Special Article

Analysis of Manpower in Anesthesiology

J. S. Gravenstein, M.D., J. E. Steinhaus, M.D.,† P. P. Volpitto, M.D.‡*

An analysis of the tasks performed by the anesthesiologist shows that anesthesiologists as well as nurse anesthetists do many things that could be done equally well by personnel with less training. It is possible to design a system in which one anesthesiologist directs anesthetic procedures in more than one room with the help of an anesthesia team. Members of the team may include nurses and technicians.

Patients rarely, if ever, have surgical procedures without the benefit of anesthesia; however, many question the universal adequacy and quality of anesthesia. Some suspect that surgical treatment is at times handicapped by anesthetic deficiencies. These questions become more pressing as standards of medical care are raised and as care is extended to all levels of our society. With advances in medicine, and with the introduction of new techniques, our shortages today may become definite bottlenecks tomorrow. While we cannot know what the future will bring, we are obliged to examine the present system under which we deliver anesthesia care and to search for improvements.

Since both quality and quantity of anesthesia are concerned, both the numbers and the training of anesthesia personnel must be evaluated. At present, there is no consensus about the optimal numbers of anesthesiologists and other personnel needed in this country.

Although anesthesia was first used in the United States, it was the English who at the outset established that "anesthesia was the task for the expert and that his knowledge and skill were far more important factors in successful anesthesia than the drug and the method of administration which he chose to employ."[1] The English to this day have had only physicians as anesthetists.

In the United States until the 1930's anesthesia was administered largely by surgical assistants, nurses, or medical students working under the direction of senior surgeons. As the population grew and more hospitals were needed, the Roman Catholic Church built community hospitals largely staffed by Sisters who resided on the premises. The availability of the Sisters resulted in their being pressed into anesthesia service by surgeons. As this practice grew, informal training of graduate nurses began to flourish in the 1920's, culminating in the establishment of the American Association of Nurse Anesthetists, which now sponsors about 200 training schools. These schools are conducted primarily by nurse anesthetists, with approximately 1,200 students in training. On completion of 18 to 24 months of training, a nurse takes an examination and, if successful, qualifies as a Certified Registered Nurse Anesthetist. The American Association of Nurse Anesthetists has a membership of about 13,500, of whom about 11,000 administer anesthetics.[2]

Training of physicians in anesthesia in the United States was sporadic until the late 1920's, when residency training began, the numbers increasing slowly until the end of World War II. Since then, the demand for anesthesiologists has grown and many training

* Professor and Chairman, Department of Anesthesiology, Case Western Reserve University, Cleveland, Ohio.

† Professor and Chairman, Department of Anesthesiology, Emory University, Atlanta, Georgia.

‡ Professor and Chairman, Department of Anesthesiology, Medical College of Georgia, Augusta, Georgia.

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programs have been conducted in both medical school and nonaffiliated hospitals. At present we have about 200 residency training programs approved by the Council on Medical Education of the American Medical Association. In these programs about 1,500 physicians are registered at various levels of training from the first to the third year; 22 per cent of first-year positions were unfilled in 1967–68; foreign graduates made up about 50 per cent of the physicians in training.

The American Society of Anesthesiologists (ASA) in June 1970 had an active membership of 7,500. The Society certifies as Fellows of the American College of Anesthesiologists candidates who have had at least 18 months of approved residency training and have passed a written and an oral examination. Higher qualifications are required of the candidate by the primary certifying body for anesthesiologists, the American Board of Anesthesiology, established in 1939. At present the Board lists 4,200 diplomates. In addition to active ASA members and 1,500 residents, about 1,000 other physicians devote some time to anesthesia in their medical practices.

How many anesthesiologists are needed today and how many will be needed in the next ten to 30 years are questions that remain unanswered, though they have been argued with vigor.[3, 4, 5, 6, 7] Based on a population of 200,000,000 in the United States today, we estimate that between 15,000,000 and 20,000,000 surgical and obstetrical anesthetics are given each year. Disregarding matters of both quality and uneven distribution, and considering only numbers of personnel and anesthetics administered, we calculate roughly a distribution of 800 anesthetics per anesthetist (21,000 personnel, *i.e.*, 10,000 physicians and 11,000 nurse anesthetists, and 17,500,000 anesthetics). This is a higher figure than generally conceded for total anesthetics given annually by many a nurse anesthetist and a lower figure than those cited by some anesthesiologists in their practices.

