

Anesthesia on the Western Front: The Anglo-American Experience of World War I

Frederick W. Courington, M.D.,* Roderick K. Calverley, M.D.†

WRITING THE OFFICIAL account of World War I anesthesia for the U. S. Army, the renowned American surgeon, Dr. George Washington Crile, stated: "The pink patient can not die."¹ He was underscoring, of course, the importance of avoiding cyanosis, a frequent companion of anesthesia then; but Crile was conveying more. His statement, quaint to modern practitioners, captured a sense of anesthesia of the time. It was a field still lumbering uncertainly between art and science when it was yanked into service beyond its readiness. That sense emphasizes how long the distance seems between then and now, longer than the 70+ years. Looking back that distance to 1914, anesthesiologists of today can barely generate the thoughts, much less the sense, of the anesthesia of the time. Nor can they easily appreciate the importance of anesthesia to the Great War, as it was known; or of the Great War to anesthesia. Yet that war dramatized the pressing need for anesthesia to become a medical specialty—and, indeed, it did much more.

To follow is a recounting of British, Canadian, and American anesthesia experiences, derived largely from the professional literature of the time. Contributions from available French writings are included where available and germane. Unfortunately, German, Austro-Hungarian, Italian, and Russian contributions and experiences have eluded searches to date, and thus cannot complete this review. The focus must be on the Western Front because the great majority of significant war anesthesia writings come from there.

* Chairman, Department of Anesthesiology, Naval Hospital, Portsmouth, Virginia.

† Clinical Professor of Anesthesiology, University of California, San Diego; Staff Anesthesiologist, VA Medical Center, San Diego, California.

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Address reprint requests to Dr. Courington, Department of Anesthesiology, Naval Hospital, Portsmouth, VA 23708.

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Anesthesia before the War

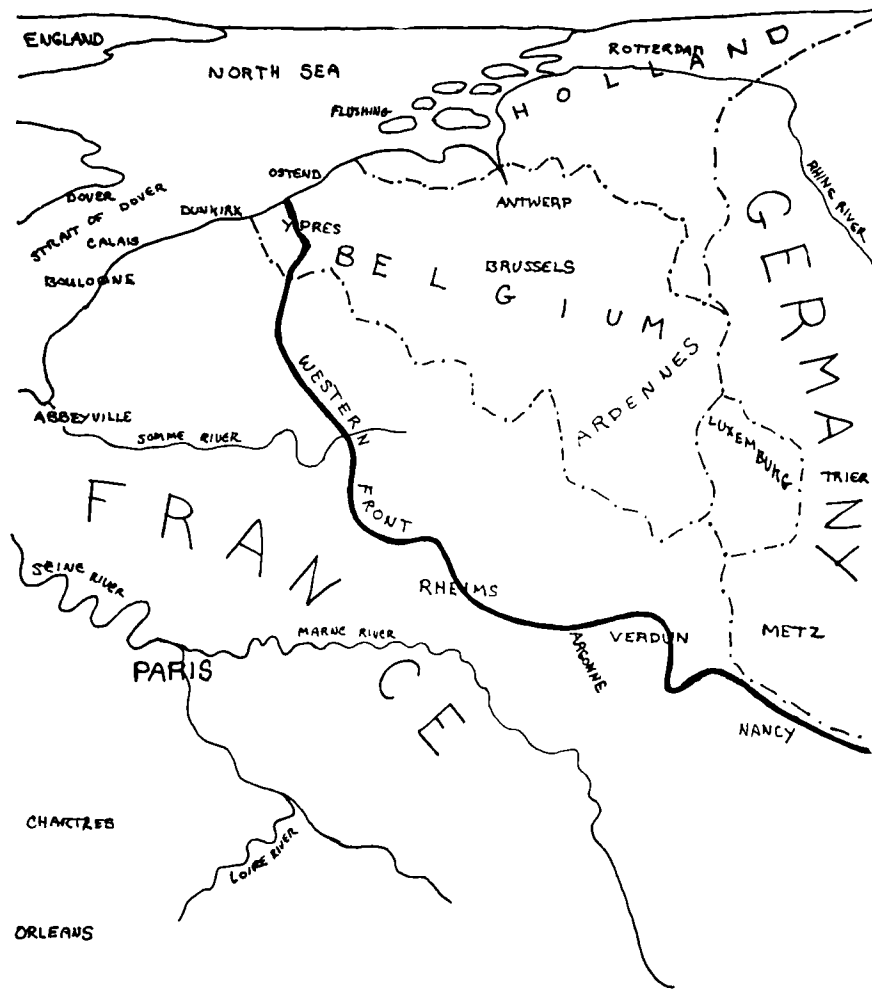
By the late 19th century, anesthesia, as practiced by anesthetists, was general anesthesia; regional anesthesia belonged to the surgeons. General anesthesia was administered by whomever. Anyone could do it, and did it. Dr. Thomas D. Luke in his 1908 *Guide to Anaesthetics for the Student and General Practitioner*,² addressed this lack of training:

There are few subjects to which a student gives less attention during his curriculum than that of anaesthetics. As Sir Frederick Treves has said: "There is a widespread impression that to give chloroform is a minor act—that the power comes with the granting of the diploma—and the significance of the procedure is sometimes emphasized by the remark. 'Well, if a man cannot give chloroform, what can he do?' " From some of our schools men are sent out year after year, absolutely ignorant of the elementary principles of anaesthetic administration, or at the most, with a very imperfect knowledge of one anaesthetic—usually chloroform. . . . It has been recently pointed out that the anaesthetic mortality has more than doubled during the last ten to twelve years.

A few efforts were being made to change this state, but they were meeting both inertia and active resistance. For the Great War to come, these efforts were too little, too late, for England, and little better for Canada and America.

