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The Role of Anesthesia in Surgical Mortality

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The role of anesthesia in contributing to surgical mortality has been studied in 33,224 patients given either spinal anesthesia or a general anesthetic to which muscle relaxants were added. There were no deaths atributable to anesthesia in the 16,000 physically fit patients anesthetized by either technique. As the patients' physical condition worsened, deaths related to anesthesia increased in incidence; in the moribund patients, 1 in 16 patients given spinal anesthesia died of causes related to the anesthetic, and in 1 in 10 patients, general anesthesia could not be excluded as contributing to death. Of 6,000 physically fit patients who received a muscle relaxant, none died. No evidence of an inherent toxicity of muscle relaxants could be found. When deaths were related to the use of muscle relaxants, errors of omission or commission were always apparent.

WHEN should an anesthetic be regarded as having contributed to the death of a patient? This question involves consideration of the *degree* of contribution as well as the *nature* of the contribution. For example, if the continued inhalation of ether by a healthy subject is followed by cardiac arrest before operation has begun, and resuscitation is unsuccessful, the degree of contribution of anesthesia to the fatality is essentially 100%. This will be viewed as an anesthetic death by all. At the other end of the scale are cases wherein the relationship is less clear. In these instances the skill of the anesthetist may be unquestionable, the technique faultless, and the selection of drugs and dosage of drugs quite proper, yet the patient dies during anesthesia without there being any apparent surgical error. The state of anesthesia and the performance of an operation are stresses, and the patient, healthy or desperately ill, must call on reserves to withstand these stresses. Viewed from this standpoint, if the patient cannot tolerate stress, there will be deaths about which one can only say that anesthesia and operation proved to be the "last straw." To some, a properly administered anesthetic is not a stress. When classifying anesthetic deaths, these individuals would exclude fatalities such as the second group described. Until more is known about anesthesia, these factors must remain a matter of opinion. However the different "mortality rates" which would result from using different criteria are evident.

Nor has the nature of the contribution of anesthesia to death been defined in a fashion acceptable to all. In some instances this definition involves a clarification of the responsibilities of the anesthetist. If failure to discharge these responsibilities is followed by the death of a patient, should the fatality be termed an anesthetic death? As examples: Is death from an air embolus secondary to the anesthetist's administering blood intravenously under pressure and failing to note that the bottle is empty an anesthetic death? Is blood replacement during operation a responsibility of the an-

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esthetist, and should inadequacy of transfusion resulting in death from hemorrhagic shock be called an anesthetic death? When does the responsibility of the anesthetist cease in the postoperative period? Is death from circulatory collapse incident to moving a patient on an elevator after discharge from the recovery room an anesthetic death? Dozens of other illustrations come to mind as one attempts to define the scope of responsibility in anesthesiology.

Our attitude on these matters can be summarized as follows: There is nothing to be gained in a mortality study by omitting a particular death merely to lower a statistical death rate. Avoiding responsibility or taking refuge in the fact that a patient was desperately ill prior to anesthesia and operation may improve one's mortality figures, but it will not advance general knowledge or change one's own practices. On the other hand, one should not resort to self-flagellation, assuming responsibility for a fatality merely because an anesthetic was administered and death occurred.

If it is difficult to blame or exonerate the anesthetic management in its entirety, it is even more difficult to assess the role of a single component of the anesthetic management, e.g., the muscle relaxants. The Beecher-Todd[1] report has been criticized in this respect, for the authors could not prove that the relaxants contributed to death.[2] All they could do was to point out that relaxants had been a part of the anesthesia in patients whose subsequent death was judged to be related to anesthesia. Inherent toxicity of the relaxants was suggested, but the role of these potent drugs in causing death was assessed in a fashion unsatisfactory to many readers. We even question Beecher and Todd's contention that use of muscle relaxants caused a mortality rate greater than if these adjuvants had been omitted.