If one were to take the viewpoint that every anesthetic should be given by an anesthesiologist rather than a nurse anesthetist or untrained physician, we should have to more than double the present number of anesthesiologists. However, the record shows that despite concerted effort the specialty has grown only slowly during the past ten years.

Many[3, 8, 9, 10, 11] acknowledge that an overall shortage of physicians exists, and other specialties, such as general practice, are singled out as fields in particular need of physicians. Anesthesiology, together with other specialties in short supply, will continue to try to recruit the medical graduate. Therefore, the hope of markedly increasing the number of medical students entering the field (at present 2 to 3 per cent annually) does not appear justified. The increasing demand for nurses in all fields of medicine and the large deficit in the available supply cast doubt on the possibility or advisability of encouraging more nurses to specialize in anesthesia.

Many Americans today do not receive adequate medical care. As our medical resources are made available to the underprivileged, additional anesthesia services will be required. Simultaneously, anesthesiologists are assuming more responsibilities for patients in intensive care units, pulmonary care centers and obstetrical services. Finally, the general trend in the past has been that advances in medicine have led to greater demands for specialists, surgical procedures have become more rather than less complex, and we may anticipate that all these factors will lead to a crushing requirement for additional anesthesia services.

To satisfy present and future demands we must train more anesthesiologists, but we must also explore how nurse anesthetists and other non-physicians could best fit into a pattern of care that would assure the high quality of anesthesia services society demands for all patients.

An optimal system surely would place an anesthesiologist with every patient requiring an anesthetic. Since this is not feasible, other systems should be analyzed and recommendation made on how best to utilize available personnel and what new personnel to train. In preparation for such an analysis, the authors, representing three university anesthesia departments, joined forces. The goal of this effort was to analyze current practice and to offer recommendations for the future.

Task Analysis

In order to define the roles of several types of personnel in anesthesiology and to describe the training and function of new personnel, it was necessary to analyze and identify the several aspects of work required of individuals providing anesthesia care. After the tasks are identified in a representative number of cases, these must be judged as to skill and experience required to do them. Some tasks, such as caring for equipment, can be performed adequately by individuals with modest education and training. On the other hand, the evaluation of complex and serious situations and the prescription of treatment has always been the practice of medicine, requiring the most highly skilled and experienced person that can be provided, namely, the trained physician.

Analysis upon which the task assignments in anesthesia must be based should include the following steps:

1) Define tasks that require the skill and experience of anesthesiologists, nurse anesthetists, technicians, and aides.

2) Determine the times required for execution of different tasks.

3) Determine and weight tasks in terms of urgency during any given anesthetic administration.

4) Ascertain the number of patients simultaneously anesthetized for whom one anesthesiologist could assume responsibility. The analysis would have to take into account the urgency of the tasks, types of operation and anesthesia, the layout of operating suite, the personnel available for tasks assigned to nonphysicians. We should determine whether an anesthesiologist has to be present at certain phases of every anesthetic regardless of task level, if complications are known to arise with particular frequency at such specified times.

5) Analyze the items in 4, above, under different assumptions, *e.g.*, assignments of more or fewer tasks to the anesthesiologist.

Definitions of Tasks

The tasks performed in anesthesiology can be arranged in levels. Here we chose six levels, ranging from one, the simplest, to six, the most demanding. The levels are:

1) Simple tasks for which standard procedures have been established. These are performed with little or no need for exercise of independent judgment. The work is largely manual. Samples are: cleaning, checking of supplies, transporting patients and machines, disconnecting equipment after anesthesia.

2) Routine tasks performed in response to general or specific direction. These tasks require skills easily learned. A moderate degree of judgment may be required. Examples: discriminating between types of drugs (by identifying label) during storing activities, applying blood pressure cuff, stethoscope, or ECG electrodes to the patient.

3) Semiroutine tasks performed in response to general direction. These tasks require moderate degrees of manual dexterity and mental application. Independent action may be required within prescribed limits. Examples: inserting intravenous needles, administering on direct or standing orders standard i.v. fluids, recording pulse and blood pressure and giving the alarm when these values exceed predetermined limits, using equipment for analyses of blood gases.

4) Semiroutine tasks performed in response to general or specific direction. The tasks require a high degree of skill and mental application. Examples are: injecting drugs, adjusting gas flows, inserting esophageal stethoscope or endotracheal tube, manually assisting ventilation, adjusting the patient's position prior to operation. Injection would be limited to specified drugs, and dosages given for clearly identified circumstances and on direction by an anesthesiologist responsible for the management of the anesthesia.