Anesthesia machines were new and hardly widely accepted. There was no standardization of equipment; nothing fit together. Bottled gases were available, but miserably cumbersome. Continuous-flow anesthesia with quantification of gas flow was scarce. Wire screen vaporizers, with names like Schimmelbusch, were simple, available, cheap, and "good enough." There were other vaporizers, but most were little improved since the time of Joseph T. Clover, 50 years before the war. Airways were sometimes available, but endotracheal intubation meant that a small, cuffless tube was inserted into the trachea through the glottis for insufflation of ether. Oxygen enrichment of air was uncommon. Nitrous oxide, known in England as "gas" and almost unknown in Europe, was frequently given in various pseudoscientific asphyxial mixtures. There were no muscle relaxants, nor was there an understanding of controlled ventilation or of the need for it. Venipuncture was a surgical cutdown. Rational fluid

FIG. 1. The Western Front. The western front meandered from the French mountains in the east to the Belgian coast, shifting only small distances over the war. (Adapted from Abbott⁶).



therapy would not become routine for decades, while blood transfusion was a near perfunctory act, rarely used. Trauma and shock, the unavoidable ingredients of war, were not understood, and therefore not effectively treated. Sir Frederic Hewitt had published a major text of anaesthesia in England by 1893, and Dr. James Tayloe Gwathmey, a prominent New York anesthetist,³ published the first comprehensive American anesthesia text in 1914.

War and the Western Front

“There was hardly a hint, in that golden summer of 1914, that the world was about to come to an end.”⁴ On August 1, 1914, at 1910 hours local, the Kaiser opened the war. At midnight, August 4, the British joined it. “The English . . . Parliament went into the war, like the Elizabethan seafarers, with bursts of laughter. . . . German newspapers requested that, for economy of administration, the Allies send in their declarations of war ‘by the dozen’.”⁵ The first weekend in August 1914, an armored tidal wave swept into Belgium, rolling relentlessly toward

Paris. The speed of its advance was so great that Paris was expected to fall by September—but it never happened. The wave broke at the River Marne, at the prophetically bloody First Battle of the Marne. Thereafter, for more than four years, the tide neither advanced nor receded very far. Small bits of territory washed from one side to the other and back again, as millions of young men of Europe, Canada, distant dominions and colonies—and later of America—were swept away forever. The battle front became a meander, winding from the French mountains in the east to the sea coast of Belgium. It became known as the Western Front (fig. 1).

On the Western Front, stalemated armies dug enormous trench systems. Troops were supplied from the rear of each trench system. From these trenches, opposing troops shot at each other, while artillery batteries farther behind these lines bombarded each other and the strip of earth between sets of trenches. Between bombardments, troops with rifles and officers with pistols charged over the open ground in vain attempts to penetrate enemy trenches. But the war belonged to the machine gun. Few

TABLE 1. CCS No. 36 Standard Preoperative Instructions¹⁰

"If feasible, castor oil, 1 ounce, will be given the night previous; an enema before going to the theater and the bladder emptied. Omnopon and scopolamine, 1 ampoule (unless counterordered) one hour before operation. Parts adjacent to the wounds must be shaved. Patients will invariably be sent to the theater dressed in clean bedclothing, and during cold weather every patient must have a pneumonia jacket with him. All cases on admission to the preoperative ward will have a small pellet of wool inserted into each ear, which will be left until the patient is quite convalescent. During any heavy shelling of the neighborhood all surgical cases in bed will have cotton-wool plugs placed in their ears."
[emphasis theirs]

men could face it and live. The corridor between sets of trenches entered history and common language forever as No Man's Land.

The Allied side of the Western Front had its own structure beginning with the Firing Line. Medical and surgical care became more definitive in each zone, the farther back each was from the Firing Line. The first was the Zone of Advance, some seven miles deep. In it were first aid dressing stations, field hospitals, divisional ambulances, and mobile surgical units (Autochir). In this zone, conditions were most unfavorable for the administration of anesthesia to severely injured battle casualties, or *blessés*, as they were popularly known. Surgery was done—occasionally with anesthesia—but it was only for the most desperate cases. One anesthetist affirmed from his experience that only the best anesthetists could work in such an environment, and even then too often with poor results.⁷ The Intermediate Zone extended from seven to 50 miles behind the Firing Line, directly behind the Zone of Advance. Here were the evacuation hospitals (French) and casualty clearing stations (CCS) (English) where most initial surgery was done. Last was the Zone of the Interior, lying some 50 miles behind the Firing Line, holding the base hospitals, the first permanent medical establishments of the military system. Many base hospitals were located in French chateaux, hotels, and spas, but some were across

TABLE 2. CCS No. 36 Standard Postoperative Instructions¹⁰

"Orderlies must not allow undue exposure of patients recovering from anesthesia. Fatal postoperative bronchopneumonia may result from such exposure. In cases of collapse the foot of the bed should be raised, except in abdominal cases, and saline, 8 ounces, administered per rectum, to be repeated every three hours if necessary. Subcutaneous saline will be given only when wounds are in the vicinity of the rectum or when rectal injection is difficult. All abdominal and serious chest cases will receive saline, 8 ounces, per rectum—three hourly—for two injections, then continuous soda bicarb. and glucose aa/5 per cent for 48 hours. All cases to receive 10 or 20 grains (depending on the severity of the case) of soda bicarb. by the mouth four hourly, and, except abdominal cases, to receive 8 ounces of 2 per cent glucose by the mouth every two hours until the patient is convalescent."

the channel in southern England and even in America. Most definitive surgery was performed in base hospitals and specialty hospitals,⁸ where new specialties such as plastic surgery took root.

The Casualty Clearing Station

Most of the history of anesthesia of the Great War took place in CCSs that were developed to receive great numbers of injured directly from the field of battle. Base hospitals in the rear received and treated patients in a more orderly fashion,⁹ but the personnel of these forward hospitals operated on staggering numbers of casualties even while they were under artillery fire. Most of the accounts cited in this report were written by anesthetists who served close to the Front in CCSs.

CCS No. 36, as a typical example, was a mobile unit of 800 beds with capability for major expansion. It had seven medical officers, nine nursing sisters, 180 orderlies, and three chaplains. Surgical teams augmented the CCS when there were major allied or enemy offensives. A surgical team consisted of one surgeon, one trained orderly (who acted as an assistant), one sister, and one anesthetist—listed in that order.¹⁰ Tables 1 and 2 impart some of the flavor of the day in the standing preoperative and postoperative instructions for CCS No. 36.

