Clinical Anesthesia

Instrumentation and Anesthesia

Wm. H. L. Dornette, M.D. / Editor

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Introduction

Clinical anesthesia as we know it today had its beginning some one hundred and twenty years ago. Its advent signaled the end of an era of physical pain and emotional trauma. It heralded the beginning of a science and an art that have striven continually for the perfection of the anesthetic state and the surveillance of patients placed in that state. The science of medical anesthesia, along with that of surgery, has advanced over the years, especially during the past several decades. The advances of each science have tended to complement those of the other. Operative procedures of greater and greater hazard are being undertaken, and on patients of poorer and poorer physical status. This increasing boldness on the part of the surgeon has been supported and nurtured by the increasing skills of the physician-anesthetist. As the risk of anesthesia and operation has been compounded, there has developed an increasing need for methods of assessing more carefully, more completely and more or less continually the condition of patients before, during and following anesthesia and operation.

Research and development in the manufacturing field have paralleled the advances in the medical and scientific areas. The modern physician, in consequence, has available for his use a multiplicity of devices that were unheard of just a few short years ago. In the field of physiological monitoring, many instruments are at hand for assessing a wide variety of phenomena. Competition in the marketing of these devices is quite keen, and in many instances more than one manufacturer produces more than one system for a given purpose. To the legitimate facts about such systems must be added a plethora of advertising claims, counterclaims, half-truths, and meaningless information. All of these factors have made the science of monitoring complex; so complex, in fact, that in many instances physicians are confused. They may be hard-pressed to answer such basic questions as: What parameters or parameter should be monitored? Why? How should this parameter be monitored? What are the relative merits of different monitoring systems designed for a given purpose?

One of the purposes of this issue of CLINICAL ANESTHESIA is to transmute this confusion into order; to bring monitoring and instrumentation* out of the closet of the electronics engineer and advertising copywriter and into the daylight of elucidation at scientific levels. To this end the editor has assembled a group of authors who have worked in their specific areas of patient monitoring for some time. Each of these individuals has become an expert in that particular area. The information that he or she imparts—indications, applications, limitations, equipment, interpretations and significance of results, problem of artifact, and other aspects of monitoring—

* These terms are closely equated but not synonymous. See page 2.

is presented in depth. Up-to-date bibliographic references are included to afford the reader access to further information.

In contrast to most issues of CLINICAL ANESTHESIA, this one is not necessarily written to be read through from cover to cover, as one would read a novel. It is suggested, however, that the reader first peruse the material contained in Chapter 1, especially if he is not interested in a particular aspect of monitoring covered by a specific chapter. This first chapter discusses some of the basic fundamentals of instrumentation. It answers the questions of why, what and how to monitor in a general way. Each of the subsequent chapters is complete in itself, however, and the reader need not review any one chapter as a prerequisite to understanding a subsequent one.

Chapters 2 through 8 cover specific aspects of patient monitoring, and the titles are self-explanatory. The initial chapters tend to deal with systems that are used generally, the final chapters with devices used more specifically. Chapter 9 elucidates one physician's ideas on monitoring in the operating room. Practical and ideal as well as actual (and often not-so-ideal!) aspects are considered. The treatment is down-to-earth and somewhat philosophical. It is suggested that all readers, no matter what their specific interests, review this chapter. Chapter 10 considers central monitoring from historical, theoretical and practical standpoints. The advantages to the employment of such a system in an intensive care facility and recovery room are mentioned. There also is a brief discussion on how a hospital may install a low-cost system. Chapter 11 contains hints on what will or might be in store for us in the future. A glossary of commonly employed terms is included on pages 187-190. The index rounds out the material.

The authors have covered their particular areas of instrumentation as they see fit. The treatment of individual subjects thus varies quite widely. Some material is presented to a high degree of complexity. The editor realizes that not all readers will be interested in all the information contained herein. He realizes, too, that each reader's interest, background, and need for information will vary widely. Every effort has been made, however, to present material to as broad a readership as possible. Admittedly, certain aspects of monitoring are slighted, some in part and some completely. The material selected is, in the opinion of the editor, the most pertinent necessary for everyday patient care, and for an understanding and appreciation of the present status of monitoring the candidate for clinical anesthesia.

