Instructor , Abdul Rahman R ,mohmmed

Terminology, Modeling, and Measurement

Terminology

The term medical physics refers to **two** major areas: -

1. The applications of physics to the function of the human body in health and disease.
2. The applications of physics in the practice of medicine.

The first of these could be called the physics of physiology; **the second** includes such things as the physics of the stethoscope, the tapping of the chest (percussion), and the medical applications of lasers, ultrasound, radiation, and so forth.

The word ***physical*** appears in a number of medical contexts. Only a generation ago in England a professor of physic was actually a professor of medicine.

The branch of medicine referred to as ***physical medicine*** deals with the diagnosis and treatment of disease and injury by means of physical agents such as manipulation, massage, exercise, heat, and water.

Physical therapy is the treatment of disease or bodily weakness by physical means such as massage and gymnastics rather than by drugs.

The field of medical physics has several subdivisions: -

1. Most medical physicists in the United States work in the field of ***radiological physics***. This involves the applications of physics to radiological problems and includes the use of radiation in the diagnosis and treatment of disease as well as the use of radionuclides in medicine (nuclear medicine).
2. Another major subdivision of medical physics involves ***radiation protection*** of patients, workers, and the general public. In the United States this field is often called ***health physics***. Health physics also includes radiation protection outside of the hospital such as around nuclear power plants and in industry.

1-6

3. Very often an applied field of physics is called ***engineering***. Thus, medical physics could be called ***medical engineering***.

4. In some areas, such as the applications of ultrasound in medicine and the use of computers in medicine, you are likely to find medical physicists and medical engineers in nearly equal numbers. (The word ***medical*** is sometimes replaced with the word ***clinical*** if the job is closely connected with patient problems in hospitals, i.e., clinical engineering or clinical physics).

Modeling

Even though physicists believe that the physical world obeys the laws of physics, they are also aware that the mathematical descriptions of some physical situations are too complex to permit solutions.

If you tore a small corner off this page and let it fall to the floor, it would go through various gyrations. Its path would be determined by the laws of physics, but it would be almost impossible to write the equation describing this path. Physicists would agree that the force of gravity would cause it to go in the general direction of the floor if some other force did not interfere. Air currents and static electricity would affect its path.

In trying to understand the physical aspects of the body, we often resort to analogies; physicists often teach and think by analogy. Keep in mind that analogies are never perfect.

In many ways the eye is analogous to a camera; however, the analogy is poor when the film, which must be developed and replaced, is compared to the retina, the light detector of the eye.

Some models involve physical phenomena that appear to be completely unrelated to the subject being studied.

A model in which the flow of blood is represented by the flow of electricity is often used in the study of the body's circulatory system. Also, all analogies have their limitations.

Blood is made up of red blood cells and plasma, and the percentage of the blood occupied by the red blood cells (the hematocrit) changes as the blood flows toward the extremities. This phenomenon is difficult to simulate with the electrical model.

Other models are mathematical; equations are mathematical models that can be used to describe and predict the physical behavior of some systems. In the everyday world of physics we have many such equations. Some are of such general use that they are referred to as laws.

Measurement

One of the main characteristics of science is its ability to reproducibly measure quantities of interest. The growth of science is closely related to the growth of the ability to measure. In the practice of medicine, early efforts to measure quantities of clinical interest were often scorned as detracting from the skill of the physician.

Even though body temperature and pulse rate could be measured during the seventeenth century, these measurements were not routinely made until the nineteenth century. In this century there has been a steady growth of science in medicine as the number and accuracy of quantitative measurements used in clinical practice have increased.

The following figure illustrates a few of the common measurements used in the practice of medicine. Some of these measurements are more reproducible than others. Fig 1.1, Appendix C

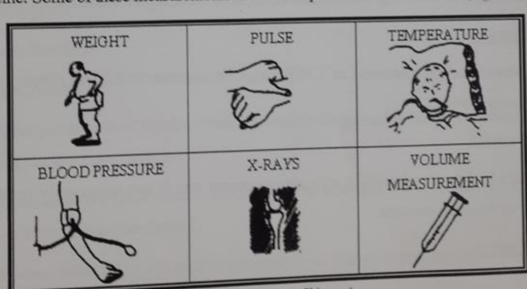

Fig 1.1

For Example: -

An x-ray gives only qualitative information about the inside of the body; a repeat x-ray taken with a different machine may look quite different to the ordinary observer.