Dr. F. Hoeffler McMechan, editor of *The Yearbook of Anesthesia and Analgesia 1917-1918*, stated: "It was in the surgery of the Casualty Clearing Stations that anesthesia by experts came into its own. Specialists in anesthesia were practically the only ones who could handle the anesthetic service in a way to meet the exigencies and demands of the overwhelming influx of seriously and slightly wounded."¹¹

Consider the sheer volume. During September 1916, in the latter part of the Battle of the Somme, CCS No. 36 received 17,000 stretcher cases and experienced 700 deaths. During one push alone, it received 5,000 casualties in five days.¹⁰ Canadian anesthetist, Dr. William B. Howell, recounted the Battle of the Somme during the summer of 1916 at CCS No. 1 (Canadian General Hospital):

In a severe action, a CCS is very busy and I cannot imagine any place where the services of a skilled anesthetist would be more useful. A CCS cannot, however, afford to have too much cumbersome apparatus as when the army moves, it moves too. We had four operating tables going simultaneously. One day we had over 70 operations. A few days before we had admitted 760 wounded within 24 hours. There were a great many severe chest wounds.¹²

In the second edition of his text, *Anesthesia*, Dr. Gwathmey illustrated the operating room arrangements that centered on the anesthetist, who cared for three patients in rapid sequence (fig. 2). While one patient was being

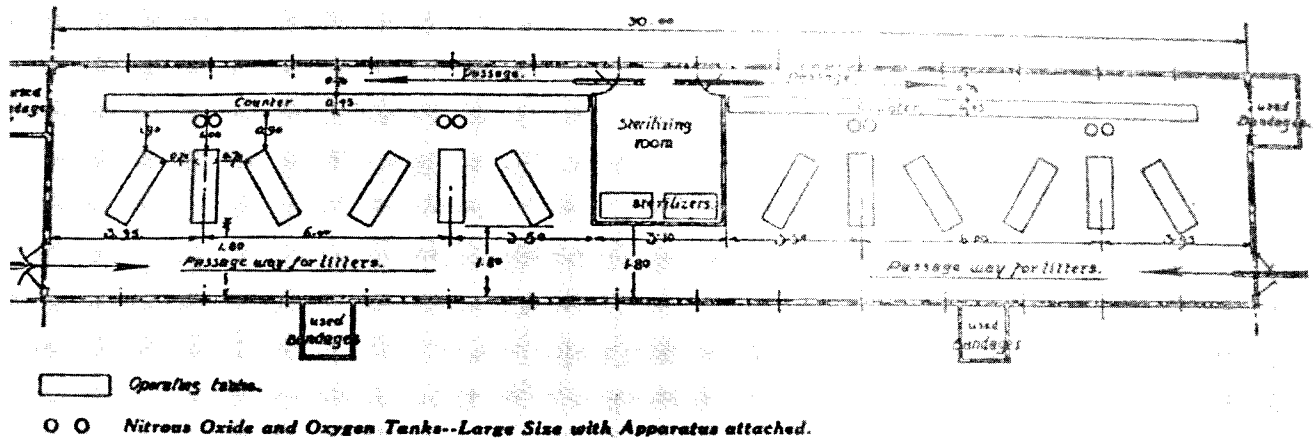


FIG. 2. Operating table arrangement in a casualty clearing station. Dr. Gwathmey's drawing shows the anesthetist at the center of three operating tables, able to move rapidly from case to case to accommodate the heavy surgical volume. Reprinted from Gwathmey JT: *Anesthesia*, 2nd edition. New York, Macmillan, 1924, with permission from the publisher.

operated on, another was being prepared for surgery, as the dressing was being applied to the third. This arrangement permitted Dr. Gwathmey himself to give anesthesia for 34 cases in one exceptional day.¹³ Similar numbers and similar arrangements were reported by other anesthetists.^{12,14,15}

Anesthesia at the Outset of Hostilities

When war broke out in 1914, British anesthetists went to the Western Front armed only with chloroform; within a few months, ether became readily available.¹⁶ Dr. Charles Corfield, from Bristol, England, described "Six Months Anesthetic Service at a Casualty Clearing Station on the Somme": "On arriving at the CCS, I found the usual anesthetic equipment, *viz.*, chloroform, ether, ethyl chlorid [sic] with Schimmelbusch masks. I added to this by indenting for nitrous oxid [sic] and apparatus, and I fortunately was able to procure them."¹⁷ In 1916, the new Shipway warm ether/chloroform insufflating apparatus¹⁸ quickly became the favorite of the British CCSs. In contrast, Dr. Crile began reporting from early in the war on how valuable nitrous oxide and oxygen were proving to be for the seriously wounded, no matter how bad the condition.¹

Manpower

The need for the anesthetic specialist was apparent from the outset of the war. The British *History of the Great War, Medical Services, Surgery of the War*, outlined British anesthesia manpower problems:

At first, anaesthetics were administered by one or other of the medical officers of the medical units in army areas, and it was not until 1916 that special anaesthetists were appointed as additional officers on the staffs of the casualty clearing stations. In 1918 these were supplemented by over 200 nursing sisters who had been specially trained during the previous year.¹⁶

From America, "... the need for physicians specially trained in anesthesia was felt keenly; physicians whose duties were those of special anesthetists were first appointed as officers in the medical corps of the United States Army and Navy in 1916."¹⁹ Dentists were drafted for anesthetic services as well.⁵ From Canada: "There [were] in the Canadian Army Medical Corps in England and France not more than four or five specialists in anesthesia. The anesthetic [was] given by the most recently joined officer, with results to the patient . . . not necessary . . . to specify."¹²

