

Sources of Measurement Error in Noninvasive Electronic Instrumentation

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Technologic advances during the past 20 years have resulted in the increased use of electronic instruments for the surveillance and monitoring of hospitalized patients. Growth in the use of instrumentation has been phenomenal: The first coronary care units were set up as recently as the early 1960's, and today 75 per cent of all inpatient facilities of greater than 100 beds have coronary care or intensive care units containing sophisticated electronic devices.² Cardiac monitors, respirators, hypothermia machines, and dialysis equipment are now regarded as essential to direct patient care. Electronic instruments maintain records, aid diagnosis, and provide research data. The potential uses for electronic instrumentation in the health care area are seemingly endless, and an ever-increasing extension of use is to be anticipated.

Nursing concerns reflect this increased use of instrumentation. Instruments assist nurses by providing information to help them survey change, monitor physiologic parameters, and perform treatments knowledgeably. They extend the range and degree of the nurse's ability to sense and record data, thus supplying a more accurate and reliable foundation for clinical judgments.

In order to provide knowledgeable and safe care, nurses using instrumentation must have some understanding of the purposes and functions of the instruments. They must have an appreciation of instrument capability and fallibility; they must understand the common sources of measurement error; and they must know how to take steps to decrease the amount of error. They must understand why an instrument is being used, what it does, and how it does it.

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INSTRUMENT CLASSIFICATION

An *instrument* is any device that is used to extend the human senses. Examples of instruments used in nursing include thermometers, sphygmomanometers, cardiac monitors, and defibrillators. Some of these instruments gather data; some of them provide treatment. Some are invasive; some are noninvasive. Some are electronic; some are nonelectronic. Some are confined to special settings; some have broad usage. Many instruments fit into several of these categories or into a combination of categories.

For example, the common clinical thermometer may be electronic or nonelectronic. Although it is primarily a data-gathering device, it can be incorporated into a hypothermia machine to provide temperature set-point control for treatment procedures. A thermometer is classified as an instrument because it extends the sense of touch. Patient care is improved by the increased accuracy in temperature measurement that it provides, and this information is used as the basis for valuable clinical judgments and action.

Treatment-providing instruments include dialysis equipment, cardiac defibrillators, and the sphygmomanometer (when used in a rotating tourniquet procedure). Monitoring and surveying instruments elicit data reflecting physiologic parameters needed by the nurse; examples include stethoscopes, thermometers, and various types of monitors.

Electronic instruments require either alternating or direct current in order to operate. Generally, any instrument that plugs into a wall outlet or needs batteries is called *electronic*, and any instrument that does not is called *nonelectronic*. Examples of nonelectronic instruments are Wright respirators, glass thermometers, stethoscopes, and manual mercury sphygmomanometers.

Noninvasive instruments employ surface attachments. Although they may enter body cavities, penetration of the skin or mucous membrane is not required. *Invasive instruments* do penetrate the body surface. For example, pressure monitors that require arterially placed catheters are invasive instruments. Other examples of noninvasive instruments are the electrocardiograph, the thermometer, and many endoscopes.

By extending the limits of sensory perception, instruments provide additional data upon which clinical decisions can be made. Nurses also use instruments to provide treatment and to gather research data. Instruments are used for patient care in all settings where nurses work. Instruments are not infallible, however. This paper explores some common sources of measurement error in the use of instruments, concentrating on noninvasive, electronic, data-gathering, and monitoring devices that are commonly used in inpatient settings — specifically, the cardiac monitor, radiotelemetry units, and temperature-sensing devices.

THE PATIENT-INSTRUMENT-NURSE SYSTEM

An electronic instrument, when applied to a patient, senses a physiologic parameter and processes it. The instrument gives a reading that is a direct reflection of that parameter. The parameter, in its final form as a displayed measurement, is perceived by the nurse and acted upon. The instrument is incapable of terminal data evaluation; it cannot make final judgments or take action. It is the nurse who determines the measurement's impact on patient care. For instance, an alarm on a cardiac monitor can be triggered either by lethal arrhythmias or by a harmless muscle artifact; the nurse must respond appropriately to the meaning of the alarm.

