Arthur Guedel, M.D., and the Eye Signs of Anesthesia

Selma Harrison Calmes, M.D.

Today anesthesiologists rarely examine a patient's eyes to determine the depth of anesthesia. Our sophisticated monitors usually tell us all we need to know. In the early days of anesthesia, however, eye signs were enormously important. Physiologic monitors were nonexistent then, anesthetic techniques were simple (usually only one agent was used) and eye signs were easy to observe. This article discusses how Arthur Guedel, M.D. (1883-1956) developed the eye signs of anesthesia during World War I.

Dr. Guedel, who made many vitally important contributions to anesthesia practice, equipment and knowledge, began his career with severe handicaps. Born in Indianapolis, Indiana, to a poor family, he had to leave school at age 13 to work. A machine shop accident led to the loss of the first three fingers of his right hand — and he was right-handed. Guedel dreamed of practicing medicine, even though he had no high school diploma and no financial resources. With the assistance of his family's physician, he was able to graduate from the University of Indiana Medical School in 1908. Dr. Guedel administered his first anesthetics while an intern at Indianapolis City Hospital. This was a common duty for interns at the time because there were so few physicians interested or trained in anesthesia. Dr. Guedel established a practice in Indianapolis in 1909 and earned additional income by giving anesthesia in hospitals and dental offices.[1] Part-time anesthesia practice was also common at the time.

Lieutenant Arthur Guedel, "The motorcycle anesthetist of World War I." Photo courtesy of Guedel Memorial Center

From the earliest days of anesthesia, physicians had tried to define the "stages" of anesthesia. When Dr. Guedel began administering anesthetics, four stages of anesthesia were generally accepted:

Induction: Beginning of administration until loss of consciousness.

Stage of struggling, breath-holding, delirium: From loss of consciousness to onset of surgical anesthesia.

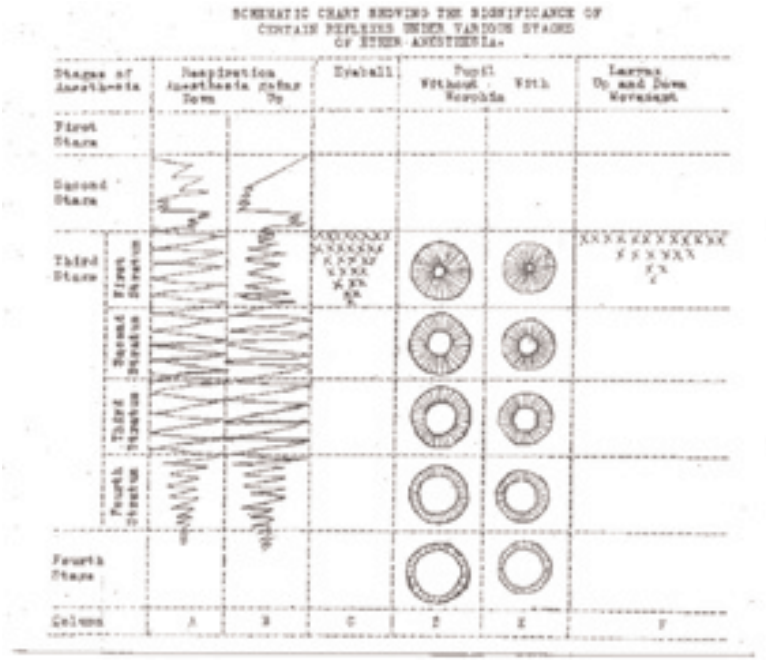
Surgical anesthesia: Characterized by deep, regular, automatic breathing. Some authors also noted loss of the corneal reflex.

Overdose, or stage of bulbar paralysis. No exact signs except shallow, irregular breathing and dilated pupils that no longer reacted to light.[2]

Dr. Guedel was a careful observer. As he anesthetized his patients, he tried to verify these observations and to look for other possible signs, for example, the characteristics of respiration and what was happening to the eyes. He then tried to organize these observations. Dr. Guedel's contributions better defined stage III, the all-important level at which surgery could be done, by further dividing it into four planes and by adding the eye signs.

The eye signs were new[2] and the most significant contribution to Dr. Guedel's signs of anesthesia. His eye signs included the activity of motor muscles of the eyeball, pupillary dilatation and, later, the eyelid reflex. (The eyelid reflex is tested by gently raising the upper eyelid with the finger. If the reflex is present, the eyelid will attempt to close at once or within a few seconds. The corneal and

Selma Harrison Calmes, M.D., is Clinical Professor of Anesthesiology, University of California-Los Angeles, Department of Anesthesiology, Olive View-UCLA Medical Center, Sylmar, California.