The gap between the need for anesthesia specialists and the actual supply was not solely one of numbers of medical personnel. Lyn McDonald, in her book of first person accounts, *The Roses of No Man's Land*, wrote of the CCS, "... at the height of a push, two surgeons would be working between them at four or even six operating tables, moving from one to the other, leaving less qualified, and sometimes even unqualified assistants to handle the routine tasks of stitching up, dressing and even anaesthetizing." An English chaplain recounted to her his experiences in CCS No. 44:

I spent most of my time giving anaesthetics. I had no right to be doing this, of course, but we were simply so rushed. It was a question of operating as quickly as possible. There was a sort of

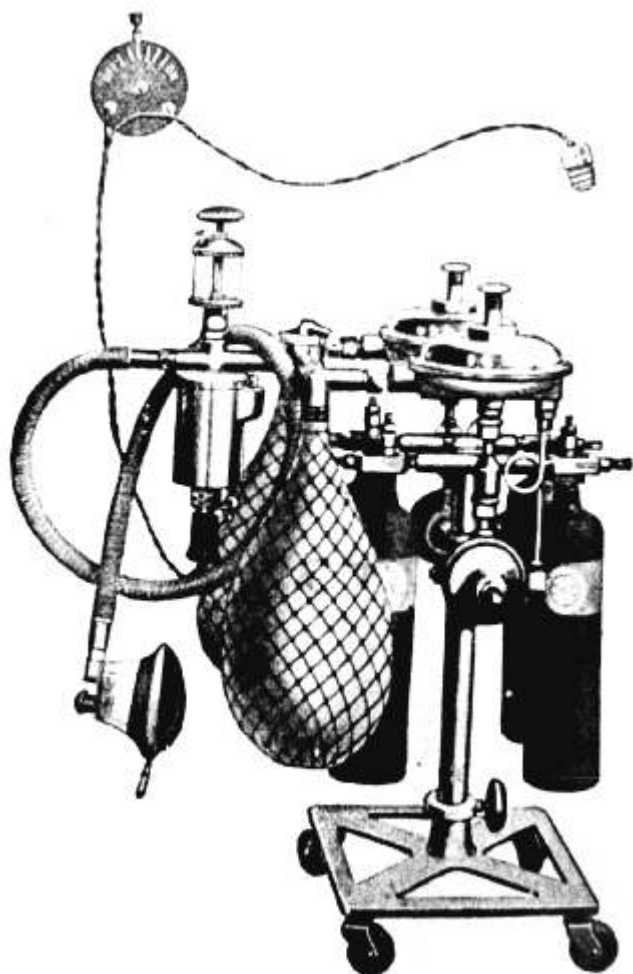


FIG. 3. The Ohio Monovalve anesthesia machine²¹: Dr. Howell described how popular this advanced apparatus from North America became in Europe with its advantages of continuous flow, multiple gases, and heated vaporizers. Reprinted from Gwathmey JT: Anesthesia. New York, Appleton, 1914, with permission from the publisher.

cup, a wire cup with gauze in it, and you had to hold it over the man's nose and mouth and drop the anaesthetic on to it very carefully, keeping a close eye on the patient.

I remember one case, . . . a man of tremendous size, a colonel. . . I couldn't get the man under. . . [The surgeon said], "You must get him under". . . Then, to my horror, the fellow ceased breathing. . . Just when I thought I would have to give up, he took one gasp and began to breathe . . . but as soon as the operation began he started to sink and he died on the table. . . [The surgeon told me], "I expected the man to die because his physique was not up to the life within it". . . I went on giving anaesthetics because no one else could be spared to do it.⁴

Yearbook editor McMechan identified the administrative obstacles adding to the anesthesia manpower crisis: "The fact that anesthetic service was mishandled by the medical

corps of all the armies in the World War was due to two causes, (1) because anesthesia was not given the importance it deserved and (2) because anesthetists were not commissioned for special service." He added that whenever specialists in anesthesia were placed in charge of anesthetic service, the emergencies and demands of war surgery were usually met.²⁰

Equipment and Supplies

Dr. William B. Howell from Canada—recruited to the No. 3 General Hospital formed from the Medical Faculty of McGill University—embarked for England May 6, 1915, on his way to France. Before leaving, he needed to procure equipment:

A Canadian lady living in the United States wrote us that she had heard that anesthetics were needed at the front and offered to buy us a supply. It was suggested to her that she should present a gas and oxygen apparatus. Her answer was that she had made inquiries and had been told that this could be bought for about twenty-five dollars and that she would like to give something which would cost more. When it was explained how much the real cost would be she at once sent a check for \$1000. With this an Ohio Monovalve was bought and a plentiful supply of nitrous oxid [sic] and oxygen in both large and small cylinders.¹²

The new gas machine (fig. 3) became immensely popular and drew a crowd wherever it went in England because it provided a steady flow of gas at a uniform pressure, by contrast to the less advanced British machines.¹²

Near the front, in the CCSs, anesthetists were lucky to have any sophisticated equipment. The meaning of making equipment work in those days of no standardization was conveyed by Dr. Corfield, from his days at the Somme:

Nitrous oxid [sic] cylinders take up a considerable amount of room. Cylinders carelessly screwed on to the stand lost half their contents by leakage. I, therefore, always fitted them on myself, and tested the joints under water afterwards. I found that greasing the screwthread with vaseline, and having the cylinder nozzles cleaned of grit and dirt were very effective in making them screw up and so fit accurately. Washers I always cut from a large size drainage tube, and renewed them every time the cylinder was changed. Occasionally, a 100-gallon cylinder would be sent, and as this would not fit the stand, the India-rubber tube connection was screwed directly on to the nozzle and man-handled by a key. This entailed an extra orderly, and so such cylinders were kept for slack days.¹⁷

Future anesthetists would be taught the dangers of using petroleum grease on pressurized gas connections.

