The Quest for Anesthetic Depth:
Albert Faulconer, Electroencephalography and the Servo-Controlled Anesthesia Machine

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This article won the 2001 AHA Resident Essay Contest Award and has been peer reviewed and accepted for publication in the Bulletin of Anesthesia History.

Introduction
In October 1996 the Food and Drug Administration approved the use of a new monitoring device of anesthetic effect that integrates various electroencephalogram (EEG) descriptors into a single dimensionless, empirically calibrated number, the Bispectral Index (BIS, Aspect Medical Systems, Natick, MA).1 The BIS monitor is the latest innovation in the quest for a reliable monitoring device of anesthetic depth, the “holy grail” of monitoring for anesthesiologists.2 This new monitor is gaining acceptance in the anesthesia community, but the basic concept of this idea goes back to the early 1950’s. At that time Albert Faulconer and Reginald Bickford from the Mayo Clinic first systematically investigated EEG changes induced by various anesthetic agents.3-5 In a pioneering project, they went a step further and attempted to create the first closed-loop anesthesia delivering device, the servo-controlled anesthesia machine, aimed at automatic control of anesthetic depth via EEG guided delivery of anesthetic agents.6

The following is an illustration of some of the problems associated with this groundbreaking idea.

Electroencephalography and anesthesia: the early years
Richard Caton, a physician in Liverpool, first noted the occurrence of electric potentials in the brains of animals in 1875.7 In 1890, von Marxow described the effects of chloroform anesthesia on brain waves.8 In 1929, Hans Berger, a psychiatrist in Jena, Germany and the “father of electroencephalography,” demonstrated that the electric potentials of the human brain could be recorded from electrodes placed on the surface of the head.9 Four years later he described the loss of alpha-waves in the EEG caused by chloroform anesthesia.10 In 1937, Gibbs and associates noted that the EEG was sensitive to anesthetic agents and postulated:

A practical application of these observations might be the use of the electroencephalogram as a measure of the depth of anesthesia during surgical operations. The anesthetist and surgeon could have before them on tape or screen a continuous record of the electrical activity of both heart and brain.11

 Shortly thereafter, EEG changes were reported with the use of cyclopropane12 and barbiturates.13 In the early 1950’s, Faulconer and his colleagues studied the EEG changes produced by ether,3 sodium thiopental,4 and cyclopropane5 under actual surgical conditions. They classified the results of administration of an anesthetic agent into distinct patterns identifiable on the EEG, based upon the observation that “the electric output of the brain would decrease progressively from the stage of light anesthesia to that of deep anesthesia.”4 After identifying 7 distinct EEG levels (Fig. 1) with ether administration,6 with cyclopropane anesthesia,5

Fig.1: Characteristic patterns of successive electroencephalographic levels of ether anesthesia as described by Courtin, Bickford and Faulconer in 1950.7 Levels IV to VI represent progressively increasing suppression of burst intervals. Level VII is isoelectric. (From Faulconer A, Bickford RG: Electroencephalography in Anesthesiology. Springfield, Charles C Thomas, 1960. Courtesy of Charles C Thomas, Publisher, Springfield, Illinois).
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Coming Full Circle: The Recrudescence of Ideas in Anesthesiology

Objective: After attending this panel the learner will gain an appreciation for techniques in anesthesiology that have been used for a variety of purposes. The learner will gain an appreciation for the versatility and periodicity of ideas within the specialty. The learner will also gain an understanding of a small part of the history of anesthesiology that may engender new ideas to apply these tested techniques.

Moderators:

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Associate Professor of Anesthesiology
Mayo Clinic
Rochester, Minnesota

Maurice S. Albin, M.D., M.Sc.(Anes.)
Professor of Anesthesiology Emeritus
University of Texas Health Sciences Center
San Antonio, Texas

1. Circulating CSF: The Birth, Death and Resurrection of Spinal Anesthesia
   Douglas R. Bacon, M.D., M.A.

2. Induced Hypothermia—is it cool again?
   Edwin H. Rho, M.D.
   Instructor in Anesthesiology
   Mayo Clinic
   Rochester, Minnesota

3. Off-On-Off: The heart in search of Perfect Perfusion
   Charles Hantler, M.D.
   Professor of Anesthesiology
   Washington University St. Louis
   St. Louis, Missouri

4. Induced Hypotension: How Low Should You Go?
   Maurice S. Albin, M.D., M.Sc.

   Donald Caton, M.D.
   Professor of Anesthesiology and Obstetrics
   University of Florida Gainsville
   Gainesville College of Medicine
   Gainesville, Florida

6. TIVA—the 1930s revisited?
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   Professor and Vice Chair
   Department of Anesthesiology
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   Department of Anesthesiology
   Grady Health System
   Atlanta, Georgia

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and 5 with pentothal anesthesia, \textsuperscript{4} Faulconer was convinced that the EEG could be used “as a reliable index of the depth of anesthesia.” \textsuperscript{15} His finding that increased arterial ether concentrations correlated nicely with greater EEG depression linked the electrophysiologic effect of ether to a measure of anesthetic uptake and lent further credence to the use of EEG as a measurement of anesthetic depth. \textsuperscript{16}

