

The Journal of Thoracic and Cardiovascular Surgery

VOLUME 42
AUGUST 1961
NUMBER 2

Original Communications

PRESIDENTIAL ADDRESS

THE ROAD AHEAD FOR THORACIC SURGERY

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MEMBERS of The American Association for Thoracic Surgery: I am deeply appreciative of the honor conferred by you in electing me President of this young Association. I say "young" advisedly. Thoracic surgery was in an embryonic state when this Association was founded in 1917. Today thoracic surgery is in its youth and has not yet attained maturity. My own professional life has spanned the last 34 of the 44 years that this Association has been in existence. In these 34 years the surgery for pulmonary tuberculosis has shifted from collapse to exsisional therapy. Thirty-four years ago a one-stage pneumonectomy was unheard of, and lobectomies were performed crudely, using a tourniquet. After the pioneering work of our former presidents, Graham¹⁶ and Blades,³ one-stage pneumonectomies and lobectomies are performed at the present time with precision and individual handling of the arteries, veins, and bronchi leading to the lung or lobe.

Twenty-three years ago, the first successful resection of the esophagus for cancer with restoration of continuity of the gastrointestinal tract was reported by a former president, Adams, and Plemister.¹ Five years later, a former president, Haight,¹⁹ reported the successful treatment of congenital atresia of the esophagus by immediate restoration of continuity rather than with a gastrostomy and a mucous fistula in the neck. Today the entire esophagus can be removed and replaced with another organ within the chest, joining the

Presented at the Forty-first Annual Meeting of The American Association for Thoracic Surgery at Philadelphia, Pa., April 24-26, 1961.

pharynx to the stomach, so that patients may eat normally. The surgical treatment of esophageal hiatal hernia is now a routine operation, thanks to the pioneering efforts of a former president of this Association, Harrington, and the work of our Honorary Member from England, Mr. Philip Allison.

Thirty-three years ago, our former president, Churchill,⁵ performed the first successful pericardectomy for Pick's disease. At that time, the only operations performed on the heart or the pericardium were the drainage of pus from the pericardial sac and the suturing of stab wounds, aside from the early attempts to open stenotic mitral valves by Cutler, Levine, and our former president Beck.⁶

Operations on the thoracic aorta began with the first successful ligation of a patent ductus by Gross¹⁷ in 1939 and the excision and restoration of continuity of the aorta in patients with coarctation in 1945 by Crafoord,⁷ our Honorary Member from Sweden, and by Gross.¹⁸ These operations are now commonplace. Great strides have also been taken in the replacement of the diseased aorta, including even the arch itself, first with homografts and then with prostheses of plastic materials. Our former president De Bakey has made monumental contributions in this field.⁹

A great step forward in the treatment of cyanotic congenital cardiac disease was taken 16 years ago by a former president, Blalock, and Taussig⁴ when they reported the alleviation of the symptoms of the tetralogy of Fallot by the anastomosis of a systemic artery to a pulmonary artery. Operations within the heart were pioneered by Harken²⁰ in 1948 and Bailey² in 1949 with the successful opening of stenotic mitral valves. During the next 7 years, many ingenious methods were devised to operate within the heart by the sense of touch, without being able to see the structure being operated upon. An improvement occurred when the body temperature of patients was lowered sufficiently to permit the interruption of the flow of blood through the heart and lungs for as long as 4 to 8 minutes.²⁴ During this brief interval, the empty chambers of the heart could be opened and the structure operated upon could be seen. Cross circulation between the patient and a suitable donor²¹ was also used for the same purpose until better and safer methods of opening the heart became available.

Eight years ago, your president was fortunate enough to operate successfully within the heart under direct vision and to close a large atrial septal defect.¹⁴ This was accomplished by using an extracorporeal circulation which temporarily took over the function of the heart and lungs. The development of this extracorporeal circulation was begun in 1934, and its successful use in animals was reported in 1937 and 1939.^{12, 13} At present, prolonged delicate operations within the opened chambers of the heart are performed all over the world, using either an extracorporeal circulation to bypass the heart and lungs, or hypothermia, or a combination of the two. The surgical conquest of the heart has been achieved.

This brief review of some of the highlights in our field of surgery necessarily skips over much important work. These achievements of thoracic surgery would have been impossible without many concurrent developments in other fields.

The availability of heparin some 25 years ago opened the way for the development of the extracorporeal circulation. First sulfonamides and then antibiotics have aided in eliminating the crippling empyemas which so commonly occurred when thoracic surgery was in its infancy. Improvement in anesthetic techniques and an increasing and more widespread knowledge of cardiopulmonary physiology has enable many patients to survive operations which formerly were attended with a forbidding mortality.

