

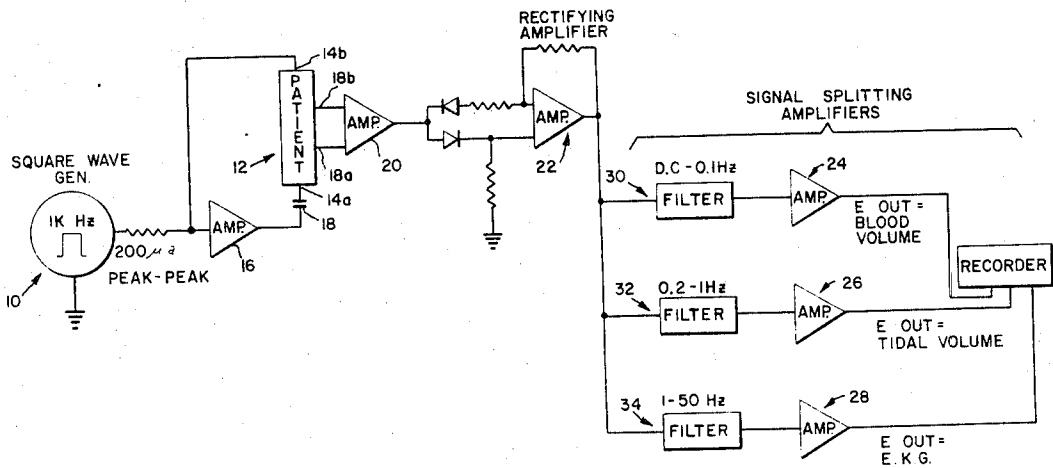
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[21] Appl. No. **529,306**
[22] Filed **Feb. 23, 1966**
[45] Patented **Oct. 6, 1970**
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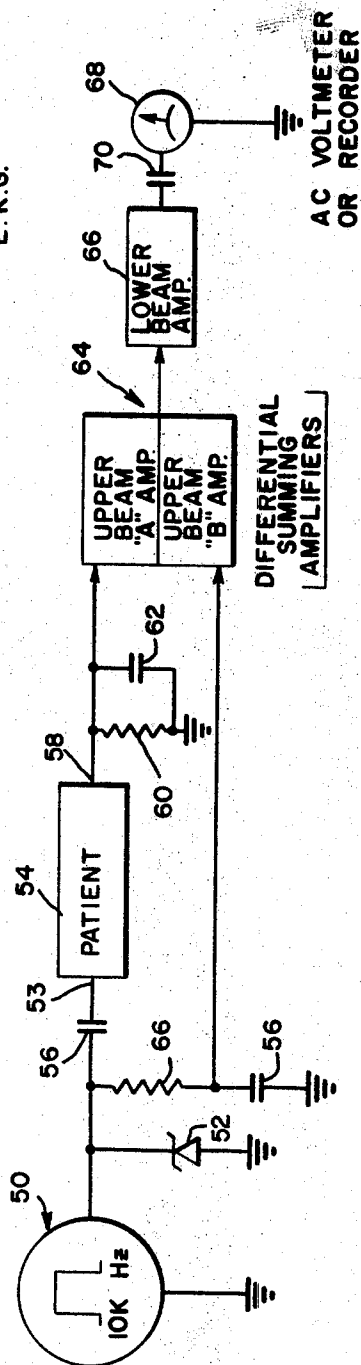
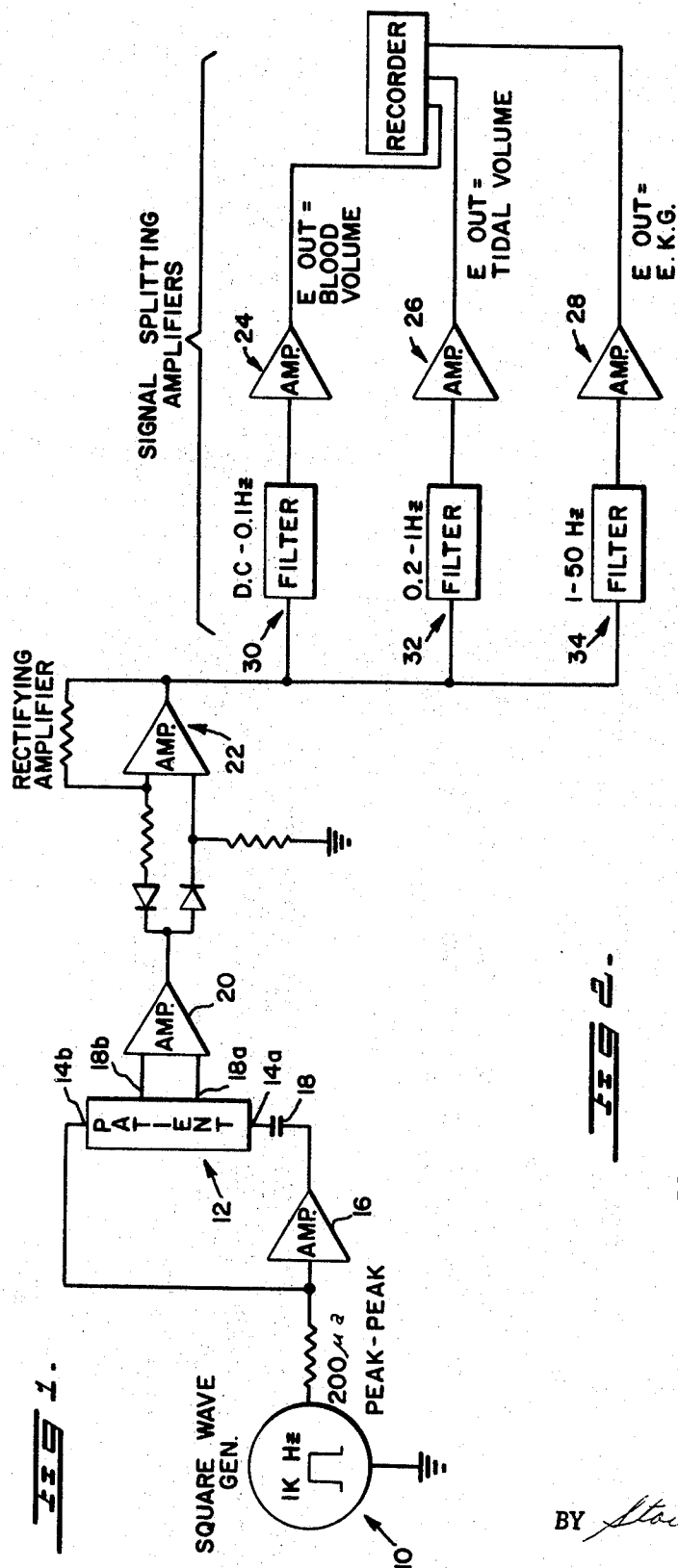
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[54] **METHOD AND APPARATUS FOR DETERMINING**
BLOOD LOSS OF PATIENTS
2 Claims, 2 Drawing Figs.
[52] U.S. Cl..... **128/2.1,**
128/2.06
[51] Int. Cl..... **A61b 5/02**
[50] Field of Search..... **128/2, 2.1,**
2.05; 324/30, 57(Cursory)