In order to inform ourselves on these matters, we have made a survey of our experience in the 10-year period 1947 to 1957. During this period, approximately 120,000 patients were anesthetized. There were 1,285 operative deaths (death within 30 days of operation), or a gross mortality rate of 1.1%. We have carefully scrutinized the records of all patients classified as operative deaths who received (a) spinal anesthesia which might or might not have been supplemented by thiopental with or without nitrous oxide, or (b) general anesthesia to which muscle relaxants were added. There were 33,224 patients in these 2 anesthesia groups. The patient's history, physical examination, laboratory data, operative and postoperative course and autopsy findings (if any) were reviewed. According to our custom, detailed reports, often running to 10 or 15 pages, had been written at the time of death except in those instances in which anesthesia had obviously not contributed to the death. A decision was made as to whether anesthesia was definitely or possibly contributory to death.

All patients had been assigned a physical status prior to administration of the anesthetic. The physical status (PS) rating was as follows: PS 1, normal healthy patient for elective operation; PS 2, patient with a mild systemic disease; PS 3, patient with a severe systemic disease that limited activity but was not incapacitating; PS 4, patient with an incapacitating systemic disease that was a constant threat to life; and PS 5, moribund patient not expected to survive 24 hours with or without operation.

Physical Statuses 1, 2, 3, and 4 correspond to the classification proposed by the American Society of Anesthesiologists. In the event of emergency operation, the only change in classification was to precede the number with an E. PS 5 corresponds to ASA Classification 7. Whenever a classification other than PS 1 was used, the anesthetist indicated his reasons for the designation. Patients were anesthetized by staff and resident physician anesthetists and by interns and medical students. Resident anesthetists were supervised to a degree commensurate with their stage of training, whereas interns and medical students were supervised more closely.

Results

There were 18,737 patients to whom spinal anesthesia was administered. Twelve of these patients died from causes definitely related to the anesthetic, a mortality of 1:1560. Twelve additional patients, in whom anesthesia possibly contributed, died—a mortality of 1:780 (Table 1).

Table 1.—Contribution of Anesthesia to Death

	Spinal Anesthesia			General Anesthesia and Relaxants		
	No.	Deaths	Incidence	No.	Deaths	Incidence
Definite						
All Patients	18,737	12	1:1560	14,487	27	1:536
Male	9,501	6	1:1585	5,049	20	1:252
Female	9,232	6	1:1540	9,438	7	1:1350
Definite & Possible						
All Patients	18,737	24	1:780	14,487	56	1:259
Male	9,501	12	1:790	5,049	31	1:163
Female	9,232	12	1:770	9,438	25	1:379

Of 14,487 patients receiving general anesthesia supplemented with a muscle relaxant, 27 died from causes directly related to the anesthetic, a mortality of 1:536. The anesthesia possibly contributed to death in 29 additional patients, a mortality of 1:259. The distribution of the patients by sex and age is contained in Tables 1 and 2. In this hospital for many years the surgical services have dealt with more males than females in the latter decades of life, and the physical status of the male has been less satisfactory. These 2 aspects appear to explain the increased death rate in males noted in Table 1.

Mortality is compared according to physical status in Table 3. There were no deaths in either the spinal or general anesthesia groups in patients in PS 1. In PS 2, deaths occurred. As the physical status worsened, the mortality rate increased. When the mortality was compared between patients given spinal or general anesthesia, little difference was found except in the PS 2 group. In both the definite

Table 2.—Distribution of Deaths by Age

Years	Spinal Anesthesia, %	General Anesthesia, %
0-9	0.1	1.0
10-19	5.0	5.2
20-29	16.1	11.7
30-39	17.2	18.5
40-49	18.6	24.5
50-59	19.8	20.1
60-69	16.2	13.8
70-79	5.9	4.5
80+	1.0	0.6

and possible PS 2 groups, the mortality in the patients given spinal anesthesia was 3 to 4 times lower than in those given general anesthesia.