Perhaps it was Dr. Howell who first commented in print about the inferior quality of European ether, but he certainly was not the last.¹² Later, and in a somewhat more vitriolic tone, Lt. Arthur Guedel from the Mackey-Roosevelt Base Hospital Unit in France wrote McMechan in

the latter's capacity as editor of the *Quarterly Supplement of Anesthesia and Analgesia, American Journal of Surgery*:

I am beginning to understand why ether in Europe has been so slow in displacing chloroform. The ether they are using here is *rotten*. It is not much better than our wash ether at home. It is difficult indeed to put a patient to sleep with it, to say nothing of securing a quiet state of anesthesia. From the coughing and great quantities of mucous secreted it would seem to contain more sulphuric acid and formalin than anything else. Also it is about as volatile as alcohol. You never get any frosting on the mask. Usually a patient will walk right out from under anesthesia with this ether in spite of continuous administration. . . . They say over here that it requires a very skillful man to give ether, and take it from me it does.²²

The American Red Cross finally cabled home for 100,000 half-pound tins of ether and paraphernalia.

Dr. Howell solved one of ether's problems in the battle casualty, as did many European and American anesthetists, by using a small amount of chloroform for rapid induction. He also used chloroform in the Vernon Harcourt inhaler, which was less commonly used by many anesthetists than the older Junker Chloroform Bottle. Anesthetists sometimes bought their own equipment, which caused them concern about costs that seem infinitesimal today, as Dr. Howell expressed when he wrote about purchasing his Vernon Harcourt Inhaler, "The initial outlay is rather high as it costs twenty-five dollars but the saving in anesthetic is wonderful."¹²

The War Through 1916

The war broadened throughout 1915. Battles became notorious for their slaughter without military success. No significant territory changed hands from 1914 to 1916; nor did it during the entire war.²³ Nevertheless, the cost in wasted lives mounted to a horrible degree.

While most of the British and American wartime anesthesia articles were anecdotal, Capt. Geoffrey Marshall, RAMC, provided fine clinical observations. His paper, "Anaesthetics at a Casualty Clearing Station," was read to the Anaesthetic Section of the Royal Society of Medicine, February 2, 1917, and published that year in the *Proceedings of the Royal Society of Medicine*. Said Dr. Marshall: "Surgical operations performed at a Clearing Station are for the most part urgent. It is often imperative to operate on men within a few hours of their injury while they are still suffering from the effects of shock and haemorrhage. The patients have had to travel some miles from the line by motor ambulance over indifferent roads, and many have been exposed to cold and wet. A correct choice of anaesthetic is of the first importance: the patient's life will be as much imperilled by faulty judgment on the part of the anaesthetist as by a wrong decision on the part of the

surgeon."²⁴ Dr. Marshall had previously related to U. S. Navy surgeon, LCDR. Bainbridge, ". . . The bulk of preventable deaths at a casualty clearing station was due to improper anesthesia, 'giving the wrong anesthetic, or giving the right anesthetic wrongly.'"¹⁰ Continuing his article, Dr. Marshall wrote: "Our patients have not been prepared for an anesthetic, so that when brought into the theatre the bowel is full and often stomach as well. In winter months, difficulty is further increased by the prevalence of bronchitis. A large proportion of the men have cough with expectoration."²⁴ The gas casualty, when he made it to surgery and anesthesia, was managed in the same manner as were the patients with bronchitis (fig. 4).

Capt. Marshall observed that measuring the hemoglobin concentration was a useful means of assessing circulating volume status. He was able to predict which patients would be able to receive a spinal anesthetic without vascular collapse, which he assessed with the Riva-Rocci sphygmomanometer and stethoscope over the brachial artery—a novel anesthetic practice then. Furthermore, he arrived at the conclusion that patients with demonstrable blood loss, anemia, and wounds less than 40 hours old would suffer severe, even fatal, hypotension from a spinal anesthetic, but he was unable to understand why: "I will leave it to others to explain why men who have recently lost blood should collapse under spinal anesthesia. Perhaps loss of blood is not the only factor." Fluid for the war injured was given preoperatively as several pints of tea orally or by clysis, and ". . . to collapsed patients we give saline intravenously, toward the end of the operation."²⁴ It should be noted that while type-specific blood transfusion was practiced, and was sometimes helpful, it was not a standard instrument of casualty care management.

America Joins

A pivotal year was 1917. The war got bigger, and America joined April 6, 1917. On a sector of the French front near Nancy, October 23, 1917, 0605 hours local, Americans pulled their triggers as combatants for the first time.²³ Military medical historian Fielding Garrison noted: "On September 4, 1917, through the bombing of the hospital groups at Dannes Camiers by a German aeroplane, Lieut. William T. Fitzsimons and others were killed. The first American to render the supreme sacrifice was a medical officer."¹⁵ Fitzsimons Army Medical Center in Colorado carries his name.

While American medical, surgical, and anesthesia personnel had been present in CCSs and base hospitals long before the war had been declared, America's involvement in medical care accelerated rapidly. Six fully equipped American base hospital units managed to slip past enemy



FIG. 4. Anesthesia administered for surgery in a tunnel in France. This photograph of a French surgical team at work illustrates the primitive conditions of World War I surgery and anesthesia. (Courtesy National Archives.)

submarines to join the British Expeditionary Forces. These came from Cleveland, Boston, New York, Philadelphia, St. Louis, and Chicago. In all, 50 base hospital units made it overseas by June 18, 1918.⁵ From 1915, Dr. Harvey Cushing, like Dr. Crile, had been serving as a volunteer surgeon in France. Following America's declaration of war, he headed the Harvard Unit Base Hospital and Dr. Crile the Lakeside Unit from Cleveland.

Despite the efforts of these famous men to motivate American preparedness, the American military was poorly prepared for the declaration of war. At that time, the regular army of 128,000 men was served by 491 regular medical officers and 342 temporary service physicians. The April 1917 *Supplement to the Manual for the Medical Department, United States Army* listed only ether, chloroform, and ethyl chloride as anesthetic agents and had no listing for equipment.²⁵ Furthermore, there were no specialist anesthetists in uniform. After Congress declared war, the medical might of the great centers of America poured into the Army, taking expertise and, literally, supplies to the Western Front to augment meager Army medical resources.