5) Nonroutine tasks performed under little supervision. Tasks require a high degree of skill and mental appplication in many areas. Examples: assimilating information and making decisions for immediate action during anesthesia, inserting intra-arterial and spinal needles or catheters, judging indications for dosage of drugs and anesthetics. However, responsibilities are still limited, and the full range and dosage of drugs available to the specialist would not be employed in this task category.

6) Nonroutine tasks performed without supervision. These tasks require the highest degree of skill and mental application. An intimate knowledge of medicine is required to make diagnoses quickly and bring to bear independent judgment. Judgments and action resulting therefrom imply overall responsibility for patient care.

These tasks do not exist independently, but can be identified as part of an overall activity, such as visiting a patient preoperatively, inducing anesthesia, etc. In table 1, therefore, we show the activities, the tasks that can be identified during these activities, the task levels as outlined in the classification above, and finally the overall levels that would encompass the majority of tasks occurring during given activities.

Although no one would propose that a physician should carry out task levels one and two, we realize that opinions diverge when task level three is considered. Some argue that the physician should attach the blood pressure cuff himself, others insist that only a physician can start an intravenous infusion, others that history taking and physical examination could be carried out by properly trained non-physicians. Here, we do not wish to enter into an argument defending our division of tasks. The assignment of tasks should be based on relevant studies rather than opinion or tradition. Our categorization of tasks follows current practice at least at the extreme of the scale.

Task Duration and Distribution

Measurements of the durations of the different tasks were made at the University of Florida under the direction of Dr. John R. Freeman and Mr. Joseph D. Marsh, Jr. A group of engineering students was assigned to the operating suite for a month and the activities of an anesthetist through preoperative rounds to postoperative visits were recorded. His activities were broken down into observable acts that could be timed. If the act was short, only a check mark indicated that the event had taken place. The activities and tasks observed are shown in table 1.

The study had one principal limitation: every time the observer noticed a task, such as adjusting an anesthesia machine or checking blood pressure, he entered data on a form. The data collected,[12] therefore, reflect entirely actions taken but provide only indirect and incomplete evidence of judgment applied by the anesthetist. For example, an anesthesiologist might, on observing the operative field, decide that muscle relaxation was inadequate, leading him to inject a drug or adjust gas flow, events recorded by the observer. On another occasion the anesthesiologist may have decided that muscle relaxation indeed was not optimal but that because of a trend apparent from the chart or because of a read-out on a monitor no drug should be given and gas flows should not be adjusted. In this instance, therefore, complex medical judgment did not result in an action that could have been recorded by the observer.

The data collected show that in general the tasks recorded early and late during maintenance of anesthesia occurred with approximately equal frequency. Certain surgical procedures, however, differed from others in that during some superficial operations in healthy persons blood pressure was recorded and drugs were administered less frequently than during radical operations. Here, then, we have indirect indication that during certain procedures less medical judgment was applied and fewer activities observed than for other anesthetics and operations.

If the requirement for medical judgment is not frequent at certain phases during the maintenance of anesthesia, then we can inquire whether non-physicians could serve adequately as monitors and data collectors, so that a physician could be available for other services more urgently needed.

Delays in Task Execution

In a system in which an anesthesiologist assumes responsibility for more than one patient at a time many tasks must be assigned to non-physicians. We must then measure the delays that will occur if the anesthesiologist is treating one patient and he is called to see another patient. The delay will be influenced by the layout of the operating suite, the task that the anesthesiologist has to complete before he can answer the call, the number of patients he