ABSTRACT: A method for determining blood loss during an operation. An alternating current of constant amplitude is fed through the body. The IR drop thereacross is detected and rectified. The rectified output voltage contains a spectrum of signal components. The component in the range d.c. to 0.1 Hz is indicative of blood volume. Other signal components contain information about respiration and E.K.G.





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METHOD AND APPARATUS FOR DETERMINING BLOOD LOSS OF PATIENTS

This invention relates to a method and an apparatus for determining the blood loss from patients during surgical operations, after trauma and during childbirth.

In the field of surgery, it is important in many instances to ascertain the amount of blood lost by a patient during an operation. Heretofore, such determination has been difficult to make. During surgery, the major portion of blood lost from patients is absorbed by sponges and gauze disposed in the critical areas of the surgery, and when these are removed a considerable amount of blood collected therein becomes coagulated, making a volumetric determination of the blood a difficult problem.

The present invention has for its object to provide an improved, simple and effective method and apparatus whereby the amount of blood lost from a patient during a surgical operation may be accurately and continuously determined during surgery.

It has been established that the volume of blood contained in a body segment, such as a limb or digit, influences the electrical impedance or resistance of that segment. It has also been discovered that changes in the total blood volume of a patient cause changes in the electrical resistance or impedance of the patient and provides a method for instantaneously measuring loss or gain of total blood volume in the patient.

These and other objects of the invention are provided by a method of continuously monitoring blood loss during surgery comprising determining the electrical resistance or impedance of a patient, and thereafter continuously monitoring changes in the determined electrical resistance or impedance of the patient during surgery; and by apparatus for determining blood loss during surgery comprising first electrode means for directing an electrical signal into the body of a surgical patient, second electrode means sensing said signal as affected by said patient and means electrically connected to said second electrode means for measuring a parameter of said affected signal.

