United States Patent [19]

McIntyre

[11] **3,776,221**

[45] **Dec. 4, 1973**

[54] **DETECTING IMPAIRED HEART MECHANICAL PERFORMANCE AND APPARATUS THEREFOR**

[76] Inventor: **Kevin M. McIntyre,** 1400 V.F.W. Pky., Jamaica Plain, Mass. 02136

[22] Filed: **Apr. 2, 1971**

[21] Appl. No.: **130,572**

[52] **U.S. Cl.** ..... **128/2.05 R**

[51] **Int. Cl.** **A61b 5/02**

[58] **Field of Search** ..... 128/2.05 A, 2.05 E, 128/2.05 F, 2.05 G, 2.05 M, 2.05 N, 2.05 P, 2.05 Q, 2.05 R, 2.05 T, 2.05 V

[56] **References Cited**

UNITED STATES PATENTS

2,667,159	1/1954	Goldberg et al.	128/2.05 V
3,154,066	10/1964	Grindheim et al.	128/2.05 P
3,400,709	9/1968	Funfstuck	128/2.05 A
3,412,729	11/1968	Smith, Jr.	128/2.05 R

FOREIGN PATENTS OR APPLICATIONS

1,053,723	3/1959	Germany	128/2.05 Q

OTHER PUBLICATIONS

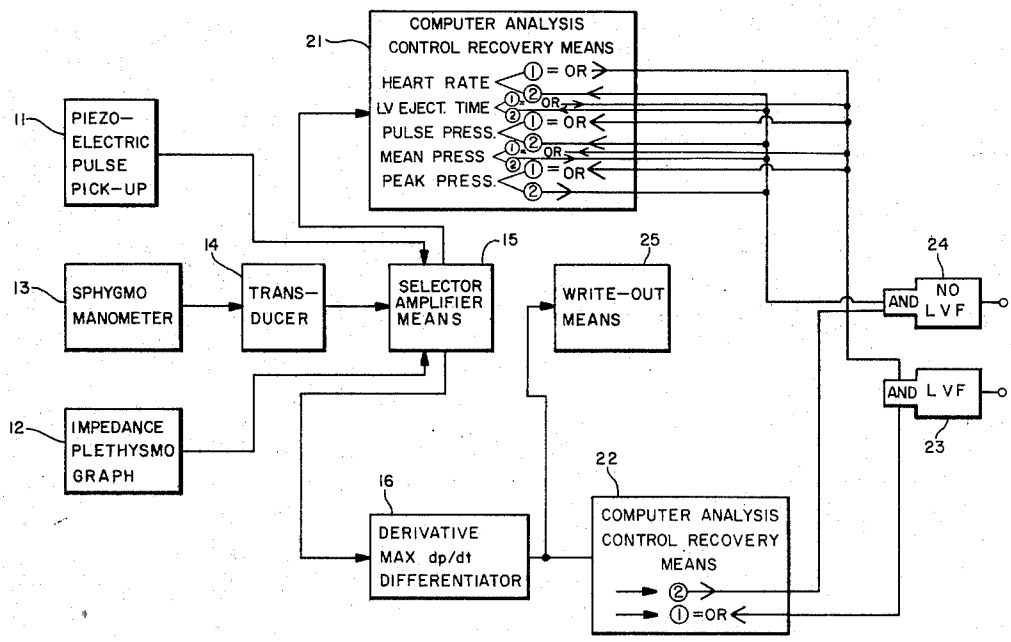
George et al., "Medical Research Engineering," 4th quarter, 1967, pp. 21–24.

Primary Examiner—William E. Kamm
Attorney—Charles Hieken

[57] **ABSTRACT**

A pressure-sensitive device contacts the skin of a patient near an artery noninvasively to provide a signal representative of systemic arterial blood pressure both before and after a Valsalva Manoeuvre. This blood pressure signal is differentiated, and the changes in amplitude before and after the Valsalva Manoeuvre detected to indicate potential left ventricle failure when the change is less than a predetermined value. Signals representative of pulse pressure, the means systemic arterial blood pressure, heart rate and left ventricular ejection time are also provided to facilitate detection of impaired mechanical performance of the heart.