Problems for American Anesthetists

The U. S. Army failed to provide physician anesthetists with a rank comparable to their surgical colleagues or

their allied counterparts. Dr. Gwathmey wrote: "American anesthetists at the front are placed at a very great disadvantage as far the men with whom they are thrown are concerned. Most of the English army physicians giving anesthetics have the rank of captain, some are majors, and a few even lieutenant-colonels." He then asked the *Quarterly* editor, "Would it be possible for you to help correct this matter by writing to Surgeon General Gorgas and urging him to rank American anesthetists, at least on a par with their English associates in the same specialty?"²⁶ The surgeon general had given the rank of second and first lieutenant to those anesthetists enlisting in the Medical Reserve Corps, while the British had given anesthetists equal status with physicians, surgeons, and dentists.²⁷ In response, Dr. McMechan wrote a forceful editorial in support for the January 1918 *Quarterly Supplement of Anesthesia and Analgesia*.²⁸ By the end of hostilities, Major Gwathmey was the highest-ranking American anesthetist.

Women physician anesthetists during this period are among the least mentioned persons. Dr. McMechan noted in his July 1918 *Quarterly* Editorial: "Those in authority have taken a very progressive step in according women physician anesthetists contract service with the rank of Lieutenants. The patriotic women of the profession and its specialties deserve this recognition and there is not the slightest doubt of their making good."²⁹ Very little in-

formation about these women and their contributions has been uncovered. However, there is greater information about America's nurse anesthetists who uniquely contributed to battlefield medicine. Many nurse anesthetists served overseas, providing much of the anesthesia administered near the front as well as in base hospitals. Prior to the America's declaration of war, they served as members of American Ambulances. Their greatest value came from their skill at administering nitrous oxide anesthesia, which had become very popular for battle casualties. Crile brought two nurse anesthetists to France in early 1915 from the Cleveland Clinic, including Agatha Hodgkins, who later became the first president of the American Association of Nurse Anesthetists. Anne Penland, the only anesthetist of the New York Presbyterian Hospital Unit, inspired the training of British nurses in anesthesia and was decorated by the British government.³⁰⁻³²

American Anesthesia Techniques

Hemorrhagic shock had been with war since wars began; it had always eluded understanding and treatment. This war saw shock begin to give up many of its secrets to Drs. Crile and William B. Cannon. As an outgrowth of his studies of shock around the turn of the century, Dr. Crile pioneered an excellent anesthetic technique. Reasoning, erroneously, that shock was due to noxious stimuli flooding the nervous system, he combined local and regional anesthesia, beginning with morphine and scopolamine premedication, and added infiltrations of procaine in the operative areas along with the inhalation of nitrous oxide in oxygen to round out the anesthetic. He called his method "anoci-association,"³⁰ and it found excellent application on the Western Front. Writer after writer of anesthesia during the war and after praised nitrous oxide for the battle casualty, and all decried its major limitation: SUPPLY.

The problem of supply for nitrous oxide was never adequately solved. Dr. Arthur Guedel summed it up: "Nitrous oxide here is almost out of the question. I understand Major Crile brought a lot of it over for the Lakeside Unit, but I do not know of any other available source here at our part of the front. A number of units have gas apparatus, but at present *nothing to use in them.*"²²

Dr. Crile was able to get the American Red Cross to buy, disassemble, ship, and reassemble a nitrous oxide manufacturing plant: "It had a capacity of 125,000 gallons per eight-hour operations and was the largest in the world at the time of its construction. It was completed, tested, approved, and shipped from Cleveland early in January, 1918 . . ."; but, ". . . owing to the exigencies of transport, the shipment was lost track of after it left New York and did not reach its destination in France until May 30, 1918." It was put together and in operation within six

weeks, two weeks ahead of schedule. Where to store the nitrous oxide became the next problem. Wrote Dr. Crile, ". . . This was soon overcome by the acquisition of a number of captured German [gas] cylinders. . . ."¹

Dr. Cushing in the Harvard Unit had already had a distinguished career before the War. In his earlier years, he had introduced the anesthesia record, the precordial stethoscope, and the monitoring of blood pressure³³; and, he introduced the phrase "regional anesthesia."³⁴ Whenever possible, Dr. Cushing believed regional anesthesia was preferable in the repair of brain injuries because it avoided the complications of general anesthesia, which included cerebral vasodilation, hypotension, and a protracted recovery. He also reasoned that regional anesthesia demanded a more delicate approach, which could only be to the patient's advantage.

Over the course of the war, spinal and regional anesthesia grew in popularity, in part because inhalation inductions were difficult to perform in surgical patients with respiratory disease. Bronchitis and pneumonia were common among front-line soldiers, as was quite heavy smoking. Stovaine (amylocaine) and procaine were the most popular spinal anesthetic agents, but when spinal anesthetics were administered to hypotensive patients, the results could be lethal, as Dr. Marshall had documented. Nevertheless, strong support existed in some quarters; in France, Victor Pauchet—anatomist, surgeon, and teacher of Gaston Labat—strongly advocated spinal anesthesia for all surgery below the tenth thoracic nerve.³⁵

Regional anesthesia was performed by surgeons for amputations, rib resections, and the like, and most use of local anesthetic drugs was for true local anesthesia. Some practitioners resisted regional anesthesia because, they felt, it failed to provide suitable surgical conditions, and, the more common complaint, it took too long. As today, its use was related to the expertise of the user. Dr. Louis Hirschman, publishing his base hospital experiences, strongly supported the use of local anesthesia with many arguments, the most powerful of which was the shortening of hospital stays; he had trimmed a week off the hospital stay for hernia patients,³⁶ for example.

By the latter part of the war, chest surgeons, selecting from the best techniques available, came to prefer local anesthesia, combined with nitrous oxide and oxygen. They expressed the views that ether and chloroform caused severe intrathoracic bleeding. At best, however, chest surgery was extremely hazardous for all patients, and the anesthesia contributed significantly to surgical mortality.