The measurement provided by an instrument is considered to be a direct quantitative and qualitative reflection of the physiologic parameter sensed, but it should not be assumed that the measurement is an absolute counterpart of the sensed parameter. All instruments function within certain design limitations and capacities, and these must be considered in measurement interpretation. Instrument limitations determine the accuracy, precision, and reliability of the measurement obtained. The measurement can be erroneous owing to incorrect application of the instrument. The following definitions should help to explain the properties and limitations of instruments.

Characteristics of Instruments

The *range* of an instrument is the set of physiologic values over which it operates.² Range is limited by human characteristics. A thermometer with a range of 0° C to 100° C, for instance, would be impractical for monitoring human temperatures because its range is excessive for human temperature values.

The *frequency response* of an instrument is its ability to produce a response that will parallel both rapid and slow changes in the event presented to it.⁴ In an electrocardiographic tracing, for example, it is desirable to have the instrument equally sensitive over the entire range of the parameter sensed (the cardiac cycle) to ensure its faithful reproduction.

Sensitivity refers to the degree of change in the physiologic parameter that the instrument is able to detect. It should be appropriate to the information desired: A thermometer insensitive to temperature variations of less than 5° C would not be clinically useful.

Highly sensitive instruments measure small changes. The display or output signal should reflect the input units of change being sensed by the instrument; it would be useless to have a thermometer sensitive to small changes in temperature if the changes were not reflected in the

display. Thus, sensitivity determines *resolution*, which is the minimum variation that can be read on the display. Sensitivity is often expressed in scale length per measured quantity — for instance, as millivolts per degree.³

Stability refers to the instrument's ability to maintain calibration. Any instrument is said to be calibrated when it accurately measures known quantities under known conditions. Instruments that drift from calibration quickly are less stable than those that hold calibration for long periods of time. All instruments have some degree of instability.

Linearity is the extent to which an input change from the sensed physiologic parameter is directly proportional to an output change, as reflected in the measurement.³ An example of linearity is the extent to which a 0.1° C change in temperature is reflected as a 0.1° C change on the thermometer that is assessing it.

Hysteresis is a characteristic reflecting a fading away above or below a linear relationship in the output trace of an instrument. Usually, specifications of the instrument provide for dampening of the oscillation so that a clear (linear) trace is obtained.

Signal-to-noise ratio refers to the extent to which an electronic instrument allows unwanted input signals to be processed along with desired input signals. The higher the ratio, the more noise or artifact eliminated from the measurement — that is, the clearer and truer the measurement.³

Characteristics of Measurements

All these characteristics of instruments will directly affect the accuracy, precision, and reliability of the measurements provided. The *accuracy* of a measurement is the degree to which the parameter, as displayed on the instrument, reflects the actual value. If body temperature is 36.99° C and the thermometer measures it at 37.01° C, the reading is inaccurate by 0.02° C. *Precision* is the discriminatory power of the instrument in sensing changes. The smaller the change sensed, the greater the precision: A thermometer that indicates each 0.01° C change in temperature provides more measurement precision than one that indicates every 0.02° C change. *Reliability* refers to measurement accuracy over time. A measurement is reliable if an unchanging parameter is reported over time to be unchanging.

While accuracy, precision, and reliability are measurement characteristics, they are also qualities ascribed to the instrument. The extent to which they are desired in clinical measurement determines the limits of range and sensitivity required of the instrument.

SOURCES OF MEASUREMENT ERROR

Measurement error can occur at one or several points within the patient-instrument-nurse system. In Figure 1, the instrument consists of a transducer, a signal processor, and a signal display unit. When the instrument is attached to a patient — in this instance by a noninvasive interface — it transmits data that is interpreted by the nurse-perceiver. The transducer is that portion of the instrument that senses physiologic parameters, converts them into an electrical signal, and sends the signal to the processor. Following this, the processor modifies and conditions the electrical signal for display by one or several units. The display unit may be housed within or apart from the processor; if apart, it may be located close by or some distance away (as in radiotelemetry). It is the display that is perceived and interpreted by the nurse.

