# Reports of Scientific Meetings

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## Workshop on Electrical Hazards in Hospitals

Ventricular fibrillation is a complex re-entry phenomenon. It is caused by currents as small as 20 microamperes if density is high and stimulation occurs during the relative refractory period. Two factors are increasing exposure to electric shock hazards in hospitals: (1) more frequent use of electrical devices; (2) low-resistance paths to the heart provided by electrodes and catheters.

Concern of a Committee on Hospitals of the National Fire Protection Association matured into a Workshop on Electrical Hazards in Hospitals that convened in Washington April 4 and 5, 1968. Aiming to "define the hazards and explore the technology available to minimize the risks," the Workshop was sponsored by the Committee on Shock and the Committee on Anesthesia of the Division of Medical Sciences of the National Academy of Sciences and the National Research Council. Support was provided by the National Institutes of Health and by the Surgeons' General of the Department of the Army and the Department of the Navy.

Nothing really new was presented at this meeting, and no manifestoes were issued. Nonetheless, it was a signal event because it brought together 120 individuals of divers disciplines—people who do not ordinarily communicate with each other but whose skills and interest are essential for progress toward safe and rational use of electrical apparatus in hospitals. From power tools to implantable pacemakers, industry was represented, along with government, the military, utilities, standards organizations, hospitals, and several specialties in clinical medicine. The common bond of the practitioners, designers, inspectors, administrators, and educators was expertise in some facet of the use of electricity. Carl Walter, Peter Bent Brigham surgeon, corralled 30 scheduled speakers who provoked vigorous discussions that carried on through meals and strategically placed coffee-breaks. From the discussions emerged ten topics summarized in this report. Full proceedings of the Workshop on Electrical Hazards in Hospitals will be published by the National Academy of Science.

*Epidemiology.* Patients have been electrocuted, but sound data on the incidence of electrical mishaps in hospitals are conspicuously absent. Do we really have a problem? Stringent new regulations are being considered. Are they intelligently directed, or will dangers persist because expensive regulations are aimed at the wrong targets? Reassuring answers are not available. There is no central agency to which accidents must be reported, and fear of legal retaliation discourages voluntary disclosure.

A disinterested agency such as a National Registry of Electrical Incidents should be created to collect information, or the task should be assumed by Underwriters' Laboratories or hospital associations. While the United States Public Health Service Injury Control Program under Dr. Barry King seeks cooperation in applying epidemiologic methods to the prevention of electric shock hazards, the importance of obligatory information-gathering is exemplified by the role of the Bureau of Mines in shaping an effective safety and health program in an inherently dangerous industry.

*What level of current is dangerous?* Eventually a number must be assigned to "dangerous current." At Duke in 1964, Weinberg and associates showed that currents down to 20 microamperes applied directly to the heart could cause ventricular fibrillation. There are no published confirmatory studies. Lubin and Staewen at Baltimore's Mount Sinai, however, recently produced ventricular fibrillation in dogs by 15-microampere leakage currents from electrically-operated beds. Whether the code

writers' final choice is 20, 10, or 2 microamperes, it is agreed that milliampere leakage is no longer acceptable.

*Isolated versus grounded circuits.* If tiny currents cause disaster, how may patients be protected? Workshop participants divided into two camps, one favoring isolated power lines, the other viewing isolated power systems as worthless protection from microampere electrocution. A powerful plea for isolated power systems in all patient-care areas was made by Richard Lloyd of Underwriters' Laboratories. In this scheme, each patient room, and individual segments of wards and intensive care areas, would be provided with isolation transformers feeding small numbers of outlets. Ground fault detectors are valuable and noisy indicators of defective equipment, said Carl Walter. Opponents emphasized that isolated circuits are expensive to install and difficult to maintain. Ground fault detectors actually introduce leakage. Isolated power circuits simply do not guarantee protection from electrocution by microampere currents because even the capacitance in a 20-foot power cord produces about 20 microamperes of leakage.

*Equipment grounding.* If safety cannot be provided by circuit isolation, the logical alternative is equipment grounding. It must be effective and reliable, and we must know what we are talking about. The shibboleth "It's grounded" has been beaten into meaninglessness in hospitals. Even the experts had semantic problems in describing novel permutations of "grounding." "Grounded" is defined in the National Electrical Code, and distinct applications are described: (1) power circuits and systems; (2) conductor enclosures (boxes, conduits); and (3) equipment. The frame of an electric device may be grounded though the device is powered from an ungrounded (isolated) circuit. "Grounding" must be differentiated from "conductivity" applied to minimize hazards from static electricity. "Conductive" is not "grounded," and "grounded" is not "explosion-proof."