The operations proposed or performed on the patients in whom anesthesia was thought related to death are listed in Table 4. Of the 56 patients in

Table 3.—Mortality Related to Physical Status

	Definite					
	Spinal Anesthesia			General Anesthesia and Relaxants		
PS	No. Pts.	Deaths	Incidence	No. Pts.	Dearts	Incidence
1	10,164	0	0:10164	6,028	0	0:6028
2	6,789	2	1:3390	5,365	5	1:1075
3	1,593	4	1:390	2,477	7	1:354
4	174	5	1:35	546	12	1:46
5	16	1	1:16	71	3	1:24
	Definite and Possible					
1	10,164	0	0:10164	6,028	0	0:6028
2	6,789	3	1:2260	5,365	9	1:597
3	1,593	11	1:228	2,477	16	1:155
4	174	9	1:19	546	24	1:23
5	16	1	1:16	71	7	1:10

the general anesthesia group who died, 24 had operations on the heart, within the thoracic cavity, or on major abdominal blood vessels. Three patients had craniotomies, 2 had operations on or within

Table 4.—Relationship of Operations to Mortality (Definite and Possible Groups, 80 Patients)

	General Anesthesia	Spinal Anesthesia
Heart operations	12	
Thoracotomy (lung or stomach)	6	
Major thoracic or abdominal blood vessels	6	
Craniotomy	3	
Spinal operations	2	
Abdominal operations	19	19
Adrenalectomy or sympathectomy	3	1
Transurethral resection	3	1
Extremity	1	3
Radical mastectomy	1	0
Total	56	24

the spinal canal, and 1 had a radical mastectomy, operations for which spinal anesthesia is not generally given.

The major reasons why anesthesia was judged to have contributed to the patient's death are listed in Table 5.

Table 5.—Contribution of Anesthesia to Surgical Mortality

	Spinal Anesthesia	General Anesthesia
Preoperative		
Inadequate preoperative preparation	5	10
Complication of preanesthetic medication	3	2
Intraoperative		
Hypotension	19	32
Hypoxia	1	11
Error in judgment	1	4
Inexperience		
Choice of anesthetic	9	6
Anesthetic management	10	22
No anesthetic or surgical error in light of present knowledge		
Cardiac	—	2
Cerebral	—	2
"Last straw"	—	6
Postoperative		
Inadequate ventilation	—	14
Inadequate immediate observation and management	—	6
Inadequate diagnosis and management of hemorrhage	—	2
Aspiration of vomitus	—	1
Circulatory collapse with movement	1	1

An attempt was made to determine if the use of a relaxant per se contributed to the patient's death. Again, classification was on the basis of definitely contributory, possibly contributory, or noncontributory. For example, if during the course of an anesthetic with cyclopropane and d-tubocurarine, major hemorrhage occurred, blood replacement was inadequate, and the patient died, the death was believed unrelated to the relaxant. However, if a patient had respiratory inadequacy after this same anesthetic, and ventilation remained poor with the patient dying on the third postoperative day, we thought there was a possible relation to the relaxant. Finally, if a patient with a full stomach was given succinylcholine, developed regurgitant vomiting, aspirated the vomitus, and died, this was thought definitely related to the relaxant. These data are presented in Table 6. Relaxants were believed to have contributed to death in only one half of the deaths in the general anesthetic group. The specific contribution of the relaxant to death in the 12 patients in whom the relationship was considered definite is contained in Table 7.

Table 6.—Did Use of Relaxant Contribute to Death?

	Definite and Possible Groups			
PS	Deaths	Definitely	Possibly	Not at All
1	0	0	0	0
2	9	2	2	5
3	16	3	5	8
4	24	7	5	12
5	7	0	4	3
Total	56	12	16	28

Table 7.—Contribution of Relaxant in 12 Deaths

Failure to provide adequate pulmonary exchange	8
Poor choice of drug(s)	2
Regurgitant vomiting with aspiration after relaxant	1
Inadequate dose of relaxant	1
Total	12

A similar analysis was made to determine if the spinal anesthetic per se contributed to death (Table 8). Here the relationship between anesthetic mortality and technique was more definite. In only one patient was the spinal technique considered unrelated to death.