If the transducer is faulty, it may send electrical signals that do not accurately reflect physiologic events, and thus measurement errors will occur. Sometimes the transducer-relayed information may be accurate, but a faulty processing unit will display erroneous measurements. Again, it may be the nurse-perceiver who reads the information incorrectly. The nurse must be concerned with eliminating as many sources of measurement error as possible, so that changes in the displayed measurement can be more confidently attributed to changing patient parameters.

The Transducer

Noninvasive electronic instruments are usually attached to the patient via the transducer. Regardless of type, a transducer converts a physiologic parameter into another form — for example, voltage or temperature into electrical signals. The parameter can then be displayed in a form that can conveniently be interpreted. Specifically, the transducer converts ionic potentials within the body into electrical signals suitable

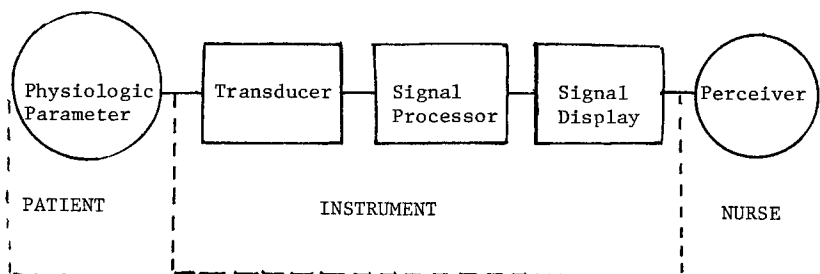


FIGURE 1. The patient-instrument-nurse system.

for amplification and modification by the processor. Electrodes placed on the skin sense differing potentials — that is, different numbers of positive and negative charges. Current flows across the interface between the patient and the electrode because the two differ in electrical potential. The greater the voltage at the electrode site, the greater the flow of electrical current; and, likewise, the greater the flow of electrical current, the greater the voltage.

RESISTANCE. Resistance will oppose the flow of current across the patient-transducer interface. At any given electrode site, resistance can be either fixed or variable. *Fixed resistance* results both from conditions of the human body and from the electrode. Thick, keratinous, or poorly hydrated skin will offer more resistance to current flow than normal skin. If possible, electrodes should be placed to avoid areas of obvious skin thickening or scarring. The second type of resistance — that of the electrode — is fixed by construction and design. Frequently, silver and copper are used for electrodes because they are considered good conductors — which means that their resistance to current flow is low.

Variable resistance is of greater importance because it is amenable to change. Resistance at the interface tends to decrease toward levels determined by human and electrode characteristics. If resistance across the skin, usually quite high, is allowed to increase further, there is a decrease in the ability of the transducer to sense input accurately, and measurement error is introduced. Consequently, anything that changes the character of the skin at the electrode site has the potential to alter resistance.

Most surface electrodes require the use of a conductive medium, often a gel or a paste, to decrease resistance between the electrode and the skin. Some electrodes require a gauze pad soaked in electrolyte solution. If conductive media are not used, high skin resistance to the flow of current results in a tendency toward surface burns. If the conductive material dries and is not removed, a barrier to current flow is created. Dried conductive gel and paste — as well as dirt, oil, dead skin, and perspiration — should be vigorously removed, using alcohol and friction, before electrodes are applied. Interface resistance is markedly increased when scant amounts of conductive media are applied or proper moisture is not maintained. However, it is equally important that electrode paste or gel under closely placed electrodes not be excessive; when this occurs, current may flow between the electrodes via the medium as well as across the electrode interface, and true potentials will not be sensed.

ELECTRODE MOVEMENT. When surface electrodes are used, current flow is affected by electrode movement. Mechanical electrode movement results in resistance changes across the interface. Resistance varies with electrode size — the greater the size, the less the resistance. If a portion of the electrode loses contact with the skin, current flow across it is

altered because, in effect, the size of the interface changes. Current flow may be altered further if movement allows the conductive medium to dry.

The use of floating electrodes has decreased signal alteration due to loss of electrode contact and shifting. With floating electrodes, the conductive medium touches the skin and is held in place by an inverted cup, often cushioned with a foam ring that adheres to the skin. In this arrangement, the electrode-patient interface "floats" above the skin and is less sensitive to patient movement artifact and signal alteration due to loss of contact. A further advantage is that during movement, the adherent ring prevents the electrode-patient interface from contacting the air, so that proper humidification and resistance are maintained.