And so thoracic surgery stands at the threshold of manhood. Much has been accomplished, yet much remains to be done. As Tennyson said: "Some work of noble note may yet be done."²⁶ We must inevitably move forward. We can no longer accept our pioneering mortality. We must increase the safety of the formidable operations we now perform within the thorax. We still know little more than our forebears about the nature of achalasia of the esophagus. We are beginning to treat that crippling respiratory disease, emphysema, by surgical methods. We have made little if any progress in improving the blood flow to an hypoxic myocardium. This problem must and will be solved. We have made a start in replacing deformed and diseased valves of the heart with artificial valves. We have also made a start in providing artificial pacemakers for the heart in a number of disease states, including the Stokes-Adams syndrome.

Homografting of organs has, with one or two exceptions, only been successfully accomplished in identical twins.²² Surgeons have the incentive to explore this field, and it may be that they will be able eventually to control the phenomenon of rejection by the host, so that hearts and lungs may be successfully homografted. We now have mechanical hearts and lungs capable of performing the cardiac and pulmonary functions outside the body. Will we be ingenious and clever enough to develop such artificial structures for use within the body? Indeed, one member of this Association has been so bold as to predict that artificial hearts within the thorax will be an actuality in 2 to 5 years.

We are just beginning to explore the effects of cold on cells, tissues, and organs. Much remains to be learned about rapid cooling and warming of the whole body and the biochemical effects of different rates of cooling and warming of the organs of the body. Hibernation is still a mystery. The solution of this mystery may have vast implications in the field of surgery. The preservation of the cellular elements of the blood without disruption of cellular structure by ice crystals, by controlling of the speed of cooling and the use of glycerol, is only a start. Much remains to be learned about the effects of temporarily slowing down metabolism by lowering the temperature. This knowledge is needed for the successful preservation of organs and tissues preparatory to homografting. It is an exciting age to live in, and I wish I were young again!

How shall this transition of thoracic surgery from youth to manhood be accomplished? What is needed to solve the problems which lie before us? Money is required to support investigators and technicians and to buy equipment and supplies. Laboratory space is needed in which to work. The money is here in abundance. The Department of Health, Education and Welfare

spent 44 million dollars in 1953 for medical research and 176 million dollars in 1958,¹⁰ a fourfold increase in 5 years. There are hundreds of well-equipped surgical laboratories in this country and Canada and in many other parts of the world. These, however, are merely tools. The essential requirement is the investigator himself who must use these tools to dig knowledge from the morass of ignorance around us.

Many young men are studying today some of the problems which I have mentioned as well as many others. Have they been properly educated in the methods of scientific investigation? Are they being lent a guiding hand when needed by someone experienced in these methods? Have they been properly chosen to undertake these tasks? Are they engaged in research because of a genuine desire and excitement in solving a problem and contributing to man's knowledge? Or is the work an unimaginative chore to be gotten through with as quickly as possible and the results rushed into print, in order to further their advancement in academic rank in medical school and their professional reputation? Without impugning the integrity of the many devoted investigators working in our surgical laboratories, I fear the answer to the latter question is all too frequently in the affirmative. This is an unhealthy situation which results in the publication of many mediocre or worthless articles which should never see the light of day. Many good young surgeons interested in teaching and practice, I am sure, feel frustrated and baffled by this constant pressure to engage in research and to publish. As the Prophet said of the teacher, "If he is indeed wise, he does not bid you enter the house of his wisdom, but rather leads you to the threshold of your own mind."¹⁵

It is true that the good investigator is frequently an excellent teacher, but this is not invariably so. It is also true that an excellent teacher may have never engaged in research. Certainly the great medical schools of our country should have a place on their faculties for those who teach and investigate, and for those who teach but do no research.

Now let us consider the qualities of the man who is most likely to provide the solutions to some of the riddles confronting us. First of all, he need not be Nietzsche's Superman,²³ but he must be honest with himself and others. As Polonius said, ". . . above all, to thine own self be true, and it must follow, as the night the day, Thou canst not then be false to any man."²⁴ The investigator must have a deep-seated integrity. His passion must be the discovery of the truth. He must be critical of any slipshod work on his part. He should not be anxious to report premature results, but should wait until his work is finished and has been well controlled. His desire should be to be right, and to produce the evidence that will convince others that he is right. The seeker after truth, therefore, must be the incorruptible man. If he be otherwise, he will not find the truth, but only illusory shadows of the real world which will mislead others as well as himself.