Earliest version of Guedel's stages and signs of anesthesia.[5] Courtesy of Guedel Memorial Center

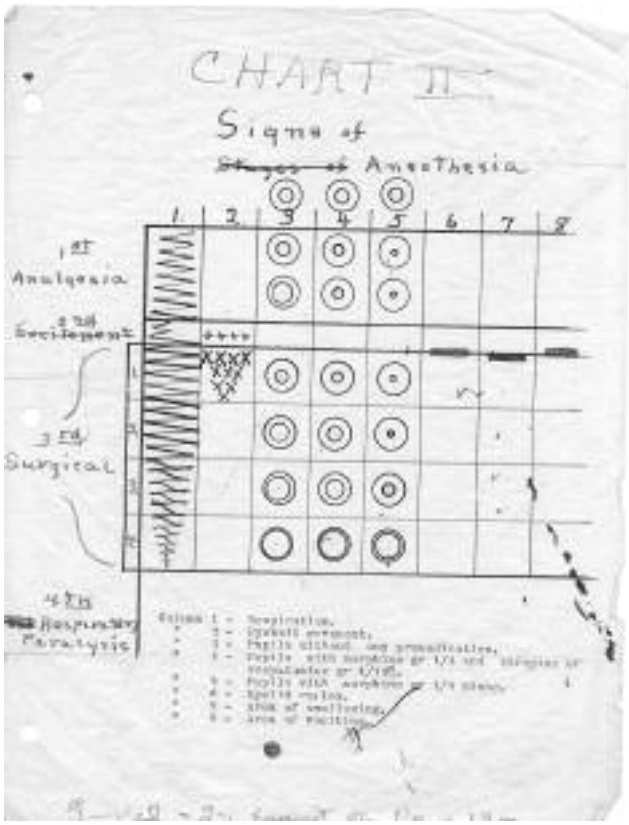
eyelash reflexes are better known to us today but were not mentioned.)

The setting for these contributions was the great need for anesthesia during World War I. When America entered the war in April 1917, the U.S. Army had not a single trained specialist in anesthesia among its 491 medical officers.[3] Dr. Guedel was called to service in June 1917 and arrived in France in August. Due to a crush of casualties from a major battle, his staff of three physicians and one dentist needed to run as many as 40 operating room tables at a time. After working 72 hours straight, Dr. Guedel decided that other staff would have to be trained quickly to meet this overwhelming need. He developed a school that trained physicians, nurses and orderlies in open-drop ether.[4] However, how could he help these trainees work safely once they left the school and Dr. Guedel's immediate supervision? He prepared a little chart of his version of the signs and stages of ether anesthesia, the most common agent in use at the time and an agent with a wide margin of safety. This chart was a visual version of the concepts he had been developing for himself before his Army service.

Armed with their charts, the trainees went out to nearby hospitals to work on their own. Dr. Guedel was given a motorcycle to make weekly rounds of the six hospitals for which he was responsible. He would roar from hospital to hospital through the deep mud that characterized WWI's battlefields, checking on his trainees. This led to his becoming known as "the motorcycle anesthetist of World War I."[3]

Dr. Guedel returned to the United States in April 1919.[4] The same month, he presented the chart at a meeting of the Indianapolis Medical Society and later at the state medical society and the Interstate Association of Anesthetists. In 1920, it appeared in *Anesthesiology*, the only anesthesia journal of the time.[5] There were still the four accepted stages of anesthesia, but stage III had now been divided into four planes. There were only two eye signs, eyeball oscillation and pupillary dilatation, in the original chart. Entry into stage III, where surgery could be performed safely, could now be determined by the onset of eyeball oscillation. Eyeball oscillation indicated a safe plane; it meant the patient could have surgery and was not too deeply anesthetized. A more dangerous level began when the oscillation stopped. Pupillary dilatation was an indication of deep anesthesia. Dr. Guedel also emphasized the need for the lightest anesthesia possible and the need for deeper anesthesia at certain points of the operation. Because of their simplicity and usefulness, Dr. Guedel's stages and signs became widely known.

Dr. Guedel moved to Los Angeles, California, in 1929 because of his health. In addition to practicing anesthesia, he continued work in his research laboratory at home. Items to come out of the home laboratory during this period were studies of cyclopropane and CO_2, the Guedel laryngoscope blade and the Guedel oropharyngeal airway, which is still in use today. (Work in his home laboratory in Indiana led to the cuffed endotracheal tube while in collaboration with his close friend Ralph M. Waters, M.D.) Dr. Guedel continued working on his chart, further refining it based on his careful observations of clinical cases. A series of four articles on his signs and stages of anesthesia appeared in 1935-36.[6A-C] In 1937, this revised material appeared in his notable book, *Inhalation Anesthesia: A*



Original hand-drawn copy of the 1937 version of Guedel's stages and signs of anesthesia. Courtesy of Guedel Memorial Center