ELECTRODE DESTRUCTION. When metal electrodes are allowed to decompose or become corroded, interface resistance changes. Nondisposable electrodes should be routinely maintained by cleaning them with alcohol to remove corrosion, and they should be inspected for loss of protective or functional coatings that maintain a given resistance. They should also be wiped clean after each use to avoid a build-up of conductive paste or gels and perspiration residue. Plastic floating electrodes, if reused, should be cleaned according to directions, and if they are damaged they should be discarded. Electrodes should not be used longer than their known life expectancy.

When surface electrodes have small amounts of direct current flowing through them, and when they are in place for long periods of time, perspiration is decomposed by the flow of current and yields a chemical burn.² In addition to being painful and a safety hazard, the burn also alters skin resistance and modifies the input signal from the transducer. When direct-current electrodes are used, the skin must be carefully inspected and cleaned at intervals, and the electrode placement should be altered as necessary.

ELECTRODE PLACEMENT AND REPLACEMENT. Electrode substitution should comply with equipment specifications. The size and composition of the electrode affects current flow, and it can contribute to measurement error. If two mismatched electrodes are used, direct-current voltage between them may cause a current flow that enters the transducer along with the desired signals. Voltage due to different electrode potentials is called "electrode offset voltage," and it must be avoided to minimize measurement error.³

Electrode placement is always important in avoiding measurement error. Since resistance across surface electrodes is altered by heat and loss of contact, areas of extreme surface temperature or excessive body heat should be avoided. For standard EKG monitoring, deviation from standard electrode placements, unless extreme, will not significantly affect the clinical usefulness of measurements made. However, changing electrode placements, like changing standard leads, will alter the wave-

form configuration, because the ionic potentials sensed differ according to electrode placement. Unwanted signals can be introduced into the transducer if reference electrodes are placed too near the recording electrodes.

THERMISTOR DAMAGE. The thermistor is a second type of transducer in common clinical use (the first type being surface electrodes). Thermistors are used clinically in the electronic thermometer, in the rectal probe of hypothermia equipment, and in automatic warmers. They utilize the principle that resistance to flow of current is dependent upon temperature; as temperature increases, resistance to flow decreases. Electrical resistance, as determined by body temperature, is converted into a clinically useful and accurate reading. For most thermistors, a four to six per cent change in resistance occurs for each centigrade degree of temperature change.⁴ Unlike the surface electrode, which converts ionic potentials into usable electrical signals, the thermistor converts heat into an electrical signal.

Damage to the thermistor or a change in it can alter the input signal and cause measurement error. In electronic thermometers, the thermistor element can be damaged by the absorption of electrolytes. After contact with electrolyte solutions, thermistors need recalibration. Any heat generated by the power source is also potentially damaging to the thermistor. In electronic thermometers, the correct battery must be used, and the thermometer should be periodically recalibrated to determine whether errors in measurement are present. Some thermistors deteriorate with age and normal use.⁴ Thermistors, like electrodes, must be carefully placed and secured to insure accurate readings. Mechanical damage due to cleaning or careless use is not only possible but also prevalent.

Noninvasive pressure transducers, such as those used for certain types of plethysmography, have not achieved common clinical application, and they are therefore not considered here.

The Processor

Once the physiologic parameter is sensed and altered by the transducer, it enters the processor and then is transferred to the display unit. The processor is vulnerable not only to unwanted input signals from the transducer but also to unwanted signals introduced directly from external sources.

CURRENT LEAKAGE. All electronic instruments in clinical use that are powered by alternating current (AC) are grounded. This means that somewhere in the circuitry, a route exists for the escape or discharge of unwanted, potentially dangerous electrical signals, which are also sources of measurement error. This escape route is the third prong of the instrument plug; it connects the instrument to the earth (hence the

term "ground"). If the ground is disturbed, electrical signals may enter the instrument from a variety of sources and will not be discharged, thus creating artifacts or "noise" in the readout. If, however, the electronic circuitry is defective, an intact ground system can still be associated with artifact and noise as well as with shock hazard.