The hospitalized patient cannot be isolated from ground because of contacts with plumbing, his bed, and other fixtures. Assume that he *is* grounded, and then insure every item in his environment is "equipotential"—at the same voltage. If there is no pressure difference, no current can flow through the patient. Ingenious methods of providing equipment grounding were introduced, but overriding concerns are (1) maintenance, and (2) user education. If the power cord or three-pin plug are damaged, if proper outlets are not available, or if the equipment is not adequately maintained, then grounding fails and safety fails with it.

*The need for adequate information about devices.* William B. Kouwenhoven recalled his pioneer investigations into electric shock initiated by a $10,000 grant from Consolidated Edison to Johns Hopkins in 1928. Referring to the attending physician, Kouwenhoven emphasized, "It's his responsibility when he puts a piece of equipment on the patient." The manufacturer must furnish information on devices, "just like we have in the drug book." Circuit diagrams and complete data about applications and hazards must be included.

Professor Kouwenhoven poked a festering controversy. On one hand, spokesmen for industry claim that devices are well tested, that additional information for physician guidance is not necessary and may even be harmful, and that one must have faith in the integrity and wisdom of the manufacturer. Opposed are physicians who are dissatisfied with the present standards of safety and reliability, and claim that manufacturers will not provide information pertinent to intelligent care of patients.

*Shall preclearance of medical devices be required?* Preliminary testing of medical devices is not required. Only after injury, death, or blatant misbranding has been revealed may the Federal government initiate action through the courts. Of two bills presently before Congress, that introduced by Representative Reinecke provides for a five-year study of the proposed need for Federal legislation. The Medical Device Safety Act introduced by Representative Harley O. Staggers would require preclearance of devices, extending to these the current regulations of the Food, Drug and Cosmetic Act.

*The problem of maintenance.* The industry-accepted concept of preventive maintenance is virtually unknown in hospitals. Much electrical apparatus is in disrepair, a potential for shock and fire hazard. Failure of grounding

connections is common, owing to breaks in power cords or defacement of the grounding pin on molded plugs.

Time and money must be set aside specifically for training and for maintenance. The program must have the support of the hospital administration. Better reporting and study of electrical incidents may delineate areas most deserving of attention. An inspection program is essential and may require outside contractors or part-time utilization of semi-retired skilled individuals such as Bell Telephone Company Pioneers. A logical point of attack and enforcement lies in establishment of purchasing policies to insist on standards and prepurchase inspection of equipment. The task of writing specifications may fall to the purchasing authority.

*Education.* Four factors contribute to electric shock hazards: (1) carelessness, (2) manufacturing faults, (3) design errors, and (4) misuse. Carelessness and misuse are rampant in hospitals since equipment is in the hands of persons who are not familiar with its purposes and hazards, know nothing of how it works, and exhibit little concern for its proper care. Lack of regard for one's own safety is not confined to hospital people. A manufacturer of power tools pointed out that only 15–25 per cent of his products were properly grounded by persons using them to make a living, and only half of the power tools returned for service had the grounding provisions intact.

Extensive education efforts are indicated. "Nuances are not necessary," says Rudolph Camishion. Simply exposing medical personnel to the fundamentals of electricity and concepts of safe practice in handling equipment would be an improvement.

*Electrosurgical instruments.* Though it is the surgeon's instrument and his responsibility, the high-frequency "cautery" is of general concern because of the high incidence of misadventures associated with its use. Burns reported at the site of EEG electrodes, temperature probes, and ECG electrodes are "the fault of an improperly-connected unit—not the unit itself," says Charles Battig, engineer and anesthesiologist. Manufacturers and users of this device should look into its radio-frequency output, shielding, and the problems of interference with monitoring devices. Anesthesiologists will be interested in a review by Dr. Battig in this issue of the Journal and another in the Journal of the American Medical Association (J.A.M.A. 204: 1025, 1968).