The development of the servo-controlled anesthesia machine

Faulconer was searching for a more scientific basis to assess anesthetic depth, as he recognized that since John Snow’s early clinical observations in 1858 \textsuperscript{17} “the diagnosis of depth of anesthesia in this manner has never been an exact science but is truly an art.” \textsuperscript{6} Convinced that “EEG changes occurring during surgical anesthesia might provide a basis for a more objective and exact estimate of the depth of anesthesia,” \textsuperscript{6} he and Bickford developed the first automatic EEG controlled anesthesia delivering system. Bickford was the driving engineering force behind the project. \textsuperscript{18}

Their servo-controlled anesthesia machine was based upon the principle that “the output of cortical electrical energy falls off consistently in relation to increasing depth of surgical anesthesia” \textsuperscript{19} and consisted of an EEG monitor recording cortical electrical activity obtained from a single fronto-occipital electrode pair placed on the scalp of the patient. The EEG voltages were summed with an integrating circuit and converted to pulses proportional in number to the time-integrated EEG potential. These integrator output pulses triggered a stepping relay leading to a syringe pump-driven administration of a unit dose of the anesthetic agent into the circulation or anesthesia circuit (Fig. 2). The frequency of dosing and thus anesthetic depth was independently adjustable by changing the gain of the EEG voltage output. Thus the servo-controlled anesthesia machine delivered a predetermined unit dose of anesthetic agent at a rapid rate when the summed EEG potential was high (fast or high amplitude EEG activity), and at a slower rate when the pattern revealed less activity. Bickford compared the principles of this design to “application of engineering principles to the human that have been known since James Watt invented the governor for his steam engine.” \textsuperscript{6}

Testing this closed-loop system in animals showed “that a desired level of surgical anesthesia could be maintained automatically for long periods of time (two to three days) without human interference.” \textsuperscript{6} In 1950, the first human trial with 50 patients undergoing major abdominal surgery was presented before the section of surgery, general and abdominal, at the 99th annual session of the American Medical Association in San Francisco. The authors concluded that “as an outcome of this work it was seen that there were changes in the electroencephalographic pattern of sufficient clarity, magnitude and consistency to allow these changes to be related to depths of anesthesia progressing from loss of consciousness to complete respiratory paralysis.” \textsuperscript{6} The researchers also noted that “the EEG foretells a change in depth of anesthesia many seconds before the change is apparent to an anesthetist. Thus the system is more capable than an anesthetist of maintaining a constant level.” \textsuperscript{6} In a letter of discussion accompanying the publication, William Estes, a surgeon from Bethlehem, PA remarked:

My only qualification to discuss this report is that I have seen this remarkable machine in action. It is most uncanny and dramatic to observe the automatic record of the patient’s condition unfold, including both the electrocardiographic changes and the electroencephalographic record, while the little click every few seconds indicates the automatic administration of small increments of the anesthetic agents. The mechanism by which all this is accomplished is most baffling to a

Fig. 2: The principle of the servo control mechanism after Faulconer and Bickford \textsuperscript{15}. The patient EEG (left) is the physiologic variable measured and ultimately drives the electromechanical translator (top center) of the drug delivery system (top left). The raw EEG is integrated over specified time intervals and amplified to increase output (see integrator pulses on right) to the drug delivery system as a function of total EEG amplitude. (From Faulconer A, Bickford RG: Electroencephalography in Anesthesiology. Springfield, Charles C Thomas, 1960. Courtesy of Charles C Thomas, Publisher, Springfield, Illinois).
mere surgeon. Although the full significance of a machine of this character in the field of anesthesia is at this time difficult to predict, the immediate potentialities are most impressive and seem epoch making.6

With limited data-processing resources at that time, Faulconer and Bickford refined the servo-controlled anesthesia machine by trying to minimize outside electrical interference from sources other than the EEG signal.23 Falcons also noted significant individual variability in observations early in his research.24 But in contrast to “the transient and somewhat inconstant nature of the clinical signs, and the variations in their interpretation by different individuals,”16 he found the EEG patterns of anesthesia to be more objective16 and believed in the clinical and research applications of his “servo-anesthesia”—a notion that was not shared by all of his colleagues.21 However, both Faulconer and Bickford were well aware, that “automatic control cannot be more reliable than the electroencephalographic information on which it operates.”22

This statement reflects one of the fundamental problems associated with automatic anesthesia control: the need for a reliable neurophysiologic endpoint to provide an assessment of anesthetic depth to guide the unit dosing of a closed-loop anesthetic administration system. While the spectrum of effects constituting general anesthesia and anesthetic depth is still hotly debated,23,24 blocking the somatic motor response to painful stimuli is widely used as an indicator of anesthetic adequacy. The end-tidal concentration of anesthetic agent required to achieve this unresponsiveness (MAC) remains the benchmark of anesthetic potency.25,26

More than a decade before the concept of MAC was introduced, and in an era where muscle relaxants were not yet routinly used, the servo-controlled anesthesia machine was designed to achieve immobility during surgical stimuli by increasing the concentration of the anesthetic agent until burst suppression in the EEG occurred.19 Although this level of anesthesia would be considered unnecessarily deep by modern standards, it was an appropriate way to provide satisfactory surgical conditions at a time when sophisticated pharmacological tools and monitoring equipment were limited.

Why the servo-controlled anesthesia machine did not gain widespread popularity following its introduction into clinical practice remains unclear, but the need for constant supervision and adjustment and the development of new pharmacologic agents, particularly muscle relaxants, may have played significant roles (Professor P. Southorn, Mayo Clinic, Rochester, MN; personal communication). Faulconer and Bickford, however, deserve recognition for opening a new chapter in the quest for monitoring anesthetic depth by first recognizing the potential usefulness of EEG monitoring to guide the delivery of anesthetic agents almost half a century before the BIS monitor.