Sahn and Vaucher tell of a gravity-drip controlling unit that was reported to be the source of current leakage that caused an unusual EKG artifact in a newborn infant.⁵ In this case, although the ground was intact, current generated within the controller entered the infant through intravenous tubing and caused artifact on the tracing. Artificial ventilators and drainage pumps also have been associated with EKG artifacts. The artifacts produced resembled premature ventricular contractions with baseline oscillations produced by an unknown mechanism.⁸ In another instance, a corroded screw fitting on a gastroscope interrupted current flow to such an extent that when the gastroscope was connected to an external power source, discharge through the patient resulted in cardiac arrest.⁶

Electrocautery equipment can also introduce high-frequency noise into instrument systems. Thus, unwanted and possibly lethal current can enter the instrument whenever electrical signals that are not part of the desired signal find any entry path and are not properly discharged.

Patient contact with metal objects, other electronic appliances, or materials capable of generating current without requiring power sources can act as entry routes for current that will result in artifact or noise. The body can act as an antenna to receive electrical signals and charges from the atmosphere, and these can cause artifact or noise in the display. It has been reported that television video signals present in electronic circuitry have interfered with the thermostatic control on an automatic newborn warmer; the heater functioned erratically as surface thermistor leads were moved, but it functioned normally when the video signals were screened out by a lead-shielded room.⁷ Although this case did not result in artifact, it demonstrates that unwanted video signals can interfere with thermostat function and can cause thermistor malfunction.

ARTIFACT OR NOISE. The problem of eliminating or minimizing artifact or noise from EKG tracings and cathode ray tube displays is well known to nurses using electronic equipment. Sixty-cycle (60 hertz) interference is a common artifact exhibited by a wide baseline in the trace due to small, regular oscillations. (Alternating current proceeds in one direction along a wire and then reverses itself 60 times per second. This produces 60 hertz or 60 cycles per second.) When this kind of interference is suspected and the ground system appears to be intact, the subject should be checked for proximity to metal objects or other instruments. Instruments not in use should be disconnected from electrical outlets to eliminate additional sources of electrical current flow and noise. If 60-cycle interference persists, the instrument should be re-

placed or checked for defects. When interference is confined to one instrument, to one electrical outlet, or to a particular patient, an expert in the field should be consulted.

Under no conditions should the ground be disturbed. If it is not intact, the equipment should not be used. In addition to introducing noise or artifact, current not discharged through the ground wire may flow through the patients or other people in the area to create a shock hazard or result in faulty instrument function, permanent damage, and measurement error. "Cheater" plugs, extension cords, and the chaining of one instrument to another are all hazardous. When a plug is removed from an outlet, the cord itself should not be pulled, because this will produce a strain on the wires and can disturb the ground, thus introducing more artifact and more safety hazards.

LOSS OF CALIBRATION. Artifact and the loss of instrument calibration can be caused by gross patient movement, muscle tremor, power surges, changes in the resistance of wires connecting the processor to the transducer, or loose processor-transducer connections. The loss of calibration results, in effect, in baseline wander, also called "drift." While in use, instruments should be recalibrated after excessive patient movement. Mechanical strain on lead wires, as in EKG monitoring, should be avoided, and lead wires should be positioned so that there is sufficient play to allow for normal movement. Lead wires that are stretched excessively should be replaced.

The improper assembly of an instrument after repair has been cited as a source of artifact. In this instance, the lead wires were improperly connected to a telemetry unit monitoring cardiac activity. Contact was lost intermittently during respiratory excursions, and various types of conduction blocks and bradycardia were simulated on the display. This suggests that recently repaired instruments should initially be used with caution; repair of one part of an instrument may result in damage to another part.¹ Line voltage fluctuations, with subsequent loss of the electrical signal, have also been said to simulate cardiac asystole.⁸

INTERFERENCE FROM ELECTRONIC EQUIPMENT. Another source of measurement error is damage to an instrument that is used in connection with other electronic equipment. Cardiac monitoring equipment, for example, is designed for use with defibrillators, and it is assumed that the monitor will remain undamaged and that the effects of shock can be observed. After defibrillator use, however, if the tracing is unusually distorted — in configuration, size, or placement — and there are no supporting clinical signs, monitor damage should be suspected.