*Other apparatus.* Anecdotal evidence did not support indictments against two controversial pieces of apparatus, the defibrillator and the line-operated pacemaker. While the jolt from a DC defibrillator is distressing, a patient has sustained a compression fracture, and skin burns and ignition of flammables are possible, there is no evidence of serious lasting injury to patient or operator that could not have been produced through malfunction or improper application of any other type of electrical apparatus. Over-design of defibrillators in the name of safety may compromise their prompt operation during resuscitation—one of the few medical emergencies in which seconds count. The spectre of hazard in line-operated pacemakers was unfortunately resurrected by a respected designer of implantable pacemakers. Line-operated pacemakers can be safe (check the circuit diagram and specifications), and they offer certain advantages. On the other hand, battery-operated external pacemakers do not necessarily guarantee freedom from the hazard of microampere electrocution.

In summary, the Workshop on Electrical Hazards in Hospitals posed questions rather than provided answers. It established a point of departure for future work, particularly in these areas: (1) Are isolated circuits practical, or does safety lie with provision of equipotential levels? (2) Information must be developed regarding epidemiology of accidents, with provision for more adequate testing and publication of information on devices before they are placed on sale. (3) Users of equipment must be the object of continuing educational efforts concerning safe practices and effective utilization of equipment. (4) Hospital maintenance is generally deplorable; it must be improved.

The question, said engineer Saul Aronow, is "How much do we wish to spend and where?"

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## Association of University Anesthetists

The Association of University Anesthetists is a forum for academic scientific exchange and for exploring problems in the care and training of future anesthesiologists. Both these purposes were evident at the annual meeting in the Century Plaza Hotel, Los Angeles, March 16 and 17, 1968, hosted by Dr. John Dillon and the Division of Anesthesia of the U.C.L.A. School of Medicine. The meeting, which took place during the centennial year of the University of California and the twentieth year of the U.C.L.A. School of Medicine, opened with the greetings and reminiscences of Franklin D. Murphy, Chancellor of U.C.L.A., and Sherman Mellinkoff, Dean of the Medical School.

The program, the exclusive product of the burgeoning state of California, began with a discussion of the diagnosis of air embolism by V. L. Brechner and R. M. Bethune of the host institution, U.C.L.A. They injected 1.5 ml./kg. air or $N_2O$, about a third to a fourth the lethal dose, intravenously, in 39 dogs and observed signs and symptoms during the ensuing half hour to recovery. Studies of four of 49 patients undergoing head and neck surgery complemented their series. In addition to the classical mill-wheel murmur and the appearance of ventricular arrhythmias, two modern electronic aids proved diagnostically useful: a sudden fall in end-expired $P_{CO_2}$, measured with an infrared analyzer, accompanied embolization, presumably due to impairment of pulmonary blood flow; and nitrogen, sampled with a rapid nitrogen analyzer, appeared in the expired gas. Aspiration of foam from a central venous catheter confirmed the diagnosis. The listener was left with the distinct impression that early diagnosis is probably the most important step in the successful treatment of air embolism.

E. I. Eger, II, of the University of California Medical Center, San Francisco, surveyed evidence for and against Pauling and Miller's hydrate theory of anesthesia. He discussed several possible ways to test the theory, including correlation of the pressure required for hydrate crystal formation with that required for anesthesia (defined by MAC). Eger showed that two substances, sulfur-hexafluoride, with a MAC of 4.9 atmospheres, and carbon tetrafluoride, with a MAC of 26.5 atmospheres, showed poor correlation between MAC and dissociation pressure of crystal formation, compared with other anesthetics on a log-log plot; the substances fitted much better to similar plots of MAC versus lipid solubility. He did concede that the validity of the dissociation pressures used, determined at 0° C. rather than 37° C., might account for the lack of correlation in the former case. Eger concluded that there was no more, and possibly even less, support for the microhydrate theory of anesthesia than for other theories at the present time.

From U.C.L.A. came a discussion by N. Fotias of clinical experience with Ketalar, a parenteral general anesthetic similar to Sernyl. He administered the drug to nearly 400 patients less than 15 years old for periods lasting as long as three and a half hours. Ketalar, Fotias stated, spares the cardiovascular and respiratory systems; it commonly produces elevations in blood pressure and heart rate. Pharyngeal and laryngeal reflexes are not depressed. However, detailed evaluation of respiratory and circulatory effects under carefully controlled conditions has not yet been done. Fotias found that in half his patients absence of muscle depression was associated with athetoid movements, with occasional fasciculations. Recovery was rapid after a small dose but required several hours following repeated administration of the drug. This agent may prove to be particularly useful for brief procedures, particularly multiple anesthetics (burn dressings), for situations where anesthetic equipment is difficult to use (radiation therapy), or when airway management is difficult (pneumoencephalography). This study whets one's curiosity. It is regrettable that a standard format for systematic controlled evaluation of new drugs has not been promulgated to permit a more definitive understanding of the effects on man of agents such as this one.