There are many other physical measurements involving the body and time. We can divide them into two groups: -

1. Measurements of repetitive processes, such as the pulse.
2. Measurements of nonrepetitive processes, such as how long it takes the kidneys to remove a foreign substance from the blood.

Measurements of the repetitive processes usually involve the number of repetitions per second, minute, hour, and so forth.

For Example: -

The pulse rate is about 70/min

The breathing rate is about 15/min.

Nonrepetitive time processes in the body range from the action potential of a nerve cell (1msec) to the lifespan of an individual.

In science accuracy and precision have different meanings: -

- **Accuracy**

Refers to how close a given measurement is to an accepted standard.

For Example: -

A person's height measured as 1.765m may be accurate to 0.003m (3mm) compared to the standard meter.

- **Precision**

Refers to the reproducibility of a measurement and is not necessarily related to the accuracy of the measurement.

For Example: -

An ill person measured her temperature ten times in a row and got the following values in degrees Celsius: 36.1, 36.0, 36.1, 36.2, 36.4, 36.0, 36.3, 36.3, 36.4, and 36.2. The precision was fairly good, with a variation of 0.2°C from the average value of 36.2°C.

It is an accepted fact in science that the process of measurement may significantly alter the quantity being measured. This is especially true in medicine.

The process of measuring the blood pressure may introduce errors (uncertainties). Although the data are scarce, it is generally believed that when an attractive woman is performing the measurement, the blood pressure of a young man will increase. Similarly, a handsome man may affect the blood pressure measurement of a female patient.

When the physician decides if the patient is ill or not?

-After he or she has reviewed a patient's: -

1. Medical history.
2. The findings of the physical examination.
3. The results of clinical laboratory measurements.

It is not surprising that sometimes wrong decisions are made. These wrong decisions are of two types: -

1. False Positives.
2. False Negatives.

A **false positive** error occurs when a patient is diagnosed to have a particular disease when he or she does not have it.

A **false negative** error occurs when a patient is diagnosed to be free of a particular disease when he or she does have it.

Note: - In some situations a diagnostic error can have a great impact on a patient's life.

For Example: -

A young woman was thought to have a rheumatic heart condition and spent several years in complete bed rest before it was discovered that a false positive diagnosis had been made-she really had arthritis.

In the early stages of many types of cancer it is easy to make a false negative diagnostic error because the tumor is small. Since the probability of cure depends on early detection of the cancer, a false negative diagnosis can greatly reduce the patient's chance of survival.

Diagnostic errors (false positives and false negatives) can be reduced by: -

1. Research into the causes of misleading laboratory test values.
2. Development of new clinical tests and better instrumentation.

Errors or uncertainties from measurements can be reduced by: -

1. Using care in taking the measurement.
2. Repeating measurements.
3. Using reliable instruments.
4. Properly calibrating the instruments.

In summary: -

1. All measurements are uncertain and inaccurate.
2. With special effort we can reduce the error and the uncertainty.
3. In many cases there is no need to improve the measurement because the quantity being measured is variable.

APPENDIX C

Standard Man Data

In medical physics, where we are often concerned with the anatomy and physiology of humans, it is convenient to define a *standard man*. While the standard man is nonexistent, the following somewhat arbitrary values are useful for computational purposes:

Age	30 yr	
Height	172 cm (5 ft 8 in.)	
Mass	70 kg	
Weight	690 N (154 lb)	
Surface area	1.85 m^2	
Body core temperature	37.0°C	
Body skin temperature	34.0°C	
Heat capacity	0.86 kcal/kg°C	
Basal metabolism	38 kcal/m^2 hr, 70 kcal/hr, 1680 kcal/day	
O_2 consumption	260 ml/min	
CO_2 production	208 ml/min	
Blood volume	5.2 liters	
Cardiac output	5 liters/min	
Blood pressure	120/80 mm Hg	
Heart rate	70 beats/min	
Total lung capacity	6 liters	
Vital capacity	4.8 liters	
Tidal volume	0.5 liter	
Dead space	0.15 liter	
Breathing rate	15/min	
Muscle mass	30,000 g	43% of body mass
Fat mass	10,000 g	14% of body mass

Bone mass	7,000 g	10% of body mass
Blood mass	5,400 g	7.7% of body mass
Liver mass	1,700 g	2.4% of body mass
Brain mass	1,500 g	2.1% of body mass
Mass of both lungs	1,000 g	1.4% of body mass
Heart mass	300 g	0.43% of body mass
Mass of each kidney	150 g	0.21% of body mass
Thyroid mass	20 g	0.029% of body mass
Mass of each eye	15 g	0.021% of body mass