New research over the last decade has painted an even more complicated picture about monitoring anesthetic depth than originally anticipated. Recent research attempts to relate sophisticated computer-processed EEG to clinical anesthetic depth have resulted in inconclusive findings.27,28 Other autonomic or electrophysiologic measurement techniques, such as auditory evoked potentials29 or contractility of the lower esophagus30 do not consistently correlate with anesthetic depth either.31 The BIS monitor, designed to measure the hypnotic component of an anesthetic regimen, has been shown to predict loss of consciousness and loss of recall with good probability under certain clinical conditions.22,33

Recent case reports showing intra-operative awareness despite adequate BIS values illustrate the complexity of the problem of measuring adequate anesthetic depth using cortical neurophysiologic monitoring.34,35 Furthermore, animal studies over the last decade suggest that anesthesiainduced immobility to surgical stimulus may be a subcortical or spinal cord phenomenon.36,37 With accumulating evidence that anesthetic actions at the spinal cord level determine MAC,36,38,39 we can now appreciate why measuring cortical electrical activity from the surface of the human brain does not correlate reliably with anesthetic depth as we currently define it.

Conclusions

Assessment of anesthetic depth even in the 21st century is still an art rather than a science. Albert Faulconer and Reginald Bickford from the Mayo Clinic established the first electrophysiologic attempt of measuring anesthetic depth based upon EEG monitoring. They also designed the first automatic anesthesia-delivering device, the servo-controlled anesthesia machine (Fig. 3). More than 40 years later the same idea, EEG monitoring to assess anesthetic adequacy, has been reintroduced to the anesthesia community in the form of the BIS monitor. An increasing number of recent publications in the anesthesiain literature indicate the great interest as well as the ongoing controversy, but the quest for adequate monitoring of anesthetic depth continues.

References

5. Possati S, Faulconer A, Bickford RG, Hunter...
Continued from page 5


Anesthesia History Association
Sixth Annual Resident Essay Contest

The Anesthesia History Association (AHA) sponsors an annual Resident Essay Contest with the prize presented at the ASA Annual Meeting.

A 1,500-3,000-word essay related to the history of anesthesia, pain management or critical care should be submitted to:

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200 Hawkins Drive, 6 JCP
Iowa City, IA 52242-1079
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The entrant must have written the essay either during his/her residency/fellowship or within one year of completion of residency/fellowship. Residents/Fellows in any nation are eligible, but the essay MUST be submitted in English. All submissions must be typewritten.

An honorarium of $500.00 and a certificate will be awarded at the AHA's annual dinner meeting at the ASA.

The award-winning residents will be invited to present their essays in person at the annual spring meeting of the AHA and their work will be published in the Bulletin of Anesthesia History.

All entries must be received on or before August 15, 2002.
MedNuggets

by Fred J. Spielman, M.D.
Professor
Department of Anesthesiology, University of North Carolina

One has heard among the anesthetists a certain amount of rather heated discussion as to the place of nurse anesthetist. — Frank H. Lahey
The Surgical Clinics of North America 11:227, 1931

In obstetric anæsthesia we believe that the mother is of too much importance to be given to the average trained nurse, or average hospital resident, and that even in spontaneous parturition the services of a skilled anæsthetist should be demanded. — Edward P. Davis
Surgery, Gynecology and Obstetrics 31:601, 1920

We must show them (administrators) that unless anesthesiology is permitted to grow as a specialty with a patient-physician relationship similar to that existing in other specialties, it will revert to a technical status. — Editorial
Anesthesiology 7:668, 1946

Obviously the advance of surgery depends on the progress of the specialty of anæsthesia, and yet it is too little recognized that the growth of the individual surgeon is dependent upon the skill of his anæsthetist. — Frances E. Haines
Anesthesia and Analgesia 6:25, 1927

In the past, the surgeon had adopted the attitude that he alone assumed full responsibility for the patient and that every phase of the operative procedure, including the administration of the anæsthetic, must be under his direction. However, if the patient failed to survive the operation, the anæsthetist was expected to assume complete responsibility for the unexpected fatality! — P.H.T. Thorlakson
Canadian Medical Association Journal 55:489, 1946

Proper preoperative care is many times more important than the use of any particular anæsthetic agent. — John B. Dillon
Journal of the American Medical Association 133:829, 1947

The surgeon should never force the decision as to the type of anæsthetic agent used or how it is given. The surgeon would resent being told he had to do an operation in a certain way if he knew that in some other way his knowledge and skill could be applied to give the patient a better result with less risk. — Erwin R. Schmidt
Surgery 6:177, 1939

The reasonable fit patient, like the laboratory animal, can survive physiological insults of striking intensity, and in this I include bad anæsthesia. — R.R. Macintosh
British Journal of Anaesthesia 21:107, 1948

As with many things accepted today as commonplace, as having existed always, anæsthesia began in a small way and with a relatively few agents, to blossom forth and fructify into a manifold and ingenious multiplicity of methods, ever keeping step with surgical progress, stride for stride. — Editorial
American Journal of Surgery 9:142, 1930