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Editor of Clinical Anesthesia 2/1964

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Contents

Chapter 1

Fundamental Considerations

William H. L. Dornette, M.D.

The importance of monitoring the patient during anesthesia and operation is obvious. Yet monitoring is a generic term that may mean many things to many people. What monitoring is and how it can be fitted best into the over-all pattern of patient care may not be so obvious. The term "monitor" comes from the Latin word *monere* which means *to warn.* The monitoring system or systems that we employ during anesthesia and in the postoperative period serve to warn us of serious or potentially serious changes in the condition of our patients. The terms "monitoring" and "instrumentation" often are used interchangeably. They are not synonymous, however.

WHAT IS MONITORING?

While we usually employ instruments for monitoring, we do not always do so. Many monitoring tasks still can be performed solely with the physician's own five senses. Conversely, instrumentation (with monitoring equipment) usually, but not necessarily, is monitoring. For example, the physician can become so wrapped up in his instruments that *the monitoring of the patient is neglected!*

Monitoring must be approached on a scientific basis and with a definite purpose in mind. The use of a monitoring system may be likened to use of anesthesia. As a prerequisite to selection and administration of an anesthetic, the physician first must become aware of the patient's past history, present illness and physical findings. He also must know what operative procedure is contemplated, and what the surgeon's needs for that procedure will be. The physician then takes stock of his "bag of tricks" and decides which combination of agent (s) and technique (s) will best fit the pattern woven by the interaction of the needs and desires of the patient, surgeon and himself. Choice of an anesthetic agent is a rational decision deducted from a group of scientific facts. Selection and employment of a monitoring system should be a like decision, since monitoring is a scientific procedure based upon scientific disciplines (physics, mechanics, electricity and acoustics as well as biomedicine and physiology).

SELECTION OF A MONITORING SYSTEM OR SYSTEMS

As with selection of an anesthetic, selection of a monitoring system involves three individuals: the *patient,* the *surgeon,* and the *physician* who will *administer the anesthetic.* Certain indications and applications relate to each of these individuals. Table 1 outlines this information.

The ultimate aim of any monitoring system is to enhance patient safety. An increase in either complexity of a given monitoring system or number of systems used in itself does not assure a net increase in safety.* For

* This and the following statements refer to devices employed for more-or-less-continuous patient surveillance during and following anesthesia and operation. Not all instruments described in this issue of CLINICAL ANESTHESIA are designed to be so employed. The fact that these instruments do not meet all or any of these criteria does not imply that they are not "good" monitors.

Table 1. Indications for Monitoring*

	Arterial pulse, finger on	Blood pressure, direct	Blood pressure, indirect	Blood volume determ.	Electrocardiography	Heart sounds, stethoscope	Electroencephalography	Chromatography, gas	Respiratory CO_2 content	Respiratory depth	Thermometry
Needs of Patient											
Candidates for anesthesia, all	...	...	★	...	...	★	...	...	...	★	...
Cardiovascular disease, mod. to severe	★	...	★	...	★	★	...	...	...	...	...
Circulatory arrest, prior	★	...	★	...	★	★	★	...	...	★	...
Hypovolemia	★	...	...	★	...	★	...	...	...	...	...
Shock	★	...	★	★	...	★	...	...	...	...	★
Carcinomatosis	...	...	...	★	...	...	...	...	...	...	...
Geriatric problems	...	...	...	...	★	...	...	...	★	★	...
Endocrine and miscellaneous											
Carcinoid, malignant	...	...	★	★	★	...	...	...	...	...	...
Diabetes	...	...	...	...	...	...	...	...	★	★	...
Hyperthyroidism	...	...	...	...	★	★	...	...	...	...	...
Hyperthermia	...	...	...	...	...	...	...	...	★	★	★
Kyphoscoliosis	...	...	...	★	★	...	...	...	★	★	...
Pheochromocytoma	...	...	★	...	★	...	...	...	...	...	...
Hepatic disease	★	...	★	★	...	★	...	...	★	★	...
Pediatrics	...	...	...	...	...	★	...	...	...	...	★
Respiratory disease, mod. to severe	...	...	...	...	...	...	...	...	★	★	...
Needs of Surgeon											
Cardiac operation	★	...	...	...	...	...	...	...	...	...	...
Hypotension, induced	...	★	★	★	...	...	...	...	...	...	...
Hypothermia											
Moderate	...	...	★	...	...	...	...	...	...	...	★
Marked	...	★	★	★	...	...	...	...	...	...	★
Needs of Physician-anesthetist											
Good patient care during anesthesia	...	...	★	...	...	★	...	...	...	★	...
Research with new agents and techniques	★	...	★	...	★	★	★	★	★	★	...
Pedagogy	★	★	★	★	★	★	★	★	★	★	★
Recovery Room—ICF needs (page 170)											
Exchange transfusion	...	...	...	...	★	★	...	...	...	...	★
Renal dialysis	...	...	★	...	★	...	...	...	...	...	★
Atrial defibrillation	★	...	★	...	★	...	...	...	...	...	...
Neurologic damage, post arrest	...	...	★	...	★	...	★	...	...	★	★
Page reference, this book		10	24	128	62		88	146	36	36	110

