a dread of ether and chloroform, she inhaled the oxygen mixture in the proportion of one-third free oxygen to two-thirds nitrous oxide. In forty seconds she was perfectly anæsthetized, without any blueness of the countenance, or laboring for breath. There was a little pallor about the lips. I broke up the adhesions of the joint by flexing and extending it forcibly. She probably inhaled the gas about two minutes, felt no pain, and awaked without nausea.

EXP. 7. A young woman took in my presence the mixture as prepared by Dr. Rogers, dentist, for the extraction of a tooth. There was, as before, a slight pallor of the prolabia, but no asphyxiated purpling of the face. The tooth was extracted without pain, and the patient awoke without nausea.

EXP. 8. A woman, aged 42, had anchylosis of the right hip, with contraction of the flexors of both knees, fixing those joints at a right angle. I desired to cut all the hamstring tendons of both limbs, and to break up by force the adhesions of the anchylosed hip. The gas was given from a 30-gallon elastic bag,

with an imperfect inhaler. The mixture contained one-third free oxygen. Owing to the imperfection of the inhaler, it was found impossible to prevent the patient getting considerable atmospheric air with the gas, so that the anæsthesia was less perfect, and slower than in the former instance. After inhaling it for nine minutes, she became unconscious, and I severed all the hamstrings. I then endeavored to break the adhesions of the head of the femur, but found they were too firm, and I desisted. The operations lasted about three minutes, when she was allowed to recover, which she did without nausea, though she had a meal in the stomach. Twice during the inhalation there was a sort of pallor of the face, with very faint duskiness, which induced me to suspend the administration of the gas a few respirations.

EXP. 9. Mrs. R. had ingrowing, painful nails on both feet. Ten months ago she took ether for the extraction of one of them. She was of a very nervous temperament, was slow in coming under the influence of the ether, and after partially awaking remained delirious, and distressed a considerable time. Three months afterwards she took pure nitrous oxide for the extraction of a tooth. She was anæsthetized in about one minute, and felt no pain, but the countenance was blue with asphyxia, and she was delirious a good while after waking. She felt uncomfortable for several days. Six months afterwards she was again anæsthetized by Dr. Reber, a dentist, who had prepared the oxygen mixture at the suggestion of Dr. Sherman. The gas contained one-third free oxygen. She was anæsthetized in one and three-quarter minutes, and in that condition Dr. Sherman split the offending toe-nail and tore out the proper half of it without causing any pain. She inhaled the gas for three minutes in all. On awaking, she was as usual delirious, which state, however, continued only fifteen minutes, a much shorter time than after ether or pure nitrous oxide. There was no blueness nor pallor of the lips during inhalation, and on her waking she was much more comfortable than after anæsthesia with the other articles.

Dr. Reber has given the oxygen mixture to several patients

for the extraction of teeth, and states that it uniformly acts more agreeably than unmixed nitrous oxide.

Dr. Rogers, a dentist of this city, states that he has used a mixture containing one-third free oxygen for several years, and that in his opinion it is far pleasanter than unmixed nitrous oxide.

Some months ago some such mixture was proposed in England, but was overthrown, I think, by the influence of Dr. Richardson, who argued, on theoretical grounds merely, that it would not be successful, nor safe. I cannot learn that it was ever actually tried in Europe.

Prof. Watt, of the Dental College in Cincinnati, has been experimenting, I understand, on what involves partly the same principle. I am informed that he gives alternately inspirations of nitrous oxide and atmospheric air, and thus both avoids the asphyxia, and is able to continue the inhalation a long time. I have written to him inquiring about his results, but have received no answer.

The above experiments are by no means sufficient to settle the value of the oxygen mixture, but they give strong reason to think that it will prove the safest, and by far the pleasantest, anæsthetic known. As to its safety, it is highly significant, that a rat which had been twice immersed in the mixture for half an hour without injury, was killed in two minutes by ether; and yet ether is far safer than chloroform.

It is my impression that the best proportion of oxygen will be found to be one-fifth by volume, which is the same as in the atmospheric air. There are some points requiring care in the management, in order to insure success. As the oxygen dilutes the nitrous oxide, it is necessary to be very careful to exclude all atmospheric air, or else the anæsthesia will be imperfect. The inhaler must be taken into the mouth, the lips very carefully closed around it, and the nares compressed by the person administering the anæsthetic. For the same reason, great care should be taken to secure purity of the gases, otherwise the mixture will be too weak to control some patients. I have found, by introducing phosphorus into a bell glass of what was

supposed to be very pure nitrous oxide, that it contained considerable free oxygen, which doubtless was from included atmospheric air; and therefore four times the bulk of free, inert nitrogen must have been present also, to weaken the power of the article.

The oxygen is best prepared by taking pure chlorate of potash mixed with a little black oxide of manganese, and placing them in a copper retort and applying heat. The gas should pass through four washing-bottles, just as the nitrous oxide does. The same bottles will answer. As the nitrous oxide is fifty per cent. heavier than oxygen, it is better to pass it into the gasometer first. The oxygen coming afterwards, passes up through it, and hastens the mixing. It is better to let them stand a day or two, if possible, before using, to complete the mixture, but this is not essential.

Dr. Evans, the well-known American dentist in Paris, asserts that the ordinary nitrous oxide is very far from pure, even when well made. He states that he has been in the habit of purifying his gas by mechanically condensing it to a liquid under high pressure. This liquid, being absolutely pure nitrous oxide; is then allowed to reassume the gaseous form in a bag, or a gasometer. He finds that gas thus purified, only requires about half the usual quantity to anæsthetize a patient.

It seems probable, therefore, that the oxygen mixture will enable us to anæsthetize a patient for the longest as well as for the shortest surgical operations, and that it is safer and pleasanter than any anæsthetic known. There are, however, some inconveniences about it, on account of its great bulk. For office use, and also in hospitals, this is no objection, as it can be kept in a gasometer; but for outside patients it can only be carried in a large rubber bag. In city practice, among the higher classes, however, this is no obstacle, as the bag can always be taken in a carriage, without attracting observation.

I shall continue my experiments, and report the results at a future time.





THE  
**British Medical Journal.**

THE JOURNAL OF THE BRITISH MEDICAL ASSOCIATION.

EDITED BY

ERNEST HART, ESQ

---

VOLUME II, 1880

---

JULY TO DECEMBER.

London :

PRINTED AND PUBLISHED AT THE OFFICE OF THE BRITISH MEDICAL ASSOCIATION,  
429, STRAND, W.C.

## CLINICAL OBSERVATIONS

ON THE  
INTRODUCTION OF TRACHEAL TUBES BY THE  
MOUTH INSTEAD OF PERFORMING TRACHE-  
OTOMY OR LARYNGOTOMY.

BY WILLIAM MACEWEN, M.D.,

Surgeon and Lecturer on Clinical Surgery, Glasgow Royal Infirmary.

A FEW facts concerning the introduction of tubes passed through the natural passages into the trachea, instead of having recourse to operations for opening the windpipe through the neck, are considered worthy of attention; and in presenting these, it is thought advisable to confine the remarks as far as practicable to the relation of facts, refraining from entering into the merely discursive side of the question.

In considering the practicability of such a procedure, facts were looked for from various sources. *Post mortem* experience showed that instruments of the tube kind could, after a little practice, be passed with facility through the mouth into the trachea. This was accomplished by introducing the finger into the mouth, depressing the epiglottis on the tongue, and so guiding the tube over the back of the finger into the larynx. In experimenting with various instruments, it was found more easy to introduce those of a large calibre, such as Nos. 18 to 20, than instruments of the size of 8 to 10 catheters—the latter being more liable to catch on the various irregularities on the internal laryngeal surface.

While it was easy to introduce instruments by the mouth into the trachea, it was difficult to pass them through the nose into the air-passages. The nasal passages being on each side of the middle line, catheters passed through them were found to glide to the side of the pharynx, away from the middle line, and consequently away from the larynx; so much was this the case, that it was found impossible to introduce a nasal unarmed catheter through the nose into the trachea by any manipulation outside the mouth. A catheter, having a strong properly curved stylet, after considerable labour and many efforts, might find its way into the larynx; but even this could not be depended on. An instrument can, however, be passed through the nose into the pharynx; then, by introducing the finger into the mouth and hooking the catheter forward and toward the middle line, it can be guided into the larynx, and in this way respiration in the living might be carried on through the nose; but, though nasal instruments can be so introduced into the trachea, it is yet difficult to pass them when compared to the passage of like instruments through the mouth. The nasal tubes have also a decided disadvantage; they are necessarily of much smaller calibre than the tubes which are admitted through the mouth; in most people, one or other nasal aperture does not admit a tube of sufficient calibre to enable the respiration to be carried on easily.

The facility of introducing tubes by the mouth into the trachea having been ascertained on the "subject", the question which next presented itself was: whether there were any obstacles in the living body which would prevent or contraindicate their use. The instructions given in almost every text-book teaching the introduction of œsophageal tubes, would lead one to suppose that not only could such instruments be passed into the trachea, but that it was necessary to give special indications of their presence there, in order to avoid the awkward mistake of injecting fluid or food into the lungs. These precautionary indications are necessary, as, on several occasions, the stomach-pump tube has been unwittingly introduced into the trachea and left there, for shorter or longer periods, before the mistake has been recognised. Among these, may be mentioned the mistake made by no less a surgeon than Desault, who passed a tube into the trachea, left it there for some hours, and only became aware of its true situation when he began to inject food into it.\* After the performance of tracheotomy, tubes have been passed through the trachea into the mouth, and the reverse way; and, from the scanty reports of those cases, one gathers that the parts have exhibited considerable tolerance to the presence of those instruments. A couple of cases of cut-throat, which came into my wards about the same time—the one having the windpipe severed immediately above the vocal cords, the other beneath them—showed a great and growing tolerance to external impressions; so much so that, even when the cords were digitally pressed on and held aside, no spasm was produced. Besides these, the passage of metallic and vulcanite instruments, as proposed by Trendelenburg and

carried out by Schrötter, with the view of dilating strictures in chronic laryngeal stenoses, prove that instruments can be passed by the mouth and temporarily retained in the trachea without exciting an unsurmountable degree of spasm. And I would say that if they can be retained for ten minutes they might, as far as the fear of spasm is concerned, be retained for a much longer period. With these brief introductory observations, I will pass to the series of successful cases which I had during the year 1878.

CASE 1.—*Removal of Epithelioma from Pharynx and Base of Tongue: Introduction of Tube into Trachea through Mouth to occlude Hemorrhage from Larynx, and for administration of Anæsthetic.*—W. P., aged 55, a plasterer,\* was sent me by Dr. Anderson, Duke Street, Glasgow, who stated he believed him to be suffering from epithelioma of the mouth. There was an ulcerated surface of the tongue, and also one on the anterior pillars of the fauces. The last two right lower molars were very sharp and rugged, and, though the ulcer had an epitheliomatous look, it was thought advisable to try palliative measures in the first instance. The two lower molars spoken of were removed, and he was placed under a course of iodide of potassium. After a very full trial, these measures were found inefficient, as, when he was seen by me two months afterwards, the disease had extended. He was then admitted into the hospital.

On admission, he stated that he had experienced for over a year sore-throat, pain in the right ear, and shooting pain in the back part of the tongue. On examining, an ulceration was found on the right side of the fauces, extending from the anterior pillar backward to the posterior wall of the pharynx—the latter of which was invaded for about an inch. From the fauces it spread downwards and inwards to the dorsum of the tongue, and the raised ulcerated margins extended from a point opposite the last right molar to the immediate vicinity of the epiglottis. Histologically, the characters of this disease were epitheliomatous.

With the patient's concurrence, it was resolved to remove the growth. As it was an operation which would cause considerable bleeding, precautions had to be taken to secure the air-passages from occlusion. Hitherto this had been effected by opening the windpipe, by laryngotomy, and the introduction of Trendelenburg's tampon-cannula. Instead of this, I had determined, should an opportunity present, to introduce into the trachea, by way of the mouth, a tube, which would extend beyond the vocal cords, and through which the patient would respire. The upper laryngeal opening could then be plugged outside this tube, so as to prevent the entrance of blood into the larynx. The plug could then be effected in various ways, by causing the tracheal tube to perforate a close sponge of suitable size, which, after the tracheal tube had been introduced, could then be fixed in the laryngeal orifice; by fixing to the tube, at a convenient part, a piece of fine muslin or other material, which would act as the *canule à chemise* used after lithotomy; by inflation of a circular closely fitting bag, etc.

Preparatory to the operation, a tube was several times inserted through the mouth into the trachea, beyond the vocal cords; and it was found that, with the exception of the cough which ensued immediately on its insertion, he bore the tube sufficiently well to warrant the success of the procedure. He could breathe freely through it, and the mucus expectorated was expelled through the tube with considerable force.

The operation was performed on July 5th, 1878. The usual cough followed the introduction of the tube; but it ceased as soon as he received a few whiffs of chloroform, and long before he became constitutionally affected by the drug; the chloroform seemed to exercise a local sedative effect. The upper opening of the larynx was stuffed with a sponge to prevent the entrance of blood. The tube projected several inches beyond the mouth, thus enabling the administration of the anæsthetic to be continued uninterruptedly during the whole operation, without in any way interfering with the manipulative procedure. The entrance and exit of air through the tube was both felt and heard distinctly, so that Dr. Symington (who administered the chloroform) had a ready guide to the state of the respirations. After the operation was finished, when the hæmorrhage had ceased and the patient had regained consciousness, the tube was withdrawn, it having acted throughout without the slightest hitch.

The operation may be briefly described as follows. An incision was made through the right cheek, from the angle of the mouth to the angle of the lower jaw—the latter being sawn through. This line of incision, once previously used by Dr. Foulis, though objectionable on *à priori* grounds, was followed chiefly on account of the extensive view of the internal parts afforded by it. The diseased surfaces were thoroughly removed by the knife, the instrument passing wide of the affected parts. The sawn angle of the jaw was afterwards drilled, and coupled by two strong silver wire stitches. The cheek was accurately brought together,

\* Desault, by Bichat, (*Œuvres Chirurgicales*, vol. ii, pp. 250.

\* The patient was afterwards shown at the Glasgow Medico-Chirurgical Society.

and a bandage applied to secure immobility of the lower jaw. His after-treatment consisted in perfect quiescence and fluid food. In a week the wound was for the most part healed, the only portion remaining open was that where the wires uniting the jaw protruded through the skin. In a month the wires were withdrawn, the jaw being then firmly united. He was dismissed to the Convalescent Home July 26th, 1878. Since then, he has several times presented himself, and, as he has cultivated a vigorous growth of hair, the facial linear cicatrix is no longer visible. The larynx in no way seemed to suffer, and the voice was in no way affected. The administration of the anæsthetic was carried on through the tube, which projected several inches beyond the mouth, quite uninterruptedly, and without in any way interfering with the operator. The respiration was felt and heard by the administrator; the tube, as it concentrated the flow of air, increased the sensation to the hand and ear. Once or twice during the time he was under the chloroform, mucus was thrown from the tube by an explosive expiratory effort. It must be obvious that as long as the tube which went beyond the vocal cords remained patent, there could not possibly be any fear of asphyxia, and the most frequent cause of fatality under chloroform would be avoided.

REMARKS.—It may be noticed that the tube answered all the purposes for which it was intended. 1. The chloroform was easily, uniformly, and uninterruptedly administered during the whole operation. 2. The administration of the chloroform in no way interfered with the performance of the operation. 3. The ingress and egress of air through the tube were both felt and heard, so that the administrator had a ready indication of the state of the respiration. 4. No blood entered the larynx. 5. The after-result was excellent.

CASE II.—*Œdema Glottidis: Tube inserted into Trachea through Mouth.*—W. L., a commercial traveller, aged 42, was admitted into the Glasgow Royal Infirmary at 1.20 A.M. on 14th Sept., 1878, suffering from acute œdema glottidis. He had a note from Dr. Macmillan of Paisley Road, Glasgow, headed, "urgent case", and stating, "case of inflammation of trachea, probably requiring operative interference". After the patient was examined by my house-surgeon, Dr. Symington, he considered it necessary to send for me, and at 2.15 A.M. I found the patient in the following state. He sat in bed supporting himself with stiffened arms; his head was thrown forwards, and he had the distressed anxiety so characteristic of impending suffocation depicted on his countenance. His inspirations were crowing and laboured, and there was a very frequent forced attempt to swallow, attended by extreme pain, at the termination of which a long crowing inspiration ensued. He spoke in a muffled whisper, and confined his answers, when possible, to monosyllables, or substituted signs by head or hand. He complained of intense pain—a feeling of suffocation, and begged that something should be done for his relief. On examination, it was seen that the base of the tongue and the fauces were covered with whitened mucous membrane, at parts shrivelled up and peeling off, at others adherent. The parts not so covered were in a reddened congested state. The fauces and the upper portion of the larynx were much swollen, and had a hard thickened feeling, as if they had been slightly burned. The respiratory orifice was so much constricted that the tip of the forefinger occluded it. He constantly signed for cold water, which he took into his mouth, and after abortive attempts to swallow, he rejected it during a fit of coughing.

History.—It was afterwards ascertained that he had entered the kitchen of his house just as the boiling water had been poured from the potatoes preparing for dinner; snatched up a small potato in his fingers, and, finding it too hot for them, unthinkingly threw it into his mouth and attempted to swallow it, but it stuck at the back of his throat and nearly choked him. This happened twelve hours prior to his admission into the hospital. An hour after this mishap he felt somewhat relieved, and went out to transact some very pressing business, but finding his breathing becoming rapidly impeded, he had to return and send for his medical attendant. From this time the symptoms steadily increased, until he arrived at the hospital in the condition already mentioned.

Treatment.—It was just such a case as required prompt operative interference. Instead of opening the windpipe through the neck, it was resolved to introduce an instrument by the mouth. As the passage was so constricted, a No. 12 catheter was first introduced, and, the orifice being found so far patent, a catheter of larger calibre, and in shape resembling a rectal tube, was introduced. On its introduction there was evinced considerable excitement, accompanied by a spasmodic fit of coughing, which lasted for about a couple of minutes. In order to gain the patient's confidence, he was asked to hold with his own hand the portion of the tube which projected from his mouth, and told that he was at liberty to withdraw it if he felt it necessary. Half an hour afterwards he withdrew the tube, stating that he did so as he wanted to cough. When it was withdrawn, even after this short interval, he could speak

more distinctly, and stated that his breathing was relieved. The tube was then reinserted, and fixed *in situ* for twelve hours. It was then removed, washed, and, after the patient had something to drink, it was reintroduced, and retained for other twelve hours. After the end of the first twenty-four hours, when the tube was withdrawn, he could breathe very much more freely, and could swallow solid food. It was, however, considered prudent to introduce and retain the tube in the trachea for other twelve hours, which was done. During the last period, he slept for four or five hours with the tube in the trachea. After the end of this time, the swelling round the orifice of the larynx had almost entirely subsided. The tube was then finally removed. This would be about thirty-nine hours from the time the tube was first introduced; but, excluding the time during which the tube was withdrawn for the purpose of cleaning it and feeding the patient, the instrument would be retained *in situ* for thirty-six hours. He afterwards made an uninterrupted recovery, and went out of the hospital six days after admission.\* Regarding this case, the following facts seem worthy of note. The first introduction of the tube was followed by a prolonged (fully two minutes) spasmodic cough, which evidently gave pain. The second insertion was likewise followed by a spasmodic expiratory effort, but much slighter and of short duration. The sequence of the third intromission was a single abrupt expiratory effort, resembling a person clearing his throat, but there was neither cough nor pain. On the occasion of the first and second introductions, I perceived that the cough and the painful sensation subsided at the moment when a long inspiration took place. Before introducing the tube a third time, the patient was instructed to take a long inspiration as soon as the tube was inserted. He did so, and it is possible that this affected the result.

It will be observed that the word cough is used; and physiologists will be apt to say that, if the patient coughed, the tube could not have been passed through the vocal cords. The tube was passed into the trachea until the rings of that organ were felt, so that there can be no doubt that the tube had penetrated further than the true cords. The sound, which has been called a cough was at times rather like a person violently clearing the throat, but at others it was a distinct explosion—at such times generally sending some mucus forcibly from the orifice of the tube. A cylindrical tube of the calibre used does not fill the whole larynx at the level of the cords, but, resting chiefly on the respiratory portion, still permits the cords to come into contact anteriorly, to a greater or less extent. It is, therefore, possible that the portions of these structures remaining free could exercise sufficient restraining power on the air on the outside of the tube in front, so as to enable an explosion to take place, provided the volume of air coming from the lungs be greater than what could find ready egress through the tube itself. Whether this explanation be correct or not, there can be no doubt that the patient could say "Yes" and "No" distinctly while the tube was *in situ*—leading the air to the outside of the mouth—and to attempt other sounds and phrases, though the latter were unrecognisable.

Mucus was expelled from the tube by coughing. Sometimes a little mucus would be heard in the tube for a number of seconds, when a sudden expiratory effort would send it to the outlet of the tube, where it would be wiped away, or the cough might be strong enough to expel the mucus clear of the tube. In this instance, the mucus in the tube formed an impediment which was sufficient in itself to permit a distinct explosion when an effort to expel it took place.

This patient was extremely thirsty, constantly crying for drink, owing probably to the burned state of the parts. After the tube was inserted, he demanded a drink, and was much annoyed when he was presented with a teaspoonful of fluid. It was explained to him that it was feared the fluid "would go down the wrong way". This fear on our part was soon dispelled by the patient taking several mouthfuls of milk, and swallowing it while the tube was *in situ*. This he afterwards many times repeated, the parts encircling the tube so as to prevent the ingress of fluid.

CASE III.—*Acute Œdema Glottidis, following Chronic Laryngeal Affection: Insertion of Tube into Trachea through Mouth.*—M. R., a housewife, † aged 38, was admitted into the Royal Infirmary on December 8th, 1873, suffering from a laryngeal affection requiring operative interference. For more than a month previously she had suffered from a throat-affection, supposed to be ulceration of the larynx, for which she was treated by Dr. Nairn of Glasgow. From this she partially recovered, but on December 5th she took a relapse. She then experienced pain in the throat and right ear, and difficulty of deglutition, which increased until, when she attempted to swallow, the fluid passed by the nose. Her respirations became greatly impeded until, on the day of admission, her medical attendant considered operative interference imperative, and with

\* This man was shown by me afterwards at the Glasgow Pathological and Clinical Society.

† This patient was afterwards shown at the Glasgow Medico-Chirurgical Society.

this view advised her to go to the Royal Infirmary, whither he himself conducted her in a cab. On admission, she was in the following condition. She had an anxious pained look; her respirations were laboured, crowing, and much impeded. The saliva trickled from her mouth, as she could not swallow, and very often a spasmodic cough took place, ending in bringing up some mucus mixed with saliva and slightly tinged with blood. She had aphonia; attempts to whisper evidently gave pain, so she curtailed them to monosyllables, or substituted a sign, such as a shake or nod of the head. She hesitated about making any attempt at deglutition; she did try, however, and apparently took a spoonful of milk, but after four or five seconds it was expelled during a fit of coughing. This was repeated with a like result. On examining the throat, the orifice of the larynx was found to be very much narrowed—oedematous tissue surrounding it on all sides and extending backwards in the form of a tumour, which completely blocked the pharynx. The tip of the forefinger could occlude the portion of the laryngeal orifice that remained patent. The epiglottis was not active, and neither it nor the surrounding parts exhibited the usual sensitiveness to touch. In consequence of the tumour-like extension of the oedema behind and to the sides, the larynx was pushed well forward and fixed in that position. Her pulse was rapid and weak; her skin was hot and clammy. She was about three months pregnant. It was just such a case as would have been operated upon by tracheotomy under ordinary circumstances.

A fresh No. 12 catheter was passed into the trachea by way of exploration, and then the smallest sized tracheal tube that was at the time obtainable. This was found to be just on the thick side, but it passed. A fit of coughing, which lasted more or less for a couple of minutes, ensued; after which she had comparative ease. The tube was inserted at 6.20 P.M. on December 8th, and was retained till 8 A.M. on December 10th—it being removed at intervals of about twelve hours to be cleaned and to permit an œsophageal tube to be inserted for feeding purposes. In all, it was in the larynx thirty-five hours. At the end of that time, the oedema had greatly subsided; she then breathed easily. She could swallow and speak a little, and from this time she made an uninterrupted recovery.

The following points are particularly noted. The introduction of the tube was easy, as the laryngeal orifice was thrown well forward and fixed, owing to the great amount of oedema; and from the same cause the parts had an impaired sensibility, which rendered the manipulation tolerable. The first tube seemed to fill the entire free portion of the larynx above the cords. The next tube was very slightly narrower, at the same time thinner in its walls, thereby affording a large internal diameter relatively to the size of the tube. The ease which this gave was great, and, after it was introduced, the patient marked her appreciation of it by grasping and clapping the hands of the operator by way of thanks. She turned on her side afterwards, and soon fell asleep. The two last times the tube was inserted, it did not cause any cough or spasm.

In the former case, it was noticed that there was a distinct cough; in this case, the expiratory explosion of air was not what could come clearly under the physiological term cough, except toward the end of treatment, when there were sounds which were more purely explosive in character. Again: at first, after the introduction of the tube, the patient could not give the monosyllables as noted in the former case. It must be remembered, however, that she had complete aphonia on admission. Toward the end of the first twenty-four hours, she began to say "Yes" and "No"; and, after the thirtieth hour, the monosyllables were sounded distinctly.