Table 8.—Did Use of Spinal Anesthesia per se Contribute to Death?

		Definite and Possible Groups		
PS	Deaths	Definitely	Possibly	Not at All
1	0	0	0	0
2	3	2	1	0
3	11	3	7	1
4	9	4	5	0
5	1	1	0	0
Total	24	10	13	1

Comment

The conclusions drawn from the data must be considered against the background of the criteria for selection of cases to be included in the study. We cannot provide individual protocols because of lack of space. This we realize is a serious omission, because it prevents others from gauging our material by their own standards.

The death rates listed are not to be regarded as absolute. Classification of the cause of death is often difficult. Since knowledge itself is so frequently fragmentary, classification can also be incorrect. Indeed, reanalysis of our older death reports in light of present information has led occasionally to conclusions differing from those originally drawn. We would not expect everyone to arrive at identical figures had they examined our material, yet *if* our yardstick of viewing the role of anesthesia is accepted, we would expect death rates in this same general range.

It should be emphasized that this is a study of the *contribution* of anesthesia to surgical mortality, and, as pointed out earlier, the degree of contribution varied considerably. In assigning the cause of death on a death certificate, anesthesia rarely was entered, except in those circumstances where the contribution was major and unequivocal. Hindsight might also account for the cause of death listed on the certificate being different from the causes listed in this paper.

Our data appear to permit several conclusions:

1. The number of deaths related to anesthesia increases directly with deterioration of the preanesthetic condition of the patient.
2. "Inherent toxicity" of the muscle relaxants could not be demonstrated, at least for healthy patients.

Deaths attributable to anesthesia did not occur in any of the 16,000 physically fit patients given either spinal anesthesia or general anesthesia supplemented with a muscular relaxant. However, as the patient's physical condition worsened, deaths related to anesthesia increased in incidence until in the moribund patient, 1 in 16 patients given spinal anesthesia died of causes related to the anesthetic; and in 1 in 10 patients, general anesthesia could not be excluded as contributing to death.

It would seem obvious that the more ill a group of patients, the higher would be the death rate regardless of the stress under study. This may be all that our data represent. Certainly they indicate that healthy subjects compensate well for whatever challenge anesthesia poses to them. The data, therefore, dispute statements that anesthetic catastrophes are on the increase in so-called "good risk" patients.

Beecher and Todd [1] stated, "when 'curare' is used, death occurs in the same ratio, good risk group to bad risk group of patients, whether 'curare' was used or not. This strongly suggests an inherent toxicity, not a selective killing of the bad risk patient." While Beecher and Todd reported 1 death in every 370 patients given "curare," our data include over 6,000 healthy patients receiving relaxants, none of whom died. Furthermore, when the case reports were analyzed to determine the role played by relaxants in leading to death, we believed that they had nothing to do with death in 28 of the 56 patients, even though other anesthetic factors did participate. This meant that relaxants contributed to death definitely in 1:1210 patients, and definitely or possibly in a 1:520 ratio. Here again there was a direct relationship with the patient's physical status.

Nor do our data agree with Beecher and Todd's statement that "No evidence is detectable that experience or training of the anesthetist protects from disaster with 'curare.'" [1] When we analyzed the 12 deaths in which relaxants were thought to contribute definitely to death, we found an error of omission or commission in every instance. The errors were failure to maintain adequate respiration during the period of total paralysis or until normal respiratory exchange had returned, an improper choice of relaxants (as, for example, tubocurarine after decamethonium) vomiting with regurgitation and aspiration after succinylcholine in a patient with a full stomach, and an inadequate dose of d-tubocurarine after thiopental followed by tracheal intubation, coughing and bucking, hypoxia, and ventricular fibrillation. We believe our study indicates a relationship between anesthetic mortality and experience with our knowledge of the relaxant drugs.