Fundamental Guide.[7] There was now another eye sign, the eyelid reflex (previously mentioned) and further refinement of pupillary dilatation. For unknown reasons, the lash and corneal reflexes were still not mentioned. This book went through three editions and was enormously successful, further popularizing the chart. Copies of the chart appeared in other anesthesia texts and also were used by the military for teaching in World War II. A 1972 study of minimum alveolar concentrations (MAC) of various anesthetic agents documented that the pupillary changes of ether correlated with its alveolar concentrations, confirming Dr. Guedel's observations. This was not true of most other agents that were not available in Dr. Guedel's time.[8]

Although of little use to us today, the eye signs developed by Arthur Guedel, M.D., were an important innovation for the time, and their usefulness lasted for many years. They resulted from his careful, precise observations of his patients in a time of little or no monitoring and limited anesthetic agents. The eye signs were one of the many contributions that led to Dr. Guedel receiving the ASA Distinguished Service Award in 1950.

References:

1. Calverley RK. Arthur E. Guedel (1883-1956). In: *Anaesthesia—Essays in Its History*. Ruphreht J, van Lieburg MJ, Lee JA, Erdmann W, eds. Berlin: Springer-Verlag; 1985:49-53.
2. Gillespie NA. The signs of anesthesia. *Anesth Analg*. 1943; 22:275-282.
3. Courington FW, Calverley RK. Anesthesia on the western front: The Anglo-American experience of World War I. *Anesthesiology.* 1986; 65:642-653.
4. Unpublished manuscript, no author. Arthur E. Guedel, MD: Public Servant of Mankind. Guedel Collection, Guedel Memorial Center, San Francisco:24-28.
5. Guedel AE. Third-stage ether anesthesia: A sub-classification regarding the significance of the position and movements of the eyeball. *Am J Surg.* (suppl) 1920; 34:53-57.
6. Guedel AE. Anesthesia: A teaching outline. Stage of Anesthesia. *Anes Analg.* 1936; 15:1-4.

6a. Guedel AE. Anesthesia: A teaching outline. *Anes Analg*. 1936; 15:55-62.

6b. Guedel AE. Anesthesia: A teaching outline. Anesthetic depths, surgical reflexes, stages and various operations. *Anes Analg.* 1936; 15:120-127.

6c. Guedel AE. Anesthesia: A teaching outline. Preparation of the patient and mechanism of varying anesthesia requirements. *Anes Analg.* 1936; 15:157-162.

7. Guedel AE. *Inhalation Anesthesia: A Fundamental Guide*. New York: The Macmillan Co; 1937:25.
8. Cullen DJ, Eger EI, Stevens WC, et al. Clinical signs of anesthesia. *Anesthesiology.* 1972; 36:21-36.

SPECIAL ARTICLE

Anesthesiology
65:642-653, 1986

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.

Accepted for publication July 23, 1986.

Abbreviated presentation given at the American Association for the History of Medicine Annual Meeting, May 5, 1984.

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

Key words: History of anesthesia. Military Anesthesia. World War I. Western front.