The expectoration was profuse, semi-purulent, fluid, and streaked or mixed with blood; but it afterwards, towards the end of the first twenty-four hours, began to be thick and tenacious. The expectoration was thrown to the outside of the tube, sometimes by a distinct cough, when a quantity of the mucus had partly occluded the tube for a moment. On several occasions, when the mucus began to be tenacious, a little brush, mounted on a wire of definite length, was pushed into the tube and the expectoration removed. Twice, when the breathing was not quite so free, the tube was removed, and a very thin coating of mucus was found in the interior; this was washed off and the instrument returned.

Remembering the state of the pharynx, rendering deglutition impossible, and the loss of sensibility of the larynx prior to the introduction of the tubes, she was not asked to swallow during the first twenty-four hours while the tube was in position. Several times, a catheter was introduced into the œsophagus, and beef-tea, eggs, milk, and brandy were injected. At the end of the first day she began to swallow a little, and about the thirtieth hour she took several mouthfuls with the tube *in situ*. Several times she slept for hours with the tube in the trachea, and often she had snatches of sleep besides.

In this case, the oedema glottidis, mechanically blocking the pharynx, was so great as to exercise pressure on the superior laryngeal nerves,

exhibited in the non-sensibility of the epiglottis and the parts of the larynx above the true cords. This constituted a danger, as was shewn when she attempted to swallow. The impaired laryngeal sensibility, coupled with the fixity of the structure from the oedema, prevented the epiglottis and the neighbouring parts from closing the laryngeal orifice, when an attempt at deglutition was made. As a consequence of this and the pharyngeal obstruction, the fluid entered the larynx, passing down into the trachea before it produced the irritation necessary for its expulsion. A few seconds of quiescence ensued after the attempt to swallow the fluid before it was again brought up by coughing, and it is likely that the time might have been extended if persistent efforts to feed the patient were made. From cases which I have seen and heard of, this is not an unfrequent cause of at least hastening a fatal issue in children affected with oedema of the glottis. It is satisfactory to note that the patient, who was pregnant at the time when she was suffering from the throat-affection, afterwards had a well-developed strong child at full time.

[To be continued.]

## ON A NEW METHOD OF ARRESTING GONORRHOEA.

By W. WATSON CHEYNE, M.B., F.R.C.S.,  
Assistant-Surgeon to King's College Hospital.

HAVING been for some time past occupied with the problem of the infective diseases of wounds, the subject of gonorrhœa, as an affection probably belonging to the same class of diseases, has occupied my attention. The extreme contagiousness of this disease, the existence of a distinct period of incubation, and the steady spread of the inflammation from a given spot, all point strongly to a parasitic origin. Acting on this idea, I made, in the spring of 1879, a number of inoculations of gonorrhœal pus, under certain precautions, into flasks containing infusion of meat or infusion of cucumber. In these flasks micrococci grew in large numbers, and also sometimes bacteria, showing that these organisms were present in the gonorrhœal pus. Circumstances prevented me from pursuing this subject further at that time. In the meantime, Dr. Neisser published an elaborate research on this subject, in which he showed the presence of enormous numbers of micrococci in gonorrhœal pus, and in the pus from contagious ophthalmia. He further asserted that these organisms were always of a definite size, and that they differed in respect of size from the micrococci found in wounds. The presence of large numbers of micrococci in gonorrhœal pus has since been confirmed by several observers. Whether these micrococci are the cause of the gonorrhœal inflammation or not, I do not attempt to say, but the general history of the disease, taken together with these facts, points strongly to the idea that its essence consists in the growth of these or allied organisms.

If this disease be due to the spread of organisms, where are they situated? Several facts lead to the supposition that they are not only free in the urethral canal, but that they are also present in the substance of the inflamed mucous membrane. Thus, in the case of erysipelas, it has been demonstrated that the skin at the margin of the inflammatory redness is full of micrococci. Koch found, in his case of erysipelas in rabbits, that bacilli were present throughout the inflamed part, and coextensive with the inflammation. The same writer obtained a progressive gangrene of the tissues in mice by the injection of putrid blood, and he has demonstrated conclusively that this gangrene is due to an organism—*streptococcus*—which is present in large numbers around the limits of the gangrenous part. A similar observation was made by him in a case of spreading suppuration in rabbits. Mr. Lister has long held the opinion that, in the case of putrid sinuses, the organisms were present, not only in the canal of the sinus, but also in the substance of the unhealthy granulation-tissue lining them. This view has been justified by the fact that, though formerly, by the simple injection of the sinuses with antiseptics, he did not often succeed in eradicating the septic element, yet, since he has adopted the use of Volkmann's sharp spoon, and has removed the layer of granulation tissue lining them, success is by no means uncommon. And, lastly, I have demonstrated that, though many forms of organisms will not survive if introduced into a healthy animal, yet, if an animal be previously in a state of ill health, these forms of organisms are not destroyed, but may be found alive in the blood or tissues.

In the case of gonorrhœa, then, I suppose that, at the time of infection, a small number of the specific organisms, which in all probability possess a considerable resisting power to the destroying action of the healthy living tissues, are retained in the urethra, that these go on developing, that the products of their growth irritate and weaken the

## CLINICAL OBSERVATIONS

ON THE

## INTRODUCTION OF TRACHEAL TUBES BY THE MOUTH INSTEAD OF PERFORMING TRACHEOTOMY OR LARYNGOTOMY.

BY WILLIAM MACEWEN, M.D.,

Surgeon and Lecturer on Clinical Surgery, Glasgow Royal Infirmary.

(Concluded from page 124 of last number.)

CASE IV.—In this case, the tracheal tube was intended to be used during eradication of an epitheliomatous tumour, this intention being frustrated by the demise of the patient whilst under the influence of chloroform, the tube, however, not being then used. The man was about sixty years of age, but looked older, probably in consequence of excessive alcoholic indulgence, which had been kept up for many years. He had chronic bronchitis with muco-purulent expectoration, in consideration of which considerable doubt was expressed to him about operating; but, as he was very anxious to have the rapidly extending disease eradicated, it was determined to do so.

Owing to the state of his lungs, it was deemed necessary to make a preliminary trial of the tube, in order to observe its behaviour under the profuse expectoration. The tracheal tube was passed, and, during its retention, considerable quantities of muco-purulent secretion were expelled—on several occasions quite clear of the tube, and even in some instances for a considerable distance beyond it—two, three, and even four feet beyond the nozzle of the tube. In order to lessen the secretion, a few days were allowed to elapse, during which remedial measures were resorted to. At the end of this time, the muco-purulent secretion had lessened, and the tube was again tried. On this occasion, the tracheal catheter was inserted, and all the purposes for which it had been introduced having been gained, it was removed at the end of ten minutes. The expectoration was much less; the tube, which the patient held with his own hand, was borne without pain or uneasiness. During the time it was retained, his respirations were easy; he pronounced the monosyllables “Yes” and “No” distinctly; he swallowed his saliva, and drank several mouthfuls of water without disturbing his tranquillity. The way now seemed clear, and it was resolved to operate.

Next morning, in the ward adjoining the theatre, the tube was introduced into the trachea, the patient as usual holding the outer end; he remained there for a quarter of an hour, breathing easily. He then walked into the theatre and lay down on the table. Chloroform was just commenced to be given him, when he rose up, withdrew the tube, handed it to the surgeon, said he would prefer to take the chloroform without it, and that it could be introduced afterwards. He then lay down to inhale the anæsthetic. A few minutes afterwards, he was asked to turn on his side, with which request he readily complied. He breathed quietly and regularly for ten minutes afterwards. He then had what was considered at the time to be the ordinary period of struggle. This ended, the house-surgeon, who was administering the chloroform, stated that for several minutes after the struggle passed off he both felt and heard the respirations going on quite regularly, and certainly his chest was heaving as if from normal respirations.

Nearly five minutes after the struggle had ceased, one of the gentlemen, who held the radial pulse the whole time, cried out that the pulse had stopped. The house-surgeon said: “That surely cannot be, as he is breathing all right.” A few seconds later, the breathing ceased. The moment the breathing ceased, the tongue was instinctively withdrawn, and artificial respiration established. Bloodletting was spoken of at the moment, as it was considered that there was an apoplectic element in the case, interpreting the former struggle as a convulsion; but, the heart not responding, it was not carried out. It must be clearly remembered that the patient spontaneously withdrew the tube and handed it to the surgeon, just as he was about to be anæsthetised, and before he was under the influence of the chloroform. Fully fifteen minutes elapsed from that time till the cessation of the cardiac action. The respirations were never for a moment impeded, and actually continued for a few seconds after the cessation of the cardiac impulse.

Viewing the case as it then stood, I was inclined to believe—though a positive opinion could not be formed—that there was a primary cerebral lesion, probably apoplectic, and that the cardiac cessation was secondary.

The necropsy showed an effusion of serum under the arachnoid; and the lateral ventricles were abnormally distended and filled to distension with serum, showing the chronic nature of the affection. There was no

impediment to respiration in the larynx, trachea, or bronchial tubes. The lungs were œdematous, and exhibited the appearances of chronic bronchitis and inflammation of old standing. The bronchi and bifurcation of the trachea were congested, the congestion extending for about an inch above the bifurcation. From this point, there were several inches of slight congestion, the shade becoming very slight as it proceeded upwards toward the true cords. At these isolated points, two of them above and one below the vocal cords, there were appearances of ecchymosis on the mucous membrane, each having a superficial area of about three millimètres in diameter (about the size of a small pea or a large barley-grain). In cutting into these, it was seen that they were superficial, extending no further than the mucous membrane. The cords were very slightly thicker than normal, probably due to some chronic action. There was also a slight thickening of the posterior part of the laryngeal orifice.

The appearances noted from about an inch above the tracheal bifurcation were such as would have passed without observation in any ordinary case; but, as the opportunity offered, it was considered advisable to take a minute note of them, and they are thus given in detail.

Death was due to the chronic cerebral affection, the anæsthetic perhaps acting as an exciting cause.

*Hack's Case of Edema Glottidis.*—After having had the experience of these cases, commencing in the summer of 1878, and having shown one of these patients at the Glasgow Pathological and Clinical Society, on November 12th, 1878, it was with considerable pleasure that I read, in that valuable paper the *London Medical Record*, a reference to a case of an acute laryngeal affection, in the treatment of which one of Schrötter's bougies was introduced into the larynx through the mouth. In turning to the original, which appeared in Volkmann's *Sammlung Klinischer Vorträge* for November 1878, it is seen that Dr. Wilhelm Hack had a patient who was seized with acute œdema glottidis, superinduced on a chronic syphilitic affection of the mouth and larynx; and, when he was at the point of suffocation, Dr. Hack introduced No. 3 of Schrötter's triangular vulcanite instruments, which he retained for a short time. This man was then sent to the hospital; but, on the road thither, he became violently affected with dyspnoea, when he (the patient) took the vulcanite tube, which he carried in his pocket, and introduced it into his own larynx, and so appeared at the hospital with his hands clutching the tube, “as if clinging to his last anchor of safety”. Dr. Hack continued the treatment in the Freiburg Hospital. The same evening, he introduced No. 5 of Schrötter's bougies, and, during the two following days, gradually introduced larger ones up to No. 11. He does not mention the precise time these instruments were each retained; but, in the discursive part of his essay, he says, referring to his case, the instruments were retained for almost an hour, and the patient neither complained of particular pain nor disagreeable sensation. From this, it would appear that Dr. Hack retained the instrument in the larynx for a short time only (almost an hour), and that he aims at rapid dilatation of the larynx by the introduction of Schrötter's graduated bougies. His patient ultimately made a good recovery.

*History.*—It may be advantageous to review briefly the few items of history obtainable concerning the introduction of respiratory instruments by the natural passages. Without stopping at Hippocrates, who is accredited with having entertained ideas on the subject which never found practical issue, we pass to Desault. (*Œuvres Chirurgicales. Exposé de la Doctrine et de la Pratique de Desault*; par Bichat; tome ii. Paris.) Toward the end of Desault's life, he endeavoured to introduce instruments through the nose into the trachea. He was induced to do so by having one day by mistake passed a tube into the trachea instead of into the œsophagus. Two hours afterwards, when he attempted to inject food into the tube, he found out his error. Reasoning from the tolerance exhibited by the trachea in this instance, he thought that the same procedure might be purposely adopted in laryngeal affections. He therefore determined to carry it out. The first observation is mentioned by Geraud, in which Desault passes a tube into the larynx of a man having a laryngeal affection, which afforded him relief, the breathing going on freely through it; though the man died the same evening from causes independent of respiration. The second observation was made on a man affected with something resembling œdema glottidis, on whom Desault passed a tube through the nose into the trachea, which was retained for a day and a half. During this time it was once withdrawn in order to be cleaned. Its reintroduction was attended with little cough; and the man at the end of a day and a half was cured. These observations are given in a very meagre way, almost as isolated statements, and the series of phenomena which attended the introduction and retention of such instruments into the air-passages are barely touched on. In some measure, this may be accounted for by the work not having been written by Desault, the facts not even being gathered from his lips, so that not

only do they lose the life and vivacity which personal description would have imparted, but much also that would have been of value to the surgeon. If these remarks apply to the facts, they are doubly applicable to the instruction which follows, for the introduction of nasal tubes into the trachea. Anyone who doubts this, has but to try to carry out the instructions given by Bichat for the introduction of nasal tubes, in order to convince himself of the correctness of my opinions. Equally erroneous and misleading are the signs given by which evidence may be afforded of the presence of the sound in the trachea.\*

These observations were made at the beginning of the present century, and from that time up till 1858 there is no mention of the subject.

M. Bouchut, in 1858, brought before the Academy of Medicine (*Comptes Rendus de l'Académie des Sciences*, tome xlvii, September 1858), what he termed *le tubage du larynx*. This consisted in placing in the larynx a tube eighteen to twenty-four millimètres long, and from six to fifteen millimètres wide. This little tube was inserted into the larynx on the point of a hollow sound. The sound was withdrawn after depositing the tube on the vocal ends, resting on them by means of a couple of pads. A silken bridle was likewise fastened to this little tube, in order to withdraw it when necessary.

Whatever merit this apparently ingenious little instrument may have possessed, it was brought before the Academy under very unpropitious circumstances. First, that element of success necessary for the favourable reception of a new idea was deplorably absent in his cases; as all of them were failures, five of them having died out of seven; the remaining two only recovered after recourse had been made to tracheotomy. Again, Bouchut was so unfortunate as to fall foul of tracheotomy, which at that time not only had found favour, but was warmly espoused, by the then medical Parisian demigod, Trousseau (*Archives Générales de l'Académie de Médecine*, vol. xii, 5th ser., p. 739; vol. xiii, 5th ser.), who condemned *le tubage*, at least for cases of diphtheria. A long, animated, and somewhat personal discussion followed in the Academy. Malgaigne, Velpeau, and Larrey (*Op. cit.*, Jan. 18th, 1859; also *Bulletin de l'Académie Impériale de Médecine*, tome xxii, 1857-8, tome xxiii, 1858-9), among others favoured Bouchut, and encouraged him to proceed with his observations, the latter remarking, that the Academy ought to bear in mind, that several operations, which were at that time accepted, had been opposed at the outset by that august assemblage; instancing disarticulation of the hip, and tracheotomy itself, in support of his observations. Probably discouraged, Bouchut does not appear to have again attempted the proceeding.

Passing over the abortive attempts of Jules Roux (*Gazette des Hôpitaux*, 1856) and Deprès (*Gazette des Hôpitaux*, 1869) to introduce tubes by the mouth in chronic cases after tracheotomy had been performed, the proposal of Trendelenburg to introduce solid metal bougies into the larynx in chronic cases is arrived at. Though Trendelenburg (Langenbeck's *Archiv*, Bd. xiii, p. 338) realised his proposal in one case, it was left to Schrötter to perfect the idea and to practically carry it out. It must be here clearly understood that both Trendelenburg and Schrötter (Schrötter, *Beitrag zur Behandlung der Larynxstenosen*, Wien, 1876) proposed and practised dilatation of the larynx only in chronic cases. Weinlechner (1870) proposed the use of rounded tubes in chronic cases, instead of Schrötter's triangular or three-cornered ones. There is, however, no case recorded in which Weinlechner carried out his idea on this point. This brings us down to the present time. Dr. Hack of Freiburg published his case in Volkmann's *Sammlung Klinischer Vorträge* for November 6th, 1878, in which he adopted Schrötter's tubes and principles in an acute case of laryngeal stenosis. The date of this case is not given; but from the context it is clear that it must have been not later than the summer of 1878. In the present paper, I detail three cases, the first of which occurred in the summer of 1878, and the other two in the latter part of the same year, all of them being successful. Hack adopts Schrötter's instruments and principles (being a pupil of Schrötter's). I introduced cylindrical tubes by the mouth, retaining them *in situ* for twelve hours at a stretch, and removing them for purposes of ablation. The object in doing so was twofold: first, to enable respiration to be carried on; and, secondly, to cause absorption of the fluid by the presence of the tube exercising pressure of a slight kind.†

*Historical Résumé.*—There are, first, nasal tubes, proposed at the beginning of the present century by Desault, who in two cases passed them into the trachea. One of his patients died; the other recovered.

*Second.* *Le tubage du larynx* was proposed in 1858 by Bouchut, and practised by him in seven cases, all of them being failures.

\* Mention is made in Desault's works of a Toulouse surgeon who attempted to relieve a lad affected with polypoid growths round the larynx. Six times he tried to introduce the catheter, but each time the instrument appeared only to produce irritation, and eventually he desisted.

† A clear distinction must be drawn between respiratory catheters and instruments used for aspirations or insufflation, such as Chaussier's tube.

*Third.* Trendelenburg and Schrötter within the last few years have passed three-cornered vulcanite tubes into the trachea in chronic cases, and retained these cases *in situ* for a portion of an hour at a time; Dr. W. Hack having carried out the same principles with the same instruments in one acute case during or before the summer of 1878.

*Fourth.* The writer introduced cylindrical tubes by the mouth into the trachea, and retained them *in situ* for thirty-six hours, removing them when required for ablation (say every twelve hours); two such cases having been treated with perfect success.

*Is the Introduction of such Tubes easy?*—The following is a question very often asked: Is the introduction of tubes into the trachea easy? This at all times must be a difficult question to answer for others, as the case will depend on the experience of the operator. Personally, having had considerable practice in the passage of oesophageal bougies and catheters, I would be inclined to say that the introduction of tracheal tubes would be more difficult than the passage of urethral catheters into normal urethra; but they could be passed a great deal more easily than catheters in most cases of urethral stricture. Before passing tracheal instruments in the living, it would be well to practise on the "subject", as this helps to cultivate the touch. Given a quiet patient in health, the introduction of the tracheal tube will be found almost as easy for the operator as its passage *post mortem*. In the two cases of oedema glottidis which I have treated in this way, the introduction of the tubes was more easy than in the cases with healthy larynges. In the former, the parts were fixed, thrown further forward in the mouth, and much less sensitive, all favouring the introduction of the tubes. The first insertion is for the patient the most disagreeable, the subsequent ones being attended with comparatively few manifestations of uneasiness.

*Mode of Introducing the Tubes.*—The mode of introducing the tubes has already been alluded to in the remarks on the dead body. The only difference is that, if any hitch occurred at the level of the cords, it might be overcome by asking the patient to take in a deep inspiration, during which the instrument ought to be passed. The head ought to be thrown back during the insertion of the tubes.

*Advantages over Tracheotomy.*—Besides the superiority which the simple introduction of a tube into the trachea through the mouth has over a cutting operation, which in itself is not unattended with danger, the following points may be noted as advantages on the side of the former. The air, as it passes through the natural passages into the lungs, becomes warmed, moistened, and filtered. When a wound is made into the trachea through the neck and a short tube is inserted, the cold dry unfiltered air gets access to the lungs, and often produces fatal congestions. Every surgeon knows how difficult it is, even in hospital, to maintain for days continuously an uninterrupted supply of extraneous warmth and moisture; and how, now and again, in spite of the very best arrangements, a hitch occurs, during which cold dry air gains access. The tubes introduced through the mouth do away with the necessity of supplying extraneous warmth and moisture. A tubular instrument, passed through the mouth into the trachea, will convey heated moist air into the lungs, and to a considerable extent will filter it of its dust and organic particles. Even a tube, with one end in the trachea and the other projecting from the mouth, will attain, a few minutes after insertion, the same heat as the human body; and as a consequence will temper the air as it passes into the lungs. After a short time its interior will be covered with moisture, which will offer an extended surface for adhesion of organic particles, and so help to filter and at the same time moisten the air.

*Cases in which these Tubes might be Used.*—It will be observed that I do not particularise the kind of cases in which tracheal tubes passed through the mouth may be used, further than by stating, that there are obvious reasons for preferring tracheotomy or laryngotomy when foreign bodies are in the windpipe; and, on the other hand, for preferring tubes through the mouth where there are effusions of blood or serum, or collections of pus, into or about the submucous laryngeal tissue; or when anything overhangs or threatens to occlude the laryngeal orifice. Again, it may be asked, whether such instruments might not be of very considerable service in cutting short many spasmodic affections of the cords and upper portions of the larynx—such as spasmodic croup, laryngismus stridulus, and in some cases of incarceration of the epiglottis, etc. Tubes inserted in some such cases might not only relieve the spasm, but also help to cure the disease by destroying the habit.\*

Cases in which the disease, or at least the necessity for using the tubes, would be of short duration, are the most suitable for this procedure. Again: where the person is too weak or objects to have tracheotomy performed, or where the practitioner does not care about perform-

\* Baginsky agrees with Bretonneau, Gerhard, etc., that the dyspnoea in croup is the result of mechanical obstruction only, and does not believe in the absolute paralysis of the abductors of the vocal cords.



ing it, the tubes passed through the mouth might be used, even in the latter case, to gain time to allow an operative surgeon to be called.

The tubes must necessarily be of various sizes, so as to suit the various larynges into which they may be introduced. At present, a tube of a better shape and form than that now in use, and one which will present other advantages, is being prepared for me.

It must be obvious that the time during which the tubes are retained must depend on the case. In some, a few hours might be sufficient to dispel the oedema; in others, a much longer period is necessary.

*How to recognise that the Instrument is in the Trachea.*—How would one recognise the presence of the instrument in the trachea? 1. By finding the instrument pass over the first ring or two of the trachea; 2. By finding that the air flows into the tube during inspiration and out during expiration—the opposite being the case if it be in the oesophagus; 3. By the mucous expectoration being expelled from it; 4. By the negative signs that it is not in the oesophagus or stomach—i.e., blowing up the stomach through the tube, etc. Before introducing the tubes, an examination by the laryngoscope ought to be made to ascertain the precise state of the parts.

*Deductions.*—The practical deductions which may be drawn, tentatively at least, from these cases are as follows.

1. Tubes may be passed through the mouth into the trachea not only in chronic, but also in acute affections—such as oedema glottidis.
2. They can be introduced without placing the patient under an anæsthetic.
3. The respirations can be perfectly carried on through them.
4. The expectoration can be expelled through them.
5. Deglutition can be carried on during the time the tube is in the trachea.
6. Though the patient at first suffers from a painful sensation, yet this passes off, and the parts soon become tolerant of the presence of the tube.
7. The patient can sleep with the tube *in situ*.
8. The tubes, in these cases at least, were harmless.
9. The ultimate results were rapid, complete, and satisfactory.
10. Such tubes may be introduced in operations on the face and mouth, in order to prevent blood from gaining access to the trachea, and for the purpose of administering the anæsthetic; and they answer this purpose admirably.

#### NOTE ON HOMICIDAL MANIA.

By JAMES RUSSELL, M.D., Senior Physician to the Birmingham General Hospital.

THE following particulars given me by the mother of an out-patient at the Birmingham General Hospital, and by the patient himself, explain themselves. In a forcible manner, they tell the tale of what passes in the mind of many an epileptic when driven by his disease to sudden acts of violence; and explain the homicidal tendency which sometimes springs up under such circumstances.

A young man, aged twenty-nine, has been under me, at times, for several years, a confirmed epileptic, and the son of a father equally confirmed in the same disease. His fits were kept under by moderate doses of bromide of potassium, but, after the 31st of last January, his medicine was suspended in consequence of the want of an out-patient ticket. The fits then returned with frequency; about two severe ones, with tongue-biting, occurring in a week, but very numerous slighter ones. In March, the first attack of the mental disorder, to which this communication refers, took place: it lasted for a fortnight, and yielded to medical treatment. The patient was violent for three days, and then fell into a condition of melancholy, "as though a cloud were on his brain". In a week after his recovery of mental health, the fits returned—they had been absent during the period of mental disorder (of course, I speak only from the mother's report)—but again, at the end of eight weeks, the mental affection returned, and again yielded to treatment at the termination of about a week. As before, the recovery of sanity was followed by recurrence of the epileptic fits, mostly in a slight form; and for the third time the mental disorder attacked him (May 19th), and yielded to remedies in ten days.

The mother gave the following description of the mental disorder. He had a constant fear of being dared to hang himself; he told her that, if she did not take every care of him, he would be obliged to do it; he did not like to be considered a coward by people standing before him (in imagination); they kept showing him how to do it; and he thought that if his mother took him to a doctor, he would drive the figures away. This "thought over him" lasted all the time. He wandered about, sensible in other respects, but with a sort of pitiful expression, more child-like, and with a tendency to cry. "It is ridiculous," he said, "to talk of anything else, for I have got it in my mind, but it never

comes when I am right." He dared not sleep, for, if he closed his eyes, "he saw so many".