As soon as hospitals begin to pay adequate salaries for the service of doctors trained in anæsthesiology they will receive the important benefits of better anæsthetics. — E.C. Drash
Virginia Medical Monthly 74:394, 1947

Since the earliest days in anæsthesia, respiration has provided helpful signs for those who conduct fellow human beings on journeys through unconsciousness. We have no reason to suspect that the last secret has been revealed, that no more useful information is forthcoming. Let us then apply ourselves with renewed vigour to the study of respiration, and progress in anæsthesia will surely result. — H.J.V. Morton
Anæsthesia 5:112, 1950

It is becoming increasingly more difficult to define the poor-risk patient. With present day skilled interns, surgeons, and anesthesiologists it is rare to deny patients any necessary operations. — Charles S. Coakley
American Surgeon 21:800, 1955

It is our belief that deaths which occur during spinal anæsthesia are primarily due to cardiac dilatation and respiratory failure. We are of the opinion that debility associated with high temperatures are factors definitely unfavorable to the employment of this type of anæsthesia. We believe that fever produces changes in the cardiac musculature and in the respiratory center in the brain which tends to make patients more susceptible to the drug. — Joseph A. Lazarus
Annals of Surgery 97:757, 1933

Expertness of the grade necessary for the employment of these various types of highly refined anæsthesia will, of necessity, command salaries of considerable size, and I would, therefore, call your attention to the fact that sometime within the fairly near future, the problem of full-time position anæsthetists commanding fairly high salaries must be met by hospital trustees and surgeons, if they wish to keep their surgery up to the standards of progress. — Frank H. Lahey
New England Journal of Medicine 207:725, 1932

If but a few members of the younger generation of the highest integrity and competence can but see the opportunity and decide to spend their lives and efforts in the service of anæsthesia, the future is bright indeed. — Noel A. Gillespie
The History of Surgical Anæsthesia (Thomas E. Keys) p. 171, 1945
Report on the Ralph Waters 75th Anniversary Meeting

by Selma H. Calmes, M.D.
Chair
Department of Anesthesiology, Olive View-UCLA Medical Center

A meeting celebrating the 75th anniversary of the beginning of academic anesthesia was held in Madison, Wisconsin, June 6-8, 2002. The meeting marked the arrival of Dr. Ralph Waters in February, 1927, at the University of Wisconsin as chair of the division of anesthesia. The Waters department went on to train the leaders of our specialty and still plays an important role today through descendents of the original Waters trainees. Meeting sponsors were the Wood Library-Museum of Anesthesiology, the Anesthesia History Association, the History of Anaesthesia Society (Great Britain), the Department of Anesthesiology at the University of Wisconsin and the Wisconsin Society of Anesthesiologists. Aqualumni (those trained by Ralph Waters) who attended were Drs. Lucien Morris of Bainbridge Island, WA; Carlos Parlsoe of Sao Paulo, Brazil, and Merel Harmel of Chapel Hill, NC. Videotaped messages were received from Aqualumni Drs. Jone Wu of China and Torsten Gordh of Sweden. The remaining Aqualumna, Dr. Rosalie Wilhelm of Oakland, CA, was unable to attend. Other attendees included large contingents from Great Britain and the Wisconsin Society of Anesthesiologists.

The opening event was held in the Senate Chambers of the Wisconsin State Capitol. The building had been recently renovated and was a grand and striking location for the opening. The dean of the University of Wisconsin (UW) Medical School began by announcing the new Ralph M. Waters Chair which was awarded to current UW department chair, Dr. Susan L. Goelzer. This new chair designation had been voted on by the Regents of the University that very day. Dr. Robert Joy, Professor Emeritus and founding chairman of the Department of Medical History at the Uniformed Services University of the Health Sciences, was the opening speaker, reviewing the history of teaching medical history. A reception was held in a side room to the Senate Chambers afterwards.

The next day, Dr. Ted Smith reviewed Madison in 1927 and why the UW Medical School might have been the stimulus for the development of academic anesthesia. Three simultaneous sessions of papers followed, including sessions related to the careers of important Aqualumni such as Emery Rovenstine, Robert Dripps, Austin Lamont, William Neff and Virginia Apgar. At lunch, Dr. Alan Jay Schwartz of the Children's Hospital of Philadelphia presented some current issues of professionalism (the meeting's subtitle was "Professionalism in Anesthesiology, A Celebration of 75 Years). More papers followed in the afternoon.

The Friday night banquet included two of the Waters' children and their families. On Saturday, Sir Keith Sykes presented the effect of Waters on British anesthesia. The Saturday lunch program was dramatic, featuring videos from international Aqualumni who were unable to attend, Drs. Jone Wu of China and Torsten Gordh, Sr. of Sweden. Both trained at Madison and then went back to their own countries to establish modern anesthesia practice under difficult circumstances. Torsten Gordh, Jr., also an anesthesiologist and chair of the Department of Anesthesiology at Uppsala University, Sweden, introduced his father's videotape.

This meeting generated some unusually creative papers. An example was "Planting the Seed: Ralph Waters and the Class of '45" by LeRoy Misuraca of Long Beach, CA. The class of '45 was the last class of the UW Medical School class to be lectured to by Dr. Waters. Ten of the 73 graduates entered anesthesia. Dr. Mischraca, a Dr. Torsten Gordh, Jr. introduces his father's videotape.
member of the class of '45, did a survey of remaining class members and led a panel discussion on the situation in relation to medical students and anesthesia training at that time. Another was Dr. David Wilkinson's thoughts on receiving Dr. J. Alfred Lee's copy of the first edition of Selected Scientific Papers and Addresses of Ralph Milton Waters, MD, published when Waters received his honorary degree of Doctor of Science from his medical alma mater, Case Western Reserve, in 1957. Other papers were on people related to the Wisconsin department, such as pharmacologist Chauncey Leake and surgeon Erwin Schmidt.