The major causes of death uncovered in this study are listed in Table 5. Preparation for anesthesia and operation is the responsibility of all concerned with the management of a patient. The anesthetist must share the blame if preparation is inadequate. He is a physician, not a technician. He must not reject the responsibility by saying, "that's the surgeon's job." Attention to detail even in the work-up of an individual for an emergency operation cannot be omitted.

The 2 principal intraoperative complications encountered were hypotension and hypoxia. There were also deaths during operation in which neither anesthetic nor surgical management seemed at fault. The 2 instances labelled "cardiac" might represent Beck's concept of "the heart too good to die,"[3] inequality of ventricular oxygenation being a possible causative factor. The 2 patients with cerebral complications suffered from neither hypertension nor hypotension. The causes of their deaths are a mystery. Six deaths were those termed "last straw." A carefully administered general anesthetic appeared to be too much for these individuals, all of whom were desperately ill.

Improper management of the patient unable to care for himself because of unconsciousness loomed large as a postoperative cause of death. Inadequate pulmonary ventilation, failure to provide increased oxygen in the inspired air during transport from the operating room to the recovery room, failure to recognize pneumothorax promptly, and delayed recognition and treatment of hemorrhage were all noted. Increased awareness of the hazards of the immediate postoperative period[4] has reduced the incidence of these catastrophes.

It is of interest that in the spinal anesthesia group, postoperative deaths due to anesthetic errors were rare. As a rule if a patient is to get into trouble with spinal anesthesia, it is *during* anesthesia, more often soon after its onset.

It is tempting to compare the safety of spinal and general anesthesia, yet we do not believe our data can be used with justification for this purpose. Some of the spinal anesthetics—particularly those for intra-abdominal operations—were supplemented with thiopental and nitrous oxide. Furthermore, spinal anesthesia is inappropriate for intracranial and intrathoracic operations, the 2 categories responsible for nearly one half of the deaths in patients receiving general anesthesia and relaxants. The safety of the 2 techniques appears similar as analyzed in this report in all classes of patients except those listed as PS 2. In this category we believe that the greater mortality with general anesthesia may be due to the fact that 7 of the 9 patients in the general anesthesia group had operations of greater magnitude than any patient in the spinal group. Also, spinal anesthesia could not have been used in 7 of these 9 patients.

The period of study covered by this report was one of changing concepts and techniques in anesthesia. In the 14 years since it began, many advances have been made. The muscle relaxants have become firmly established[5] and are now being used more intelligently. The respiratory depressant effect of antibiotics, such as neomycin and streptomycin, has been described. Diffusion hypoxia following the use of certain general anesthetics is known. We now manage better those patients receiving adrenal corticosteroids, rauwolfia derivatives, and major tranquilizers. Hyperventilation, hypothermia, deliberate hypotension, and drainage of cerebrospinal fluid are used separately or in combination to diminish brain size during intracranial operations. The threat to the circulation posed by metabolic acidosis and fluid and electrolyte disturbances is better appreciated. These advances have tended to reduce anesthetic mortality in all hospitals, but in some the advances have been balanced by the performance of more extensive surgical procedures upon increasingly ill patients. Cardiac valvular lesions are being repaired; pump-oxygenators have been applied; major blood vessels are being resected; hypothermia has been explored; and radical procedures for malignancy are commonplace.

This same period has seen distinct improvements in techniques of resuscitation. Not long before the start of our study, cardiac arrest or ventricular fibrillation was almost synonymous with death. Open-chest manual systole and internal defibrillation have now been succeeded by closed-chest cardiac massage and external defibrillation. Expired air resuscitation has been firmly established. Transfusions are being used more intelligently. Use of antiacid regimens in the management of the "dying heart"[6] has improved the mortality rate in this condition. Recovery rooms have become a standard of patient care, and efficient mechanical ventilators are available.