TABLE 1. Activities and Tasks in Anesthesia

Activity	Task	Preponderant Level of Proficiency to Which Task or Activity is Assigned*	
		Task Level	Activity Level
Rounds	Review chart	6	
	Examine and evaluate patient	6	6
	Prescribe medication	6	
Induction of anesthesia	Review chart	5	
	Attach blood pressure and other monitoring devices	2	
	Intravenous infusion	3	
	Insert intra-arterial or spinal needle or catheter	5	5–6
	Check suction, equipment, etc.	2	
	Administer drug		
	Select drug	6	
	Select dose	5	
	Inject drug	4	
	Intubate trachea	4	
	Insert esophageal stethoscope	4	
	Management of complications	6	
Preparation for operation	Affix screen	2	
	Attach suction and other equipment	2	3
	Position patient	3	
Maintenance of anesthesia	Measure blood pressure, etc.	3	
	Adjust flowmeters	3	
	Administer drug		
	Select drug	6	4
	Select dose	5	
	Inject drug	4	
	Management of complications	6	
Termination of anesthesia	Suction pharynx or trachea	3	
	Discontinue anesthetic flow	3	
	Extubate trachea	4	
	Administer drug		5
	Select drug	6	
	Select dose	5	
	Inject drug	4	
	Remove monitoring devices	3	
	Management of complications	6	
Communication	Communicate with surgeon	3–6	
	Communicate with nurses	3–5	
	Communicate with orderlies	1–4	
	Communicate with others	1–6	
Repairs	Machine	3	3
	Other equipment	3	
Cleaning	Machine	1	1
	Other equipment	1	
Supply	Supply cart, shelves, etc.	2	
	Supply machine	2	
	A) Bring supplies and move equipment	1	1
	Move anesthesia machines	1	
	B) Transport unconscious or critically ill patients	4	4

*For an explanation of levels one through six, see text.

has to take care of simultaneously, and the number of tasks assigned to him.

From experience, we know that difficulties are more prone to arise during induction than during maintenance of anesthesia. If an anesthesiologist is needed for certain activities during induction, it is reasonable to assign him tasks during induction that require less proficiency. However, the anesthesiologist need not be present throughout the procedure should activities that require his presence occur only infrequently. We can set limits and state that an anesthesiologist will stay with the patient if the anesthesiologist's proficiency level is called for x times in y minutes, but that he will be on call only if required less than this. We have not yet attempted to define x and y.

The question of delays that will have to be accepted if physicians are distributed according to the above considerations must be faced. Delays that occur can be examined by computer in a simulation experiment. For this, Dr. Freeman and his group used data collected at the University of Florida for a U-shaped suite of nine operating rooms. An average operative schedule was assumed, including all operative specialties. Breakdown into different procedures, their duration, the arrangement of rooms and other details are of little interest here, since we wish to report on the principle rather than specifics.

In the simulation experiment the nine operating rooms were assumed to be staffed by nine, six, or three anesthesiologists. One nonphysician per room was assumed to take the place of an anesthesiologist for all tasks not specifically assigned to the anesthesiologist.

Task assignments were varied. The physician took care of either task levels five and six, or, by comparison, levels four, five, and six.

Anesthesiologists performed either only the tasks assigned (five and six, or four, five, and six) or, in addition to performing the assigned tasks, they had to be present throughout induction and termination of every anesthesia.

In this simulation experiment we were looking at several variables and many possible interactions. We expected to see the greatest delays when fewer anesthesiologists had to assume responsibility for greater numbers of tasks (three anesthesiologists performing task levels four, five, and six always present for induction and termination of anesthesia in the nine operating rooms). No delays occurred when nine anesthesiologists covered nine rooms.

The situations examined so far have not included weighting of tasks. Even with this limitation, however, the overall average delay encountered when three anesthesiologists directed anesthetic procedures in nine operating rooms was less than two minutes even when anesthesiologists were present for all inductions and emergencies. Proper weighting of tasks should reduce this delay.

Conclusion from Task Analysis

Experience strongly suggests that proficiency levels one and two should be combined. Combination of levels three and four is suggested by clustering of activities. At some institutions employment of nurses provides practical examples of such a combination, whereas in other instances nurse anesthetists function at levels three, four, and five. However, as is true for anesthesiologists, nurse anesthetists often perform tasks assigned at lower levels.

The Anesthesia Team

Personnel Presently Available

At present, in addition to the anesthesiologist, there are two categories of personnel, the nurse anesthetist and the anesthesia aide. As noted, the nurse anesthetist has had 18 to 24 months of training in addition to experience in general nursing. The level of scientific instruction in general nursing education is limited, frequently not including college work. Anesthesia training for the nurse anesthetist is directed toward practical management rather than providing a scientific background. In many hospitals the nurse functions under the direction of an anesthesiologist. Often, however, the nurse anesthetist is placed in an unfair position when asked to work independently or at best to work under the direction of a physician with little training in anesthesiology. While many anesthetic tasks and services lie within the scope of the nurse, even superficial analysis reveals that the nurse frequently is forced to perform activities for which she has not been trained. Conversely, the nurse anesthetist has to perform work requiring little skill or experience, work that could be done competently and efficiently by aides. Hospitals have been slow to recognize the increasing complexity of anesthetic practices, and the need for aides who could improve the efficient use of nurse anesthetists and anesthesiologists.