Mementos of the meeting included two books: Anesthesia from Colonial Times: A History of Anesthesia at the University of Pennsylvania by James Eckenhoff and Scientific Papers and Addresses of Ralph Milton Waters, MD. The first was a reprint of the original volume printed in 1966. The reprinting was organized and funded by Dr. David Lai of Boston. This has an introduction by Waters. Attendees also received a copy of the "Waters Tree." This was developed by Aquilumnuus Dr. Lucien Morris, to show the importance of the Waters' department trainees in training the future leaders of anesthesia. Proceedings of the meeting are to be published by Wood Library-Museum.

This meeting will be the only one of its kind. Dr. Lucien Morris had the idea for the meeting and worked tirelessly to get it going. Dr. Mark Schroeder of the UW Department of Anesthesiology was the "worker bee" at the local level, supported by the university's CME office. A. J. Wright of the U. of Alabama at Birmingham supported the meeting by hosting the meeting's website. Congratulations to all who were involved in planning and carrying out the meeting! It was a great success.

Dr. John Severinghaus and Dr. Robert Buechel
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The Syringe: Getting to the Point

by Fred J. Spielman, M.D.
Professor
Department of Anesthesiology, University of North Carolina

Unique tools, devices, and instruments identify specific health care workers, and the syringe is an icon of the anesthesia care team. Regardless of how and where we practice, this piece of equipment is constantly used to draw up and inject drugs, aspirate blood, perform nerve blocks, and place intravenous and arterial catheters. Anesthesia care today would be impossible without an abundance of sterile, well-made syringes in a wide variety of sizes.

The development of a way to make hypodermic (under the skin, from the Greek) injections was motivated by the desire to deliver medications quickly and precisely into the bloodstream. Early physicians gave drugs by enemas, suppositories, intrarectal and intrauterine injections, and inhaled medicated steam or smoke; they even rubbed drugs onto the patient’s tongue. Medication was delivered via the skin using baths, liniments, and plasters. Aggressive techniques included the use of vesicants to blister the epidermis; medications were then applied to the denuded skin in the form a powder, ointment, or solution. Dr. G.V. Lafargue gave morphine to his patients by dipping a vaccination lancet in the narcotic and plunging it under the skin.

Most historians credit Dr. Alexander Wood, President and Secretary of the Royal College of Physicians, Edinburgh, as the first person to introduce the practice of using a syringe and hollow needle to administer medications. In 1855, the Scottish physician published a paper in the Edinburgh Medical and Surgical Journal, “New method of treating neuralgia by the direct application of opiates to the painful points.” Dr. Wood’s patient was an 80-year-old woman who suffered from cervicobrachial neuralgia. He injected her with 20 drops of vinous solution of morphia (morphine dissolved in sherry wine) at a point on her shoulder where the pain was most severe. Wood naively thought that the morphine’s most important site of action was on the nerves in the vicinity of the injection. Wood visited her the next morning, and was “…a little annoyed to find that she never wakened; the breathing was also somewhat deep, and she was aroused with difficulty.” Historians estimate that he injected her with approximately 24 mg of morphine, or about 0.5 mg/kg!

Wood and his colleagues believed that local administration of morphine was harmless, and for many years didn’t realize that it caused narcotic addiction. Shortly after Wood’s publication, morphine was frequently self-administered by patients or their servants or physicians in an attempt to treat a wide variety of complaints including hysteria, delirium, gout, and fever. Charles Hunter, a London surgeon, recommended morphine injections “…as a nerve tonic in cases of great nervous exhaustion, or of irritability or great mental depression.” Dr. Hunter understood the full potential of using injections to administer a variety of drugs in the hope of relieving a wide range of symptoms and diseases. He injected narcotics away from the location of the pain, and found that this produced exactly the same therapeutic effect. Hunter’s research confirmed the worth of the hypodermic method and significantly broadened its popularity and application. In addition to morphine, drugs such as atropine and strychnine could be given orally without side effects. In 1865 the London Medical Times and Gazette reported on a Professor Nussbaum of Munich who, in an attempt to treat his neuralgia, “…had injected morphia under his own skin more than 2000 times - sometimes to the extent of five grains (300 mg) of morphia in twenty-four hours.”

In 1870 Thomas Clifford Allbutt was the first person to speak publicly about the problem of addiction: “We are now often consulted by patients who have been injecting themselves daily or more than daily during long periods of time, for neuralgias which seem, nevertheless, as far from cure as they were at the outset.” By the 1880s the practice was declining due to recognition of morphine addiction, but by then, many doctors were as addicted as their patients. Infection, another complication of the repeated use of syringes, occurred because equipment was not properly sterilized, and fungus growth was pervasive in the aqueous preparations of morphine. In 1880 historian Kane wrote about morphinists, “In some of these persons the condition of the body is terrible. Abscesses are to be seen at every stage, from those...
just forming to those just healing or healed. Patches of gangrene of various sizes cover the body everywhere."