Problems in the concomitant use of an artificial cardiac pacemaker and electrocardiography have been noted. In one instance, the pacemaker stimulus triggered a reset switch on the electrocardiograph, causing baseline and QRS complex distortion.⁸ Unwanted signals can also be

introduced into the EKG by using the wrong operating mode. The cardiac monitor usually has both a diagnostic mode and a monitoring mode, and they differ in their response to signal frequency. In the monitoring mode, the machine has a narrower frequency response, and therefore electrically induced artifact is decreased. In the diagnostic mode, the frequency response is wider — that is, a greater range of signal frequencies is processed — and susceptibility to artifact increases. It should be noted, however, that the monitoring mode, although it decreases artifact, has a greater tendency toward baseline wander.²

The Display Unit

The display unit of the instrument, whether it is attached to the processor or not, is also a source of measurement error. Two types of display units are considered here: those attached to the processor by wire circuitry and those not directly attached — for instance, units used for radiotelemetry.

Any instrument may have one or more display features. Examples include simple on-off indicator lights and lights that indicate the presence of continuous or intermittent single events, such as “alarm on” or cardiac rate. Numerical data are displayed on a dial, a meter, or a digital readout. Waveform data are displayed on cathode ray tubes (oscilloscopes) and paper printouts. Cathode ray tubes may be of the “bouncing ball” or nonfade types. An example of a display printout is the EKG rhythm strip. Alarms and warning bells are also part of display equipment.

Display units are dependent upon the transducer and the processor to feed them what they depict. There are only a few inherent sources of measurement error connected with display devices, but they are significant.

LIGHT AND NUMERICAL DISPLAYS. For light displays, common incandescent lamps or light-emitting diodes are used; neon lamps may also be employed. Unwanted electrical current introduced into an instrument can damage a transformer that is supplying energy to the light display, and this is especially so for light-emitting diodes. In battery-powered units, the battery pack must have enough energy to power the unit adequately, or erroneous readouts will result. If there is no indicator of battery condition, the batteries should be replaced at predetermined intervals. If it is known that a new power source is required, the unit should not be used.

Nondigital numerical displays require that the meter hand or dial swing freely. Damage to the instrument casing can provide a portal of entry for dust, debris, or liquids, which may alter the reading. When aerosol sprays or powders are used around electronic equipment, the

air-suspended particles may enter the equipment and adversely affect the display operation. Mechanical injury can also jar the meter and affect the readout.

CATHODE RAY TUBE DISPLAYS. In cathode ray tube displays, a beam of electrons is projected against a phosphorus-coated glass tube. The deflection of the beam — its configuration — is directly related to the voltage received from the transducer. The coating on the tube glows as the electron beam hits it. In the “bouncing ball” displays, the electron beam is repeatedly directed across the face of the tube. The beam’s luminescence decreases as it moves; generally, by the time the signal reaches one side of the cathode ray tube, it has faded from the other side completely. Instruments containing nonfade cathode ray tubes feature circuitry that allows the EKG configuration to be projected on the entire screen. The tracing moves continuously, in its total form, across the screen. This type of monitor is easy to view. The “persistence” of a cathode ray tube relates to how quickly the display fades from view; it depends on the amount or the character of the phosphorus coating on the tube.² The coating can deteriorate with time and use, and visibility of the trace will be lessened.

ELECTROCARDIOGRAPHY. The gain control or sensitivity control on the face of the EKG monitor is used to alter the amplitude of the waveform deflection. In effect, it alters the magnitude of the input signal from the transducer. Gain, brightness, and trace position are adjusted to provide useful visualization. The EKG configuration is also altered by paper sweep speed. If gain is set very low and paper sweep speed is set high, important deflections may be missed by the observer. A paper speed of 50 mm. per second can simulate combined intra-atrial, atrio-ventricular, and intraventricular block, and this double-speed artifact may be difficult to detect if the patient has brisk tachycardia. Variable paper speed, caused by erratic take-up of the reel, can simulate atrial arrhythmias.⁸

Centrally located display units are slaves to bedside monitors. The controls are usually simple: on-off switch; gain, brightness, and position control; and heart-rate indicator. The monitor control adjustments already described also apply to these slave units.