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

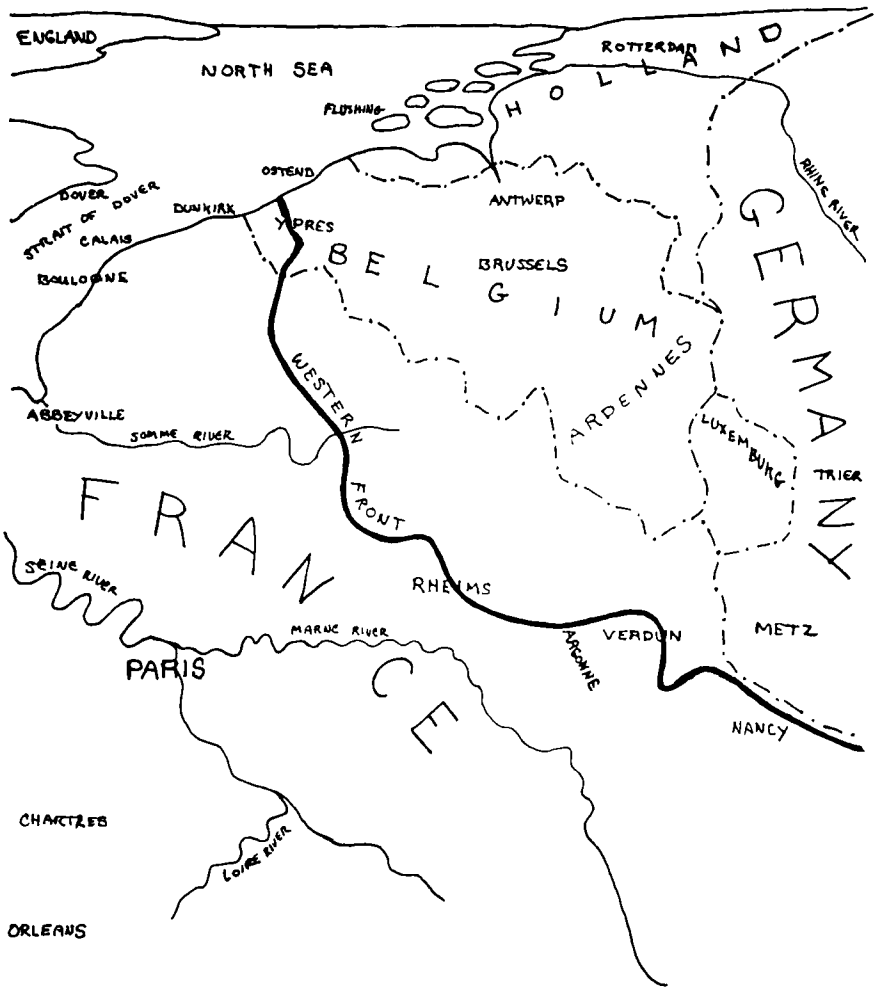


FIG. 1. The Western Front. The western front meandered from the French mountains in the east to the Belgian coast, shifting only small distances over the war. (Adapted from Abbott[6]).

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 Instructions[10]

"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, i 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 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.

TABLE 2. CCS No. 36 Standard Postoperative Instructions[10]

"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 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. Hoeffer 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

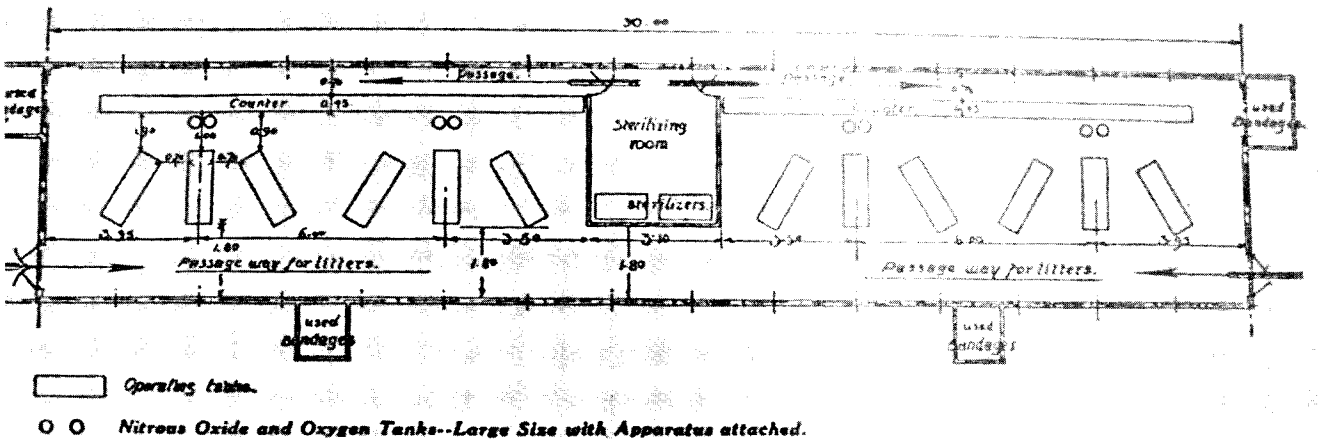


FIG. 2. Operating table arrangement in a casualty clearing station. Dr. Gwathmey's drawing shows the anesthetist at the center of three operating tables, able to move rapidly from case to case to accommodate the heavy surgical volume. Reprinted from Gwathmey JT: Anesthesia, 2nd edition. New York, Macmillan, 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 apparatus[18] 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