Early syringes were rudimentary and unsophisticated in construction. Assembled with glass, metal, rubber, and leather, they were not calibrated. The needles were dull and before inserting them, physicians had to make incisions with trocars and lancets.

In the decades after Dr. Wood's publication, several Frenchmen made modifications to the design of the syringe, and the instrument became easier to use, safer, and less painful. Pravaz and Behier included a screw-driven piston to a glass barrel. Each complete turn of the screw injected two minim (0.123 mL) of fluid. Delore conceived a syringe with "wings" that helped steady the instrument during injection. Luer, a German living in Paris, used a piston barrel and dispensed with the screw action for attaching the needle. His simple tapered end, or push-fitting, remains the most common syringe fitting in use. Needles were beveled and made sharper. Beautiful and delicate syringes were constructed to fit cases small enough to slip into a gentleman's waistcoat pocket.

One of the most important changes in syringes occurred in Paris with the invention and manufacture of the Luer all-glass syringe in about 1896. Two years later the American patent was sold to Becton, Dickinson & Company. On October 8, 1898 Maxwell Becton made the first sale of one of these syringes to Z.D. Gilman of Washington, D.C. for $2.50. The glass syringe underwent continuous improvements, including the addition of a finger and thumb rests and rings to give the operator a firmer grip, colored glass fused to the end of the barrel to facilitate quick measurements, and smoother grinding of the glass for a longer-lasting, tighter fit. Of great importance was the use of alkali-free hard glass, such as Pyrex. This glass has an extreme resistance to the erosion caused by sterilizations, medications, and repeated use.

An unexpected consequence of widespread syringe use was transmission of disease. In 1943 the Medical Society of the Study of Venereal Diseases noted that many patients who were treated for syphilis also suffered from hepatitis. Two military units recorded a jaundice incidence between 50% and 75% six months after commencement of therapy. Viral hepatitis was concluded to be transmitted after improper sterilization of the multi-use syringes used to treat sexually transmitted disease. The injection and phlebotomy equipment was not changed between patients, because of acute shortages and poor understanding of the need for sterilization protocol. Motivated in part by the outbreak of infectious diseases, disposable glass and plastic syringes were manufactured in the late 1950s and early 1960s, respectively. Unfortunately, adherence to sterile technique is not universal. As recently as the 1990s, non-sterile syringes and needles were largely responsible for over 2000 cases of HIV infection in Romanian children and infants.

The painting that accompanies this essay unmistakably emphasizes the prevalence and importance of syringes to those who administer anesthesia. The true-to-life watercolor was created by Sandy Krantz, a gifted and skilled artist, at the request of the author. Members of her mother's family were artists, and encouraged and reinforced Ms. S. Krantz's interest in creativity. Sandy Krantz excels at painting nature scenes and designing greeting cards. She is an operating room nurse in Abbotsford, British Columbia. Abbotsford, known as "the berry capital of the free world" has approximately 100,000 people. It is situated in the lush and fertile Fraser Valley. Ms. S. Krantz is married to the accomplished and internationally renowned flutist, Mr. Larry Krantz. The hospital in which she works has six operating rooms and 200 beds. The anesthetist in the painting is Dr. Paul Forrest, FRCP, DABA, one of seven anesthetists who work in the hospital. Quick and easy access to syringes is vital to Dr. Forrest. They are strategically placed on the top and in the drawers of the anesthesia cart, as well as in his shirt pocket. The ability to provide safe and complete analgesia and anesthesia today is possible because of the modest piece of equipment that has been refined and adapted over the past 150 years.

Suggested Reading

To order a copy of your choice, please contact:

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From the Literature

by A.J. Wright, M.L.S.
Department of Anesthesiology Library, University of Alabama at Birmingham

Note: In general, I haven’t examined articles that do not include a notation for the number of references, illustrations, etc. I do examine most books and book chapters. Books can be listed in this column more than once as new reviews appear. Older articles are included as I work through a large backlog of materials. Some listings are not directly related to anesthesia, pain or critical care but concern individuals important in the history of the specialty [i.e., Harvey Cushing or William Halsted]. Non-English articles are so indicated.

Columns for the past several years are available in the “Anesthesia History Files” at http://www.anes.uab.edu/anesthist/anesthist.htm as “Recent Articles on Anesthesia History.” I urge readers to send me any citations, especially those not in English, that I may otherwise miss! — A.J. Wright ajwright@uab.edu

Books


Articles and Book Chapters


Ball C, Westhorpe R. Intravenous induction agents: ketamine. Anaesth Intens Care 30(2):115, April 2002 [illus., 6 refs.; Cover Note series]

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Anesthesia Foundation Book/Multimedia Education Award

The Anesthesia Foundation announces the Book/Multimedia Education Award to be presented to the American Society of Anesthesiologists Annual Meeting.

This prestigious award will be awarded tri-yearly for excellence and innovation in books or multimedia with significant impact on the science and practice of anesthesiology, critical care, or pain medicine. Multiple authors are eligible with the stipend being divided between the first and senior authors.

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Condors over the Alps

by Ray J. Defalque, M.D., and A.J. Wright, M.L.S.
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Introduction
From 1936 through 1939, a small German military contingent, known as the Legion Condor, helped Franco's Nationalists to win the Spanish Civil War. Some of the Legion's wounded were occasionally flown to Berlin, 1,600 miles away, in 12-hour flights at 20,000 ft. altitude. This was a first in aviation medicine and its details deserve to be better known.