In common EKG tracings, deposits on the heat-sensitive stylus can contribute to measurement error. If the tracing is wide or erratic, or if the size varies with position, a dirty stylus is likely to be the cause; it should be removed from the paper and heated to burn off deposits. If the deposits are successfully removed, the stylus should then be adjusted to eliminate drag. If the deposits are not successfully removed, the stylus should be replaced.²

TELEMETRY DISPLAYS. Telemetry display units operate much as cen-

trally located monitoring equipment does. In radiotelemetry, the processor, located on the subject, sends the electrical input from the transducer to the display unit via electromagnetic waves. They are received by an antenna some distance from the transducer and, after suitable processing, are displayed in analog or digital form. The radiotelemetry range is the distance over which signals can be received. The range for inpatient monitoring is limited; it is determined by the power of the transmitter, by the location of the sending and receiving antennae, and by the sensitivity of the receiver.³

Error in telemetry can be caused by radio wave interference. The risk of interference is greater in large cities with tall buildings and radio and television transmitting stations. Transistorized electronic equipment also emits confounding electromagnetic waves.⁷ Most hospital walls are, to some extent, impervious to electromagnetic wave transmission, but radio waves can be received by any antennae that are sensitive to the waves transmitted. Telemetry has probably not received widespread use clinically because of its inherent limitations. The patient on whom the transducer and processor are located must not wander outside specified ranges, for he will be difficult to locate if a problem is noted. Telemetry units are battery-powered and present no electrical shock hazard.

The Perceiver

In one sense, all the error sources so far mentioned — equipment use and misuse, environmental factors, and lack of understanding — constitute human error, but in the present context the latter term refers to measurement error that is directly attributable to display perception and general instrument use.

The placement of electronic instruments is extremely important. Excess heat should be avoided, because it can cause thermistor damage and changes in electronic circuitry. Overheating can result from stacking instruments that are housed in hard casing, from placing them on heating elements such as radiators and obliterating vent grills, or from removing glides that allow clearance. Extremes of humidity can also affect some electronic instruments. They should not be located in the direct paths of steamers or other humidification equipment. Liquids spilled on instruments can also damage the circuitry and create a shock hazard.

Display units should be placed so that they can be easily seen. Meters should stand at eye level and should be directed so as to avoid glare. Nurses should read meters, dials, and digital displays at close enough range to be accurate. Errors sometimes occur if a digital display is used for fast-changing data; when the display is continually moving, the nurse may have difficulty deciding what the actual reading is.

Calibration must be accomplished carefully. Recalibration is indicated after power surges, power losses, and periods of gross and excessive patient movement.

When equipment damage occurs, it should be reported at once, and nurses should be insistent about not using damaged instruments. To insure maximum life, equipment should be used prudently and carefully.

SUMMARY

When electronic instruments are utilized for patient care, the measurements provided are not the sole basis on which care is based. Instrument-made measurements can be fallible. Sometimes the patient's symptoms will negate or cast doubt on the accuracy, precision, and reliability of a measurement displayed. If the measurement deviates considerably from what seems likely to be occurring in a patient, the instrument–nurse system should be suspected as an error source. The nurse should first insure the patient's safety and then systematically search for the source of the error.

Electronic instruments provide a means of reducing measurement error in clinical data. They increase the range of available data by extending human senses. They do not replace nonelectronic instrumentation or nurse-patient encounters — they augment them. Electronic instruments supply data on which critical judgments are made, and so for maximum utility they must provide measurements that are maximally free of error — that is, measurements as accurate, precise, and reliable as possible within given limitations.

Measurement error may be of sufficient magnitude to be recognizable, or it may be hidden. It can occur at one or several points within the instrument or can be a result of a failure in user perception. Error can also be attributed to instrument misuse, to poor equipment maintenance, and to normal usage. If measurement error is not minimized, it cannot be assumed that displayed measurements actually reflect patient changes — and the measurements will not be useful in the care of the patient.

A nurse who uses electronic instruments must have a mastery of their functioning and use in patient care. Without a thorough understanding of each instrument and its limitations and capabilities, the nurse will be enslaved by the instrument. With understanding, there is mastery —and with mastery, sound judgments can be made for the provision of good patient care.

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