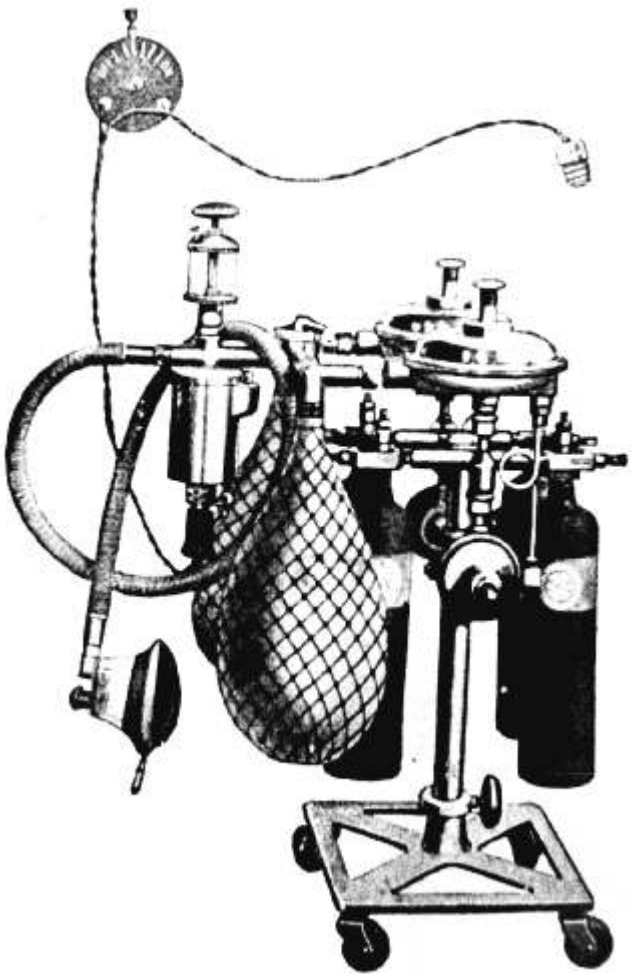


FIG. 3. The Ohio Monovalve anesthesia machine[21]: Dr. Howell described how popular this advanced apparatus from North America became in Europe with its advantages of continuous flow, multiple gases, and heated vaporizers. Reprinted from Gwathmey JT: Anesthesia. New York, Appleton, 1914, with permission 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."[5] 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 pressure[33]; 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 ⅜ 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 Hoeffer 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 pursuaded 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 men[5] 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.

References

1. Crile GW: Anesthesia, Surgery, vol XI. Washington, Medical Department of the United States Army in the World War, 1927, pp 166–184
2. Luke TD: Guide to Anaesthetics for the Student and General Practitioner, 4th edition. Edinburgh, Green, 1908, pp 1–2
3. Foregger R: Gwathmey. ANESTHESIOLOGY 5:296–299, 1944
4. MacDonald L: The Roses of No Man's Land. London, Michael Joseph Ltd, 1980, pp 26, 176–177
5. Garrison FH: Notes on the History of Military Medicine. Washington, Association of Military Surgeons, 1922, pp 191–192, 197, 199
6. Abbott WJ: The Nations at War. New York, Leslie-Judge, 1918
7. Heddy WRH: Anaesthetics in the Field. Journal of the Royal Army Medical Corps, 31:76–79, 1918
8. Flagg PJ: Anesthesia in Europe on the western battle front. International Clinics 3:210–228, 1918
9. Nodine AM: Behind the lines of Verdun. Quarterly Supplement of Anesthesia and Analgesia, Am J Surg 32:74–86, 1918
10. Bainbridge WS: Report on Medical and Surgical Developments of the War. Washington, U. S. Naval Medical Bulletin, 1919, pp 97–98
11. McMechan FH: Preface to Corfield article, Yearbook of Anesthesia and Analgesia 1917–1918, vol 2. New York, Surgery, 1920, p 231
12. Howell WB: Experiences of an anesthetist at the front, Yearbook of Anesthesia and Analgesia 1917–1918, vol 2. New York, Surgery, 1920, pp 218–224
13. Gwathmey JT: Anesthesia during the World War, Anesthesia, 2nd edition. New York, Macmillan, 1924, pp 688–710
14. Sykes WS: Experiences of an anesthetist at the front. Quarterly Supplement of Anesthesia and Analgesia, Am J Surg 33:100–106, 1919
15. Speed K: Work of the surgical teams at casualty clearing stations. Quarterly Supplement of Anesthesia and Analgesia, Am J Surg 32:38, 1918
16. Surgery of the Great War, History of the Great War, vol 1. London, Medical Services, 1922, p 178
17. Corfield C: Anesthesia at a casualty clearing station, Yearbook of Anesthesia and Analgesia, vol 2. New York, Surgery, pp 231–233
18. Thomas KB: The Development of Anaesthetic Apparatus. Oxford, Blackwell, 1975, pp 49–50, 139–142, 140, 185
19. Pender GW, Lundy JS: Anesthesia in war surgery, War Medicine, vol 2. 1940, p 3
20. McMechan FH: Preface to Howell article, Yearbook of Anesthesia and Analgesia, vol 2. New York, Surgery, p 218
21. Gwathmey JT: Anesthesia. New York, Appleton, 1914
22. Guedel AE: Foreign ether—Chloroform and ethyl chloride—Anesthetic service. Quarterly Supplement of Anesthesia and Analgesia, Am J Surg 32:38, 1918
23. Baldwin HW: World War I: An Outline History. New York, Grove, 1962, pp 54, 111, 156, 157
24. Marshall G: Anesthesia at a casualty clearing station, Yearbook of Anesthesia and Analgesia 1917–1918, vol 2. New York, Surgery, 1920, pp 225–230
25. Supplement to the Manual for the Medical Department. United States Army, 1917
26. Gwathmey JT: Proper rank for American anesthetists. Quarterly Supplement of Anesthesia and Analgesia, Am J Surg 32:37–38, 1918
27. McMechan FH: Editorial comments. Quarterly Supplement of Anesthesia and Analgesia, Am J Surg 32:34, 1918
28. McMechan FH: Anesthesia, anesthetists, and the War. Quarterly Supplement of Anesthesia and Analgesia, Am J Surg 32:28, 1918
29. McMechan FH: Are you doing your bit? Quarterly Supplement of Anesthesia and Analgesia, Am J Surg 32:102, 1918
30. Davis DA: Anesthesia in the World Wars, Historical Vignettes of Modern Anesthesia. Philadelphia, FA Davis, 1968, pp 18–29, 22
31. Thatcher V: History of Anesthesia with Emphasis on the Nurse Specialist. Edited by Reverby S. New York, Garland, 1984 (reprint of 1953 edition)
32. Lee E: History of the School of Nursing of the Presbyterian Hospital New York 1892–1942. New York, Putnam, 1942, pp 105–108
33. Hirsch NP, Smith GB: Harvey Cushing: His contribution to anesthesia. Anesth Analg . . . Cur Res 65:288–293, 1986
34. Bingham WP: The early history of neurosurgical anesthesia. J Neurosurgery 39:568–584, 1973
35. Spinal anesthesia in war surgery. Quarterly Supplement of Anesthesia and Analgesia, Am J Surg 32:135, 1918
36. Hirschman LJ: Local anesthesia in base hospital surgery, Yearbook of Anesthesia and Analgesia 1917–1918, vol 2. New York, Surgery, 1920, pp 280–282