*See also chapters in this book covering specific monitoring techniques.

example, a given system may: be annoying or hazardous to apply to the patient; overly crowd the operating room; compromise asepsis; prevent use of a flammable (but superior) inhalation anesthetic agent; detract from patient care; or be hazardous in other ways. Therefore, before the reader contemplates purchasing a given system, he should consider it within the total context of anesthesia and surgical care of the patient, and from a practical standpoint. Monitoring devices are designed and constructed by engineers who are practical men. We, as users, should be no less practical.

To be of value, a monitoring system should meet the following criteria. The system should be:

1. **Easy to apply to the patient.** The task of connecting the patient lead or leads should be straightforward and not overly time-consuming.

2. **Safe to apply to the patient.** The less hazardous the attachment or insertion and maintenance of lead (s) the better.

3. **Easy to operate.** It should be possible for the physician to administer the anesthetic and operate the instrument more or less simultaneously. The need for a second individual to operate the monitor (s) obviously is impractical for everyday patient care, except in special circumstances.

4. **Safe to operate.** Operation of the instrument should in no way compromise safety of the patient or anyone in the room.

5. **Worthwhile.** The device should detect physiological signals that are meaningful, and make information anent these signals available immediately or almost so. The trace on the screen of a cathode ray oscilloscope employed to assess electrocardiographic activity during a cardiac operation is an example of meaningful data immediately available.

6. **Able to produce a permanent record as needed.** Many physiological events are of interest only if compared to those events which precede and succeed. Hence, the need for a record to establish trends. The multiplicity of duties of the physician during, and of the recovery room nurse following, anesthesia makes a record-producing instrument almost a necessity. This ability to produce a record should be an optional feature, since it does increase markedly the cost of a given instrument.

It must be reemphasized that the just-cited criteria define an ideal device or system, one which may not as yet have even been designed. A system already on the market may fall short of meeting one or more criteria. The perspective purchaser should consider how a given device meets each criterion, and compare the device to competitive instrument (s) within the same context. There is no, and may never be an, ideal system and the merits and disadvantages of a given system must be assessed relatively with those of another comparable system or intrument.

SIMPLE VERSUS COMPLEX INSTRUMENTS

In many instances, two vastly different monitoring devices or systems are available to assess a given physiological signal. In general, the simpler device is easier and quicker to apply, costs less to purchase and operate, and produces fewer maintenance headaches than the more complex instrument. Complex devices usually possess one or more features which cannot be a part of the simpler version. Such a feature may relate to automaticity of operation, ability to produce a permanent record, or both. An example of two such systems is the blood pressure cuff-hand bulb-manometer-stethoscope combination and one of the complex devices that automatically checks the blood pressure at regular intervals. In comparing two systems with characteristics which differ so widely, one must take into consideration criteria in addition to those just cited; viz:

1. Has the complex system been perfected and accepted to a degree that it will not become obsolete or otherwise abandoned in the near future?