L. Walts, also from the host institution, tackled the problem of duration of action of succinylcholine and *d*-tubocurarine in infants, attempting to illuminate the often-stated observation that infants are more sensitive to curare and less sensitive to succinylcholine

than adults when these drugs are administered in equivalent dosages per unit of body weight. In this study the dosage was based on body surface area. The times for 10, 50 and 90 per cent recovery of thenar muscle strength were used to assay duration of action. The subjects, both large and small, received halothane–$N_2O$ anesthesia, followed by 40 mg./$M^2$ of succinylcholine or 4 mg./$M^2$ *d*-tubocurarine. Walts observed remarkable similarity between infants and adults in the rates of recovery from succinylcholine; thus, on a body-weight basis, the infant would require more succinylcholine than the adult. For curare, he found that 10 per cent recovery of twitch (from a maximum twitch depression of 68 per cent) took 10 minutes for adults and 34 minutes for infants, indicating that the infant is more sensitive to curare when the dose is calculated in relation to either surface area or weight. The discussion, mainly by A. Keats of Baylor University, provided a taste of uncertainty. With different dosages, different routes of administration and different end points (*e.g.*, duration of apnea) different relationships can be obtained. One is left with the distinct impression that the last word has yet to be conceived, much less said.

J. von der Groeben, Department of Anesthesia, Stanford Medical Center, provided a glimpse into the automated future awaiting anesthesiologists, with an illustrated exploration of computer analysis during anesthesia. With on-line monitoring, using a relatively small computer, he demonstrated that a continuous record and a detailed dissection of the electrocardiogram can be obtained. The system permits recording and display of events over a long time span, with the ability to expand any scale for closer inspection of transient responses to drug administration. For example, the anesthetist could view an oscilloscopic display of the R–R interval in a condensed record possessing a characteristic shape for different arrhythmias; these could be correlated visually with other recorded variables such as arterial and central venous pressure. The step from visual display to automatic analysis by a well-educated computer would seem to be a small one; from there on the succeeding strides to automated therapy with appropriate feedback do not seem so remote The anesthesiologist is left to speculate if this foretells early retirement, increasing complexity, or a greatly heightened capability to provide scientific patient care.

But scientific patient care requires also an understanding of what the monitors have to tell. To this end, J. L. Wade and C. P. Larson of the University of California Medical Center, San Francisco, discussed the effects of carotid endarterectomy on chemoreceptor and baroreceptor function. Following unilateral surgery, only one of six patients lost his ventilatory response to hypoxia; all four individuals who experienced bilateral endarterectomy were unresponsive to hypoxia afterward. In those whose breathing was no longer stimulated by hypoxia, resting $Pa_{CO_2}$ rose from 36.6 to 42.5 mm. Hg. Arterial blood pressure increased 29 per cent and 38 per cent after unilateral and bilateral procedures, and was highest in the first postoperative days. Testing of baroreceptor function by blood pressure response to a Valsalva maneuver was inconclusive. The implication of this work is that endarterectomy may well relieve the carotid sinus region of its functional role as a chemical and pressure sensor. The long-range impact of this denervation on the organism provides an intriguing opportunity for continued investigation.

The topping of this scientific sundae came from W. R. Adey of the Department of Anatomy at U.C.L.A., who, in a talk entitled "Windows on Sleep and Wakefulness," explored a realm which bears kinship with anesthesia. Fellow mammals, the whale and dolphin, cannot sleep without drowning. Man sleeps in a cycle lasting about ninety minutes; dreaming occupies approximately 20 per cent of the time. Sleepwalking occurs during deep or slow-wave sleep, not in the dream phase, but the walker is capable of dealing, to some extent, with his environment. Adey stated that victims of paralysis, such as quadriplegics, undergo profound changes in their sleep habits. Cyclic regularity is lost; little dream (rapid-eye-movement) sleep occurs, and a light sleep pattern dominates. These changes are accompanied by distinct changes in personality. Adey also pointed out that electrical activity of the brain loses its randomness with increasing depth of sleep. In man impedance

across the brain, which probably measures resistance through the brain extracellular space, increases with deeper sleep, possibly related to changes in calcium ion concentration in the brain extracellular fluid. Reminiscent of Dr. von der Groeben's approach to the electrocardiogram, Adey illustrated density plots of electroencephalographic frequencies related to time for astronaut Frank Baumann during 55 hours of orbital activity, revealing the nature of sleep–wakefulness during this still-uncommon upset of the normal circadian rhythm. The potential implication and applications of such an approach to anesthesia challenge the imagination.