The invention will be more particularly described with reference to the accompanying drawing, wherein:

FIG. 1 is a diagrammatic view of a preferred apparatus for carrying out the method of the invention; and

FIG. 2 is a diagrammatic view of a simplified form of apparatus constructed in accordance with the teachings of the present invention.

Throughout the specification and claims, the term "patient" is intended to include both animals and human beings.

Referring particularly to FIG. 1 of the drawings, apparatus is shown for continuously monitoring three distinct physiological parameters; that is, blood volume, respiratory volume and electrocardiogram. In the apparatus of FIG. 1, blood volume and respiration are both monitored as a changing electrical impedance in time and the electrocardiogram is provided by an electrical signal generated by the physiological system.

In FIG. 1, 10 generally designated a 1 kHz. square wave generator having a 200 microampere peak-to-peak square wave signal output. 12 generally designates a patient who is connected by first electrode pair 14A and 14B to the square wave generator through an amplifier 16 and a DC blocking capacitor 18.

The capacitor prevents direct current polarization from taking place on the electrodes 14A and 14B attached to the tissue of the patient 12 while the amplifier 16 assures that regardless of impedance the 200 microampere peak-to-peak current flows through the physiological system of the patient. Since the peak-to-peak current output from the generator 10 is constant then the voltage developed across the physiological impedance will be directly proportional to that impedance. To detect this impedance a second pair of electrodes 18A-18B are connected to the patient interior to the two current electrodes 14A-14B. These electrodes 18A-18B are connected to a high gain, high input impedance, low level amplifier 20 capable of passing a 1 kHz signal with a bandwidth of, for example, about 200 Hz. For this purpose a Tektronix Type 2A61 oscilloscope preamplifier is quite suitable.

In the illustrated embodiment of the invention the detection is done through the additional electrodes 18A-18B to eliminate the sensing of any polarization potentials which can occur at the current electrode tissue interface. Such potentials would normally appear as artifacts of the same voltage and frequency as the physiological signals to be measured. The differential input to amplifier 20 also minimizes the 60 Hz and radio frequency common mode signals always present in physiological systems. Electrodes 14A-14B and 18A-18B may be connected to the patient by making electrical contact with the surface of the skin, or by implanting the electrodes in the flesh or in a blood vessel.

The amplified 1 kHz square wave at the output of the amplifier 20 is full-wave rectified in an operational amplifier circuit generally designated 22 which can provide additional gain if necessary. The output of this amplifier 22 is a DC signal with two kHz "spikes" present from rectification which are easily filtered electrically. The absolute DC level of the signal varies in accordance with the electrocardiogram (EKG), the changing impedance caused by any blood volume changes, and the changing impedance caused by respiration.

The frequencies of each of these signals are sufficiently different as to be readily separable by electrical filtering. The output of amplifier 22 is then fed to three additional amplifiers 24, 26 and 28. Each of these amplifiers incorporates filters 30, 32, 34, respectively, to tailor the bandpass to that required to pass only one of the three physiological signals.

Amplifier 24 has a bandpass from 0 to 0.1 Hertz which is suitable for monitoring the DC impedance of the subject which is proportional to the blood volume and it rejects those frequencies above 0.1 Hertz which includes the EKG and respiration signals.

Amplifier 26 passes frequencies from 0.2 to 1 Hertz which is appropriate for the respiration signal but not for the blood volume and EKG signals.

Amplifier 28 passes frequencies from 1 to 50 Hertz thus providing EKG but not blood volume or respiration. In general the gain of each of these amplifiers 24, 26 and 28 can be adjusted to make the signal amplitude appropriate for the selected recorder illustrated at 36. It should also be recognized that each signal at the output can, if desired, be made approximately the same peak amplitude.

From the foregoing description it will be seen that apparatus is provided which will determine changes in blood content of a patient brought about by losses due to surgery, gains due to infusion, and at the same time the device would be useful in studying changes in blood content under such conditions as shock, anesthesia, ganglionic blockade, cardiopulmonary bypass, body acceleration or weightlessness.

While it will be appreciated by those skilled in the art that changes in body impedance or resistance will be detected only in the area between the pair of electrodes 18A and 18B, studies have shown that a very close approximation of total body impedance or resistance changes can be obtained by the method even though the electrodes are placed, for example, at opposite ends of a patient's arms.