Dr. Gwathmey, combining animal research with surgical team reports from the front, devised an effective anesthesia for chest surgery. Using a liberal morphine premedication, usually $\frac{3}{8}$ gr (24 mg), he administered 3:1 nitrous oxide and oxygen under 5–7 mm continuous

positive pressure with a mask, adding light ether as required. Greatly improved anesthesia now permitted battle casualties—even gassed soldiers—who previously died from lack of intervention to have often life-saving thoracic surgery.¹³

Elsewhere in France, Dr. Guedel wrote about anesthetic practice as he found it: "As it is, the methods are slipshod and careless to a degree that causes an enormous wastage of anesthetic material and occasional accidents which are costly to the Government to say nothing of the occasional loss of life of an American soldier. As it is, the surgeon, no matter what his experience or rank, has full control of the anesthesia for his cases, and as a rule he knows nothing about anesthesia. . . . A system of suggestions and instructions . . . in the matter of surgical anesthesia would go far toward saving money, time and life. . . ."⁸ Dr. Guedel found he would have to do the instructing himself, if it was to be done, and certainly if it was to be done right. He and his colleagues could not attend all the wounded in the hospitals of his area, so he developed training programs for lay personnel near Chaumont and Contrexville to instruct his students in airway management and the monitoring of anesthetic depth.³⁷ In order to supervise anesthetic care in several hospitals, he often dashed about on his daily rounds by motorcycle and became known as the "motorcycle anesthetist of World War I."³⁸

Dr. Guedel and his fellow Americans also studied the techniques of their French counterparts but found little information that they could apply. Writing Dr. McMechan, Dr. Guedel commented on French anesthesia practice: "It scares me green to see the way they pour on chloroform here. They use it about as we do ether back home. They don't seem to fear it at all, but that may be because of the extremely low price fixed on human life in this war. They have their accidents, of course, but they seem to think them infrequent."²² But chloroform, although more widely used by the French, stirred the same pro and con controversy in France as it did in England and America. In general, the French preferred ethyl chloride for general anesthesia, followed by chloroform that they used in the Ombredanne inhaler. Their preference for ethyl chloride derived from the need to induce quickly, perform minimal surgery, and transport *blessés* sitting up in ambulances. While several French writers took stances at some variance from their allied counterparts, such as strong advocacy of spinal anesthesia for battle casualties, local anesthesia with morphine supplement, and, of course, strong advocacy of chloroform, the papers available are too few to permit general statements about French practice.³⁹⁻⁴¹

Other important accomplishments occurred at home in America. For one, schools to train nurse anesthetists

developed in response to the demands of war and the demonstrated value of the nurse anesthetist. In addition, the contributions of two men, Paluel J. Flagg and Francis Hoeffler McMechan, deserve mentioning.

Dr. Paluel Joseph Flagg had become a prominent anesthetist in Manhattan by 1916 when his book, *The Art of Anesthesia*, was published. It was the second 20th century American anesthesia text; and, because it was in a format suitable for beginners, it became the text for American medical officers new to anesthesia to take to the Western Front.⁴² In addition, he trained new anesthetists at the Rockefeller War Demonstration Hospital in Manhattan.^{8,43} Dr. Flagg strongly advocated proper training for anesthesia to improve the quality and minimize its risks; thus, in October 1917, he formally proposed a school of anesthesia for training wartime physician anesthetists.⁸ Denied a commission because of a clash with Army officials, he devoted his energies to the war effort at home not only training but inventing,* and one invention was his vaporizer for use by war anesthetists. [To correct a historical error in the anesthesia literature: Flagg's can with clear reference to war development appeared first in the 1919 edition of his text,⁴³ and not in 1939.^{18,44}] This drawover vaporizer was made from an ether can with holes punched in the top, connected by a rubber hose to oral or nasal airways, or to an intratracheal cannula on the patient end (fig. 5). Anesthesia depth was regulated by covering or opening the holes and by clasping the can with the hand to provide heat when needed.† Becoming known as the "Flagg can," this simple vaporizer proved invaluable to Dr. Robert MacIntosh, who used it during the Spanish Civil War in 1938 to provide anesthesia when no compressed gases or equipment were available, and from there, Flagg's can served world wide throughout World War II.^{18,45,46} It also inspired the Oxford Vaporizer, the EMO, and the OMV vaporizers that have been used with great success by British military forces.¹⁸

Thanks to Dr. McMechan, we know much of what we do about World War I anesthesia. Forced out of practice and permanently into a wheelchair by arthritis in 1911, Dr. McMechan turned his efforts to establishing anesthesia as a scientific and organized field. Relieving Dr. Gwathmey, who went to the Western Front, Dr. McMechan served as president of the American Association of Anesthetists. From this position, he persuaded Dr. Howell, the editor of the *American Journal of Surgery*, to make

* From the unpublished biography of P. J. Flagg's early years by James A. Flagg, "My First Forty Years in Anesthesia as Related by Dad." 1951, p 4. Provided by the courtesy of the Wood Library-Museum, American Society of Anesthesiologists, Park Ridge, Illinois.

† From an April 1986 interview with John Rizzi, M.D., former student of Dr. Flagg.

space for anesthesia publications, and so were born the *Quarterly Supplement of Anesthesia and Analgesia* in October 1914, and the annual compilation, the *Yearbook of Anesthesia and Analgesia*. Articles, letters, and communications—many referenced or quoted in this review—found publication, and American anesthetists found strong support. After the war, Dr. McMechan founded the International Anesthesia Research Society and its journal, *Current Researches in Anesthesia and Analgesia*, to mention only a few of his accomplishments.⁴⁷

Armistice

At 1100 hours, on November 11, 1918, the killing finally, and officially, stopped, after four years and 100 days. Historian Hanson Baldwin put it well, "In World War I, an earthquake shook the history of modern man." More than 8.6 million soldiers died, and 21.2 million soldiers were wounded. The number of civilians who died world wide as a result of the war has never been fully known but is believed to be astronomic. Gas caused 91,198 deaths and 1,205,655 injuries.²³ Germany took 65% casualties of its uniformed men, and Austria, 90%. Hundreds of thousands were left homeless. The United States lost about 400,000 men⁵ and "started a national debt which devours us now."²³

Epilogue

What sort of knowledge did the surgeons and anesthetists take home? We know a few answers. Brigadier-General J. M. T. Finney and Colonel George Crile assembled the Eleventh Session of the Research Society of the American Red Cross in France November 22 and 23, 1918, to discuss the responses to a questionnaire entitled "Surgery at the Base" with American, British, French, and Italian surgeons. Dr. Crile and the assembled surgeons compiled table after table of which anesthetics were best for which surgeries,⁴⁸ but 20 years later, the lessons from the war had been largely forgotten.