Problems of medical education in general and anesthesiological training in particular were the subjects of several presentations. J. Field, Associate Dean of the U.C.L.A. Medical School, reviewed the evolution of medical education in the United States during this century. Building on an early European foundation, via the Flexner report, he discussed the problems causing the current major changes in medical school curricula in an attempt to provide more time for individually-oriented direction.

Interim Report-II on SIM I was given by J. S. Denson of the Department of Anesthesia, University of Southern California. From an anesthesiologist's point of view, SIM I might represent man's most impressive attempt, thus far, to manufacture himself from something other than sperm and ovum. Dr. Denson pointed out the human qualities of the mannikin whose central nervous system occupies a small bank of computers in an adjoining room; anesthesia can be administered to a subject capable of airway obstruction, cyanosis, vomiting, arrhythmias and a variety of other true-to-life reactions designed to age anesthetists. The appropriateness of the anesthetist's response to each stress is automatically recorded for his later bemusement and education. The state-of-the-art has progressed to the point where studies of intubation by beginning anesthesia residents using SIM I have resulted in a learning rate about twice as rapid as for the same procedures performed in patients. Whether or not total energy expenditure on the part of the teacher was altered wasn't clear, but the psychological stress of learning intubation on a nonviable mannikin in a realistic situation was deemed worthwhile. One of the greatest benefits to be derived from this effort may be the formulation of a step-by-step approach to the teaching of intubation. Future models of SIM will become even more realistic, with tearing, hand movements, pharyngeal bleeding, chest splinting, breath sounds. The next phase, SIM II, would appear to be an automated trainer to eliminate the need for a flesh-and-blood instructor, and the obvious finale is to simulate the learner as well. One consideration, possibly mundane but important in this age, is the relationship between cost and effectiveness; this may be the factor that determines the life expectancy of SIM.

Problems of continuing education were tackled by D. F. Brayton, Director of Continuing Education at U.C.L.A. Medical School. He reported on the application of closed-circuit television for physician education in the Los Angeles area by documenting increasing use and decreasing cost (about $3.00 per physician-hour at present). The usefulness of closed-circuit TV or video-tapes for paramedical personnel and for physicians in outlying areas is apparent, but this represents only one part of the solution to an ever-increasing problem: how to avoid dating the timeliness of each man's practice of medicine from the moment he finishes his formal training.

Dwight Wilbur's concern was future medical manpower. As President-elect of the American Medical Association, he came with facts, not all of them comfortable. He reviewed the recommendations of the President's Commission on Health Manpower as well as the A.M.A.'s point of view. Expenditures for medical care will increase from 7 per cent to about 20 per cent of the gross national product by 1985. Closer to home, he expressed his feelings that total M.D. anesthesia coverage in this country was neither realistic nor demanded. In 1965, 11.5 million anesthetics were given by about 7,000 physicians, 10,000 nurses and 3,000 others. By 1975, about twice as many anesthetics will be given; at the present rate of growth, anesthesiology will meet only about one-third of that need. The number of U. S. physicians going into anesthesiology each year has decreased, from 450 in 1960 to 300 in 1967. Half of these residents are graduates of foreign medical schools who bring with them

socioeconomic problems, a language barrier, and inferior training. The number of physicians entering the U. S. (about 7,000 each year) is nearly equal to the yearly quota of graduating physicians. Dr. Wilbur's recommendations were: 1. to attract physicians into anesthesia, the specialty should continue to broaden its field of interest and activity and bridge the gap of clinical–applied pharmacology (as recommended by the Dripps Committee) by assuming an active teaching role in all hospitals. 2. To train other manpower, and provide adequate, responsible supervision for non-MD anesthetists who are currently practicing. He felt that supervision of nurse anesthetists by surgeons and hospital administrators was not in the interest of the best patient care; anesthesia should be unified, not fragmented. Dr. Wilbur felt certain that the associated problems of ethics and economics are soluble.

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Mrs. Natale Graziano of Marion, Ohio was the first prize winner in the drawing category at the 1967 Physicians' Art Exhibit at the 1967 Annual Meeting in Las Vegas.