Through the use of apparatus illustrated in FIG. 1 of the drawings changes in the order of approximately one-half ohm have been detected when changing the blood volume of a 24 pound dog by as little as 20 cc.

The above described process may be considered as passing a carrier wave through the body, and then separating several modulation components from the carrier after passage through the body. The modulation components correspond to the three parameters total blood volume, respiration, and E.K.G.

As indicated hereinabove, it is not necessary to employ two pairs of electrodes in order to determine changes in resistance or impedance of a patient. Such a simplified form of apparatus is illustrated in FIG. 2 of the drawings wherein the output of a constant voltage 10 kc square wave generator 50, driven by a conventional waveform generator and grounded through a 5 volt zener diode 52 is fed to an electrode 53 connected to the body of a patient 54 through a 5 mf capacitor 56. The ground return 58 from the patient 54 is via a 47000-ohm resistor 60.

The signal to be examined is taken from the ungrounded side of the resistor 60 which is shunted by a 5.5 mf capacitance condenser 62 and fed to the A channel of the upper beam amplifier of a dual beam type oscilloscope generally designated 64.

The square wave produced by the generator 50 is also fed through a 470-ohm resistor 66, which is shunted to ground by the 2 mf capacitance condenser 68 and fed to the B channel

the other over the lower lumbar area. A large bore cannula was placed in a femoral vessel for bleeding and reinfusion.

Bleeding or infusion of blood produced a consistent and reproducible change in voltmeter readings in all experiments.

5 Bleeding caused a decrease in voltage, and replacement of the blood resulted in return of the meter to the original value. Table 1 shows the average observed voltage change resulting from repeated bleedings and reinfusions in each animal.

TABLE 1.—CHANGE IN VOLT-METER READINGS WITH REPEATED BLEEDING AND REINFUSION

[100 ml. in dogs, 10 ml. in cats]

Experi- ment	Species	Weight (kg.)	Estimated blood volume in ml. (7% body weight)	Number of determina- tions	Average observed voltage change in volts	Average calculated voltage change for 10% blood volume change
1.....	Dog.....	16.0	1,120	3	0.15	0.17
2.....	Dog.....	16.0	1,120	5	0.16	0.18
3.....	Dog.....	16.0	1,120	5	0.15	0.17
4.....	Dog.....	16.0	1,120	3	0.15	0.17
5.....	Dog.....	16.0	1,120	3	0.14	0.16
6.....	Dog.....	25.0	1,750	4	0.12	0.20
7.....	Dog.....	14.0	980	3	0.17	0.16
8.....	Dog.....	25.0	1,750	3	0.12	0.20
9.....	Dog.....	25.0	1,750	6	0.11	0.18
10.....	Cat.....	2.7	190	3	0.13	0.24
11.....	Cat.....	2.5	175	4	0.13	0.23

amplifier of the upper beam of the dual beam oscilloscope 64. The amplifier for the dual beam oscilloscope is set for subtraction and the gain of channel B is preferably set for slight decancellation and the resulting signal from the vertical output of the upper beam section of the oscilloscope is introduced into the lower beam amplifier 66 intended to obtain additional gain. The output of the lower beam amplifier 66 of the oscilloscope is preferably fed through, for example, a 0.1 mf capacity 70 to an AC voltmeter 68, employed as the data read-out means.

It will be appreciated that while the apparatus of FIG. 2 is simpler than that of FIG. 1, the structures shown in FIG. 2 do not provide readings corresponding to tidal volume and EKG.

EXAMPLES

Two cats weighing 2.5 and 2.7 kg., and nine dogs weighing from 14 to 27 kg. were used. General anesthesia was induced with pentobarbital and maintained with endotracheal halothane nitrous oxide-oxygen. Needle electrodes were placed subcutaneously, one over the suprasternal notch and

We claim:

1. A method of measuring changes in total blood volume in a patient which comprises passing a constant amplitude alternating carrier current through at least a portion of the body, detecting the voltage drop in said carrier current in the body, separating from said detected voltage drop the modulation components thereof having a frequency not exceeding 0.1 Hz and indicating the separated components.

2. Apparatus for measuring changes in total body fluid content comprising means for passing a constant amplitude carrier current through at least a portion of the body, means for detecting the voltage drop in said carrier current in the body, band pass filter means for separating from said detected voltage drop the modulation components thereof having a frequency not exceeding 0.1 Hz and indicating means responsive to the signal passed by the band pass filter.

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