The patient himself told me that it was like a man before him; there was like a scaffold and a rope, and they kept showing him the way to do it. They said, "You dare not do it! you dare not do it!" Something felt very heavy on his forehead, and all was dark about him. "I could not bear the thought of hanging myself, but nothing else would come into my mind." When these "feelings" were passing off, something passed from the forehead, over the face, then down the arms, out at the fingers, and then he became himself again, and could think of other things.

This young man has been more or less epileptic from infancy, but he has only suffered once before from any mental derangement. He then had an idea that his mother loved his brother best, and that seemed to work on his mind. He thought he must get rid of his brother. One day his mother heard him threaten his brother, and open his knife; he was easily induced to part with the knife, observing that he thought he had better do it to himself instead.

The patient's attestation to the compulsory nature of this suggestion, and to the impracticability of his varying it by any effort of his will, and at the same time his half-consciousness of the unreality of the whole, are worthy of notice. What if this countercheck be weakened or removed?

#### COLOUR-BLINDNESS AMONGST THE MEDICAL PROFESSION.

By B. JOY JEFFRIES, M.D., Boston, U.S.A.

In the JOURNAL for October 25th, 1879, Mr. Herbert W. Page published an article on "Colour-blindness: its Examination and Prevalence". I have commented at some length on this subject in a previous communication, and would now merely report in reference to a suggestion he then made. He proposed that the members of the British Medical Association should be most carefully tested at the Cambridge meeting in August next, to ascertain the proportion who are colour-blind "among those who neither lack education, observation, or cultivation".

To partly answer this suggestion, I have recently tested 465 of the members of the American Medical Association at the New York meeting, and of the members of the Massachusetts Medical Society, at the annual meeting here in Boston. I found, among these 465 physicians, 22 colour-blind. Of them, 14 were red blind, 2 green blind, and 6 incompletely colour-blind, using the standard of Professor Holmgren. The whole number of males I have so far tested is 17,327. Of these, 724 were colour-blind in a degree to be included in the classes proposed by Holmgren. I have also tested 13,813 females, finding only 10 colour-blind.

Unless the whole of a large number of people are tested, the ratio, we find, may be quite above or below 4 per cent., which seems to be the true average for males. For instance, in New York I found but 6 out of 195; here in Boston, 16 out of 270. As a general thing, perhaps, as many colour-blind, from various reasons, stay away as apply to be tested. Here in Boston none of my professional brethren whom I *knew* to be colour-blind came to me. Could I have tested the other 2,000 of the medical profession attending these two meetings, I am quite convinced that the whole would have given me the usual 4 per cent. average. If the members of the British Medical Association are tested at Cambridge, the proportion found colour-blind will depend on the number examined, and whether those thus defective apply or stay away. If 1,500 be present, they can all be tested in three days by one person working six hours each day, provided it could be so arranged as to have a steady stream before the examiner.

Now what method of testing could accomplish this with certainty and accuracy? A pretty extended experience, theoretically and practically, convinces me that such investigations can be carried out only by Holmgren's method, with which none other compares. Certainly with it, as with all methods, it depends largely on the examiner, who must be all eyes in watching the face, fingers, and look of the examined. The latter had far better not speak, or at least confine this to a question of what is asked of him to do. The examiner can explain what is needed, and one after another sees what is done by those before him. *It is also a test of mental and physical quickness.*

In a previous communication to the JOURNAL I have defended the accuracy of my published results. In these tests of my medical brethren, I of course had the advantage of their being desirous to appear the best, and also do as nearly as they could just what was asked of them. The bystanders constantly wondered that I did not mark as defective many who seemed so to them. This test of my friend, Professor Holmgren, when the *right worsteds* are used (a most important point), and the





ON THE AVOIDANCE OF SHOCK IN MAJOR AMPUTATIONS  
BY COCAINIZATION OF LARGE NERVE-TRUNKS  
PRELIMINARY TO THEIR DIVISION WITH  
OBSERVATIONS ON BLOOD-PRESSURE  
CHANGES IN SURGICAL CASES

By HARVEY CUSHING, M.D.

*Reprinted from*  
*ANNALS OF SURGERY*  
*Vol. XXXVI, No. 3, 1902*  
*pages 321-345*



# ON THE AVOIDANCE OF SHOCK IN MAJOR AMPUTATIONS BY COCAINIZATION OF LARGE NERVE-TRUNKS PRELIMINARY TO THEIR DIVISION.

WITH OBSERVATIONS ON BLOOD-PRESSURE CHANGES IN  
SURGICAL CASES.<sup>1</sup>

By HARVEY CUSHING, M.D.,

OF BALTIMORE,

ASSOCIATE IN SURGERY, THE JOHNS HOPKINS HOSPITAL.

(1) By common usage the term "shock" has come to represent a peculiar state of depression of the normal activities of the central nervous system. Such a condition is ordinarily brought about by traumatism, of one sort or another, to peripheral afferent nerves. In order to produce shock, the impulses resulting from this traumatism must have acted reflexly upon the vasomotor mechanism in the medulla in such a way as to occasion a marked fall in blood-pressure. This diminution of arterial tension is the most characteristic symptom of shock.

(2) Under ordinary circumstances injuries of only moderate severity to peripheral nerves cause a rise in blood-pressure. If, on the other hand, these injuries are extensive or frequently repeated, or if they are complicated by certain primary or secondary anæmias, they are commonly productive of a fall in blood-pressure, indicating a state of shock.

Shock consequently need not be occasioned even in most extensive surgical procedures on the extremities, provided due regard is given to perfect hæmostasis. In operations of considerable magnitude, however, during which the division of many large nerve-trunks becomes necessary, or in operating upon such

<sup>1</sup> Being the basis of the Address in Surgery before the Wisconsin State Medical Society, June 4, 1902.

traumatic cases as have been already complicated by extensive injury to peripheral sensory nerves, so-called operative shock is rarely avoided.

When, therefore, any condition is existent which predisposes to shock, such as loss of blood, prolonged anæsthesia, etc., or when a certain degree of shock is already present before operation, especial risk is attendant upon the division of important sensory nerve-trunks.

(3) Cocaine injected into a nerve-trunk effectually blocks the transmission of all centripetal or sensory impulses. Cocainization, therefore, of main trunks of nerves central to the proposed site of their division in a major amputation, prevents the conduction of those impulses resulting from the traumatic insult which otherwise, by acting reflexly through the medullary centres, might become the chief factors in the production of shock.

Three years ago, during the progress of an interscapulo-thoracic amputation for a metastatic sarcoma of the shoulder and before the principles laid down in the foregoing introductory paragraphs were sufficiently appreciated, it was the writer's misfortune to have occasioned a profound and almost fatal condition of shock by the division of the brachial plexus of nerves. This case and a subsequent one of ablation of the entire upper extremity, in which precautions of anæsthetization of the plexus before its division were observed, illustrate so well from the clinical side the principles which will be emphasized in this communication that they will be briefly summarized.

CASE I.—(Surgical Number 9803.) *Ablation of Breast, Upper Extremity and Shoulder-Girdle for Sarcoma. Profound Operative Shock in Consequence.*

Miss A., forty-one years of age, entered the hospital, December 22, 1899. A pigmented cutaneous mole had been removed from the left forearm two years before her admission. In May, 1899, following an injury to her left shoulder, a secondary growth appeared in the axilla, which increased slowly in size up to the past few weeks. This has enlarged very rapidly of late, and a mass of glands has appeared above the clavicle.

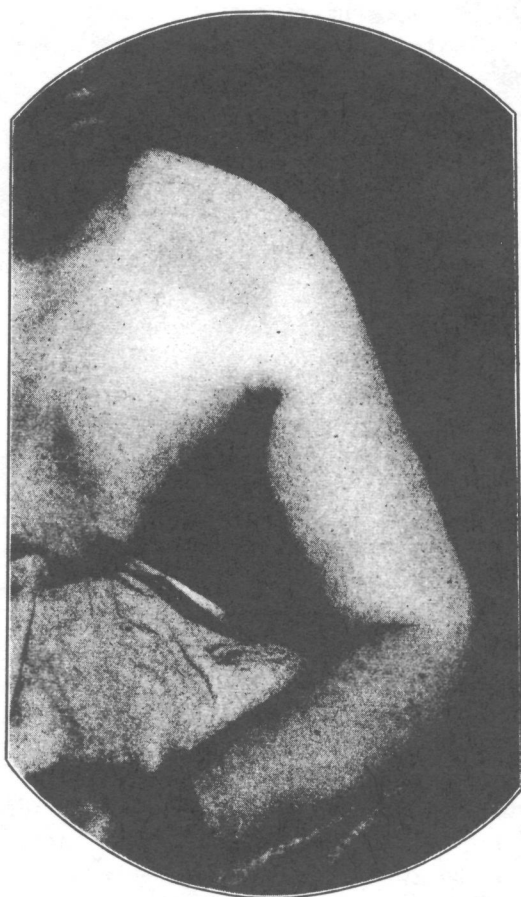


FIG. 1.—Case I. Showing axillary tumor and oedematous extremity before operation.

During this period of rapid growth of the axillary tumor the pain in the arm has become so severe that large doses of morphine have been necessary to control it. The patient has lost greatly in strength and weight from pain and sleeplessness. The pain evidently is occasioned by pressure on the brachial plexus, and is referred over its entire sensory distribution from shoulder to finger-tips.

Physical examination showed a large, fleshy woman, apparently suffering acutely, holding her left arm abducted forty-five degrees from her side in order to avoid pressure against a large axillary tumor the size of her head (Fig. 1). This growth extended from the clavicle almost to the nipple and from the parasternal line to the outer border of the scapula. The tumor seemed to be attached to the chest wall, and attempts to move the arm or the growth caused severe radiating pains. It imparted a sensation of pseudofluctuation, and the skin which was thinned over it was covered with dilated venules. The entire arm was œdematous and the hand slightly cyanosed. The tumor measured sixty-seven centimetres in its partially exposed circumference. The metastatic growth above the clavicle, the size of a hen's egg, was firmly adherent to the neighboring structures and caused pain when it was handled. The case seemed most unpromising, but was undertaken in the hope of relieving the patient's suffering by division of the brachial plexus should it be found impossible to do a complete operation.

*Operation*, December 26, 1899. Ether anæsthesia. An incision, starting just below the mastoid process, was carried downward across the clavicle and along the inner margin of the breast. The clavicle was exposed and divided with a Gigli saw. The axillary artery and then the vein were ligated and divided. The tumor with the breast, pectoral muscles and arm were then turned outward and the growth fortunately found to be unattached to the thorax. The operation up to this point was without incident; practically no blood had been lost, and the only remaining step was the completion of the scapular part of the amputation.

As the tumor with the breast, arm, and clavicle dropped away from the chest wall, the brachial plexus was exposed and the nerve-trunks under some tension were divided with a few strokes of the knife. It was necessary to pick up with clamps the central bleeding ends of a few of these nerve-trunks. Immediately the



FIG. 2.—Case I. Twelve days after operation.



patient's pulse jumped from 110, which represented its "ether level," to 150, where it remained until the shoulder amputation was completed.

The mass of glands in the neck had been freely exposed by the high incision and was readily enucleated. Several large branches of the plexus, however, were spread out over this growth, and a secondary division of this portion of the plexus consequently was necessitated. When this was done, the patient's radial pulse immediately became impalpable (see accompanying chart, Fig. 4). It continued thready and almost imperceptible during the remainder of the operation, which was rapidly completed, and for almost twenty-four hours afterwards. During this postoperative period the patient's general condition closely resembled that seen in cases of shock such as accompany serious traumatic crushes of an extremity.

The patient finally made a complete recovery. The wound healed by primary union throughout (Fig. 2). The size of the tumor in comparison with the arm is shown in the photograph (Fig. 3). It was a round-celled sarcoma.

It doubtless has come within the experience of most operators to see patients brought into a profound condition of shock before the termination of major amputations of this nature. It is, however, unusual to be able so definitely to attribute to one particular step the exact occasion of the upset to the vasomotor and cardiac mechanism. For some years it has been our custom to have the anæsthetist plot a so-called "ether chart," which records the variations in pulse-rate during the period of narcosis. Such charts were, I believe, first introduced by Dr. Codman for use in the Massachusetts General Hospital, and very valuable data as to the patient's condition may be obtained therefrom. The pulse-rate, however, thus graphically represented during an operation, may give no real indication of the degree of actual or impending shock for the true estimation of which observations upon the blood-pressure are necessary. It must be borne in mind that a pronounced rise or fall in arterial tension may be unassociated with any change in pulse-rate. However, a persistent increase in the rapidity of the pulse in cases in which loss of blood has been



FIG. 3.—Case I. Showing size of tumor mass in comparison with œdematous arm.

slight may be taken as in a measure indicative of a corresponding fall in blood-pressure, and so representative of the degree of shock. The accompanying chart (Fig. 4) represents the pulse-rate as plotted during the operation upon this particular case, and shows by the marked alteration in its rapidity the reflex effect upon the neurovascular mechanism which was produced by the division of the brachial plexus in each instance as described.

The following case, one of similar nature and in which

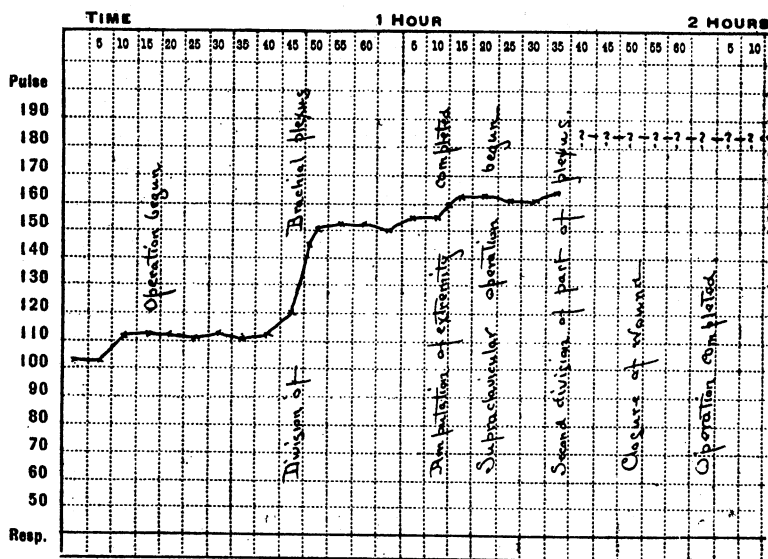


FIG. 4.—Chart recording pulse-rate during operation on Case I, December 26, 1899.

the same operative procedure was carried out, illustrates how the disturbing effects of nerve section observed in Case I might have been avoided.

CASE II.—(Surgical Number 9828.) *Large Sarcoma of Upper End of Humerus with Pathological Fracture. Interscapulo-thoracic Amputation. Cocainization of Brachial Plexus and without Production of Shock.*

J. E., thirty-two years of age, entered the hospital, January 11, 1900. The patient had had pain of supposed "rheumatic"

nature in the left shoulder for four years. Following an injury, which occurred six months before his admission to the hospital and which was associated with severe contusion of the shoulder, the pain increased, and a short time later the present tumor began to be evident. During the past two or three months the growth has increased rapidly in size (Figs. 5 and 6).

The patient was in good physical condition in spite of his suffering, which was considerable and had been constant for four months. The character of the tumor is better shown by the photographs than by a description. A pathological fracture was present in the centre of the growth, and the slightest motion of the arm was forbidden. The entire arm was œdematous and cyanotic, and neurotrophic disturbances were evident in the fingers and hand. The tumor measured sixty-six centimetres in circumference.

*Operation*, January 2, 1900. Ether anæsthesia. The entire left half of the shoulder-girdle with the arm was removed in the usual way. On account of the inaccessibility of the subclavian vessels from the encroachment of the tumor upon the operative field, it was easier to divide the vein before the artery. This was done, though it was doubtless an error in judgment and a procedure which occasioned the loss of considerable blood into the extremity. Nevertheless, after preliminary cocaineization of the brachial plexus, the bundle of nerves was severed; the extremity with clavicle and scapula was removed, the dry wound closed without drainage, and no shock resulted from the operation. The patient was up the following day; began rapidly to gain in weight; the wound healed by primary union (Fig. 7). He was discharged on the fourteenth day, and has since been actively engaged in his former occupation of farming. Fig. 8 shows a section of the tumor in illustration of the extensive destruction of the humerus. The tumor proved to be a medullary sarcoma.

However much alike, as in these two cases, individual conditions may seem to be, it is impossible to say that the same physiological response on the part of the central nervous system would follow in each instance a given insult to peripheral sensory nerves. As will be emphasized hereafter, the same afferent impulses may, under certain circumstances, determine reflexly a rise in blood-pressure from augmentation

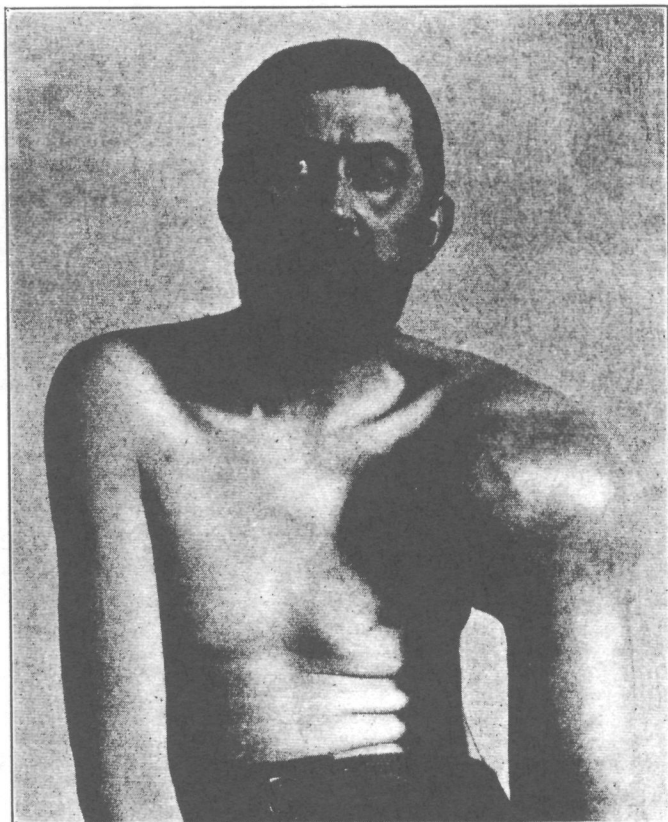


FIG. 5.—Case II. Tumor and œdematous extremity before operation.

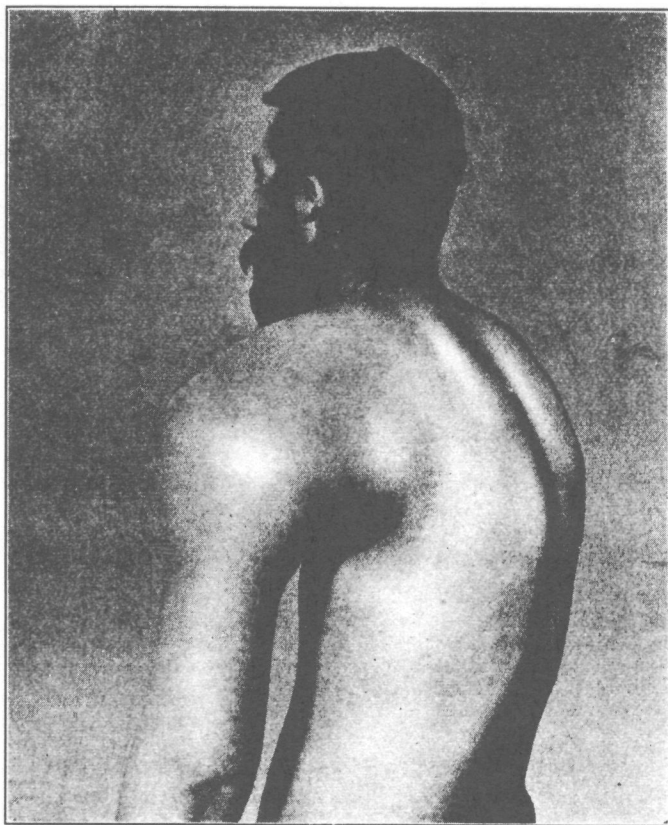


FIG. 6.—Case II. Posterior view.

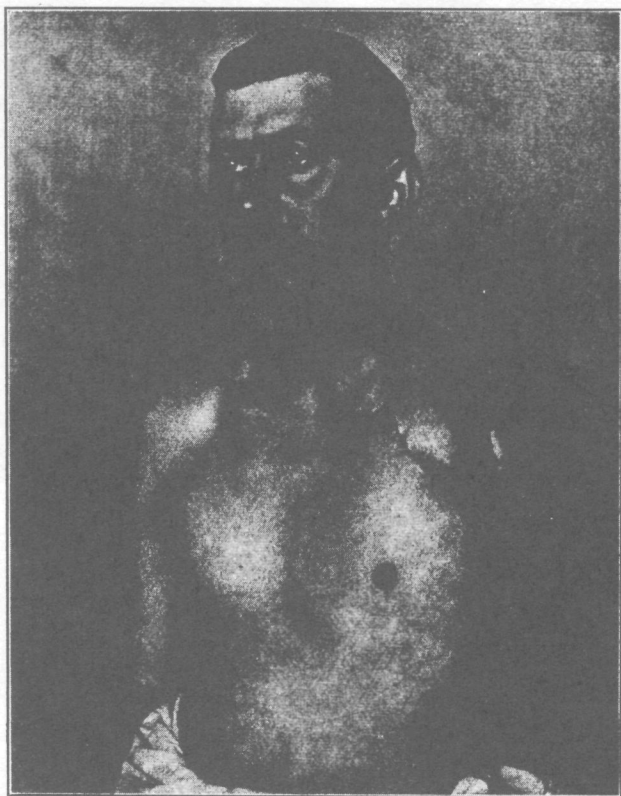


FIG. 7.—Case II. Ten days after operation.

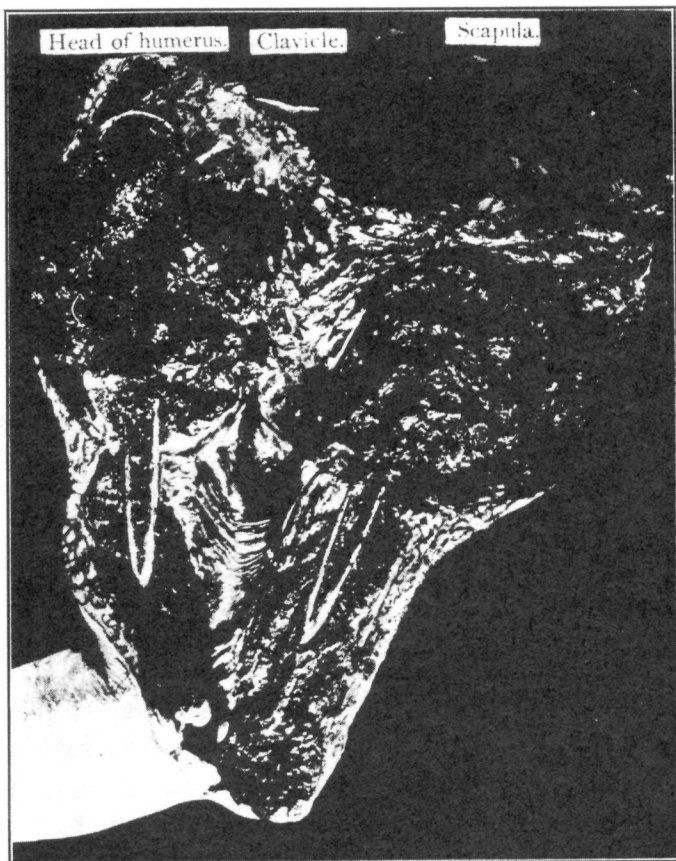


FIG. 8.—Case II. Photograph of section of very soft, diffuent tumor, receiving large amount of hæmorrhage into it and organizing blood-clot, accounting for rapid growth. Very little new bone formation.



of vasoconstrictor action, which under other indefinable circumstances might determine a fall, from diminution of the same. These two patients, however, presenting as they did such close similarity in clinical condition, and subjected as they were to an operative procedure of such close correspondence, may, for the sake at least of pointing a moral, be considered to have stood upon the same physiological level.