Second, this incorruptible man must have great patience, persistence, and industry. He must be willing to devote infinite attention to detail. He must cultivate preciseness. He will often be discouraged. What true investigator has not been? Picture Johann Kepler, working for 22 years, seeking to discover

the laws of planetary motion from Tycho Brahe's precise observations of the positions of the planets. Had Kepler been easily discouraged, he would never have formulated those majestic laws of motion of the planets around the sun.

Men with the qualities I have mentioned may never engage in research because they have no desire to do so. Frequently a brilliant medical student who graduates at the top of his class and has the aforementioned qualities may be put under pressure by the faculty of his medical school to engage in research. This is understandable, but undesirable. If a man does not want to do research, he will never be an investigator. The best way for a man to discover whether he is interested in research is for him to spend a period of time, seldom less than a year, working under supervision in a laboratory. During this trial period, he will discover whether research appeals to him or not; his supervisor will also quickly learn whether the beginner is a "self-starter." The man with potentialities as an investigator will see problems that need solution and will outline methods of approaching these problems. The methods he proposes may be inadequate because of his inexperience, but the fact that he recognizes the incompleteness of his knowledge in a certain area, and that he formulates an attack upon the problem, indicates that he is a potential investigator. On the other hand, the individual who spends the year intelligently and faithfully carrying out the suggestions of his supervisor, adding little or nothing of his own to the solution of the problem under consideration, is not the man to continue to do research.

I would thus suggest that in every institution where surgeons are educated and research facilities exist, the opportunity be presented to the embryo surgeon of spending a year in a laboratory if he so desires. Both he and his mentor will have a good idea at the end of that period as to whether he has a capacity for research. If he has not, the time will not have been misspent, because the year's experience will enable him to be a more critical reader of surgical literature during the rest of his professional life. On the other hand, he may experience a genuine excitement in discovery and great satisfaction in devising experiments which will indicate the truth or falsehood of his concept. This man is the true investigator. He must be encouraged and supported because he is the one who will add to the store of human knowledge.

Having discovered the man, how can we best further his progress? It is my belief that having completed his formal surgical education, he should then spend some time under the tutelage, guidance, and discipline of an experienced investigator. I believe that this second period is best spent at an institution other than the "parent" one, and that the investigator under whom he works should be engaged in research in one of the sister disciplines of medicine rather than in surgery. Both suggestions are made for the purpose of giving the young investigator greater perspective. This second period of research should prove to be an invaluable experience. The young investigator will learn something of the scientific method, how to use the necessary tools, the necessity for control experiments, and something about the errors in his methods and in his results.

In planning this second period in research, the young surgeon should select the investigator rather than the subject. He will learn from the man rather than from the subject under investigation. This, of course, is true of all educational experience. Any subject can be fascinating when illuminated by the mind of an inspiring teacher and investigator. I realize that others would point out the desirability of sending young surgeons who are potential investigators to other institutions to learn the techniques, tools, and methods of some basic science which might prove fruitful in its application to surgery. Nevertheless, the heart of the matter is the philosophy, the approach, the conduct of the experiment, and the handling of the results. This is the very essence of science and the scientific method. If the technology in a special field is essential to the solution of a problem, it can and will be learned easily. To put the technology before the philosophy of the scientific method is to put the cart before the horse.

Now as to the actual conduct of the research, perhaps the easiest way to approach the subject is to point out some common errors which may be made by the inexperienced. I shall discuss six of these. One is the failure to be aware of pertinent work by others in the field of investigation. The second is the failure to make a detailed plan of the conduct of the experiment or the failure to adhere to such a plan, when and if made. The third is the failure to evaluate continually the work in progress by calculating and studying, day by day, the results of the experiments performed. Fourth is the failure to perform adequate control experiments and to appreciate the errors in the techniques employed. Fifth is the failure to report *all* results no matter how bizarre they may appear. The sixth error is the drawing of unwarranted conclusions from the evidence.

The first error—not knowing the work of others in the field—is the least of the errors. Confirming the work of others, or repeating the work independently by a slightly different method, has value in itself. However, failing to give credit to the work of others in reporting one's own results is an egregious error and can be the source of great embarrassment, no matter how innocent the omission. This mistake is not likely to occur often because reading and studying the results of others in the field of inquiry should not only precede the research but should continue during the conduct of the experiments and, by the time the work is finished, the investigator should be well conversant with the results of others.

The second error—the failure to make a detailed plan—is not uncommon among the inexperienced. The youthful and enthusiastic investigator may perform a series of experiments, modifying each succeeding one in order to improve it, hoping like Mr. Micawber¹¹ that something better will turn up. After much hard work has been expended in this fashion, the investigator ends up with a series of observations, each one differing slightly from the one before, and with results, therefore, from which no valid conclusions can be drawn. One should make a careful distinction between such haphazard work and the performance of pilot experiments designed to help the investigator to arrive at a detailed plan, to which he must thereafter adhere. Such pilot work may prove to be a great saving in effort, time, and money.