2. Will the disadvantages of the more complex instrument be offset by its ability to save enough time or effort; or allow other tasks to be carried out better or sooner; or produce a more accurate or more frequent indication or recording; or permit signals to be detected with greater accuracy or sensitivity?

MONITORING WITHOUT INSTRUMENTS

Since this issue of CLINICAL ANESTHESIA relates primarily to instruments used for patient monitoring, little effort has been made to stress the subject of monitoring without instruments. Many phases of monitoring, however, can be carried out by the physician using his own five senses solely or primarily. For example, the physician looks at the skin to judge cyanosis; feels it to estimate skin temperature; squeezes the rebreathing bag to assess adequacy of ventilation and patency of the airway; palpates one of the peripheral pulses to judge its fullness, count heart rate and check for the presence of gross arrhythmias; and smells the gas escaping from the pressure relief valve to estimate roughly the concentration of certain inhalation agents.

In some instances, using the physician's own five senses is the best, and at times the only, way to perform certain tasks of monitoring. Everyone should keep this basic concept in mind, especially in view of the high cost of some monitoring devices and the *desirability of preventing or minimizing further increases in the cost of patient care.* Clinical anesthesia has not yet reached the stage wherein one individual can administer more than one anesthetic simultaneously. Very elaborate and completely automatic monitoring systems may not be really necessary except in certain experimental situations. Therefore, *I make a plea for simplicity in monitoring when practical.*

HOW INSTRUMENTATION SYSTEMS FUNCTION

Fundamentally, two types of systems are employed for patient monitoring—those which merely augment one or more of man's own five senses, and those which are more complex. A classic example of the former type is the anesthesiologist's best friend, the stethoscope.[2] More complex systems, which run the gamut from the electroencephalogram and electrocardiogram to devices which determine at periodic intervals respiratory rate, blood pressure, pulse rate, temperature and the like are described elsewhere[1, 4, 5] and at varying locations throughout this book. All of these systems, no matter how complex, operate on certain basic principles which have comparable counterparts in man's own monitoring network, the so-called somesthetic system.[3] The function of man-made systems resembles so closely that of the neurophysiology of human instrumentation that a direct comparison is germane. Whether a human or man-made monitor is to be employed, the signal must be *detected, transduced, amplified* and *read out* (converted to meaningful and useful information). In the following tabulation a mercury thermometer and an "educated" hand are compared.

Mercury Thermometer	Educated Hand
Detection	
Temperature is detected by placing the reservoir (sensing) bulb of the thermometer in direct contact with the skin or mucous membrane of the patient. The temperature of the mercury soon reaches equilibrium with that of the environment surrounding the bulb.	As the physician squeezes the rebreathing bag, pressure against the palmar surfaces of his hand and fingers affects Meissner's and Vater-Pacini's corpuscles located in the skin and subcutaneous tissues. Movement of the fingers is detected by muscle spindles which are responsive to stretch and tension. Golgi corpuscles sense tendon movement.
Transduction	
The coefficient of expansion of the mercury produces a change in its volume in direct proportion to the change in temperature.	Meissner's, Vater-Pacini's, and Golgi's corpuscles and muscle spindles act as transducers and convert stretch, pressure and mechanical movement into electrical signals.
Amplification	
The changes in volume of the mercury are amplified by directing the mercury into a small capillary tube. The apparent size of the tube is amplified by shaping the thermometer stem in the form of a longitudinal lens.	The electrical signals are conveyed to axons entering the dorsal horn of the gray matter of the spinal cord. There the axons synapse with dendrites of neurons of the spinothalamic tract. The signal ascends in this tract to again synapse in the thalamus. The signal subsequently reaches the appropriate area of the cerebral cortex. Amplification of the signal can occur wherever terminal arborizations of one neuron synapse with the dendrites of more than one neuron.
Readout	
The height of the mercury in the capillary is compared to calibrations on the thermometer stem, and the temperature read directly from these calibrations.	Man interprets the electrical signals reaching the cerebral cortex as adequacy or inadequacy of ventilation and patency or lack of patency of the airway. The information then may be stored in memory cells or made to operate motor fibers to enhance assistance of respirations or check for causes of respiratory obstruction.