Dr. Flagg summarized the challenge of war anesthesia in the preface to the second edition of his text in 1919: "Military anaesthesia resembles anaesthesia in civil practice with the following exceptions—the patient is not prepared for operation; induction must be rapid and recovery must follow quickly; a large number of cases require treatment at one time, and, finally, the anaesthetic is often administered under trying conditions with improvised apparatus. If these difficulties are recognized and met, the well-trained anaesthetist in civil life will not fail to render his country a great service when called to the battle line."⁴³

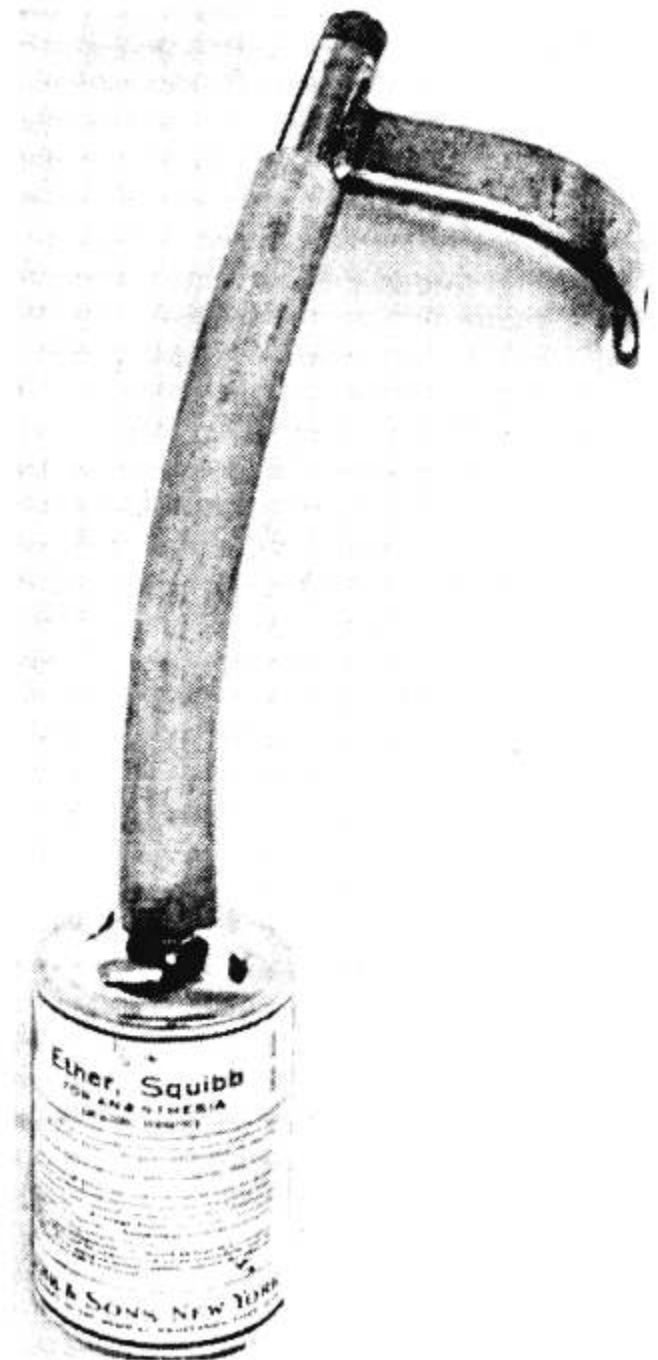


FIG. 5. The Flagg can draw-over ether vaporizer.⁴³ This simple apparatus was invented for World War I use, but proved itself invaluable in multiple wars. Reprinted from Flagg PJ: *The Art of Anesthesia*, 2nd edition. Philadelphia, JB Lippincott, 1919, with permission from the publisher.

Physicians who returned from the battle line accelerated the development of postwar anesthesia. During the immediate postwar period, two British medical officers,

Ivan Magill and Stanley Rowbotham, were assigned to give anesthetics to war casualties at Queen's Hospital in Sidcup, where Harold Gilles specialized in facial surgery. From that experience, Drs. Magill and Rowbotham revolutionized anesthesia by introducing their wide-bore, single-lumen endotracheal tube.^{49,50} Dr. Gwathmey's ceaseless inventiveness^{3,18}—which had perfected the elegantly simple American Red Cross metered flow system^{1,16}—cross-pollinated with that of H. E. G. Boyle to influence the development of the English Boyle machine^{18,51}; and, Dr. Gwathmey's text, incorporating the new knowledge, was published in a revised edition in 1924. Arthur Guedel published his landmark article in 1920 on the planes of anesthesia, from his experiences in France.^{37,38} George Crile, his theories of shock eclipsed by Cannon's,⁵² nevertheless went home venerated and wrote the official summary of anesthesia in the Great War for the Medical Department of the Army, among numerous postwar contributions. Dr. Cushing's accomplishments continued into the early 1930s. Unfortunately, so much is not known about so many of the others.

The anesthetists of the Great War went home to join others to found, fertilize, establish, and further the revolution in anesthesia that was to come in the 1920s and 1930s. Departments of anesthesia, with residency training programs, transfusions, fluid therapy, rebreathing anesthesia machines, intravenous anesthesia, and so on, were to come into being. The road was to be difficult, but the journey had begun. Twenty-one years later, the job still not finished, these burgeoning anesthesia resources would be called on anew when the nations of the world once again descended into global war.

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