37. Guedel AE: Third stage ether analgesia: A subclassification regarding the significance of position and movements of the eyeball. Quarterly Supplement of Anesthesia and Analgesia, Am J Surg 34:53–57, 1920
38. Calverley RK: Arthur E. Guedel (1883–1956): Anaesthesia—Essays in Its History. Berlin, Springer-Verlag, 1985, pp 49–53
39. Yearbook of Anesthesia and Analgesia 1917–1918, vol 2, New York, Surgery, 1920, pp 218–265
40. Desplas: Research society reports. War Medicine, 1:447–452, 1918
41. Ether anesthesia in war surgery without pulmonary complications. Quarterly Supplement of Anesthesia and Analgesia, Am J Surg 32:38, 1918
42. Flagg PJ: The Art of Anaesthesia. Philadelphia, JB Lippincott, 1916
43. Flagg PJ: The Art of Anaesthesia, 2nd edition. Philadelphia, JB Lippincott, 1919
44. Churchill-Davidson HC: A Practice of Anaesthesia, 4th edition. Philadelphia, WB Saunders, 1978, pp 1467–1473
45. MacIntosh RR, Pratt FB: Anaesthesia in war time. Br Med J 2: 1077–1079, 1939
46. Hotten WIT: Anaesthesia in relation to war conditions. Med J Aust 1:132–139, 1940
47. Seldon TH: Anesthesia and Analgesia—50 Years of Publication. Anesth Anal . . . Cur Res 50:571–577, 1971
48. Surgery at the Base. War Medicine, 2:1281–1350, 1919
49. Condon HA, Gilchrist E: Stanley Rowbotham—Twentieth century pioneer anaesthetist. Anaesthesia 41:46–52, 1986
50. Bowes JB, Zorab JSM: Sir Ivan Magill's contribution to anaesthesia, Anaesthesia Essays in Its History. Berlin, Springer-Verlag, 1985, pp 13–17
51. Boyle HEG: Nitrous oxide–oxygen anesthesia with rebreathing in war surgery, Yearbook of Anesthesia and Analgesia 1917–1918, vol 2. New York, Surgery, 1920, pp 246–249
52. English PC: Shock, Physiological Surgery, and George Washington Crile. Greenwood, Westport, 1980, pp 201–202

Brit. J. Anæsth. (1952), **24**, 292.

EMINENT ANÆSTHETISTS, No. 7

ARTHUR E. GUEDEL

By RALPH WATERS

BEFORE the first World War the number of true specialists in anæsthesia among doctors of the U.S.A. could be almost counted on the fingers of one's two hands. In March of 1918, one of these (Leslie Burwell of New Rochelle, New York) reported for duty at the Medical Headquarters of an American unit at Vittel in the Vosges, France. Upon his insistence that he wished to be assigned to work for which he was particularly fitted, the medical officer in command said, "You will have to see Guedel. He runs the Anæsthesia in this region. He blows in here every day or two, like a wild Indian, on a motorcycle. Wait for him." Sure enough, the next afternoon, with a roar and a put-put the motorcycle arrived in a cloud of dust.