The third error—failure to calculate and study the experimental results while the work is progressing—is a common fault in the unsophisticated investigator. In making the original detailed plan, some variable may have been overlooked which may vitiate the experimental results. Continued careful analysis of the results of the experiments in progress will reveal such an overlooked factor and obviate the performance of experiments without value. When such an overlooked factor is surely discovered, the plan of the experiment must then be altered. This continuous current analysis of results is always carried out by the sophisticated investigator to ensure that he remains on the path of exploration which he originally intended to follow.

The fourth error—the failure to perform control experiments—is perhaps uncommon. However, the control experiments performed may be inadequate or of insufficient variety. The investigator must be sure that the results he is reporting are due to the conditions which he has set up and not to some extraneous factor. Some control experiments may be performed before beginning the investigation, others concurrently with the investigation, and still others when the research has been completed. Those performed at the start are generally done to determine the errors inherent in the techniques to be employed. For example, duplicate determinations of cardiac output on normal individuals would certainly be performed before studying cardiac output in patients with pathologic conditions. The control experiments performed during the course of the investigation, and those performed at its conclusion, arise from an analysis of the experimental results and a realization that additional controls are necessary to rule out certain variables which may have influenced the results obtained.

The fifth error—failure to include all observations in reporting results—arises from human frailty. Our postulated, incorruptible man would be incapable of making this error, yet I suspect that it occurs more commonly than is realized. Suppose a series of experiments are performed with uniform and consistent results which tend to support the hypothesis which the investigator originally made and then, one day, the results of an experiment turn out to be grossly at variance with all the previous results. Regardless of how the researcher racks his brain to explain this sport, he is unable to see how the experimental procedure varied one iota from all the preceding experiments. What is more natural to the unsophisticated than to conclude that the experiment must have been performed under conditions differing from the others, although he is unable to say how it differed? Hence, the erroneous conclusion is reached that the results of this particular experiment should be discarded. To the sophisticated investigator, on the other hand, such a sport is welcomed and reported. A too consistent nicety of results disturbs him and an occasional sport is reassuring. There has been more than one instance in which a technical assistant has arranged matters so that the results which the investigator desires are consistently achieved beyond his fondest hopes. In my own laboratory, a number of years ago, we discovered that a technician was arranging the experimental results in this fashion.

The sixth error—drawing unwarranted conclusions from the evidence—is common in clinical reports in the surgical literature and is not uncommon in the reporting of research results. In the first place, the evidence may be insufficient to justify the conclusions drawn. For example, numbers in a series less than 100 have been expressed in terms of per cent sometimes carried to the first, or even to the second decimal point. This, of course, is absurd. The concept of significant numbers should be thoroughly comprehended by the young investigator. If a measurement can be justifiably expressed in only three significant numbers, then the results of calculations from these measurements cannot be expressed in four or five significant numbers. The figures would then indicate a degree of accuracy greater than was possible in the original measurements. This seems so obvious from the common sense point of view that it hardly needs stating, yet the surgical literature abounds with examples in which this is done.

Another mistake in reporting results is to apply elaborate statistical methods to figures which are quantitatively and qualitatively insufficient to justify such treatment. Inspection and common sense will frequently provide the clue as to what conclusions are justified and what are not. Finally, if results are reported accurately and completely, a good summary at the end of the article will frequently serve to round out the report, allowing the reader to draw his own conclusions from the evidence.

The following summary of my remarks is a good example of drawing conclusions from inadequate evidence or, indeed, from no evidence at all except the writer's experience and convictions. We have passed through a period in which thoracic surgery has shown an amazingly rapid growth. Much still remains to be done to increase the safety of the operations we perform, to learn more about the diseases we treat, and to devise methods and techniques for the therapy of diseases and congenital abnormalities which are now beyond the scope of our surgical capabilities. We have finances and laboratories but we need properly qualified and motivated men to find solutions for the problems which confront us. I believe that the subtle, or sometimes obvious, pressure on young surgeons today to engage in research should be done away with. The stimulation of the association with an experienced investigator should be all the incentive needed to arouse curiosity and interest in the younger members of our profession. Society will be better served by the concentrated endeavors of a few properly motivated and qualified investigators, adequately supported, than by the unenthusiastic and disinterested work of the many. I am confident that the future generation of surgical investigators will contribute to human knowledge in general, and thoracic surgery in particular, far more than those of us who are finishing our "work in the vineyards of surgery."⁶

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