It can be seen by consulting the "ether chart" (Fig. 9)

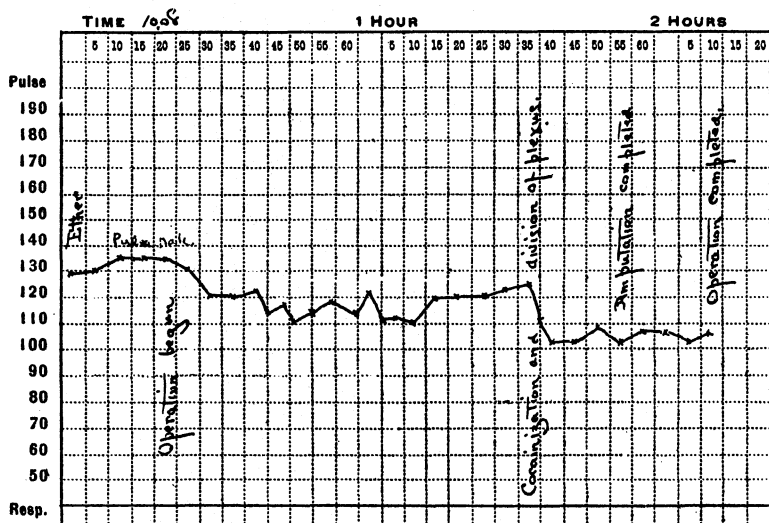


FIG. 9.—Ether chart recording pulse-rate kept during the operation on Case II.

kept during the operation on this second case that at the moment of cocainization and subsequent division of the plexus there was an associated retardation in pulse-rate from 120 to 102 beats per minute. The slight increase in cardiac activity which preceded this division for ten or fifteen minutes doubtless was due to the dragging upon the nerve-trunks brought about by the weight of the hanging extremity and shoulder. Such an acceleration of cardiac rhythm accompanying a reflex pressor effect is the normal response to such a stretching of peripheral mixed nerves. On repeating this operation on animals, I have seen this early pressor effect

followed, after crushing the plexus with forceps and dividing it, by a marked fall in blood-pressure, recovery from which might or might not take place, depending on the previous condition of the animal.

Although an interscapulo-thoracic amputation may be regarded as an operation of considerable magnitude, it should be a comparatively bloodless performance, and the wide experience at this hospital with an operative procedure of possibly greater extent, carried on in a neighboring situation and one which demands a greater amount of time for its performance, namely, the complete Halsted operation for carcinoma of the breast, has shown that a condition of shock rarely supervenes, provided that principles of absolute hæmostasis have been carefully observed. In illustration of this and for comparison with the ether charts which accompany the first two cases, a representative chart of the type of those which are plotted during this extensive operation is here reproduced (Fig. 15). In this procedure the chest wall is completely bared of both pectoral muscles; the entire axillary contents are removed, leaving exposed the axillary artery, vein, and brachial plexus; the contents of the supraclavicular triangle furthermore are often removed, laying bare the vessels and brachial plexus a second time in the neck. Although this is one of the most extensive operations of the present day surgery, provided there is no loss of blood, shock need rarely, if ever, be occasioned. This is undoubtedly due not only to the perfect control of hæmorrhage, but to the fact that no large or important sensory nerve-trunks are divided or injured. In operative cases, however, in which it becomes necessary to divide large bundles of nerves, precautions other than the avoidance of the loss of blood seem to be demanded.

Dr. George Crile, in his recent admirable monograph ("Problems Relating to Surgical Operations," Philadelphia, 1901, p. 157), has once more laid emphasis upon the physiological blocking effect of cocaine when injected into peripheral nerves, and much of the credit of the considerable employment of such a procedure in the prevention of shock has been the

result of his interesting experimental work. The same principle of "blocking" nerve-trunks has been utilized for a long time as a means of producing anæsthesia over proposed operative fields by thus throwing out of function the sensory nerves radiating from it. I would suggest that this be called "regional anæsthesia" in contradistinction to "local anæsthesia." Thus, operations for hernia, amputations of an extremity and the like, may be painlessly performed. Dr. Crile reports a case of interscapulo-thoracic amputation in which cocainization of the brachial plexus sufficed for the accomplishment of the operation. In this way risks of general narcosis were avoided as well as any likelihood of shock, and the blocking subserved the double function of giving an analgesic field for operation and of preventing central disturbances from inflowing impulses.

Unfortunately, in this particular procedure the skin incision must pass through non-anæsthetized territories supplied by cutaneous nerves of thoracic segments. These areas necessarily must be individually cocainized,—a difficult performance, and one requiring an accurate knowledge of segmental distribution. Similarly, cocainization of the sciatic nerve to produce "regional anæsthesia" for amputation of the leg below the knee does not in itself suffice for a painless operation. In the two instances in which I have so operated, care has been taken to anæsthetize locally, along the line of proposed incision, the territory supplied by the long saphenous nerve. It is worthy of note, also, that this nerve supplies the periosteum over the inner surface of the tibia which must also be cocainized. These two operations were performed for gangrene of the extremity in old people in whom general narcosis seemed to be contraindicated.

Such operations under local or regional anæsthesia are at best more difficult than corresponding ones carried out under general narcosis, and few operators seem able or will take the time to perform them satisfactorily. The blocking of nerves before division during operations under complete anæsthesia, however, is another matter, and is only related,

through the physiological principle involved, to these operative procedures under regional anæsthesia in which the sensory nerves supplying the operative field have been cocainized.<sup>1</sup>

It will be recognized immediately by operators that the surgical principles here upheld preclude the possibility of employing the time-honored methods of amputating, which, it must be confessed, are more or less a relic of the spectacular days of surgery. Operations of the sort described above are undoubtedly carried out with far greater security by the method of dry, painstaking dissection, which is now employed in most surgical clinics for practically all major amputations. The tourniquet and long amputating-knives are practically relegated to disuse. The peripheral vasodilatation which follows the removal of a tourniquet occasions the loss of blood, is an embarrassment during the closure of a large amputation wound, and usually necessitates drainage. The use of pins and other appliances for the purpose of skewering the vessels in high amputations only adds difficulties to what otherwise is a comparatively simple procedure of dissection. On the two occasions in which I have amputated at the hip with primary ligation of the external iliac vessel, with careful observance

<sup>1</sup> The physiological principle involved in this discussion covers only the blocking effects of cocainization of peripheral sensory neurones for purposes of "regionary anæsthesia," or for the avoidance of shock during general narcosis. Cocainization of the spinal cord by a subarachnoid lumbar injection, with blocking, possibly, of a higher order of neurones, is quite another thing. Here a different physiological effect comes into play in consequence of the throwing out of action in the majority of cases of the vasomotor fibres passing from the upper thoracic segments to control the splanchnic system. As a result, there is a flooding of this territory. Shock consequently, in so far as it is an expression of low blood-pressure, is almost without exception produced, not avoided. This I believe to be the real source of danger in "rhachicocainization," and not the toxic effects of the drug itself. In my estimation, it is a performance invariably attended by considerable risk on account of this associated fall in blood-pressure. Unfortunately, the enthusiasm which followed Bier's original proposition swept many an operator along with it, a result which the originator himself deeply regrets. ("Weitere Mitteilungen über Rückenmarksanästhesie." *Verhandlungen der deutschen Gesellschaft für Chirurgie*, Band I, S. 171, 1901.)



FIG. 10.—Ten days after amputation of thigh by dissecting method, showing configuration of innominate bone covered by little more than skin flap.

of complete hæmostasis during the dissection and with cocaineization of the anterior crural and sciatic nerves before their division, there was no indication of even a temporary reflex effect upon the blood-pressure or cardio-regulatory centres. No drainage, of course, is required in case such a method is employed. One of these amputations was carried out on a greatly prostrated young man suffering from a recurrent sarcoma of the thigh, an amputation of the leg lower down having been performed a short time before. In this case the amputation was of necessity made very close to the innominate bone, so that practically nothing was left to cover the wound but a flap of skin saved from the gluteal region (Fig. 10).

Should the tourniquet be used in amputations, I believe that its application distal to the site of amputation has more *rationale* than the usual proximal method of employing it. It may thus be applied as an Esmarch bandage either after the ligation of the main arterial vessel or before beginning the operation, its purpose being to prevent the loss of blood into the extremity. Such a filling up with blood otherwise not only follows the ligation of the chief venous radicle, but also the division of nerves to the member, since their section causes a flushing of the territory from local vasomotor paralysis. This flushing, however, occurs distal to the site of operation not in the stump itself, as when the tourniquet is applied proximally. The carrying of such an Esmarch bandage over the area occupied by a new growth of course should be avoided under any circumstances.

To major amputations for traumatic injuries of the extremities do these principles apply in degree almost greater than in pathological cases. Here a state of shock may already be present, and the attendant ordinarily is advised to wait for some hours, during which time a readjustment of conditions is expected to take place and the severity of shock to diminish. As a matter of fact, the very conditions are present which tend to perpetuate or to increase the already existent degree of shock. Such an increase is brought about by a continuation of afferent sensory impulses. The tourni-

quet itself, which has been applied at the time of the accident, although controlling the loss of blood, constantly adds, from pain, an increment to the shock of the original injury. The dragging of the helpless or mangled limb on the great sensory nerve-trunks, which are rarely severed, gives impulses of pain with every movement of the often restless patient,—impulses which in such a state cause reflexly a further lowering of blood-pressure. Strychnine, intravenous infusion, even though there may have been but slight loss of blood, and delay, are the usual measures advocated for such states. I believe they are, if not actually harmful, certainly not helpful. The real indication is to rid the patient of the centripetal impulses, originating in the crushed member, by cocainization and division of the large nerves, so often exposed in a mangled limb, by ligation of vessels if necessary, and the earliest possible removal of the painful tourniquet. Under proper management, with possible strapping of the abdomen to hold up the blood-pressure, with morphine in small amounts to control restlessness, and with a proper avoidance of those conditions which during the operation would increase shock, I believe that it is no heresy to advocate ether anæsthesia (never chloroform) and early operation for most cases of severe traumatism of the extremities.<sup>2</sup>

<sup>2</sup>I am rather inclined to believe that the reason why delay has come to be so universally advocated in severe cases of traumatic shock is because in the course of some hours time itself will pick out those cases which are favorable ones for operation. The border cases and the unfavorable ones grow worse from the start, and finally are abandoned as unfit for interference. Thus the results in case of delay must of necessity from a statistical stand-point be much the better. It is very much the same thing as waiting for the effects of so-called shock to pass away in cases of intestinal perforation. Here, also, delay suffices to select those cases favorable for operation. Those which progressively go down hill and do not rally are finally regarded as unfit for operation. It is the border-line case which early intervention, carried out under proper principles, may succeed in saving. I have recently seen a case of typhoid perforation in collapse improve on the operating-table during a cocaine operation, the patient's arterial tension measuring considerably higher after the closure of the wound than before the operation, no stimulants whatever having been used. Similarly in the border-line cases of trau-

Unfortunately, at the time when these two cases which I have cited were operated upon, observations upon blood-pressure, the estimation of which is much more important than the pulse-rate, could only be guessed at through the medium of a palpating finger on a peripheral artery. Although the importance of an educated touch is by no means to be belittled, it is nevertheless desirable on all important occasions to supplement tactile observation, where possible, by the data obtainable from some instrument of precision. The clinician is not satisfied, as of old, with an estimation of temperature gained by placing the hand on a patient's forehead nor by a guess at the pulse-rate, especially when comparative alterations from moment to moment are of value. That figures giving us accurate data concerning variations in arterial tension are even more desirable needs no comment. This is especially true if we wish to study intelligently the condition of shock in our traumatic and operative cases for the purpose of properly estimating its degree, its alterations, whether increasing or diminishing, the effect produced upon it by various steps of our operative procedures, and the true influence which the usually prescribed therapeutic measures have upon its course.

At the present time, happily, a simple and convenient "blood-pressure" apparatus has been introduced into the clinic, a form adapted from that described by Riva Rocci. By means of this apparatus, alterations in arterial tension may be taken during an operation with the shortest possible interval, and the figures representing millimetres of mercury immediately charted. Thus an operating surgeon may obtain, graphically represented, data concerning the patient's condition in almost exact correspondence with that which the physiologist gains

matic shock I believe that the prompt removal of conditions tending towards its perpetuation will save cases swaying in the balance which otherwise must go to the ground. Should a general anæsthetic be required, ether should be selected. Chloroform, owing to the fall in blood-pressure which accompanies its administration even in normal states, is of course absolutely contraindicated.



during an experiment by having an animal's carotid in connection with a mercury manometer whose level is constantly being recorded on a revolving drum.

By means of information obtained by this apparatus in the operating-room during the past six months, on several occasions in critical cases, have we been able to anticipate and to avoid profound states of shock and collapse, and indeed, in some instances, I feel confident that it has been instrumental in saving lives.

A study of these cases in which comparative curves of pulse-rate and blood-pressure have been kept during operative procedures is being made by Dr. Briggs, who will report upon them later, with especial reference to the therapy of shock. Unfortunately, for purposes of comparison, no interscapulo-thoracic amputations of the sort described above have been performed since the inauguration of these blood-pressure records.

A few examples, however, from Dr. Briggs's collection will be reproduced here in illustration of the way in which the physiological effects of operative procedures on the pulse and blood-pressure may be plotted in some conformity with the more familiar charts made during laboratory experimentation. Of these illustrative charts three have been selected from the groups comprising the abdominal and cerebral cases. One or two reproductions of charts showing the blood-pressure responses in peripheral operations, with which group of cases this communication more particularly deals, are also given.

CHART I.—(Fig. II.) *Abdominal Group. Visceral exposure for tuberculous peritonitis.* Shows the depressor effect brought about during an intra-abdominal exploration by exposure and handling of the viscera. This fall in blood-pressure, which might have become perpetuated as a condition of shock, was rapidly recovered from, after a hurried closure of the wound, by the application of a tight abdominal binder, which gave support to the relaxed splanchnic vessels. In such cases the vascular relaxation is probably due to direct insult to the splanchnic

end of the neurovascular mechanism and not to a reflex action such as peripheral injury occasions.

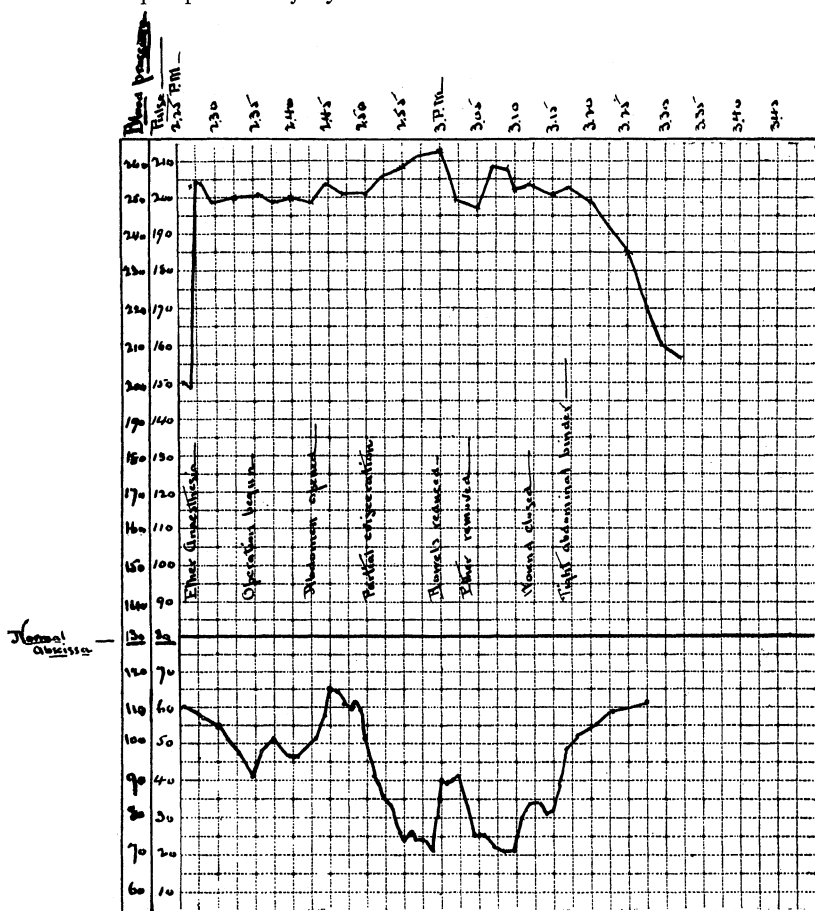


FIG. 11.—Chart I showing pulse-rate and blood-pressure curves during an abdominal operation on a feeble child for tuberculous peritonitis. The abscissa line represents an average normal pulse-rate, 80, and an average normal blood-pressure, 130 millimetres of mercury.

*Note (1)* Condition before beginning anaesthetic; rapid pulse, 150; low blood-pressure, 110. *Note (2)* Effects of evisceration. *Note (3)* Beginning of shock and fall in blood-pressure; cf. no especial change in pulse. *Note (4)* Result of application of tight abdominal binder.

CHART II.—(Fig. 12.) *Cerebral Group. Gasserian ganglion operation.* The chart illustrates the normal response in intra-

cranial cases when the brain is subjected to compression. This response is the exact counterpart of the experimental one heretofore described as accompanying cerebral compression. (*Johns Hopkins Bulletin*, 1901, Vol. xii, p. 290.) The compression anæmia apparently stimulates directly the vasomotor centre, which in turn raises the blood-pressure by constriction of the splanchnic territory, in degree sufficient to overcome the anæmia. The pulse is slowly affected meanwhile by a similar stimulation of the vagus centre in the medulla. The fall in blood-pressure associated with clamping of the ganglion and with its extraction shows that this might be a dangerous procedure if blood-pressure were already low. In critical cases of ganglion extirpation, doubtless the structure should be cocainized before handling, as in the case of any sensory nerve.<sup>3</sup>

CHART III.—(Fig. 13.) *Cerebral Group. Ganglion operation.* Shows a rapidly fatal case of shock in an intracranial operation with paralysis of the vasomotor centre and consequent fall in blood-pressure. Here the normal response with rise in blood-pressure and slowing of pulse did not take place during the compression of the brain. Possibly this was due to extensive pathological alterations present in the blood-vessel walls. The rapid fall in blood-pressure even before there was any outspoken change in pulse-rate should have been an indication to immediately abandon the operation. Owing to the low blood-pressure the ganglion was removed with a minimum of bleeding in this case. The usual therapeutic measures to restore arterial tension proved futile.

<sup>3</sup> It is important to note that this rise in blood-pressure is the occasion of the troublesome bleeding so often encountered in ganglion operations. It was my practice formerly to administer chloroform in these and in all cases of cranial operation as has been advocated by Mr. Horsley. Our blood-pressure observations have sufficed to show its great danger. In the majority of instances there is a fall in blood-pressure associated with the administration of chloroform which accounts for the lessening of hæmorrhage under this form of anæsthesia. Any further depression of blood-pressure from the operative procedure itself could easily and rapidly bring about a fatal condition of shock. Elevation of the head may often-times control the oozing in these cases. This posture is accompanied, however, with risk, which should be estimated and controlled by frequent observations on blood-pressure. The principle of cocainization of the ganglion before its manipulation and extraction has been carried out in my last cases.

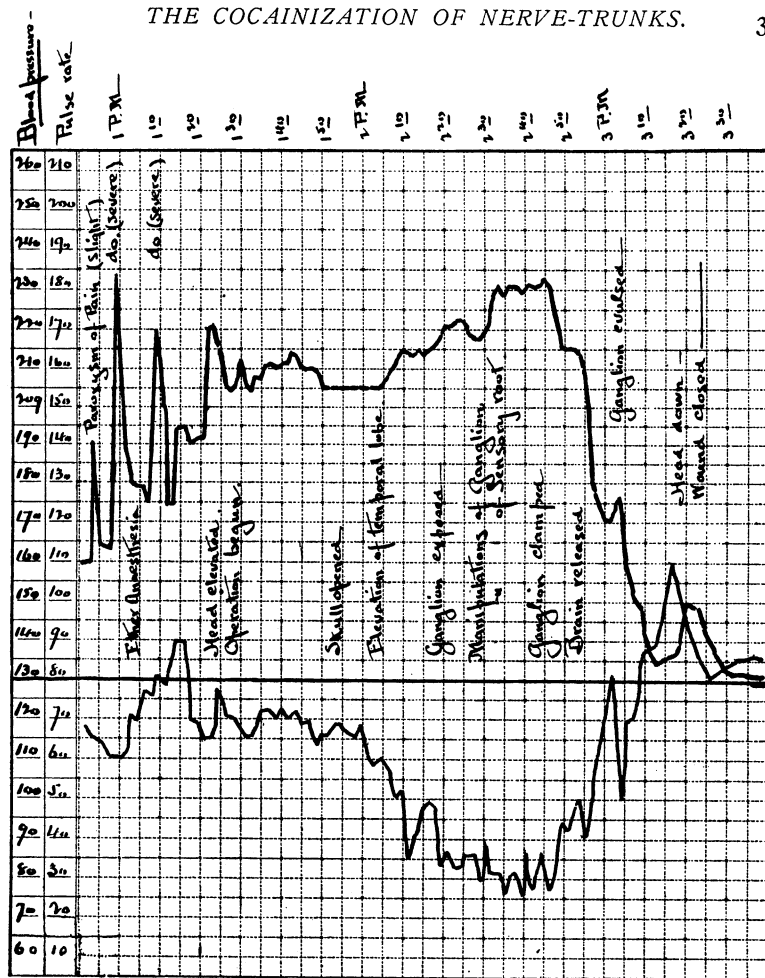


FIG. 12.—Chart II. Pulse-rate and blood-pressure curves taken during an operation for extirpation of the Gasserian ganglion; ether anaesthesia. Upper line represents blood-pressure; lower, pulse.

Note (1) Great excursions of blood-pressure during the paroxysms of the "neuralgia quinti major," unassociated with any change in pulse-rate. Note (2) The rise in blood-pressure from its "ether level" at 205 millimetres of Hg. to 230 millimetres during the elevation of the temporal lobe and associated compression of the brain.

Note (3) The corresponding retardation of pulse-rate from sixty-five to thirty beats per minute due to vagus stimulation. Note (4) The return of pulse-rate and blood-pressure to normal levels after the release of the brain from compression.

CHART IV.—(Fig. 14.) *Peripheral Group. Stretching sciatic nerve.* Shows the physiological response as a rise in blood-pressure consequent upon the handling of an important mixed peripheral nerve-trunk in a normal individual. Here an accelerator and pressor response are combined. In other instances there may be no increase in pulse-rate.

CHART V.—(Fig. 15.) *Peripheral Group. Complete breast operation.* Shows the absence of any appreciable effect on pulse-rate or blood-pressure other than the usual rise during the primary stage of ether anæsthesia. In such an operation there is no loss of blood, and no important sensory nerve-trunks are divided or handled. (Contrast pulse-rate with Figs. 4 and 9.)

In these three groups of cases—*abdominal, cerebral, and peripheral*—the blood-pressure alterations are occasioned, generally speaking, as follows: In the first group they are brought about largely by direct peripheral action on the splanchnic vascular system; in the second, by direct action on the vasomotor centre in the medulla; in the last, by reflex effect of peripheral sensory impulses acting through the medullary centres upon the vascular fields. Thus the reflex sensory vasomotor arc, so to speak, may be acted upon through any one of its component parts.

#### PHYSIOLOGICAL NOTES.

An attempt has been made in the introductory paragraphs of this communication to summarize briefly the present conception of the term “traumatic shock,” its method of production under ordinary circumstances, and the means by which in certain cases it may be avoided.

The experimental observations by Fischer, Goltz, Seabrook, Crile, and others have shown that the weakened or paralyzed condition of the vasomotor centre in the medulla, brought about reflexly by the mechanical injury to peripheral sensory neurones, plays the chief rôle in inaugurating a state of shock. The loss of control over the general arterial tone which results from this weakening of the centre results in a determination of blood in certain vascular fields. Of these

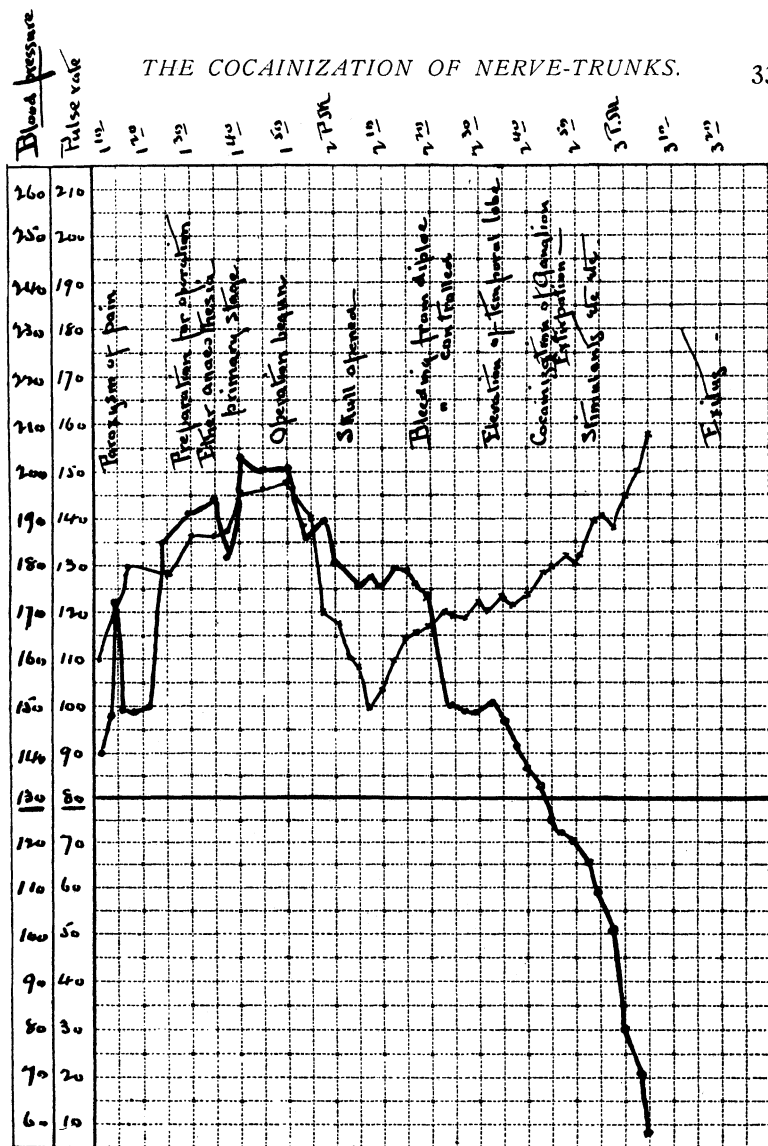


FIG. 13.—Chart III. Pulse-rate and blood-pressure curves taken during a fatal case of ganglion extirpation; ether anæsthesia. *Note* (1) The comparatively high blood-pressure and rapid pulse during the preparation of the patient and the early stage of anæsthesia.