The Legion Condor (1-4)
In mid-July 1936, Franco flew to Spanish Morocco and rallied to the Nationalist side the Spanish troops of North Africa, which formed the elite of the Spanish army at the time. The blockade of the Straits of Gibraltar by Republican war ships forced Franco to airdrop his troops to the mainland and he appealed to the German government for air support. Hitler sent him 20 Ju 52s (the world's best cargo planes at the time), a few fighters, and 75 Luftwaffe personnel. By mid-August 1936, the Germans had flown 25,000 troops and 3,000 tons of equipment.

In October 1936, in response to the USSR massive help to the Republicans, Hitler added a large number of planes, 6,500 Luftwaffe personnel, and some ground troops with tanks and guns. Those reinforcements, now called the Legion Condor, had their own uniforms and weapons and were under strict German operational control. They had a medical battalion and 2 field hospitals.

In the fall of 1938, the Legion, impatient with Franco's slow progress, requested and received an increased supply of some of Germany's newest planes, tanks and guns; its enlarged personnel was now rotated to gain combat experience and test new weapons and tactics.

On May 2, 1939, after Franco's victory, the Legion Condor sailed for Hamburg and on June 16, 1939, the 14,000 Germans who had served in Spain paraded before Hitler and a delirious crowd of Berliners. The Legion was then disbanded and its men returned to their regular units.

Spain had cost Germany 200 dead and 500 wounded. Until the legionnaires arrived in Hamburg the German government and press had denied any German presence in Spain.

Luftwaffe Activity in Spain
Until the end of 1939, the German medical journals had remained entirely silent about Spain. In January 1940, the Deutsche Militärarzt (DMA), the official publication of the Wohrmacht's medical service, published 3 articles on the successful air evacuation of 2,500 German wounded during the Polish campaign (September 1939). One of those articles, had been written by General E. Hippke, the Chief of the Luftwaffe's Medical Inspectorate. The wounded had been flown to Breslau or Berlin hospitals in 2-3 hour flights at low altitude (3,000 ft), thus sparing them a long and uncomfortable transport over the muddy, primitive Polish roads. All 3 articles gave credit for this successful operation to the Legion Condor and the recent airlift of its wounded. This was the first reference to the Legion and to its medical activity in a German medical publication.

The same issue of the DMA also contained an article entitled "Air evacuation of wounded over long distances at high altitudes" by Dr H. Kowalzig, a lieutenant colonel on Dr. Hippke's staff. Kowalzig briefly mentioned that the Luftwaffe had occasionally flown patients and physicians inside Spain but the bulk of his paper dealt with the evacuation of 43 patients to Berlin in direct flights at high altitudes. Although Kowalzig made it clear that this had been a small, experimental operation, his report was extensively quoted in the German and foreign literatures during and after WW 2, thus creating the impression that it had been a large project involving many flights and numerous patients.

Kowalzig's article seems to be the only detailed account of those flights; we have found no other primary source despite an extensive search of the literature and numerous inquiries among German archivists. Kowalzig's paper, unfortunately, omits important details.

Kowalzig's Report
Kowalzig reported the evacuation of 38 patients in 8 flights by Ju 52 ambulance planes. Another 5 patients with minor medical problems were airlifted aboard 2 cargo planes. It is unclear from Kowalzig's article how many ambulance planes were available but another source suggests that there was only one, a Ju 52 painted white, with Red Cross markings, and matriculated D-AVIA.

The Ju 52 m/3 was a trimotor aircraft with a speed of 130 MPH and, with 2 auxiliary tanks, a fuel capacity of 620 gallons. Those additional tanks, situated in the roar of the cabin, unfortunately reduced the patient carrying capacity and prohibited the installation of any heating device. The cabin was not pressurized and had no inner wall nor insulation against cold or noise. The unsealed door and windows created huge drafts. The crew included 2 pilots, a radio-navigator, and a flight engineer; all were proficient in first aid. The Ju 52 was equipped with blind-flying and radio-directional instruments. Without its auxiliary tanks a Ju 52 carried 8 stretchers and 2 to 4 sitting patients. The stretchers were attached to both walls of the cabin in 2 tiers with a narrow central aisle.

The planes took off from airstrips near the field hospitals in Salamanca or Tablada and refueled in N. Spain, in Italy, or in S. Germany, but under good wind conditions some flew non-stop to Berlin. Those 1,400 to 1,600 mile flights took 10 to 13 hours and were made by blind-flying over the clouds at 20,000 ft. altitudes to avoid the violent winds and air currents and the low ceiling over the Alps, especially during the winter months.

The patients remained aboard on their stretcher for the whole journey. The first flight had made an overnight stop in Majorca where the patients were lodged in a local facility but the transfers took so much time and effort that the experience was never repeated. The planes left Spain shortly before darkness and reached Berlin the next afternoon, thus allowing a few hours of daylight to drive the patients to the local hospitals.

The hazards of high altitudes were already well known in 1936 and the Germans had used simple but efficient precautions:

A. Air sickness due to turbulence was avoided by flying at high altitudes, choosing skillful pilots, and keeping the patients lying down. Short bouts of mild nausea had occasionally occurred during the descent towards Berlin.
B. Hypoxia: as soon as the piano reached 2,500 to 3,000 ft. the flight engineer placed an oxygen mask on the patients’ face. The masks were connected through individual hoses to a central tank situated in the rear of the cabin.