Many patients included in this report would probably have survived today because so much more is known than was the case in 1947. A survey of our mortality data for 1960 and so far in 1961 indicates a paucity of deaths attributable in any way to anesthesia. This report therefore offers an encouraging historical perspective.

Finally, we would like to make a plea for a more widespread use of death reports and more detailed discussion of fatalities occurring in patients who have received anesthesia. As indicated, we critically examine deaths of patients who have received anesthesia. There are several consequences of such a practice: The individual anesthetist is forced to review his own responsibility in the death, his associates benefit from his analysis, and common denominators appear as case records accumulate. When additional clinical observations are made and when experiences of others are read and experiments performed, cause and effect relationships previously unrecognized become apparent. By this means, pitfalls are recognized and can be avoided. The result is greater safety for the patient.

Summary

The records of 33,224 patients anesthetized in a 10-year period were analyzed to determine the contribution of anesthesia to death in surgical pa-

tients. The patients were divided into 2 groups, 1 given spinal anesthesia (18,737 patients) and the other general anesthesia and a relaxant (14,487 patients). Deaths considered unrelated to anesthesia were excluded from the study.

The contribution of anesthesia to death was found to be related to the physical condition of the patient. There were no deaths in 16,000 patients in Physical Status 1. As the physical condition deteriorated, mortality increased. No evidence of an inherent toxicity of muscle relaxants could be found in this study. When deaths were related to the use of muscle relaxants, errors of omission or commission were always apparent. A plea is made for the preparation of detailed, written death reports.

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MEDICINE AND SCIENCE II.—In his address opening the Bodley Shakespeare exhibition, Oxford, 1916, Sir William Osler remarked: ". . . Lamarck and Darwin, Wallace and Mendel are only Anaximander, Empedocles and Lucretius writ large. . . ." ". . . Pasteur, Koch and Lister are Varro, Fracastorius, and Spallanzani in nineteenth-century garb." We wonder how valid the great Osler's opinion is.

Of course, science is progressive; every contemporary scientist stands on all the shoulders of all his predecessors. Bernard Shaw said that he stood on the shoulders of Shakespeare and Shaw prided himself on his "scientific" and contemporary outlook. The question, however, is whether the Darwinian ideas and pracice are qualitatively different from those of Lucretius. To ask the question is to make the resounding affirmative. We honor the great of the past for what they were, not for what they are.

It is characteristic of those in the literary, humane, beaux arts tradition to answer our question in an equally resounding negative. At least to a first approximation, homo sapiens artisan is infinite and unchanging in his artistry. "Human nature doesn't change."

Goethe said: "Era loga, vita brevis," and this is certainly true. The humanities deal with individual creation, each ipso facto, and valuable in large measure because of its uniqueness. The conceptualizing of the scientist is certainly different from this apotheosis of the unique.

To the practicing contemporary professional, Anaximander is characteristically useless. Darwin's contribution, the piling up of evidence attesting to the fact of evolution is no longer directly used by the geneticist who has found in mutation the immediate mechanism for speciation. Darwin's interpretation of his evidence—"natural selection"—is no longer particularly appropriate—Acquired characteristics are in general not inherited.

Certainly medicine must always be concerned with humanity, and the humanities, to paraphrase Pope, are the most proper study of man. May we not, however, be betrayed into error by our humanity? Our esteem for our great men inevitably fosters in us all a reverence for their ideas, their personalities, their creations. Their creations, however, frequently are, at best, inappropriate even after the lapse of but half a generation. Osler is wrong, Koch is not Spallanzani writ large. He is a new creation who must be understood and integrated into our science. We must call upon William James and exercise our quality of "tough-mindedness" to inhibit that reverence which arises so naturally from our knowledge of achievement.