Burwell's curiosity, as to how an anæsthetist could function on a motor-bike, was soon satisfied. The several hospitals in the neighbourhood could be visited frequently only by such means. The scarcity of anæsthetically minded medical officers had made it necessary to assign non-professional, inexperienced persons to duty as anæsthetists. The manner of teaching and directing such personnel under these circumstances is an illustration of the amazing versatility and resourcefulness of Arthur Guedel. He was forced to devise not only simple methods of teaching these willing though inexperienced people but also quick and reliable ways of checking the accuracy and safety of the dosage of ether which they were able, as a result of his teaching, to maintain in the operating rooms of the several

hospitals. The difficulties which Guedel surmounted during the first World War were of immense benefit to military surgeons and soldier-patients, it is true, but of what greater value were his experiences there to all the rest of us—teachers and pupils alike—all over the world! He insisted that during ether anæsthesia movement of the patient's eyeball was a sign which could be checked quickly and which the enlisted-man technician could observe readily and reliably. How often since, have we older teachers found the observation valuable, and even essential, in trying to help medical students and young physicians safely to administer anæsthetics. Guedel's chart of physical signs of ether anæsthesia was born in the military hospitals and while riding army motor bikes over the rough roads between them. I presume we might even say that the book, later published by Macmillan, as *Inhalation Anesthesia, A Fundamental Guide*, had its foundation built in Guedel's mind in the military hospitals and along the shell-shattered roads of France, during the first war.

Arthur Guedel is a Hoosier in origin and a genius by natural endowment. " Hoosier " is a nickname, in America, for many of our distinguished citizens who come from the state of Indiana. He was born in 1883 and graduated from the Medical School of the University of Indiana in 1908. The versatility of his interests and the originality of his thoughts were evident in the first years of his medical practice. But none of his valuable medical contributions, nor all of them together, can illustrate his protean capabilities.

In his younger days, his 15 stone of bone and muscle was perfectly co-ordinated for action. An athlete of the first order, he swam with endurance and was adept in the manly art of self-defence, yet no physician I have ever known had the delicate artistic co-ordination of the smaller

muscles that was his. He played the organ and piano with the skill of a natural artist. Many of the pieces of anæsthetic apparatus which have come from his hands bear witness to this delicacy of touch. How rarely do we find in the same individual such command of execution combined with originality, imagination, and critical thought. Not only could Guedel bring music from the keyboard but he could compose the music which fitted the occasion. One of his strongest assets, in writing, in lecturing, and in conversation, was his use of the pertinent story—of the perfectly illustrative case. Like every anæsthetist with original thoughts and a desire to learn, Guedel has made mistakes. But, unlike so many of us, he has *used* mistakes, unusual and unexpected happenings, as food for thought, as a basis for personal and professional advancement and to the benefit of his pupils and associates. His lectures and conversation were much more likely to be sprinkled with the stories of the case that nearly died than of the one that paid the large fee, and always a lesson was taught or material left in one's mind for future consideration and discussion.

It was my misfortune not to have enjoyed Guedel's friendship until after the first World War. Although we were of the same age, he graduated from medical school four years before I did and had developed one of his most important contributions to anæsthesia to the point of practical application before I had acquired a medical degree. The first volume of the *American Year Book of Anesthesia and Analgesia*, edited by F. H. McMechan, was published in 1916. To it Guedel contributed a resumé of his work on analgesia up to that time. The first of his papers referred to in the review was " Nitrous Oxide-Air Anesthesia Self Administered in Obstetrics," published in *The Indiana Medical Journal* for October 1911. Since he was ever excessively conservative regarding premature publication,

this meant that considerable work had been done with analgesia at least during 1910 or earlier. This article in the *Yearbook* is a classic. Unfortunately, it has received too little notice even to the present. Not only does it contain the basic principles of mixing nitrous oxide with air or with oxygen to produce analgesia and the advantages of self-administration of such mixtures, but included is an early example of the author's superb command of the methods which he has always used so effectively, of classification and diagrammatic representation as a means of clarification in writing and teaching. Nine charts are included which analyse, for the first time so far as I know, the variations in type of uterine contractions that occur in different women during labour. Superimposed upon these simple diagrams are representations of the necessary concentrations of gas and the time factors which he had found important in relieving pain during parturition.

Many of us who have done some teaching and writing find that, as time passes, we often regret what we have said —have to "eat our words," as the saying goes. In 1938, in response to an inquiry from Madison, Guedel wrote as follows regarding nitrous oxide in labour:

> Self administration of nitrous oxide in labor is O.K. I told you that twenty some years ago. However, I do not like the idea of strapping a mask on the patient's face. There is too much danger of aspiration of vomitus. And even of asphyxia if the gas mixture goes wrong. Before I stopped doing obstetric anesthesia I had gone to the old McKesson machine because we had one at the hospital. I later developed a spring release mask for the Heidbrink but did not like it as well.
>
> For a number of years I spent a lot of time telling the patient just what to do and how to do it. Later I got tired of telling and there developed for me the best technique that I found. I would push the gas machine up to the patient, set the oxygen for twenty to thirty per cent and tell the patient to take as much as she wanted whenever she wanted it. For the first twenty minutes or half hour they would be taking it for most of the time whether they needed it or not. But they would do that anyway under the

> " Telling " system so it did not matter. After they had become sedated by the N_2O—after twenty minutes or half an hour—they would sleep between pains, awakening at the beginning of the pain. They would then put the mask to their face and breathe like the devil for a few breaths—six to twelve—and go to sleep until the next pain. I would let this go on for hours, in some cases up to the point of actual delivery, when I would take it over. They would take care of their own anesthesia better and more safely than I could do it for them. After it was all over —the next day—they would invariably report that they were in labor but a short time. The hours were not noticed and they were happy. Keep the oxygen up. Don't strap the mask to their face. I used to strap it to their hand with adhesive tape so that they could find it easily when they wanted it. And don't pay too much attention to them.