*Note* (2) The fall in pulse-rate to 100, which should probably have been "ether level." *Note* (3) The drop in blood-pressure and acceleration of pulse from slight loss of blood during opening of skull. *Note* (4) The immediate fall in blood-pressure and rise in pulse during elevation of temporal lobe, the opposite of the normal reaction.

the largest and most important is the great splanchnic territory, the flooding of which side-tracks, as it were, such an amount of blood that there results an anæmia of the brain and lungs, a weakened cardiac action, or the "empty pump" principle of Goltz, and a consequent great fall in blood-pressure.

As has been stated in the brief discussion of the two cases which, early in this paper, have been cited at some length, there are certain predisposing factors which are influential in favoring this reflex loss of vasomotor tone. It is, in the first place, a well recognized physiological fact that stimulation, of one sort or another, of a peripheral sensory nerve of an animal in normal condition occasions a rise of blood-pressure or so-called "pressor" response due to a reflex constriction of the smaller arteries of certain vascular territories. Such a pressor response is frequently seen in clinical cases, and we have had the opportunity of plotting many such curves in correspondence with the experimental observations such as Dr. Crile has carried out. A patient in an attack of biliary colic, for example, will have a rise of blood-pressure from its normal level, corresponding possibly to 120 millimetres of mercury, to a level of 200 millimetres or over. A corresponding response occurs, as I have many times observed it experimentally, when there is a forcible injection of fluid into, and so as to distend, the biliary passage of an animal under anæsthesia. Similarly an attack of pain, such as is experienced in a paroxysm of trigeminal neuralgia, will raise the blood-pressure to inordinate heights. The increase in arterial tension under these circumstances may be unassociated with alteration in pulse-rate. Certain simple operative procedures as well, such as dilating the sphincter or stretching the sciatic nerve, as has been already instanced (Fig. 14), will call forth a pressor response.<sup>4</sup>

<sup>4</sup>When one sees recorded the pressor effects, which often occur in operative cases under anæsthesia, with a rise of arterial tension to double or more its normal level, it becomes a matter of astonishment that rupture of blood-vessels does not more often occur, especially in the feebly supported vessels of the central nervous system, and in patients who show evidence of alteration in the arterial walls. It is not improbable that the

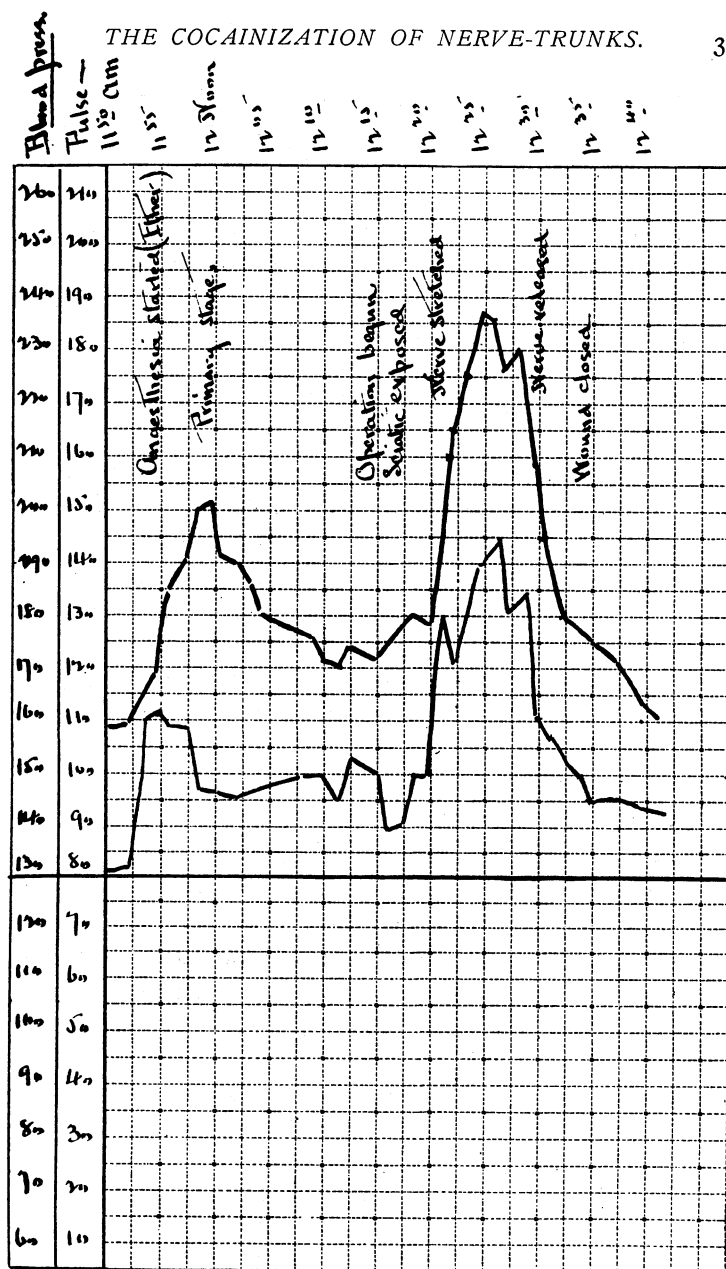


FIG. 14.—Chart IV. Pulse-rate and blood-pressure curves taken during the operation of stretching the sciatic nerve for sciatic neuritis; ether anæsthesia. Upper line, blood-pressure; lower line, pulse-rate.

*Note (1)* Rise during primary stage of anæsthesia and “ether level” of pulse, 95 to 100, and blood-pressure, 170 to 175. *Note (2)* The pressor effect (to 238 millimetres of Hg.) and accelerator response, 140 to 145, due to stretching the nerve for a period of ten minutes.

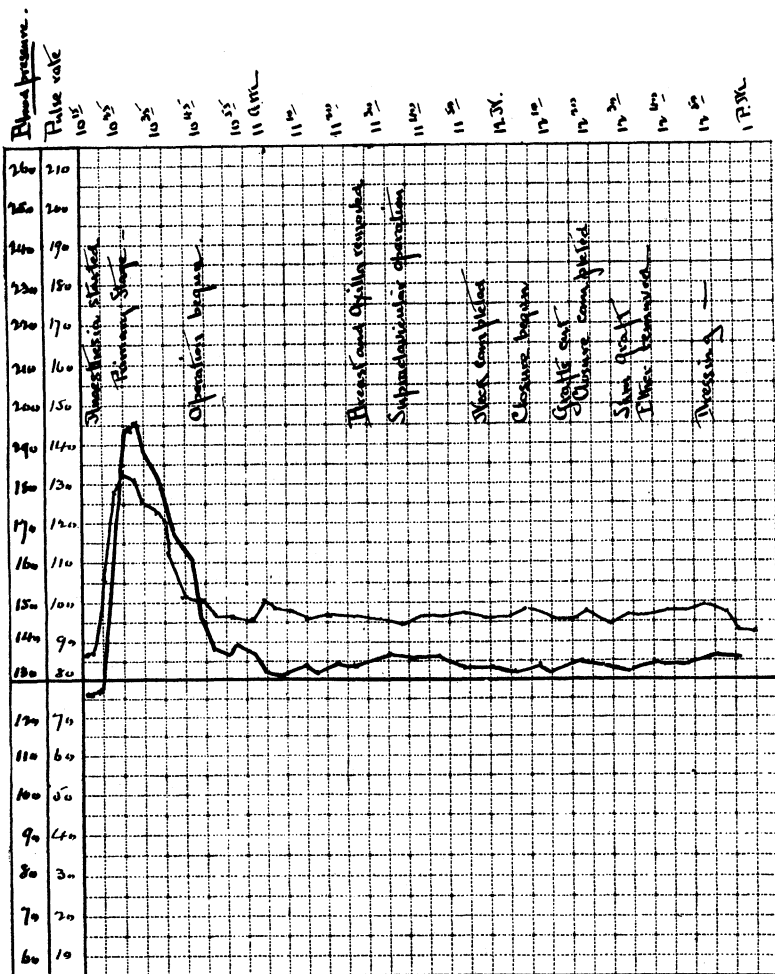


From the experimental side many observations have been made to determine the conditions which favor the calling out of the depressor rather than the normal pressor response to a given stimulus. The loss of blood or a coexistent primary anæmia, the exhaustion of an extensive operation or of prolonged anæsthetization, the repeated calling out of pressor responses from painful stimuli with consequent fatigue of the vasoconstrictor mechanism, and a great variety of other conditions might be mentioned in illustration; conditions which have long been recognized as prejudicial to the safe-conduct of certain operations.

Comparatively recent observations, chiefly those coming from Howell's laboratory, have been largely instrumental in establishing the view that in each bundle of mixed peripheral nerves there exist definite centripetal ("pressor") fibres, stimulation of which calls forth by reflex action a vasoconstrictor response, and others equally definite, which on the other hand produce when stimulated a depressor effect from reflex vasodilatation with consequent fall in blood-pressure. In the neck of the rabbit, as is well known from the classical experiments made in Ludwig's laboratory, afferent fibres subserving in a certain measures these different functions run apart and may be individually stimulated. One of these nerves has become known in consequence as "the depressor nerve," and must not be confused with the depressor fibres supposed to be present in other mixed nerves. Under ordinary circumstances, however, in the neck as well as in the nerves of the extremities, both pressor and depressor fibres run together in the same trunk and due to the fact that the former under normal conditions respond more readily and effectually to most forms of stimulation, a rise in blood-pressure is usually produced. Of these two sets of fibres, those having a pressor action seem to be the first to suffer from injury or over-stimulation, and when,

cases of sudden death, which on rare occasions have followed such simple procedures as stretching the sphincter ani for fistula, may be attributable to such an occurrence. Cases furthermore of anæsthesia apoplexy are by no means rare.

in consequence, they have become exhausted, the same irritation to the mixed nerve which previously would have called



Howell, for instance, has shown, when such a mixed nerve has been subjected to the effects of cold applied locally in its course, that it no longer calls forth pressor responses to peripheral stimulation, but that depressor effects may still be evoked. He and his pupils (Howell, Budgett, and Leonard, *Journal of Physiology*, 1894, Vol. xvi, p. 298) demonstrated, furthermore, in illustration of the fact that these two sets of fibres are functional entities, that after division of a peripheral mixed nerve those fibres calling forth reflexly a vasodilator response regenerate more rapidly than do those producing on stimulation a vasoconstrictor action.

Hunt <sup>5</sup> subsequently, working in the same laboratory, has further elaborated these studies, and has brought out the fact that in a fresh animal the depressor fibres may apparently be stimulated in excess of those subserving a pressor function by the action of weak electric currents. Strong currents, on the other hand, would produce the usual rise in blood-pressure from vasoconstrictor action. He has shown, also, in agreement with Kleen, that the mechanical bruising of muscles is apt to lead to a depressor effect. In confirmation of the observations of Latschenberger and Deahna (Latschenberger and Deahna, "Beiträge zur Lehre von der reflectorischen Erregung der Gefässmuskeln," *Pflüger's Archiv*, 1876, Band xii, p. 157) and others, Hunt's experiments demonstrate that on the repetition of a particular stimulus or injury, each of which, singly, would cause a rise in blood-pressure, a point is reached at which a pressor effect no longer occurs, but at which the same stimulus calls out a depressor response with fall in blood-pressure.

It must be confessed that there is no present uniformity of opinion among physiologists as to the nature of the depressor response. Conclusive proof even of the presence of depressor fibres, in the sense of Latschenberger and Deahna, is yet forthcoming. It is believed by some investigators that

<sup>5</sup> The fall of blood-pressure resulting from the stimulation of afferent nerves. *Journal of Physiology*, 1895, Vol. xviii, p. 381.

the fall in blood-pressure is due to alterations in the centre itself rather than the result of a reflex dilator action of specific afferent fibres. Whatever the mechanism of the response may be, however, the fact of its occurrence is sufficient for practical requirements; and, although the matter may have been presented here in an amateurish fashion, it needs but a glance to appreciate the importance to the operating surgeon of these laboratory observations. Their relation also to the clinical notes, which have been given in the first part of this paper, demands no written interpretation.

The facts remain that injuries of most diverse nature to peripheral nerves may, especially in some physical states, produce reflexly a fall in blood-pressure; that this loss of vascular tone, when it endures, is the most characteristic feature of shock, the symptom-complex of which is largely due to this one factor; that local anæsthetization of a nerve-trunk will block the transmission of the centripetal impulses which otherwise might bring about this reflex loss of vascular tone.



THE ADDITION OF EPINEPHRINE TO COCAINE  
FOR LOCAL ANESTHESIA

By H. BRAUN, M.D.

*Translated from*  
*ARCHIV FÜR CLINISCHE CHIRURGIE*  
*Vol. 69: 541-591*  
*1903*

*Reprinted by Permission from*  
*Faulconer A, Keys TE, Foundations*  
*of Anesthesiology, II, 1965; pp 834-842.*  
*Courtesy of Charles C. Thomas, Publisher*  
*Springfield, Illinois*



## The Addition of Epinephrine to Cocaine for Local Anesthesia\*

H. BRAUN, M.D.

*Chief Surgeon, Deaconess Hospital  
Leipzig-Lindenau  
Germany*

The practical importance of epinephrine in local anesthesia is considerable. On the basis of our present experience it seems to be of inestimable value to produce anesthesia—and only anemia alone—of the mucosa in rhinolaryngology and urology. The addition of epinephrine or of an extract of the adrenal glands containing epinephrine to solutions of cocaine allows us to lower the concentration and dose of the cocaine, thus diminishing the danger of intoxication and making the anesthesia more powerful. The property of vasoconstriction, so important in rhinology and laryngology, is no longer limited to solutions of cocaine alone, but can be imparted to a number of different local anesthetic solutions by the addition of epinephrine. It has been possible to obtain anesthesia of the mucosa of the bladder and urethra by means of dilute solutions of cocaine (0.1 per cent for the bladder; 1 per cent for the urethra), if sufficient time is allowed for the action of such solutions, but the efficiency of these solutions, especially with regard to duration of effect, is very much increased by addition of epinephrine.

The results of our work with normal persons justified our use of epinephrine and extract-solutions of adrenal glands in patients as well. I shall report these trials at the end of the chapter.

We did not notice any toxic side effects. Diluted solutions or extract-solutions of epinephrine did not cause local damage to the tissue. It is important to understand this point, because Blum<sup>9</sup> did observe severe damage, inflammation, suppuration and necrosis at the sites of injection in all animals he had injected with adrenal extract. The reason for this phenomenon, which has not been observed by other authors, is as obscure to me as it is to Blum himself. Nonetheless, it is best not to use such extracts for injection, since they vary in the content of epinephrine and hence cannot be controlled, and since they may even contain dangerous putrid alkaloids. We avoid the use of these extracts now. The extracts which we used occasionally in pa-

---

\* Translation from [extract from] Braun, H.: Ueber den Einfluss der Vitalität der Gewebe auf die örtlichen und allgemeinen Giftwirkungen localanästhesirender Mittel und über die Bedeutung des Adrenalins für die Localanästhesie. *Archiv für klinische Chirurgie*, 69:541-591, 1903.



tients at the beginning of our studies were always tested on my own body. We did not encounter any untoward general side effects of epinephrine. Actually, they should not be expected, if the concentration of solutions of 1:10,000 and the dose of 1 mg. are not exceeded. Even this latter dose is rarely necessary.

We use the epinephrine as follows: the commercial solution of epinephrine hydrochloride of 1:1,000 is sterilized by boiling and is kept in a sterilized, brown dropper-bottle with a wide neck and a dropper-pipet. At first, in surgical operations we used exclusively 0.1 to 1 per cent solutions of cocaine, with, of course, the appropriate content of 0.6 to 0.8 per cent isotonic solution of sodium chloride, and we added epinephrine before these solutions were used, so that we might study the effects of this combination from all sides. The epinephrine content of the solutions should be varied. For instance, when we intend to inject a 1 per cent solution of cocaine in a small quantity to take advantage of its marked long-distance action, we add 3 drops of the solution of epinephrine to 1 cc. of the solution of cocaine. This mixture then contains epinephrine in a concentration of 1:10,000, if 30 drops make 1 cc. On the other hand, when we intend to inject a 0.1 to 0.5 per cent solution of cocaine in a larger quantity (10 to 50 cc., according to the concentration of cocaine), we add only 3 drops of solution of epinephrine to 5 to 10 cc. of a solution of cocaine, respectively, measured off in half cubic centimeters, up to 50 cc., with a Pravaz syringe. In the latter instance epinephrine would be present in this mixture in a concentration of 1:100,000 and in a quantity of 0.5 mg. It has been evident that even when the solution of epinephrine is diluted to such a great extent, it still possesses a powerful capacity to produce local anemia, if it is used in larger quantities in the manner of Schleich's technic of infiltration of tissues.

A certain observation which we made in preliminary studies can now be applied in all cases. That is, the *duration* of the anesthesia produced by cocaine no longer is an important factor. Tissues once anesthetized by cocaine remain so for hours, if epinephrine is used at the same time.

At first we routinely used 1 per cent solutions of cocaine, to which were added 3 drops of epinephrine per cubic centimeter of solution, in dental extractions. Such a mixture proved to be superior to all other known preparations in reliability. If 0.5 cc. of the solution is injected subgingivally in front and behind the root of the tooth, the gums will become white and numb, to a far distance, within a few minutes. After five, or even better after ten, minutes, the tooth can be painlessly extracted, even if pulpitis or periostitis is present. The injection of course must be adequate. Patients whose eyes have been covered during the procedure often do not believe the extraction is over until they are shown the extracted tooth, and feel the empty space with their tongue. Generally, the wound caused by the

extraction does not ooze a drop of blood. Postoperative bleeding has not been observed. The few failures recorded concerned lower molar teeth, sites in which adequate injection of the lingual side often is impossible because of the overlapping of the alveolar process.

Certainly, the concentration of cocaine could be decreased considerably in many instances. In dental extractions, to be certain that anesthesia will be sufficient in cases that may be exceptional, it is necessary to use a preparation that possesses surplus anesthetic power. Yet there are definite instances in which the concentration of cocaine should be reduced, such as in multiple extractions, in which, if a 1 per cent solution were used, too much cocaine would be given in the aggregate. More details about our experiences with dental extractions will be published elsewhere.

In later studies the mixture of epinephrine and cocaine was employed to interrupt the conducting capacity of nerve trunks by infiltration of the perineural tissue, the skin remaining intact.

Anesthesia of a finger is produced after five to ten minutes when 1 cc. of a 1 per cent or 1.5 to 2 cc. of an 0.5 per cent solution of cocaine with epinephrine (3 drops = 1:1,000 in 1 cc.) is injected at the base of the finger in the usual manner, without the use of a tourniquet. Complete anemia of tissues, however, usually is confined to the basal phalanx; but bleeding from the site of incisions and amputations is always very slight. In some cases the anemia of the finger as a whole is the same as that produced by a tourniquet, except that when solution of cocaine and epinephrine is used a few drops of blood escape from the large main arteries. Vasoconstriction is not confined to the capillaries alone, as Bukofzer<sup>13</sup> assumes—a very unlikely assumption—but also affects the arteries. The large arteries of course cannot contract completely.

I shall give a few examples of the use of cocaine and epinephrine in operations.

October 22, 1902. A thirty-seven-year-old laborer sustained a machine injury of the right thumb and middle finger. A mixture of 3 cc. of a 1 per cent solution of cocaine plus 10 drops of solution of epinephrine was used; 1.5 cc. was injected around the basal phalanx of the thumb and 1 cc. was injected at the base of the middle finger. After ten minutes exarticulation of the terminal part of the thumb, and removal of the nail and dressing of the wound in the middle finger, were done. The operation was painless. Circulation in the fingers was much decreased, while the main arteries still pumped blood. Pain developed in the wounds after two hours. There was no postoperative bleeding.

October 30, 1902. A nineteen-year-old laborer sustained a machine injury of the left fourth finger. Two cc. of an 0.5 per cent solution of cocaine with 6 drops of solution of epinephrine was injected around the base of the finger. After ten minutes exarticulation of the terminal part of the phalanx was done. It was painless. Circulation was much decreased. There was no postoperative bleeding.

November 11, 1902. A twenty-four-year-old man complained of an ingrown toenail. One and a half cc. of a 1 per cent solution of cocaine with 4 drops of solution of epinephrine was injected around the base of the toe. Extraction of the nail and broad excision of the nailbed were done. There was no oozing of blood from the wound. A compression bandage was applied and the patient went home. Pain from the wound developed four hours later. There was no postoperative bleeding.

In these operations a tourniquet could have been used instead of the epinephrine, but the cases provide good examples of the action of the mixture of cocaine and epinephrine. The use of epinephrine may become more important in anesthesia of easily accessible nerve trunks, without previous dissection of them, in parts other than the fingers and toes. The greatest difficulty in the past has attended the use of the tourniquet—prolonged and painful—on the extremities. This difficulty can be overcome when epinephrine is added to solutions of cocaine, and there is no need to increase their concentration more than 0.5 to 1 per cent.

We must point out, however, that the observations of Manz,<sup>45</sup> Berndt,<sup>7</sup> Hölscher<sup>33</sup> and associates can be regarded only to a limited degree as examples of successful cocainization of nerve trunks, for in the work they report the main reason for the loss of sensibility may have been the application of a tourniquet for longer than one hour. We know that Berndt used solutions of cocaine in a dilution of 0.05 per cent, which certainly exerts no effect on nerve trunks. He even injected isotonic solution of sodium chloride in some of his cases, probably on the basis of the opinion of Schleich—which is as well known as it is wrong—that infiltration of tissues with any indifferent liquid decreases their sensibility. Personally, I have never observed the appearance of an effect of cocaine on the nerve trunks of healthy persons later than twenty to thirty minutes after injection. If an effect had not been produced by that time, it would not appear at all. The injection had failed; the solution of cocaine had not come into sufficient contact with the nerve. When an 0.5 to 1 per cent solution of cocaine is injected into the substance of the nerve after exposure and puncture of the fibrous nerve sheath, prompt interruption of the conduction of sensory as well as motor impulses results, without the need for any other aid or tourniquet. We know this from the writings of Cushing<sup>17</sup> on hernia operations, from Matas<sup>16</sup> and from Crile<sup>16</sup> (great sciatic nerve, femoral nerve, brachial plexus). I also can attest to these facts on the basis of many experiments on myself and other persons. It is not difficult, with a needle, to strike the ulnar nerve at the elbow, or the radial nerve at the outer rim of the biceps muscle, or the peroneal nerve at the head of the fibula, if the nerves in question are steadied between the fingers beforehand. This does not cause real pain, but rather, the well-known sensation of tingling. When 0.5 cc. of an 0.5 to 1 per cent solution of cocaine is injected into the peroneal nerve, for instance, at

the point mentioned, the nerve will be anesthetized within a few seconds, and the loss of sensation will be accompanied by transient complete motor paralysis of the radial and peroneal nerves, respectively. But since in actual practice it is not likely that the nerve will be thus reached with precision through the intact skin, we must resort to infiltration of the surrounding tissue of the nerve with the solution of cocaine. This is often easier said than done. Consequently, we turn to the use of solutions which exert their effects at the site of injection and at a considerable distance from it. Such a solution is afforded by the mixture of cocaine and epinephrine, and hence we have to wait some time before the nerve is blocked. I think that in this respect epinephrine is very important, because it can be substituted for the tourniquet in such cases.

Cocainization of the larger nerves which lie beneath the fascia, if they are not surgically exposed, can be done with safety in only few places of the body. On the other hand, the subcutaneous nerves are easily reached when solution of cocaine is injected in a strip across their pathways, as Krogius<sup>37b</sup> has shown. Both methods, however, if they were to come into common use, would require extensive anatomic studies on the sites and distributions of individual sensory nerves, their exits through the fascia and the possibility of reaching them with the needle. It is not within the scope of this paper to deal with such questions, and so I shall simply refer to the above-mentioned experiments among healthy persons, and confine myself to reporting some experiences with patients in order to illustrate the effects of the mixture of cocaine and epinephrine.

November 12, 1902. A twenty-one-year-old man had a deep infection between the thumb and index finger of the left hand. The radial half of the hand was anesthetized as described in Experiment 12.\* That is, 1 cc. of a 1 per cent solution of cocaine with 3 drops of epinephrine was injected at the median nerve, and 2 cc. of an 0.5 per cent solution of cocaine with 6 drops of solution of epinephrine was injected at the radial nerve in transverse direction to the course of the nerve. Fifteen minutes later the operative field was devoid of sensation. An incision from the center of the thenar eminence, between thumb and index finger through to the back of the hand, was painless. Cleaning and insertion of a drain were completely painless. Tissue anemia in cases such as this one of course is restricted to the site of injection. When a blood-free operative field is desired, a tourniquet should be applied immediately before the operation is begun.