C. Since it was known that low atmospheric pressure expanded the gases trapped in the body cavities and could increase the Intracranial pressure, patients at risk from such complications were excluded.

D. The Germans realized that hypothermia would be the main danger. Their patients, while still in the field hospital, were wrapped in warm clothing and heated blankets then bundled in a special hammock used by the German Navy to transport their wounded. The patients, thus bound to their stretcher, were then driven to the near-by airstrip, loaded aboard the plans, securely attached to the cabin wall, and left undisturbed until they reached Berlin. A urinal had been inserted between the logs and large wads of cotton had been wrapped around the buttocks to serve as diapers. Hot drinks from Thermos flasks and cognac eggnogs (two common Wohrmacht’s antidotes for hypothermia) were liberally dispensed during the flight.

All patients reached Germany safely and the medical officer or corpsman accompanying the initial flights was later withdrawn thus allowing room for additional patients. The evacuated patients suffered of burns, skull or facial injuries, and complex limb fractures. Those patients were considerably expanded later on, during the operations in the Balkans, in Libya, and, especially, in the USSR. By the end of WW 2 the Luftwaffe had evacuated 3 million patients.10

Neither Kowalzig nor his colleagues have explained the reasons for the Legion’s long flights and we are left to speculate:

a. It was Wohrmacht doctrine to send immediately to the rear wounded in need of extensive surgery and prolonged post-operative care. This insured expert treatment, kept the field hospitals free of long term patients and thus highly mobile, and avoided the dispersal of rare specialists over large battlefields. The Legion in Spain had only 2 small field hospitals in Salamanca and Tablada, and no base hospitals nor specialists.

b. The Germans may have been reluctant to send their patients to Spanish hospitals. The memoirs of the German participants in Spain1-3 suggest that they had little regard for Franco’s armed forces and were dismayed by the local socioeconomic and hygienic conditions. The Legion had reserved for its exclusive use the best hotels, restaurants and even brothels.3 Berlin had also insisted that the Legion be under absolute German control. Long, risky flights may thus have seemed to be a safer alternative to transfers to Spanish facilities.

4. Those long flight at high altitudes though new and experimental, rested on a solid scientific background. Since 1927 the German universities and research institutes had shown great interest in the physiology of aviation.9-14 When the Luftwaffe took over those facilities in 1935, it vigorously supported those institutions and generously provided personnel and money. Most medical officers of the German Air Force, like their flying colleagues, were young, ambitious and ready to try new methods.2

Conclusions
Contrary to common assumption, the air evacuation by the Legion Condor of some of its wounded to distant German hospitals was a very limited operation involving very few flights and few patients. It, however, was a bold initiative and its success gave the Luftwaffe the impetus to create and develop an air service which served the Wohrmacht well during its campaigns in remote areas and saved many lives.

Bibliography
Sixth International Symposium on the History of Anaesthesia

The History of Anaesthesia Society is delighted to announce that, in conjunction with the Department of Anaesthesia of the West Suffolk Hospital, they will be hosting the Sixth International Symposium on the History of Anaesthesia in Cambridge from 15th to 18th September 2005. The meeting will give delegates the unique opportunity to be resident in Queens’ College which is centrally placed facing onto the “Backs”. The programme is currently being planned and any comments would be welcomed by the Honorary Secretary.
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Past President, American Board of Anesthesiology
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Clinical Professor of Anesthesiology, 1972-1994, University of Pittsburgh School of Medicine

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No Reservations Will Be Accepted at the Door!
This Month in Anesthesia History*

**July 27:** Feast of Saint Pantaleon, a physician and martyr and patron saint of headache sufferers.

**1730 July 12:** Josiah Wedgewood is born. The English pottery designer and manufacturer was a major financial supporter of Dr. Thomas Beddoes and his Pneumatic Institute near Bristol. Beddoes and Humphry Davy manufactured and experimented with nitrous oxide there in 1799 and 1800. Wedgewood died in 1795, three years before the institute opened. His son Tom participated in those nitrous oxide experiments and, along with Davy, conducted an early experiment in photography around 1800.

**1814 July 19:** Samuel Colt is born. In the 1830s Colt, calling himself "Professor Coult" or "Doctor Coult", toured the United States giving nitrous oxide demonstrations to raise money to put his revolver prototype into production. Colt died on 10 January 1862.

**1844 July:** William T.G. Morton begins using sulphuric ether as a local anesthetic in his Boston dental practice. The agent was suggested to him by Dr. Charles A. Jackson.

**1865 July 19:** Charles Horace Mayo, co-founder with his brother W.J. of the Mayo Clinic, is born. Mayo is one of the youngest persons on record to administer anesthesia; according to his brother, Charles was giving the A.C.E. mixture at the age of 12 to patients in his father's surgical practice.

**1868 July:** In Paris W.T. Evans successfully liquefies nitrous oxide for storage and portability in metal cylinders.

**1868 July 15:** William T.G. Morton dies in New York City. In October, 1846, Morton made the first successful public demonstrations of ether anesthesia at the Massachusetts General Hospital in Boston.

**1876 July 15:** J.T. Clover publishes article in the *British Medical Journal* in which he introduces the nitrous oxide-ether sequence and an apparatus for its administration.


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*B For the full calendar, go to www.anes.uab.edu*