Throughout the country only a few anesthesia aides or technicians (high school graduates), usually haphazardly trained, are available for tasks at the lowest level. The role of the lowest level of anesthesia personnel should be better defined and the numbers determined for a given operating suite. Even though this category of personnel has been accepted as such by the American Society of Anesthesiologists, the aide or technician in anesthesia is not much in evidence.

New Personnel

Development of categories of personnel should take into account not only present needs but also the expected changes in the practice of anesthesia. A basic concern of anesthesiology is the maintenance and support of respiratory and circulatory function in critically ill patients during anesthesia and operation and in intensive care units. In these areas improvement in patient care requires the sophisticated physiologic measurement and monitoring now being made available by biomedical scientists. The techniques and equipment offered add to the complexity of present methods of management. Since this equipment must function reliably, maintenance and operation have become the responsibility of the anesthesia team.

Another essential in the development of new health personnel is provision of mobility so that an individual can rise to higher levels of responsibility as capability and desire permit, or move laterally into related areas if interest dictates.

The concept of an anesthesia technologist has been proposed and is now being studied at Emory University. To answer future as well as present needs, this individual's training is directed toward increased use of technology in medicine, specifically, toward further employment of physiologic measurement in anesthesiology. Although this individual is a member of the anesthesia team, he may be considered an applied physiologist.

Another consideration for development of new personnel is the manpower pool upon which it is possible to draw. In 1968–69 there were approximately 21,000 applicants for medical school. Of these, about half were accepted, with an equal number finding other occupations. By defining a position that requires the Bachelor's degree in science, including the latter group, many could be reclaimed for health occupations. Vertical mobility towards the M.D. degree could be assured as formal educational requirements for admission would have been satisfied and course work would be that required for an M.D. degree. Lateral mobility would be possible into areas where biomedical equipment and physiologic measurements were in use. These would include the recovery area, intensive care unit, inhalation therapy, clinical research unit, and equipment maintenance and development, as well as commercial services. The anesthesia technologist would have the B.S. degree, and the new program would need to grant a Master of Science degree. Consequently, the graduate might be known as a Master Anesthesia Technologist, in keeping with a terminology that relates to the level of training.

At present, as projected, the master technologists in anesthesiology would complement present personnel, the aide, nurse anesthetist, and anesthesiologist. Emphasis in his training is placed on technology and applied physiology. An individual with such training would be most useful on the anesthesia team for prolonged complicated procedures such as open-heart interventions, neurosurgery, and for operations on the poor-risk patient who requires extensive monitoring and physiologic measurement in the operating room and related areas.

An alternate proposal suggests that assistants and associates in anesthesiology be trained for specific tasks of the lower levels. Assistants may have an Associate in Arts degree, associates a Bachelor's degree. The program should be structured so that the graduates will have the chance to move on into other professions or, if they desire and their performance is adequate, into higher education, with the possibility of obtaining doctorates in medicine or other fields.[13]

The legal problems posed by the utilization of a technologist in anesthesiology would be the same as those in other allied health programs. Responsibility and immediate care of the patient must remain within the province of the anesthesiologist; consequently, personnel could not work independently but only under the immediate direction of the anesthesiologist. An advantage in manpower for the anesthesiologist would result, as he could provide attention to several patients with the proper employment of the anesthesia team, described above.

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Surgery

CLINICAL TEMPERATURE Quantitative mechanisms that regulate normal temperature and determine its clinical aberrations have been found with the methods of gradient calorimetry and tympanic thermometry. Hemostasis is achieved by warm-sensitive neurons of a "human thermostat" or "temperature-eye" in the anterior portion of the hypothalamus. These fire and excite sweating and vasodilatation for heat loss when their temperature exceeds a sharply-determined set point near 37 C (98.7 F). Similar warm-sensitive neurons inhibit, through a synaptic station in the posterior portion of the hypothalamus, the metabolic response to cold which is excited by cold-receptors of the skin firing from thresholds at 33 to 35 C (91.4 to 95 F). Pyrogens depress or extinguish firing of central thermoreceptors. The set point is shifted and fever develops. These findings provide a basis for the understanding of clinical temperature, and the tool for its reliable measurement—tympanic, not rectal, thermometry. (*Benzinger, T. H.: Clinical Temperature. New Physiological Basis, J.A.M.A. 209: 1200 (Aug.) 1969.*)