A twenty-four-year-old man had an infected tendon sheath of the right middle finger, infection of the palm and back of the hand and partial gangrene of the middle finger. One cc. of a 1 per cent solution of cocaine with 3 drops of epinephrine was injected at the median nerve, as in Experiment 12,\* and the same was done at the ulnar nerve above the wrist joint, underneath the tendon of the ulnar flexor muscle. Four cc. of an 0.5 per cent solution of

---

\* Not in this text.

cocaine with 6 drops of epinephrine solution was injected subcutaneously around the wrist joint. Twenty-five minutes later the hand was entirely devoid of sensation. A tourniquet was placed around the upper arm. Incisions were made at the volar and dorsal aspects of the hand; the flexor tendons of the middle finger were excised, and the middle finger was amputated. The hand remained devoid of sensation for three and one-half hours; then the first pain from the wound developed.

A forty-four-year-old man had gummatous osteitis of the basal phalanx of the right fifth finger. On the volar aspect was an ulcer which extended onto the palm. One cc. of a 1 per cent solution of cocaine with 3 drops of epinephrine solution was injected underneath the tendon of the flexor carpi ulnaris muscle above the wrist joint. After fifteen minutes perfect nerve block and abolition of sensation were achieved in the field of the ulnar nerve. Incision was made, curettage done, and the destroyed phalanx was removed. Sensation (pain from the wound) returned after five to six hours.

November 1, 1902. A forty-year-old woman had a subfascial infection of the palm. The median nerve was anesthetized according to the technic described in Experiment 12.\* The ulnar nerve was anesthetized thus: the needle was inserted at the ulnar margin of the hand, close to the ulna, between the ulna and flexor ulnaris muscle, and was guided 1.5 to 2 cm. beneath the tendon of this muscle. Then the injection was made. In this way the nerve can be reached securely, an action which seems to be impossible from the volar aspect of the forearm, without injury to artery or vein. In this case each of the nerves was injected with 1 cc. of a 1 per cent solution of cocaine with 3 drops of solution of epinephrine. Twenty minutes later the infectious swelling could be opened by cross incision without causing pain. To reach all the terminal branches of the ulnar nerve, and especially the dorsal branch, it sometimes is necessary to inject an additional subcutaneous area, extending from the volar surface of the forearm via the pisiform bone and dorsally along the ulnar head to the middle of the dorsal aspect of the forearm. For this an 0.5 per cent solution of cocaine with epinephrine is sufficient.

October 5, 1902. A twenty-three-year-old woman had a ganglion on the dorsal aspect of the hand. Four cc. of an 0.5 per cent solution of cocaine with 10 drops of epinephrine was injected in an area extending from the region of the radial artery on the volar surface of the hand across the dorsal aspect of the forearm over to the pisiform bone. In this way the superficial radial nerve and the dorsal cutaneous branch of the ulnar nerve can be reached. Five minutes later the dorsal aspect of the hand and the basal phalanges of all fingers and a part of the thenar eminence were anesthetized. Extirpation of the ganglion was painless. Tissue anemia of course was limited in this case to the area of injection.

October 16, 1902. A thirty-five-year-old man had a deep infection of the dorsal aspect of the little toe and the adjacent parts of the foot. The whole foot was much swollen. Injection was carried out according to the technic described in Experiment 13.\* After ten minutes perfect anesthesia was obtained in the area of the distribution of the superficial peroneal nerve and the sural nerve, so that incision of the infected area, which partially reached the metatarsal bone, could be done without causing pain.

---

\* Not in this text.

October 13, 1902. A twenty-three-year-old woman had a sebaceous cyst, the size of a small apple, on the dorsal aspect of the right forearm, 8 cm. below the head of the radius, just on the belly of the supinator longus muscle. Three cc. of an 0.5 per cent solution of cocaine, with the addition of suprarenal extract (Merck) in a quantity of 1:1,000 was injected subcutaneously. The injected area bordered the tumor in the form of a semicircle, open toward the hand. After ten minutes an area down to the wrist, in the form of a strip, was anesthetized. Extirpation of the tumor was painless and nearly bloodless. The wound was sutured. First pain from the wound developed after two hours. There was no postoperative bleeding, and healing was smooth.

It may be in good order to observe that when large nerve trunks are to be anesthetized, the surgeon ought not to stand at the side of the patient with knife at hand, while he waits for the anesthesia to become complete. Such is an intolerable burden on the patience of both parties. Rather, it is better to start anesthesia a half to one hour before the operation is to be done, and to inject the agents outside of the operating room.

Finally, we used 0.1, 0.2 and 0.5 per cent solutions of cocaine with the addition of epinephrine from 1:10,000 up to 1:100,000 (depending on the degree of infiltration to be used) in the same manner, without separate injection of the skin, to anesthetize the operative field for the excision of localized infections and for the management of fresh injuries. Production of anesthesia took five to ten minutes. The injection was carried out in the manner as is described above, in combination with the freezing technic,\* but we did not use freezing.

*Examples.* November 14, 1902. The patient had a large furuncle on the right shoulder, with much surrounding hyperemia. Three cc. of an 0.5 per cent solution of cocaine with 9 drops of a 1:1,000 solution of epinephrine was injected subcutaneously around the furuncle, according to the method of Hackenbruch. After six minutes perfect tissue anemia in the operative field was obtained, so there was no bleeding at all at the time of incision, which was painless. Pain from the wound developed after one and one-half hours. There was no postoperative bleeding.

A twenty-six-year-old woman had an infected tuberculous gland of the right lower jaw. Five cc. of a 1 per cent solution of cocaine with 10 drops of epinephrine was injected around the operative field. After eight minutes complete absence of sensation and nearly complete tissue anemia were produced in the operative field. Incision and curettage were done. The extraordinarily powerful effect of the solution of cocaine and epinephrine resulted in paralysis of the right buccinator nerve which occurred simultaneously with the loss of sensation in the operative field and lasted for three hours.

In the typical technic of infiltration of tissues according to Schleich, with 0.1 to 0.2 per cent solutions of cocaine, the addition of epinephrine is of great advantage in the matter of prolongation of the duration of anesthesia

---

\* Not in this text.

produced by cocaine or eucaïne hydrochloride. The full advantage of extension of anesthesia beyond the site of direct injection and anesthesia of the nerve trunks which supply the operative field can be utilized only if a special technic is used. The future will determine how much of an advantage this is. Often it may be useful in avoiding excessive infiltration of the skin or reducing the necessity for it.

*Examples.* Anesthesia of the abdominal wall. November 14, 1902. A ten-year-old boy had a perityphlitic [appendiceal] abscess. Twenty cc. of a 0.2 per cent solution of cocaine with 15 drops of a 1:1,000 solution of epinephrine was injected in the following manner. The site of incision above the inguinal ligament was marked by three skin wheals raised with a fine needle. From these points 10 cc. of the solution was injected with a long needle subfascially in the expansion of the intended incision; then the same quantity was injected into the subcutaneous tissue. After fifteen minutes the operation was begun. The incision in the skin was 12 cm. long, starting from the right iliac spine and carried parallel to Poupart's ligament. Cutting of the skin, fascia and muscles did not produce pain or bleeding; a few drops of blood issued from a single artery situated near the iliac spine in question. Even the action of opening the peritoneum with a small incision did not cause pain. Then, however, it became necessary to free the peritoneum from the iliac muscle to a greater extent by blunt dissection, a procedure which I had not anticipated. I therefore had the patient inhale 20 cc. of ether, after which peritoneal dissection and opening and draining of the fecal abscess (which contained a fecolith) were accomplished without further injury to the peritoneal cavity. There was no bleeding postoperatively.

It is not my purpose to advocate that an operation for such a condition as perityphlitis [appendicitis] be conducted with the aid of local anesthesia, which would be possible only in rare cases. I simply wish to show how the abdominal walls can be anesthetized.

November 21, 1902. A fifty-year-old woman had a superficial cancerous lesion of the skin, the size of a 1-mark piece, below the left eyelid and partially encroaching on the eyelid. The subcutaneous tissue of the cancer and the area of the skin flap (to be excised from the skin of the cheek and temple for grafting) were infiltrated with 20 cc. of an 0.2 per cent solution of cocaine with the addition of 0.5 cc. of a 1:1,000 solution of epinephrine. After ten minutes the tumor could be excised, the skin flap could be dissected and excised and the grafting could be carried out, all without causing pain and with only minimal bleeding. Healing was smooth.

By this time the number of operations we have carried out with anesthesia produced with cocaine and epinephrine amounts to 132, including forty-seven dental extractions. As previously mentioned, we have encountered no disadvantages of epinephrine, but only advantages. Operations suitable for the use of anesthesia with cocaine and epinephrine are chiefly in the field of minor surgery. They are done in the outpatient department, and I have restricted the use of local anesthesia largely to such procedures.

I hope that the introduction and use of epinephrine will lead to additional attempts to cocaineize the nerve trunks, so that this neglected technic will be developed on a sound anatomic basis.

To surgeons I wish to recommend epinephrine not only because of its effect on cocaine anesthesia but also because the vasoconstrictive, even vaso-occlusive, effect of this "alkaloid of Esmarch's anemia" may be of great value, for instance in the excision of angiomas of the extremities, in the control of bleeding from wounds, in skin grafting or in the treatment of hemophilic persons.

### References

7. Berndt: Ueber die Anwendung der regionären Anästhesie bei grösseren Operationen an den Extremitäten. *Münch. med. Wochenschr.*, 1899. No. 27.
9. Blum: Ueber Nebennierendiabetes. *Deutsches Arch. f. klin. Med.*, 1901. Vol. 71. p. 146.
13. Bukofzer: Ueber Adrenalin. *Allg. med. Centralztg.*, 1902. No. 44.
16. Crile: An experimental and clinical Research into Cocain and Eucaïn. *Journ. of the Amer. Med. Association*, February, 1902.
17. Cushing: Observations upon the neural anatomy of the inguinal region relative to the performance of herniotomy under local anæsthesia. *Johns Hopkins Hospital Bulletin*, März, 1900.
33. Hölscher: Beitrag zur regionären Anästhesie. *Münch. med. Wchschr.*, 1899. No. 8.
- 37b. Krogius: Zur Frage der Cocainanalgesie. *Centralbl. für Chir.*, 1894. No. 11.
45. Manz: Ueber regionäre Cocainanästhesie. *Centralbl. f. Chirurgie*, 1898. No. 7.
46. Matas: The growing importance and value of local and regional anaesthesia in minor and major surgery. *Transactions of the Louisiana State Medical Society*, 1900. p. 329.





NITROUS OXIDE - OXYGEN - ETHER ANAESTHESIA:  
NOTES ON ADMINISTRATION; A PERFECTED APPARATUS

By F. J. COTTON, A.M., M.D.

and

WALTER M. BOOTHBY, A.M., M.D., Boston, Mass.

*Reprinted from*  
*SURGERY, GYNECOLOGY AND OBSTETRICS*  
*September, 1912, pages 281-289*



can be greatly ameliorated, if not cured, by operation, and that the earlier the patient reaches the surgeon the better the result.

Although the following conditions are insisted upon by Drummond and Morison, namely: that cases selected for this method of treatment should not be complicated by cardiac, pulmonary or renal disease, and should have survived one or two tapplings, still the contra-indications are practically nil. Most of the patients come to us as a last resort, when there is no opportunity to build them up before operating. So that the cases at best are desperate, and we cannot be blamed if they die during or soon after operation. On the other hand, the results in some cases have been so brilliant that they encourage the surgeon to advise the operation even in seemingly hopeless cases.

The question of drainage is also a debatable one, the English surgeons advocating it and the American surgeons opposing it, mainly on the grounds of the liability to sepsis. In view of the fact that in the majority of cases reported in which drainage has not been used, anywhere from two to more tapplings subsequent to the operation were required to free

the abdomen of fluid, it would seem that the use of drainage, for a few days at least, is desirable. With careful technique and careful after treatment of the patient, the danger of sepsis can be reduced to a minimum, and we run no more risks from sepsis by drainage than we do from frequent tapplings. Therefore, I firmly advocate the use of drainage in all cases.

In conclusion, it is my opinion that the operation of omentopexy is a justifiable one and that the ideal technique is, under general anæsthesia, a median incision below the umbilicus, suturing as much of the omentum to the anterior abdominal wall as possible; and, above all, drainage for at least a week. This latter feature I believe to be especially essential in the after treatment.

#### BIBLIOGRAPHY

1. American Journal of Medical Sciences, Dec., 1900.
2. American Journal of Medical Sciences, Dec., 1902.
3. British Medical Journal, Nov. 10, 1906.
4. Transactions of the Southern Surgical and Gynecological Association, 1910.
5. Interstate Medical Journal of St. Louis.
6. Johns Hopkins Hospital Bulletin, March, 1911.
7. Annals of Surgery, Dec., 1907.
8. Keen's Surgery, iii.

## NITROUS OXIDE-OXYGEN-ETHER ANÆSTHESIA: NOTES ON ADMINISTRATION; A PERFECTED APPARATUS<sup>1</sup>

By FREDERIC J. COTTON, A. M., M. D., BOSTON  
First Assistant Surgeon, Boston City Hospital

AND

WALTER M. BOOTHBY, A. M., M. D., BOSTON

Assistant in Anatomy, Harvard Medical School; Assistant Surgeon, Mt. Sinai Hospital (Boston); Anæsthetist to the Boston City Hospital

PROFESSOR ANDREWS of Chicago, in 1868, and Professor Bert of Paris, in 1879, showed that a mixture of 80 per cent of nitrous oxide and of 20 per cent of oxygen would produce an ideal anæsthesia in many cases. Further experience in the use of nitrous oxide and oxygen showed that for practical work these percentages must be easily variable within wide limits, in order to meet the peculiarities of the case and the stage and duration of the

anæsthesia. More recently it has become generally accepted that in some patients, in order to obtain relaxation, a varying amount of ether vapor must be administered in conjunction with the nitrous oxide-oxygen mixture.

All experimental and clinical work has emphasized the fact that a *constant* mixture (rightly proportioned for the particular case in hand) produces a smoother anæsthesia than a mixture of varying composition; in

<sup>1</sup>This research has been performed in part under the grant of a Bullard Fellowship by the Harvard Medical School to W. M. Boothby. Through the courtesy of Prof. W. T. Porter much of the work was done in the Laboratory of Comparative Physiology.

other words it has been shown that an intermittent and irregular supply of either gas does not conduce to a smooth surgical anæsthesia.

Consequently an ideal apparatus must be one that delivers to the patient a mixture of the two gases in any desired constant proportion and at the same time provides for the addition of as much ether vapor as is needed. For practical use such an apparatus must require no more attention from the administrator than is necessary to set the valves controlling the delivery of each gas.

Hewitt of England was the first to develop an apparatus at all applicable to general surgical use. His method of overcoming the terrific pressures of the nitrous oxide and oxygen is to use semi-elastic bags, which are kept more or less full from the high pressure tanks, by means of an intermittent flow of the gases controlled directly by hand valves on the tanks, acting against the high pressures. From these bags the flow of gas to the patient is regulated by a specially constructed and graduated valve that allows definite proportions of gas to pass from each bag, providing the pressures within the same are equal.

In practice it has been found very hard to maintain the two bags evenly and equally distended, even if great pains and constant attention are being given by the operator to the manipulation of the hand valves; therefore the pressure in the two bags varies greatly and, consequently, the mixture actually received by the patient must of necessity vary greatly.

McKesson has recently described an apparatus which, like that of Teter, is built on the Hewitt principle. While McKesson's apparatus is an advance in the development of this type of machine, yet it does not actually accomplish all that it is possible for an apparatus to do, in rendering the anæsthetist free from the trouble of valve manipulation, nor does it allow for the addition of ether vapor in a quantity and with a rapidity sufficient to meet the needs of all cases.

As a result of the inadequacy of any apparatus built on the principle of the

Hewitt, we took up, now over a year ago, the study of the problem. We laid down, four fundamental requirements which we agreed must be met or the problem given up. These requirements are:

1. There must be an absolutely *regular flow of each gas* at any rate desired, without the necessity of frequent valve manipulation.

2. The flow of the gases must be rendered *visible* so that their proportions can be approximately estimated at a glance.

3. An *efficient method of adding ether vapor* gradually yet rapidly up to any amount, that even an extreme case may require, must be available.

4. The face-piece must be so modified as to be absolutely *air-tight* and also practically self-retaining.

The first point, the crucial one, is to obtain an even flow of nitrous oxide gas from its liquefied form, compressed into steel tanks under a pressure of 700 pounds to the square inch. This necessitates the use of an automatic reducing valve. The same is true of oxygen (although not in liquid form) in similar tanks under a pressure of 1,500 to 1,800 pounds to the square inch. The province of such a valve is to reduce these terrific pressures to a working basis of 20 pounds to the square inch; a good valve is absolutely automatic and requires no attention on the part of the anæsthetist; experience has shown that the reducing valves can be absolutely relied on and that they do not freeze or become otherwise obstructed.

This principle of the automatic reduction of high tank pressures is so fundamental that we consider it essential that this feature be actually an integral part of the apparatus and not secondarily attached to tanks which are then connected with an apparatus designed on the Hewitt type. For general use a tank of moderate size (containing 75 gallons of oxygen and 250 gallons of nitrous oxide) is the most practical and convenient; accordingly we have designed our apparatus for that size of tank. The smaller size can of course be used and is preferable for transportation in house operating.

The second desideratum, namely, rendering

the rate of flow of gases visible, so that the relative proportion of each gas can be estimated at a glance, also assuring the administrator of the fact that the desired flow is actually taking place, has been solved by having *each gas bubble separately through water into a glass mixing chamber.*

The volume of gas delivered to the patient is controlled by means of a hand valve of fine adjustment acting against the low pressure delivered by the reducing valve. This is entirely independent of the automatic reducing valve. The hand-valves can be set to give any desired volume, which will continue unaltered for hours; a change in the rate of flow is obtained by simply turning the valve-handle a trifle till such volume per minute as is desired is seen to bubble through the water of the mixing chamber.

The aim of the anæsthetist is to determine as early in the anæsthesia as possible the proportion of nitrous oxide and oxygen suited to the patient under his care. The greater his experience the earlier will he be able to do this with certainty. After this proportion is once ascertained the apparatus will deliver the same mixture as long as desired, thus reducing the work of the anæsthetist to a minimum; in fact it is not uncommon for him to sit for more than half an hour with nothing to do but watch the patient quietly breathing, apparently in a natural sleep, and having no need of either touching the apparatus, the mask, or the patient.

The value of being able to estimate by the eye the relative rates of flow of each gas is of inestimable value. After a brief experience one is enabled to approximate the desired proportion solely by the eye, thus rendering it easier to obtain quickly the constant mixture needed for the particular patient in hand. Further, in difficult cases it greatly helps the anæsthetist to determine whether his patient needs more or less oxygen or nitrous oxide, also in case the patient becomes rapidly cyanotic (and this is not a rare occurrence with beginners) the surgeon can see at a glance that the cause of the difficulty is obstruction of the respiratory passages and not due to an insufficient pro-

portion of oxygen in the mixture being administered to the patient.

The third essential point, which consists in being able, gradually yet rapidly, to add to the respired mixture as much ether vapor as even an extreme case may need, has been met by providing a second chamber, containing ether. The gases, after leaving the mixing chamber, pass to a three-way valve by which they are allowed to pass by the ether chamber entirely, or are made to pass either partly or wholly over the surface of the ether, or they may be forced (if desired) to bubble through the ether.

*Thus any amount of ether vapor required, from the minutest trace to a relatively high percentage can be almost instantly obtained.*

The possibility of gradually and yet rapidly increasing the strength of the ether vapor is of material advantage, for it allows the anæsthetist to just "catch" the patient within a few seconds after he gives a sudden warning of being "light" by moving the legs, contracting the abdominal wall or showing symptoms of impending vomiting. At such moments one may gradually but rapidly increase the ether percentage to that obtained by bubbling through the ether; after a few respirations the patient is seen to relax or the symptoms of impending vomiting disappear, at which time the ether should be entirely shut off. It is best as a rule at the beginning of trouble indicating a "light" condition to make no change in the rate of flow of the gas or oxygen, for when ether is administered a slight excess of oxygen is desirable; but as soon as the impending trouble is overcome the rate of oxygen may be slightly decreased, or that of nitrous oxide increased depending on the amount of re-breathing desired. In all probability the new mixture will maintain the patient for the rest of the operation in a perfect condition of anæsthesia, possibly without the necessity of again touching the valves.

Because we have emphasized the necessity of having available an appliance by which strong ether vapor can be administered we must not be misunderstood; in at least one quarter of the cases no ether at all will be required; in perhaps another quarter about

two minutes inhalation of ether will be needed during the last stages of the preparation of the patient; in another small proportion an occasional addition of ether vapor for one or two minutes through the course of the administration will be found advisable; only very rarely and in rebellious alcoholic cases will more than a total of ten minutes respiration of ether in addition to the gas mixture be needed for an hour's operation; and even in these difficult cases practically no more ether is needed after the first hour, no matter how long the operation is prolonged. Accordingly, little or no nausea and vomiting follows a properly conducted nitrous oxide-oxygen-ether anæsthesia in a great majority of cases. Of course that small proportion of cases that require the larger amounts of ether do not have such an ideal recovery as those needing very small amounts or none; such recoveries resemble those following the ordinary ether vapor method which Gwathmey has found so desirable.

The cases run somewhat more smoothly, and perhaps with an average decrease in the amount of ether vapor needed, resulting in a more nearly ideal recovery if moderate doses of morphine (gr.  $\frac{3}{8}$  to  $\frac{1}{4}$ ) and of atropine (gr.  $\frac{1}{120}$  to  $\frac{1}{100}$ ) are given hypodermically one half hour before the beginning of the anæsthesia.<sup>1</sup> At the Hospital this is a standing order but if it is omitted for any reason we are not concerned except in the case of bad alcoholics. In other words the preliminary injection of morphine is by no means essential though it is desirable unless contra-indicated by some known peculiarity of the patient.

The fourth point necessary for a gas-oxygen anæsthesia is to exclude even the minutest trace of air from leaking in between the mask and the face. This necessity holds true for every case and must be accomplished in spite of peculiarities of the facial contour or the presence of beard and whiskers. Again we emphasize the fact that such exclusion of air must be absolute and not relative. One of us (B.) has recently des-

cribed a collar that is not only air-tight but practically self-retaining (Boston Medical and Surgical Journal, 1912, clxvi, 9, 328), to which article the reader is referred. To those using this collar we call attention, elsewhere more fully dealt with, of the dangers of positive pressure; the expiratory valve must be so set that an outflow of the gases may occur whenever the pressure inside the mask exceeds 2 mms. of mercury, which is a pressure just sufficient to maintain the rebreathing bag full but not distended.

For an even anæsthesia and as an aid to the avoidance of surgical shock a certain constant amount of rebreathing is of benefit; approximately the rate of flow of the gases should be such that from a quarter to a half of the volume of each respiration is of freshly added gas mixture. Such a proportion reduces to within reasonable limits the expense of gas-oxygen anæsthesia; too much rebreathing is apt to be followed by post-operative discomfort, usually in the form of headache; and it may cause an increase of post-operative nausea and vomiting. Vomiting during the progress of the anæsthesia is often an indication of excessive rebreathing for that particular patient although it may, in comparison with other patients, not appear excessive; at all events, increasing the volume per minute of the gas mixture, frequently clears up the symptoms.

Henderson's excellent series of papers on acapnia and its relationship to surgical shock deserves careful reading. Our observations on the effect of rebreathing, so far as they go, agree clinically with the laboratory findings of Henderson; we hope shortly to be able to adopt more scientific methods in the study of this problem in the clinic. Our observations of the blood pressure under nitrous oxide-oxygen (ether) anæsthesia with moderate rebreathing is that there is a distinct rise not only at the commencement but also throughout the operation. After the removal of the mask with its accompanying necessity for rebreathing there is a distinct and rapid fall in the blood pressure. In two instances, both on very sick and debilitated patients,

<sup>1</sup>In the beginning, following the lead of Crile, we used scopolamin with the morphine. Often an efficient hypnotic, scopolamin has seemed to us too uncertain in its action to be worthy of routine use and we have come to use atropin, which does at least reliably insure us against trouble from excess of mucus.

this fall was sufficient to abolish the radial pulse; the appearance of the patients and their mental attitude remained good; recovery was prompt and within one half hour they were in fine condition and remained so. This picture may very probably be interpreted as due to a temporary relative apænia. If this should prove to be so it would be very easily dealt with by having the patient rebreathe into a paper bag in addition to routine treatment.

It is necessary once more to emphasize the fact that *a surgical anæsthesia is never obtained when the patient appears in the least degree cyanotic* on account of asphyxial spasm and rigidity. On the contrary the *patient must always be pink*.

We have no sympathy for the surgeon who allows his anæsthetist to beguile him into the belief that cyanosis is necessary for a gas-oxygen anæsthesia and, by permitting it, tacitly to assent to the hypothesis that such a condition is safe. We thoroughly believe that any anæsthesia accompanied by cyanosis is dangerous. Reports of deaths under gas-oxygen are rapidly coming in much to the apparent discredit of the method; they are obviously due to conducting the anæsthesia according to this erroneous idea of the necessity and safety of cyanosis; no deaths have been reported in which the patients color was maintained pink. Neither of us would permit an administration of gas-oxygen with cyanosis in any patient of ours; how any surgeon can or will operate under such conditions we do not understand.