This quotation illustrates very well two traits characteristic of Guedel. The first is that his early observations and opinions are apt to be checked carefully before expressing them, so that they need not be withdrawn later. The second is that his tendency, as time goes on, is towards practical simplification rather than towards more complication of methods and concepts. I doubt that anyone has added much of fundamental significance to the subject of the relief of pain in labour by inhalation, since Guedel's article in the 1915 *Yearbook*. It is to be regretted that it is not universally available in modern libraries.

From the end of the war until I moved to the University of Wisconsin in 1927, I met Guedel occasionally at anæsthetists' meetings and we exchanged infrequent letters. Our first discussions were concerned with his plans to include in his chart the physical signs of ether anæsthesia, the observation of Albert Miller of the progressive paralysis of respiration that takes place as anæsthesia becomes more profound; first the intercostal musculature and finally the diaphragm.

Later our common interests in the techniques of carbon dioxide absorption and of endotracheal intubation served to increase the frequency of letters passing between us.

After I joined the faculty at Wisconsin, our correspondence became active, our friendship real, and visits between us frequent. From 1925 to 1945, there was an average of several long letters a month. For my own part, they were all letters dictated to the secretary. While Guedel was officially connected with the Medical School in Indianapolis until he moved to California in the summer of 1928 and again with one of the medical schools in Los Angeles soon after going West, he depended upon private practice of anæsthesia in both places for his income and acted always as his own typist. As I re-read those letters now, I am impressed with the mere mechanical labour that was involved for him to keep up such a correspondence, writing often late at night after tiring hours in the operating room, in contrast to the help and convenience I enjoyed of a secretary available at all times.

During my recent re-examination of these letters, it is brought home to me more emphatically than ever how much, not only the Department of Anesthesia at Wisconsin, but American anæsthesia in general, owe to Arthur Guedel. The fact that he was the first outside the British Isles to receive the Hickman Medal (1941) testifies to such appreciation outside the U.S.A.. To me, he has been a wise adviser and a true personal friend. To both the department at Wisconsin and me he was, during 20 years, a valuable critic, and a master of argumentation and of unmerciful and inconsiderate frankness, when he believed we needed that treatment. But throughout all a wonderful and loyal friend at the times when loyalty and friendship really counted. The arguments about methods of teaching, or conducting research, of publication, and regarding experiences with new drugs and new techniques, were all subjects of hot debate throughout the twenty years; and every publication from the Department of Anesthesia

at Wisconsin was better for the critical comments of Guedel.

For many years his motto was, "Maintain Flying Speed," taken from the pilot of the time whose altitude began to fail as his forward progress diminished. But the letters I have just re-read come to a point where speed seems not so important. Here is one illustrative quotation, "There is a mighty small line between contentment and lazyness and tonight I am a bit over-contented at least." A little later he quotes a friend, "What the hell are you working for? A good obituary?"; and may I add one more quotation from these wonderful Guedel letters I have been reading? "It hurts a fellow some to see himself being slipped to the outside—but I am feeling more and more that, if he has good sense, he will slip himself clear out of it and pass the time doing something else—something entirely different." Aimed directly at me? I think so. We are now both retired and no longer write the heated, argumentative, contentious, and sometimes "scurrilous" letters regarding anæsthesia that pleased us for so many years. I believe we are no less happy because of retirement.

It has been said "If a man loves dogs he will love mankind". It is true of Guedel. The first dog that was subjected to closed endotracheal anæsthesia under water in his laboratory at Indiana was named "Airway" and shipped to my children in Madison because the Guedel family was already blessed with two dogs and "he is such a lovable mut." A sensitive man of intense personal likes and dislikes, with a "quick temper" and prompt expression of it; his intimate friendships have sometimes begun with a brief quarrel. He has been quick to admit his own fault and sincere in efforts to undo a real or fancied wrong. To friends, students, and family alike, kindness and generosity

have characterized his attitudes, often to his own disadvantage.

An appreciation of the humour of situations and an inimitable manner of expressing it, has stayed with him through happiness and adversity. No physician's family I have ever known enjoys a happier relation with father and husband.

The Guedel residence in Los Angeles has for years been a shrine visited by anæsthetists from far and near. Whether they are well or ill, whether in mood for visitors or in black despair—good will, hospitality and helpfulness shine forth from the home of Florence and Arthur Guedel.