In an earlier paper we suggested that some cases, even when respiring a mixture of gas and oxygen in which the proportion of the latter is sufficient to maintain the patient pink, might even then be brought under too profound influence of nitrous oxide and the anæsthesia be made dangerously deep. Our use of an absolutely air-tight face piece has enabled us to demonstrate that such a condition occurs not seldom but frequently. In fact toward the end of a long operation it is often necessary to use equal parts of oxygen and nitrous oxide.

The symptoms of an overdose of nitrous oxide in the presence of sufficient oxygen to

keep the patient pink is, first, stertorous respiration and the onset of an excessive secretion of mucus; unless the percentage of nitrous oxide is decreased the patient's face and hands then take on a death-like pallor (not cyanotic), there is an absolute loss of all the facial reflexes, the respirations become shallow and, probably, the blood pressure falls (that is, the temporal cannot be found so readily although the rate is not excessive). This condition if pushed would probably lead to death from paralysis of the respiratory centre, though we know of no experimental evidence to support this hypothesis.

The point we wish to make is that an excess of nitrous oxide may be given even with a proportion of oxygen that, if respirations were proceeding normally, is sufficient to maintain the patient pink; if a death-like pallor with the other symptoms noted should then supervene while respiring such a mixture the patient is rapidly approaching the danger point of excessive anæsthetisation. In such a condition no time should be lost, for as yet we do not know how soon actual respiratory failure and death may occur. In brief the mask should be removed and if necessary artificial respiration instituted together with the administration of oxygen.

We do not wish to imply that this method of anæsthesia is more dangerous than that of straight ether, in fact, we firmly believe that it is the safest when in proper hands. We have had no serious trouble but believe trouble might have developed had we not recognized and appreciated the signs of excessive nitrous oxide dosage. The use of nitrous oxide for prolonged anæsthesia is still in its infancy and its danger limits are not well understood; in consequence for several years yet its effects, good and bad, must be carefully watched.

Even a slight degree of cyanosis distinctly increases the general venous ooze from the incision, apparently by decreasing the coagulation time of the blood; we have never observed this to any serious extent and consider the point of only minor importance.

Although the patient is rapidly rendered unconscious (two minutes) by gas-oxygen yet it is nearly ten minutes before the body



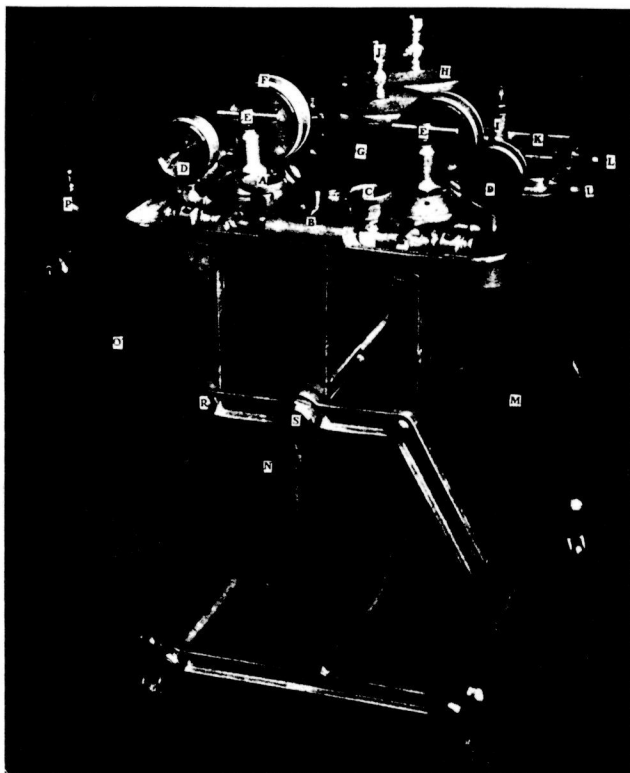


Fig. 1. A. Hand valves: to regulate the volume supply of oxygen; it works against a low pressure of about 25 pounds to the square inch therefore it can be set for and will continue to deliver any constant amount and this can be estimated by seeing the rate of flow as the gas bubbles through the water in the glass mixing chamber (G).

B. Ether valve: when pushed over to the left the mixed gases from G go directly to the patient; when in the centre (as illustrated) the mixed gases pass over the surface of the ether in chamber H; when pushed over to the right the gases must bubble through the ether.

C. Hand valve: to control the volume of nitrous oxide in same manner as A regulates oxygen.

D. Low pressure gauge: the one on the left indicates the pressure of oxygen, and that on the right nitrous oxide, after being automatically reduced by the reducing valve.

E. Regulating handle on the reducing valve: this after being set for the desired low pressure (20 lbs.) does not need to be again touched.

F. High pressure gauge: to show the pressure in the supply tank.

G. Glass mixing chamber: contains water through which each gas bubbles separately thus giving a ready

means of estimating at a glance the rate of flow of both the oxygen and the nitrous.

H. The ether chamber: by valve B the gases after being mixed in G are allowed to pass around the ether chamber, or made to pass partly or wholly over the surface of the ether, or forced to bubble through the ether thus adding any desired amount of ether vapor to the respired mixture.

I. One of four valves: introduced so that any one of the tanks may be removed and replaced by a full one without interrupting the use of the apparatus.

J. Cups to fill the chambers with water and ether.

K. Valve on tank.

L. Screw by which each tank is clamped into its yoke.

M. One of the two nitrous oxide tanks on right side.

N. One of the two oxygen tanks on left side.

O. Rebreathing bag.

P. Mask with celluloid face-piece and the Boothby air-tight self-retaining collar.

Q. Two of the four lag bolts which may be removed by unscrewing the thumb nuts on the inside to allow the top of the table to invert into the lower half.

S. Centre axis on which the top half swings.

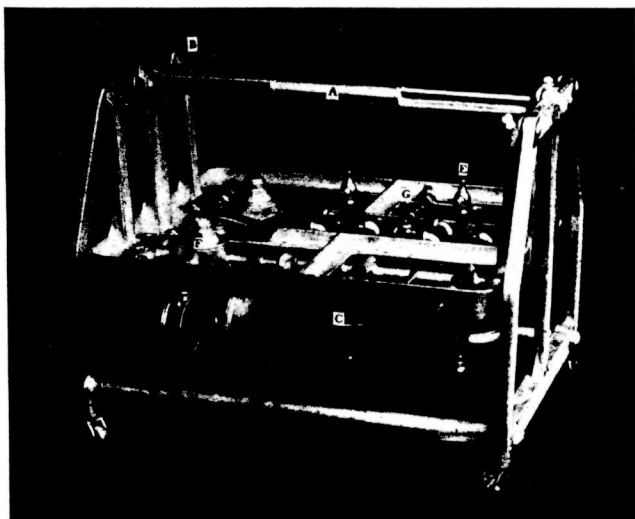


Fig. 2. A. Centre axis on which the top half swings; the middle portion serves as a handle.

B. One of the four thumb nuts which are removed to invert the table.

C. Mixing and ether chamber protected by the frame when top is inverted for transporting.

E. Pet-cocks for drawing off the water and ether from the chamber before inverting.

F. The under side of one of the automatic reducing valves.

G. The metal nipple to which the rubber tube is attached that leads to the rebreathing bag.

Size: Height, 17 inches; length, 22 inches; width, 17¼ inches; weight, 50 pounds (aluminum castings).

is sufficiently saturated with the nitrous oxide to permit the beginning of an abdominal operation. During this period which may be occupied by the preparation and draping of the patient, we allow the anæsthetist to depart somewhat from our rule in regard to avoidance of cyanosis; but even here we permit only the slightest degree of duskiess and never entertain the possibility of deep cyanosis. By the time the incision is made the patient must be actually pink and remain so throughout the operation. If then a mixture of nitrous oxide and oxygen with a proportion of the latter sufficient to maintain the patient pink will not produce sufficient relaxation to meet the demands of the surgeon the anæsthetist must add ether vapor till relaxation is complete.

For the best results close co-operation on the part of the surgeon and the anæsthetist is essential. During the greater part of the

majority of operations complete relaxation is not needed; when such relaxation is required by the surgeon he should so inform his anæsthetist who will be able within two minutes, by the proper administration of ether, to provide the same; as soon as such need is over the ether may be discontinued.

A cyanotic condition of the patient, however, sometimes quickly develops even with an evidently liberal supply of oxygen as shown by the flow through the mixing chamber. In such cases the trouble is without question an obstruction of the air passages and must be quickly remedied. Contrary to the generally accepted opinion *cheek and tongue obstruction of the air passages is extremely common under gas-oxygen anæsthesia and its prevention is absolutely essential*. The most frequent cause is an obstruction of the nares together with a valve like action of the

lips or cheeks against the teeth that occurs in mouth breathing when there is muscular relaxation. A ready means of overcoming such a condition is to slip up under the face-piece or collar a piece of gauze or a thin ribbon retractor into the angle of the mouth to keep the lips apart and the cheek away from the teeth; or pieces of rubber tubing about six inches long, guarded by safety-pins, may be introduced through the nares into the oro-pharynx. In rare cases the tongue may drop back and cause obstruction in spite of every effort to prevent the same by holding the jaw forward; in such cases a silk-worm-gut stitch should be passed through the tongue and brought out under the collar, with a dental mouth prop placed between the teeth to prevent biting of the tongue. An absolutely free air passage for the gases must always be maintained; any slight obstruction, most common on inspiration, causes a labored respiration under which conditions a smooth anæsthesia is impossible, besides throwing an extra exertion onto the patient.

Teter has, at various times, recommended an increase of pressure in the mask and in the rebreathing bag as an aid to inducing a more profound nitrous oxide anæsthesia, basing his claims for the procedure on the well known experiments of Paul Bert in 1879. In one of our earlier articles we disagreed with Teter as to the advantages of increased tension of the respired mixture, on the basis of its causing labored abdominal respiration which interferes with the surgeon's work. We wish now to go further and strongly discountenance the use of *positive pressure because it is a dangerous procedure*. In the first place the Bert and Teter methods are not comparable; Bert increased the pressure of the mixed gases as breathed to about 20 per cent of an atmosphere, but this was done in a pressure chamber in which the patient as well as the operator and assistants were likewise placed. In other words the increased intra-pulmonary pressure was compensated for by an equal increase in the atmospheric pressure surrounding the patient's body, thus causing no circulatory disturbance.

It is well known that the right heart is filled from the venæ cavæ on account of a slightly greater pressure within the latter, which, however, under certain surgical conditions may be as low as 10 mms. of mercury; as the cavæ pass for some distance through the thorax where normally there is slight negative pressure, it can be readily understood that an increase in pressure within the thorax (as produced by Teter's method) without a corresponding increase in external atmospheric pressure may hinder the filling of the heart with the consequent evil train of symptoms. An increase of the intra-thoracic pressure above that of the abdominal venæ cavæ will therefore cause sudden death from obstruction of the circulation by preventing the heart from filling. Frantic efforts to save the patient by turning on the oxygen and jamming down the mask renders matters worse.

The theoretical benefit to be obtained from an increase of pressure is less than one per cent in efficiency; accordingly, a procedure involving the dangers of collapse and of sudden death, with such a meagre beneficent return, should not be used.

In practice, therefore, the rebreathing bag should just become taut at the end of an expiration; this corresponds to a pressure of one or two mm. of mercury which is sufficient to open the respiratory valve at the end of the expiration and thus to allow the last part of the expired gases, that part which (as McKesson points out) contains the largest percentage of  $\text{Co}_2$ , to escape into the air.

The experimental apparatus recently described by us,<sup>1</sup> built on the principles enunciated above without regard to lightness and portability, has been most satisfactory and has met all expectations. In that apparatus we included other factors such as an efficient warmer for the gases and an electric motor to drive an air pump in case air should be desired as a carrier of ether vapor instead of the mixture of gas and oxygen. These accessories have been proved useless, and in consequence have been discarded. Because

<sup>1</sup>Cotton and Boothby: Nitrous oxide-oxygen anæsthesia with a description of a new apparatus. *Surgery, Gynecology and Obstetrics*, xiv, 2, Feb., 1912, 195-211.

gases absorb heat very rapidly we found that by the time they reached the patient their temperature, without any heating apparatus was nearly that of the room; by means of the heater originally described the gases could be delivered 10 to 20 degrees (F) higher. The frequent complaint by the patient, following the use of the heater, of dry parched lips which caused considerable, though of course, not serious discomfort, led us to the conclusion that an efficient heating apparatus was a disadvantage; as an inefficient appliance is an unprofitable complication, we have reversed our former opinion as to the desirability of having an attachment for warming the gases on the apparatus.

An apparatus to meet all the requirements described above must have some size and weight. These items however, have been reduced to their lowest terms by great care in the design and arrangement of the various parts. For the purpose of transportation the apparatus can be collapsed to a reasonable carrying size (height 17"; length 22"; width 17 $\frac{3}{4}$ " :) by the simple removal of four lag bolts, set up with thumb screws, which allows the top half of the machine to swing down into the lower half; the centre bar or axis acts then as a convenient handle and the framework forms a protecting cage for the valves and the glass chambers. To reduce the weight the patterns have been made as small as is consistent with the strength requisite for hard hospital use and transportation for house operating, and the castings are made of aluminum alloy (except the valves). The carrying weight is just under fifty pounds.

#### SUMMARY

I. To be safe, effective and suitable for major surgical work a nitrous oxide-oxygen anæsthesia must be so conducted that the patient is never in the least degree cyanotic; on the contrary the patient must always be pink.

II. No attempt should be made to use the dangerous procedure of increasing intrathoracic tension of the gases for the purpose of deepening the anæsthesia.

III. In those cases that cannot be sufficiently relaxed for the purpose in hand by

the use of nitrous oxide with a sufficient proportion of oxygen to prevent cyanosis, the anæsthesia should be deepened by the addition of as much ether vapor as may be needed; experience has shown that the total amount of ether used is small and has little and often no effect on the quick and agreeable recovery incident to this form of anæsthesia with its absence of postoperative "surgical shock."

IV. We believe an anæsthesia without cyanosis to be safe in expert hands. The anæsthetist, however, must have skill and experience to recognize the warning signs of too much nitrous oxide even without cyanosis (a picture not striking enough to appear to the tyro) as well as the signs of too much ether.

V. Therefore to be practical for surgical work an apparatus for the administration of nitrous oxide-oxygen-ether anæsthesia must possess the following fundamental features:

1. The apparatus must deliver, *for any length of time, any desired proportion* of nitrous oxide and oxygen, without requiring constant attention from the administrator; in other words the high pressure of the supply tanks must be automatically reduced to an easily controllable working pressure; the importance of this feature necessitates that the reducing valves be an integral part of the apparatus.

2. It must be possible to add *ether vapor in any strength* from the merest trace to a high percentage; and any desired variation in this percentage must be gradually and yet rapidly made.

3. There must be a method of instantly estimating by the eye the approximate proportion of each gas being administered.

4. The face-piece must be not only airtight but practically self-retaining.

5. The apparatus must be strong, light and reasonably portable.

VI. The apparatus herewith described and illustrated is designed to meet the clinical and the physiological requirements of surgical anæsthesia and it effectively overcomes the mechanical difficulties attendant to the successful administration of nitrous oxide-oxygen-ether.



# THE ASPIRATION OF STOMACH CONTENTS INTO THE LUNGS DURING OBSTETRIC ANESTHESIA

By CURTIS L. MENDELSON, M.D.

New York, NY

*Reprinted from*

*AMERICAN JOURNAL OF OBSTETRICS AND GYNECOLOGY*

*August, 1946, pages 191-205*

*Reprinted by permission of*

*C.V. Mosby Company, St. Louis, Missouri*

*Publisher*

## THE ASPIRATION OF STOMACH CONTENTS INTO THE LUNGS DURING OBSTETRIC ANESTHESIA\*

CURTIS L. MENDELSON, M.D., NEW YORK, N. Y.

(From the Department of Obstetrics and Gynecology, Cornell University Medical College and New York Hospital)

**I**N MOST texts on pulmonary complications, aspiration of stomach contents into the lungs during general anesthesia is considered under the heading of postanesthetic pneumonia. Aspiration of infected material is said to produce atelectasis, pneumonia, and lung abscess.

A survey of New York Lying-In Hospital records of patients that aspirated gastric contents during obstetric anesthesia revealed the following different diagnoses: suffocation, massive atelectasis, partial atelectasis, disc atelectasis, pulmonary infarct, aspiration pneumonia, bronchopneumonia, lobar pneumonia, virus pneumonia, atypical pneumonia, tuberculous pneumonia, pulmonary tuberculosis, fungus infection, pulmonary metastasis, drowned lung, cardiac failure, pulmonary edema, and paroxysmal tachycardia. Obviously, a better understanding of this condition is wanting.

### Present Study

There have been sixty-six instances of aspiration of stomach contents into the lungs in 44,016 pregnancies at the Lying-In Hospital from 1932 to 1945. The incidence of this complication is 0.15 per cent.

An analysis of the cases is presented and followed by experimental work to clarify the pathology of aspiration, and thereby gain insight into its diagnosis, prevention, and treatment.

### Analysis of Cases

The significant data in the 66 cases are summarized in Table I.

The incidence of prolonged labor was somewhat higher than that of the total clinic population, which is 10 per cent.

### Obstetric Reactions

Slightly more than half of the cases had operative intervention requiring relatively longer administration and greater depth of anesthesia than those delivered spontaneously. A mixture of gas, oxygen, and ether was employed in all instances.

### Aspiration

Aspiration was recorded as having definitely occurred in the delivery room in 68 per cent. In 32 per cent this complication went unrecognized until later. The character of the aspirated material in the 45 recorded cases was liquid in 40 and solid in five.

\*Read at a meeting of the New York Obstetrical Society, Dec. 11, 1945.

TABLE I. ANALYSIS OF 66 CASES OF ASPIRATION

Prolonged labor,	30 hours or over		9	or 14%
Type of delivery,	Normal spontaneous		29	44%
	Cesarean section		14	21%
	Operative other		23	35%
Anesthesia,	Gas, oxygen, ether		66	100%
Aspiration,	Recorded at delivery		45	68%
	solid	5		
	liquid	40		
	Subsequently diagnosed		21	32%
	Obstructive reaction		5	8%
	suffocation	3		
	massive collapse	2		
	Asthmatic-like reaction		61	92%
Cyanosis,	Recorded		55	83%
Tachycardia,	Pulse over 110 per minute		66	100%
Dyspnea,	Respirations over 30 per minute		66	100%
Chest pathology,	Diffuse		15	23%
	Right only		51	77%
	Left only		0	0%
Morbidity,	Febrile	20		30%
	chest	8		
	pneumonia	6		
	abscess	2		
	other	12		
Chemotherapy,	Sulfonamides		14	21%
	Penicillin	3		5%
	Both	2		3%
Deaths,	Immediate	2		3%
	Later	0		0%

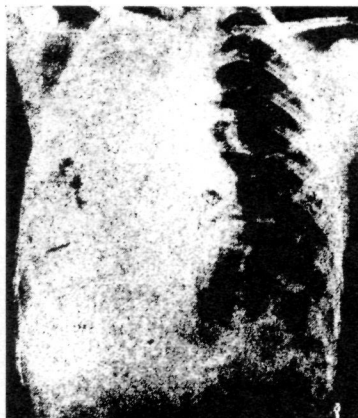


Fig. 1.—Massive collapse of right lung following obstruction by solid, undigested food. Note the mediastinal shift and homogeneous density over the collapsed area.

Obstructive reactions occurred in the five patients that aspirated solid material. Three of these had complete obstruction; two died of suffocation on the delivery table, whereas the third recovered after coughing up a large piece of meat. Two of the five patients had incomplete obstruction with massive atelectasis, and both recovered after coughing up the obstructing material. These patients exhibited the classical picture of massive collapse with cyanosis, tachycardia, dyspnea, evidence of mediastinal shift, and consolidation. Fig. 1 shows the typical chest plate in such a case. There is mediastinal shift and a homogeneous density over the collapsed area on the right side.



### Asthmatic-like Reactions

A very different type of reaction was observed in the 40 patients that aspirated liquid material. For lack of any existing description, this type of reaction may best be likened to an acute asthmatic attack.

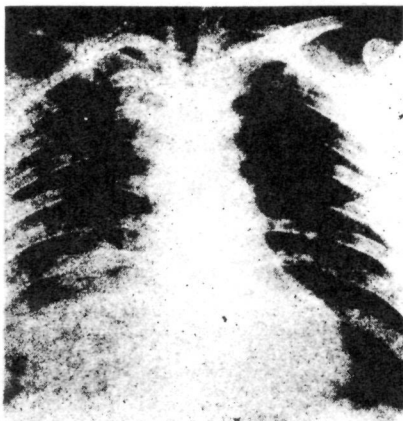


Fig. 2.—Scattered soft, mottled, confluent densities seen after aspiration of liquid gastric contents. Note the absence of any mediastinal shift.

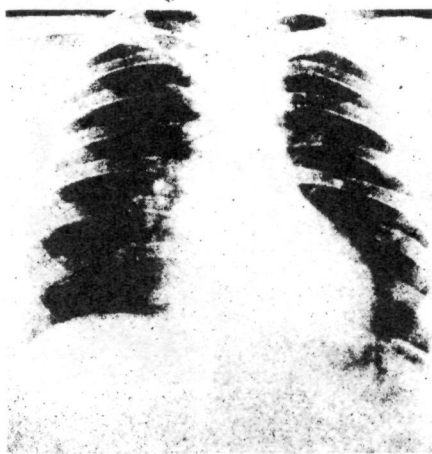


Fig. 3.—The same patient as in Fig. 2, ten days later.

Apparently liquid gastric contents were aspirated into the lungs, while the laryngeal reflexes were abolished during general anesthesia. The actual aspiration often escaped recognition. Cyanosis, tachycardia, and dyspnea developed as in the obstructive cases, but there was no massive atelectasis or mediastinal shift. Auscultation over the involved areas revealed numerous wheezes, râles,

and rhonchi. High pulse and respiratory rates were common, often reaching values of 160 and 40 respectively. Evidence of cardiac failure frequently appeared, and occasionally culminated in pulmonary edema.

The patients were critically ill during the acute episode, but there was gradual stabilization within twenty-four to thirty-six hours, and recovery was usually complete with an afebrile and uncomplicated course.

Early x-rays revealed irregular, soft, mottled densities in the involved areas, but no mediastinal shift. Subsequent films usually showed complete clearing within seven to ten days. These features are illustrated in Figs. 2, 3, 4, and 5.

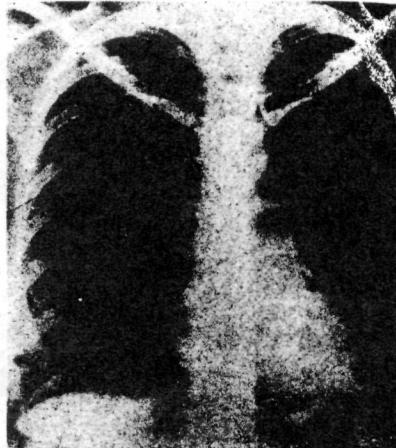
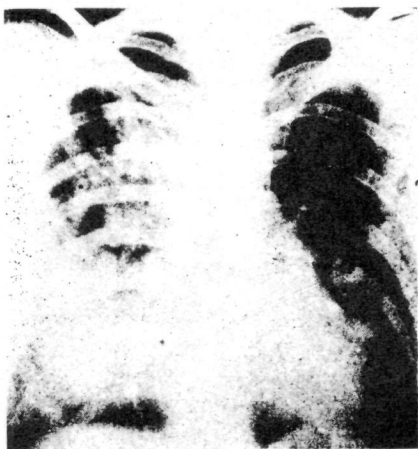


Fig. 4.—Another case after the aspiration of liquid gastric contents.

Fig. 5.—The same patient as in Fig. 4, seven days later.

### Cyanosis, Tachycardia, Dyspnea

Cyanosis, tachycardia, and dyspnea occurred in most cases, regardless of the type of aspiration.

### Chest Pathology

The right lung was most commonly involved in both types of aspiration. Massive aspiration, however, readily involved both lungs.

### Morbidity and Chemotherapy

The morbid group includes any patient with elevation of oral temperature to 38° C. (100.4° F.) during any two twenty-four-hour periods postpartum, exclusive of the first twenty-four hours following delivery. Thirty per cent of all cases were morbid, but less than half the morbidity was attributable to chest pathology. Many cases occurred before the use of sulfonamides and penicillin, so that relatively few received this type of chemotherapy, yet only six patients developed pneumonia. Two of the pneumonia cases followed the obstructive type of reaction, and four followed the asthmatic type. One of each of these groups went on to develop a lung abscess. Fortunately all these patients recovered. Infection must be regarded as a relatively infrequent but serious secondary complication.

### Mortality

The two deaths in the series were due to suffocation from complete obstruction by solid undigested food. Both patients had recently ingested a full meal; one eight hours previously, the other six hours previously. Autopsy obtained in the latter case revealed complete obstruction of the major respiratory passages by solid food particles.

None of the cases in the series suffered from pulmonary tuberculosis, primary organic heart disease, concurrent respiratory infection, or malignancy.

### Experimental

A series of animal experiments were undertaken to determine the pathology of these two different aspiration syndromes. Anyone who has aspirated the slightest amount of fluid during a vomiting seizure will remember the intense irritation produced. It was thought pertinent to evaluate the role of hydrochloric acid.

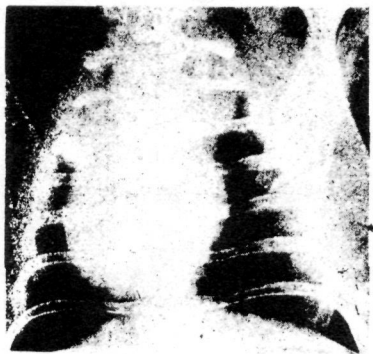


Fig. 6.—Chest film of normal rabbit.

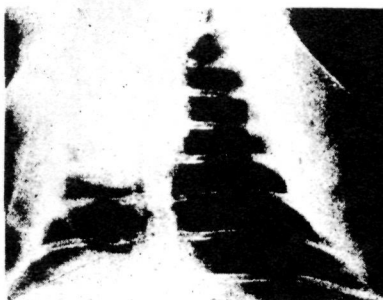


Fig. 7.—Chest film of a rabbit after obstruction by solid undigested food. Note the mediastinal shift and homogeneous density over the collapsed area.

Various materials were introduced into the lungs of adult rabbits weighing between 5 and 6 kilograms. In some instances the material was introduced using a laryngoscope during sodium pentothal anesthesia, while in others the material was introduced directly into the trachea after preliminary tracheotomy.

The following substances were used: distilled water, normal saline, tenth normal hydrochloric acid, liquid vomitus, neutralized liquid vomitus, vomitus containing solid undigested food, and neutralized vomitus containing solid undigested food. All vomitus was obtained from parturient patients, none of whom suffered from achlorhydria. Such material was used in its acid state unless subsequently modified to a neutral pH, as previously indicated.

The experimental results may be summarized as follows. After aspiration of solid undigested food the picture is invariably that of obstruction as observed in the human. This is true regardless of whether acid or neutral material is used. Complete obstruction causes suffocation. Incomplete obstruction produces massive atelectasis. The chest film of a normal rabbit is shown in Fig. 6. Fig. 7 shows the picture with massive collapse following incomplete obstruction. Note the homogeneous density and mediastinal shift. Animals relieved of obstruction recover completely. The collapsed lung shows the typical

appearance of massive atelectasis. Practically all crepitation is gone, but otherwise the gross picture is not remarkable. There is no free fluid in the pleural or pericardial cavities. The heart and abdominal viscera are normal. The typical microscopic picture of atelectasis is seen in Fig. 8.

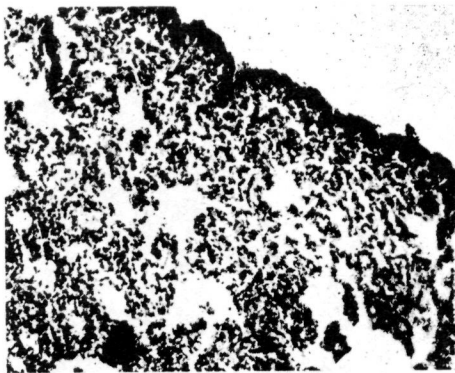


Fig. 8.—Section of a rabbit lung showing massive atelectasis.

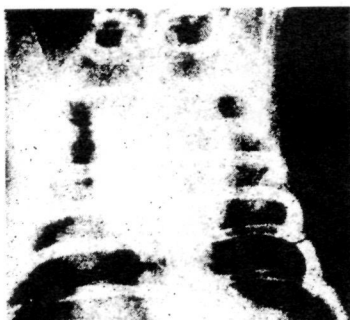


Fig. 9.—Chest film of a rabbit after aspiration of 20 c.c. of tenth normal hydrochloric acid. Note the soft, mottled, confluent densities and absence of any mediastinal shift.

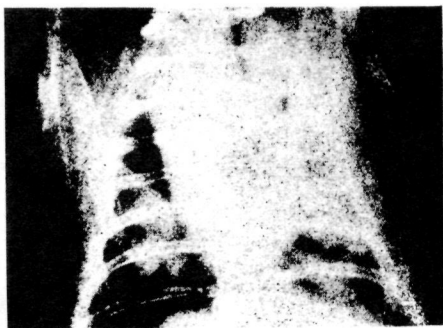


Fig. 10.—Chest film of a rabbit after aspiration of 20 c.c. of unneutralized liquid gastric contents. Note the similarity to Fig. 9.

Following aspiration of liquid containing hydrochloric acid (tenth normal hydrochloric acid or unneutralized liquid vomitus) the animals develop a syndrome similar in many respects to that observed in the human following liquid aspiration. Cyanosis and labored respirations develop immediately, but death often ensues within minutes to hours, with a pink froth exuding from the respiratory passages in the terminal stages. X-rays reveal irregular, soft, mottled shadows without mediastinal shift. Fig. 9 shows the picture after aspiration of 20 c.c. of tenth normal hydrochloric acid, and Fig. 10 shows practically identical findings after aspiration of 20 c.c. of unneutralized liquid vomitus. The gross pathologic picture may be described as follows: The trachea is injected and filled with pink frothy material. The pleural cavities contain a

serosanguineous fluid. The visceral pleura is smooth with large subpleural hemorrhages, imparting a variegated color to the lungs, ranging from normal pink through all the shades of red to a rich dark purple. The darker areas are doughy in contrast to the pink areas which retain normal crepitation. The lungs are heavier than normal. Scatter emphysematous blebs are present. Fig.



Fig. 11.—Lungs of a rabbit after aspiration of 20 c.c. of tenth normal hydrochloric acid. The darker areas are hemorrhagic and doughy.



Fig. 12.—Lungs of a rabbit after aspiration of 20 c.c. of unneutralized liquid gastric contents. Note the similarity to Fig. 11.

11 shows the lungs after aspiration of 20 c.c. of tenth normal hydrochloric acid, and Fig. 12 shows a similar picture after aspiration of 20 c.c. of unneutralized liquid vomitus. On cut section the lungs exude a pink gelatinous material. The heart is dilated and shows small subpericardial hemorrhages. There is congestion of all the abdominal viscera.



Fig. 13.—Section of rabbit lungs after aspiration of 20 c.c. of tenth normal hydrochloric acid. Note the bronchiolar pattern with necrotic epithelium partly sloughed into the lumen, and the peribronchiolar congestion.

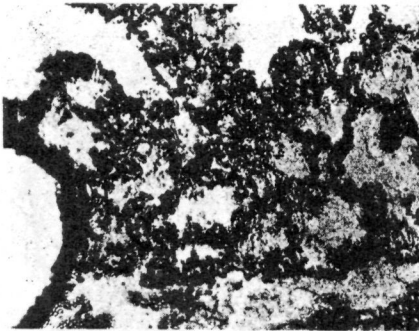


Fig. 14.—Section of rabbit lungs after aspiration of 20 c.c. of unneutralized liquid gastric contents. Note the character of the alveolar walls with pyknotic nuclei and the exudate within the alveoli.

The microscopic picture is also the same after aspiration of equal amounts of tenth normal hydrochloric acid or unneutralized liquid vomitus. The trachea and larger bronchi are congested, but the epithelium is intact. A wavy bronchiolar pattern is noted, indicative of muscular spasm. There is peribronchiolar hemorrhage and exudate with areas of surrounding emphysema. In places the bronchiolar epithelium is necrotic and sloughed into the lumen. The alveolar walls are hyaline with absent or pyknotic nuclei. Perivascular edema is marked. There is congestion and edema throughout. Figs. 13 and 14 demonstrate the above features.

Following aspiration of neutral liquid (distilled water, normal saline, or neutralized liquid vomitus) in equal quantities to the preceding series of acid experiments, the animals go through a brief phase of labored respirations and cyanosis, but within a few hours they are apparently back to normal, able to carry on rabbit activities uninhibited. There are no significant x-ray changes. Fig. 15 shows the chest film after aspiration of 20 c.c. of normal saline and Fig.

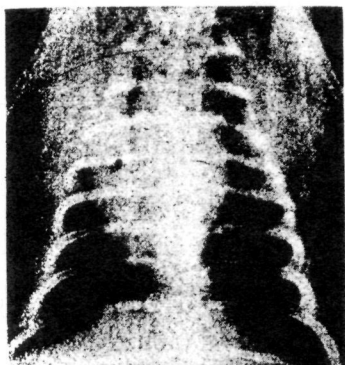


Fig. 15.—Chest film of a rabbit after aspiration of 20 c.c. of normal saline. There are no significant changes.



Fig. 16.—Chest film of a rabbit after aspiration of 20 c.c. of neutralized liquid gastric contents. There are no significant changes.

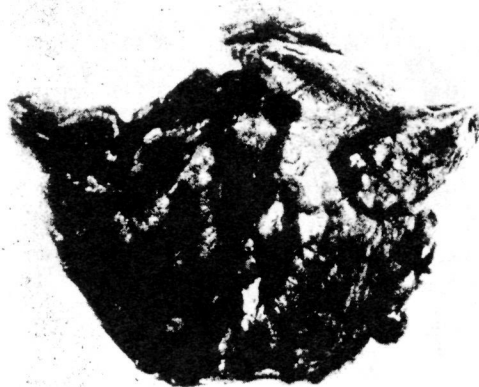


Fig. 17.—Lungs of a rabbit after aspiration of 20 c.c. of normal saline. Except for minute hemorrhagic areas, the lungs are not remarkable.

16 shows the film after aspiration of 20 c.c. of neutralized liquid vomitus. The gross pathologic changes are minimal. The trachea and larger bronchi are normal. There is no free fluid in the pleural or pericardial cavities. The lungs show minute scattered areas of atelectasis, but for the most part are crepitant throughout. Fig. 17 shows the lungs after aspiration of 20 c.c. of normal saline,

and Fig. 18 shows the lungs after aspiration of 20 c.c. of neutralized liquid vomitus. The cut surface of the lungs is normal. The heart and abdominal viscera are unremarkable.

The microscopic picture is not remarkable except for small patches of atelectasis and emphysema. There are no bronchiolar changes. Hemorrhage, congestion, edema, and exudate are absent. Fig. 19 shows a section from the lungs after aspiration of 20 c.c. of normal saline, and Fig. 20 shows a section following aspiration of 20 c.c. of neutralized liquid vomitus.



Fig. 18.—Lungs of a rabbit after aspiration of 20 c.c. of neutralized liquid gastric contents. Essentially the same as Fig. 17.

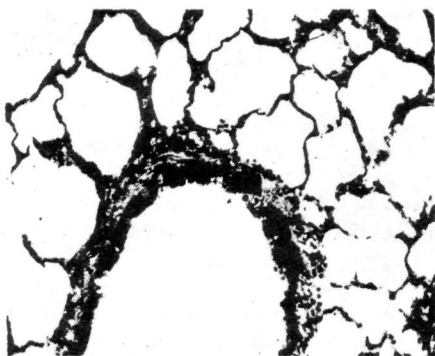


Fig. 19.—Section of rabbit lungs after aspiration of 20 c.c. of normal saline. There is slight emphysema, but otherwise the section is unremarkable.

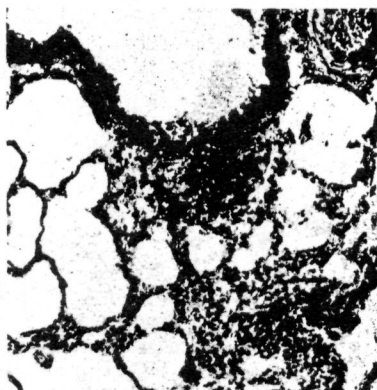


Fig. 20.—Section of rabbit lungs after aspiration of 20 c.c. of neutralized liquid gastric contents. There is a small area of atelectasis.



### Discussion

The gastric emptying time is often prolonged during labor. This applies to liquid as well as solid stomach contents. At delivery it is not uncommon for a patient to vomit food ingested twenty-four to forty-eight hours previously. As much as a liter of clear to dark green fluid has been recovered from a single patient.

Aspiration of vomitus may occur while the laryngeal reflexes are abolished during general anesthesia. Bronchial configuration favors right-sided aspiration, but massive aspiration readily involves both lung fields. Liquid material is more commonly aspirated than solid. The consistency and dimensions of solid food probably interfere with its aspiration.

This study reveals that two entirely different syndromes may follow aspiration. Aspiration of solid food usually produces the well-known picture of laryngeal or bronchial obstruction. Complete obstruction produces suffocation. Incomplete obstruction produces massive atelectasis with the classical picture of cyanosis, tachycardia, dyspnea, mediastinal shift, and signs of consolidation over the collapsed area. X-rays reveal a homogeneous density in the affected area and varying degrees of mediastinal shift. The pathology of atelectasis is well described in all textbooks dealing with the subject.

Obstruction should be promptly relieved either indirectly by external stimulation with encouragement of coughing, or directly with the aid of suction and endoscopic removal.

The value of sulfonamides and penicillin for this type of aspiration is questionable. Although the process is not primarily infectious, the seriousness of secondary pneumonia and lung abscess may make such chemotherapy worthwhile as a prophylactic measure.

Aspiration of liquid material produces an asthmatic-like syndrome with distinct clinical, roentgenologic, and pathologic features. Apparently this syndrome has escaped recognition, for to the author's knowledge it has not been previously described. There is cyanosis, tachycardia, and dyspnea, but no mediastinal shift or massive atelectasis. Wheezes, râles, and ronchi are heard over the affected portions of the lungs.

X-rays reveal irregular, soft, mottled densities without mediastinal shift. The picture has been misinterpreted as bronchopneumonia, tuberculosis, fungus infection, and even metastasis.

Progressive cardiac embarrassment and pulmonary edema may supervene, regardless of the previous normal condition of the heart. Here the diagnosis has been confused with primary cardiac failure.

The animal experiments indicate that hydrochloric acid is responsible for the changes described. The acid produces a bronchiolar spasm and a peribronchiolar congestive and exudative reaction interfering with normal intrapulmonary circulation to the extent that cardiac failure may develop.

The irritative action of hydrochloric acid on the respiratory tract has been previously studied by Winternitz,<sup>1</sup> specifically in reference to the action of chlorine and phosgene in war gas poisoning, but any relation to the pathology of aspiration appears to have been overlooked. The changes following aspira-

tion of tenth normal hydrochloric acid and unneutralized liquid gastric contents are similar to those following gassing with chlorine and phosgene, but there is less necrosis after aspiration, probably because of smaller concentration of the irritant.

Therapy in this type of aspiration should be directed against the bronchiolar spasm and cardiac embarrassment. Oxygen, atropine, adrenaline, and aminophylline will accomplish these objectives. Should evidence of cardiac failure develop, rapid intravenous digitalization is indicated. The circulatory burden may be further relieved by the application of tourniquets to the extremities to produce the effect of a bloodless phlebotomy.

The dramatic relief reported<sup>2, 3</sup> in the treatment of acute asthma by stellate ganglion block suggests that this procedure may be of value. The fundamental neurophysiology of stellate ganglion block is not clear, but the technique of performing the block is relatively simple. So far it has not been tried in the treatment of this type of aspiration.

The bronchoscope would appear to be of little value in this condition, for the pathologic process is beyond reach, and endoscopy may only increase the existent spasm and dangers of secondary infection.

The majority of patients have an afebrile recovery with complete clearing of the chest in seven to ten days. The pathologic process is primarily irritative and not infectious, but sulfonamides and penicillin may be of value in preventing secondary infection due to concurrent aspiration of nasopharyngeal flora.

It is conceivable that both solid and liquid aspiration may occur simultaneously, in which instance both the obstructive and asthmatic pictures would be found. In the present series this situation has not been encountered. Presumably the presence of any solid material so alters the consistency of the gastric contents that little material reaches the bronchioles.

It is important to appreciate that both types of aspiration are preventable. The delayed emptying time of the stomach during labor has already been discussed. The necessity of feeding the parturient has been overemphasized. Misinformed friends and relatives often urge the patient to ingest a heavy meal early in labor before going to the hospital. This food is supposed to provide strength for parturition. It is obviously dangerous to give any solid food during labor and it would be judicious to explain this to the patient during the prenatal course.

The dangers of fluid aspiration have been overlooked, for it is common hospital practice to urge water, tea, and fruit juices throughout the first stage of labor. It has already been pointed out that copious amounts of liquid may be retained in the stomach and that aspiration of liquid occurs much more frequently than aspiration of solid material.

It is common surgical practice to withhold all feeding for twelve hours or longer before any elective operation. This procedure plus the delayed emptying time of the stomach during labor probably account for aspiration being less of a surgical than an obstetric hazard. While it is true that the parturient expends considerably greater energy than the preoperative patient, it is unlikely that any serious harm would result from withholding all oral feeding for the

average duration of labor. Should fluid and caloric balance be disturbed in the event of prolonged labor, parenteral therapy is available.

Even if oral feedings were withheld during labor, it is possible that the stomach might still elaborate and retain sufficient hydrochloric acid to produce a serious aspiration hazard. This danger could be readily avoided by emptying the stomach prior to the administration of a general anesthesia. The time-honored finger in the throat method is always available, but the oral administration of a warm alkaline solution would in all probability produce the same desired effect and further obviate the dangers of residual hydrochloric acid being aspirated from the nasopharynx.

The anesthetic problem deserves special consideration. A new and inexperienced intern is frequently assigned to give obstetric anesthesia. Wider use of local anesthesia would eliminate the dangers of incompetently administered general anesthesia. Too often an active patient is rushed into the delivery room and a general anesthetic started with an opaque mask fastened over the face before information is obtained regarding the condition of the heart, lungs, or stomach. Examination of the heart and lungs is recorded on most labor sheets. The time of ingestion of the previous meal should also be recorded. This would draw attention to the possibility of a full stomach.

Once retching occurs, it is dangerous to force the anesthetic if the stomach has not been emptied. The mask should be removed, vomiting encouraged, and followed by thorough cleansing of the mouth and nasopharynx. Opaque masks are undesirable as vomitus may be concealed. It may also escape recognition if the anesthetist's attention is focused on the obstetric proceedings at the other end of the table. The anesthetist should remain with the patient until the laryngeal reflexes have returned.

Suction, laryngoscopic, and bronchoscopic equipment should be readily available in the delivery room, together with personnel trained in its use. The delivery table should be adjustable for Trendelenburg position.

### Summary

Sixty-six cases of aspiration of stomach contents into the lungs during obstetric anesthesia are analyzed. The incidence of this complication is 0.15 per cent in 44,016 pregnancies at the New York Lying-In Hospital from 1932 to 1945.

Two distinct aspiration syndromes are described. The clinical, roentgenologic, and pathologic features of each are reproduced in the rabbit, and inferences drawn regarding diagnosis, prevention, and treatment.

### Conclusions

1. Gastric retention of solid and liquid material is prolonged during labor.
2. Aspiration of vomitus into the lungs may occur while the laryngeal reflexes are abolished during general anesthesia.
3. Bronchial configuration favors right-sided aspiration. Massive aspiration, however, readily involves both lungs.

4. Liquid material is more frequently aspirated than solid.
5. Aspiration of solid material usually produces the classical picture of laryngeal or bronchial obstruction.
6. Aspiration of liquid produces an apparently hitherto unrecognized asthmatic-like syndrome with distinct clinical, roentgenologic, and pathologic features. This syndrome is due to the irritative action of gastric hydrochloric acid, which produces bronchiolar spasm and a peribronchiolar exudative and congestive reaction.
7. Aspiration of stomach contents into the lungs is preventable. The dangers of this complication as an obstetric hazard may be avoided by: (a) withholding oral feeding during labor and substituting parenteral administration where necessary; (b) wider use of local anesthesia where indicated and feasible; (c) alkalization of, and emptying the stomach contents prior to the administration of a general anesthetic; (d) competent administration of general anesthesia with full appreciation of the dangers of aspiration during induction and recovery; (e) adequate delivery-room equipment, including transparent anesthetic masks, tiltable delivery table, suction, laryngoscope, and bronchoscope; and (f) differential diagnosis between the two syndromes described, and prompt institution of suitable therapy.

NOTE.—The factors used in the animal x-ray experiments were: 50 kilovolt peak, 36 inches, 3 seconds, 40 milliamperes, using a cassette and Bucky diaphragm.

The author wishes to thank the members of the Lying-In staff for permission to use the private cases included in this study. Acknowledgment of technical assistance in the animal x-ray work is expressed to Miss Mildred Powlitis.

### References

1. Winternitz, M. C.: *Collected Studies on the Pathology of War Gas Poisoning*, New Haven, 1920, Yale University Press.
2. Leriche, R.: *De L'action Vaso-dilatatrice de la novocaïne*, *La Presse Medicale*, November, 1938: 1626.
3. Malherbe, A.: *L'infiltration Novocainique des Ganglions Stellaires dans L'asthma Nasal et Bronchique*, *La Presse Medicale*, October, 1939: 1398.

### Discussion

DR. PALUEL J. FLAGG (by invitation).—I would like to present several observations. It seems to me that these accidents may be divided into the acute emergency, the asphyxial accident that occurs on the operating table, and the postasphyxial problem presented by the aftercare. It seems strange to me that there is no anesthetist on this program, as it largely is an anesthetic problem. It confirms an impression I have had for a long time, that we need a pneumatologic service in our hospitals, and that means a group who will care for the administration of gases, for the control of open anesthesia and, of course, we include local and basal anesthesia and other methods of general, as well as the use of gases for resuscitation, and the use of gases for inhalation throughout all the postasphyxial stage.

The pathology that has been described here seems to line up very closely with the pathology we meet with in anoxia. The studies as to the effect of hydrochloric acid are rather new, but the other phenomena that were described are quite usual in anoxic anoxia and obstructive asphyxia.

I desire to present a case which bears out the need of the triple service which I have referred to.

The operation was a cesarean section, done Jan. 9, 1940. No premedication. Gas-oxygen-ether anesthesia was used. Induction was smooth—relaxation early; pronounced salivation; high oxygen concentration maintained to the delivery of the infant, which was somewhat dusky in appearance, but breathed spontaneously.

As the uterus was being closed I noted that the patient's respiratory tidal volume was shallow, that the rate was up, and that it was difficult to oxygenate the blood with concentrated oxygen. There seemed to be some form of respiratory obstruction. Filling the bag with pure oxygen produced no effect on the patient's color. The obstruction was not the kind that produces cyanosis or labored breathing, but there seemed to be something interfering with the interchange of air. The patient was laryngoscoped, and I noted gastric contents in the pharynx and dark brown gastric contents escaping from the glottis. I intubated at once a No. 7 endotracheal tube and practiced endotracheal suction, the intubation taking place without any resistance. The glottis was open. Endotracheal suction resulted in the removal of a large quantity of gastric contents from the trachea and bronchi. Respiration improved and the color returned. The respiratory rate remained increased until the patient was returned to bed. Twenty-four hours after operation the patient developed a cough with expectoration, increased respirations, and pain in the chest. Examination of the sputum showed Type XVIII pneumococcus. She was put in a tent and given sulfonamides. In order to raise the tent oxygen concentration two tanks of oxygen were used simultaneously, so that we were using 25 to 30 liters of oxygen a minute. With this delivery a tent concentration of 50 to 60 per cent of oxygen was maintained. In other words, there is no point in giving oxygen unless you are getting a flow which is sufficiently high to reduce the asphyxiation. The respirations throughout were never labored, nor did they exceed 32 a minute. There was no bloody expectoration, and the color was satisfactory at all times. The use of the tent was discontinued on January 15, and the patient had recovered completely.

After the patient had been returned to bed there was pronounced aphonia, and she complained of distress on coughing. On entrance to the hospital the hemoglobin had been 60 per cent; it dropped to 47 per cent, and then returned to 60 per cent. An admission the red blood cells had been 3,800,000; they dropped to 2,900,000, and then returned to 3,800,000.

This case suggests the following comments:

The patient was properly prepared for operation, and yet there was enough fluid in the stomach to drown her. Mouth suction should always be at hand during obstetric anesthesia and, by being at hand, it should be turned on, and the suction tube should hang on the operating table where it can be reached and used instantly. It is not a question of merely having the apparatus; it should be on hand so it can be used if necessary.

Aspiration of stomach contents may take place without cough or struggle.

If a mask is strapped to the patient's face, preventing the escape or knowledge of gastric regurgitation, drowning may easily take place.

A laryngoscope should be at hand in every operating room and the anesthetist should be familiar with its use.

An oxygen tent is useless unless it contains the required oxygen. This should be constantly and accurately determined by the attending pneumatologist or pneumatologic technician.

DR. JAMES R. MILLER.—For the last eight years we have had in the Hartford Hospital a well-conducted "pneumatologic" service. During this time we have had 26,764 deliveries with 24 deaths, or 1 per 1115. We have had no asphyxial deaths, although several times a year we come near to it. The anesthetists are under the control of men who are skilled in the use of the laryngoscope, and suction, piped in the wall, is at hand.

There have been six deaths which occurred during or at the time of delivery or soon thereafter. One was in a cesarean section, a cerebral vascular accident; one was in a case of toxemia which should not have been operated upon, but would have died in either case; one was a spinal anesthesia death, in which the procedure was used under the protest of the anesthetist; one was a rupture of the uterus before admission; another was a severe toxemia; and one other was a rupture of the uterus, with possibly an associated aspiration, though no autopsy was done; and the last one died undelivered with a massive pulmonary embolism, proved at autopsy.

We feel very strongly the necessity of having a well-coordinated physician-controlled anesthesia department which is in control of all the pneumatologic and transfusion services.