7 Claims, 3 Drawing Figures



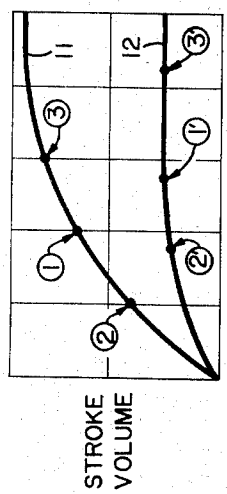


FIG. 1

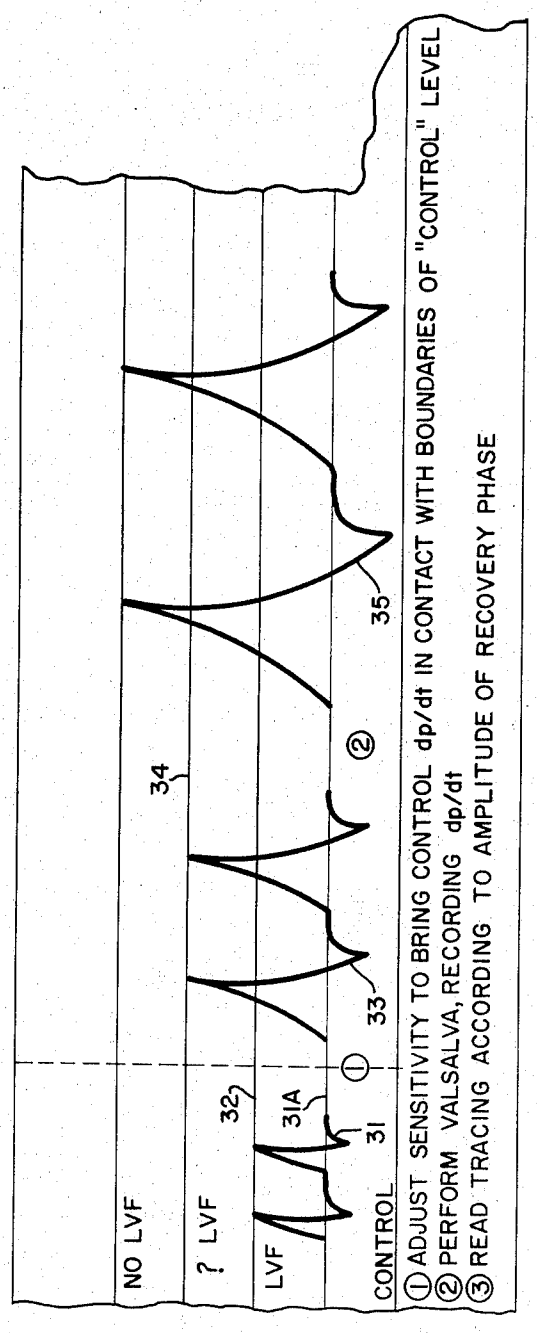


FIG. 3

INVENTOR.
KEVIN M. McINTYRE
BY
Charles Hieken
ATTORNEY

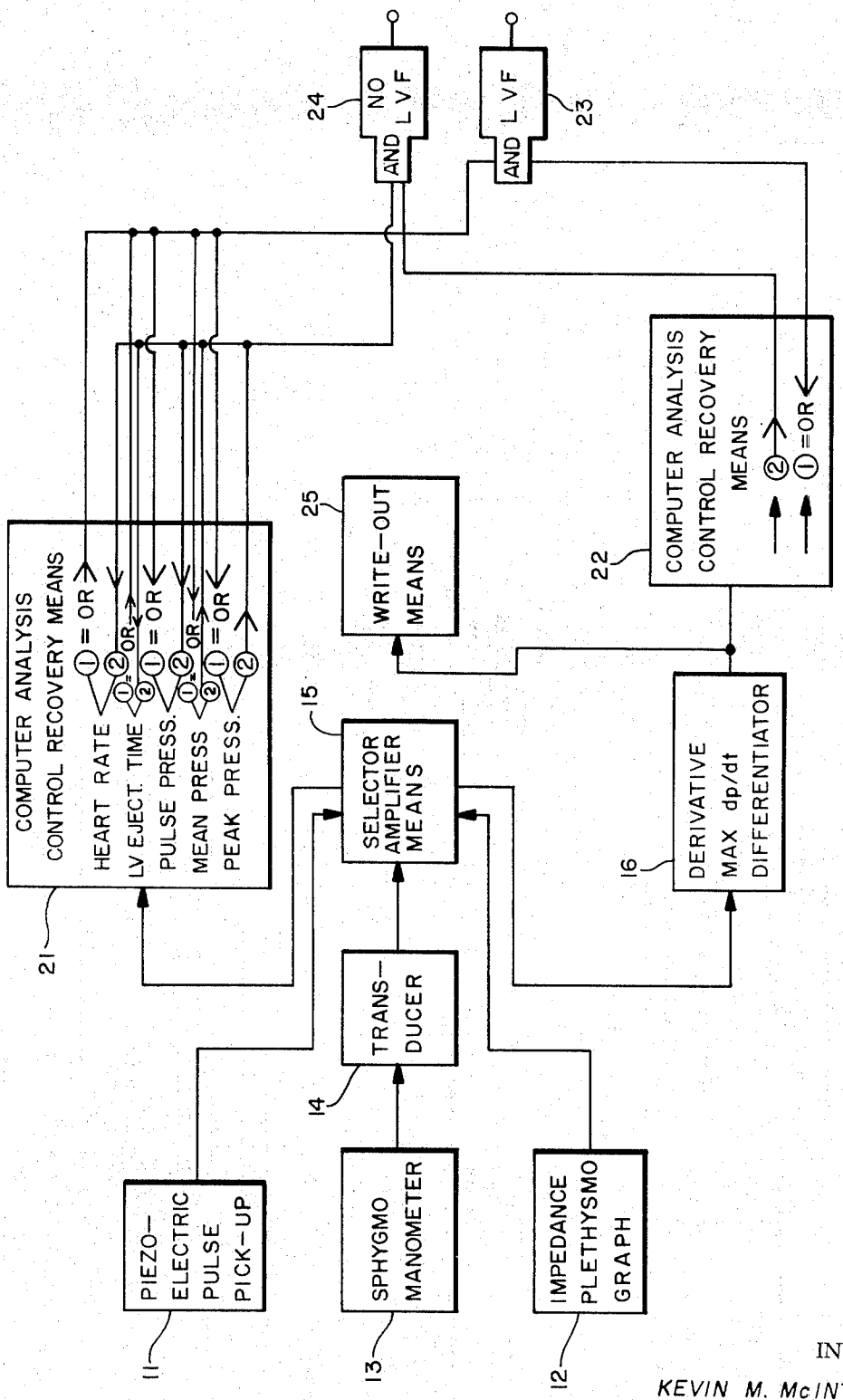


FIG. 2

INVENTOR.

KEVIN M. McINTYRE

BY

Charles Hieken

ATTORNEY

DETECTING IMPAIRED HEART MECHANICAL PERFORMANCE AND APPARATUS THEREFOR

BACKGROUND OF THE INVENTION

The present invention relates in general to detecting impaired mechanical performance of the heart and/or cardiac failure, and more particularly concerns novel apparatus and techniques for detecting such potential impairment in a reliable manner through external measurements.

Since the introduction of aortic valvotomy, the assessment of aortic valve disease has become increasingly important. On approach to such an assessment involves studying recorded arterial pressure pulse tracings. Stenosis is the narrowing of a blood passage, such as the pulmonary artery or aortic valve. One approach to studying stenosis is the so-called Valsalva Manoeuvre. The patient's blood pressure is recorded prior to holding his breath. Then the patient holds his breath and releases it while recording continues.

Reference is made to an article entitled THE VALSALVA MANOEUVRE IN AORTIC VALVE DISEASE by Doyle and Neilson. The article states that neither systolic upstroke time nor pulse pressure alone correlates well with the severity of stenosis and that the shape of the pulse derived during Valsalva Manoeuvre is an unreliable guide to the relative dominance of stenosis or incompetence. That article concludes that variations in pulse pressure during the Valsalva Manoeuvre or in atrial fibrillation and variations of upstroke time in the same pulses do not have a linear relationship to the severity of stenosis when stenosis is present alone.

It is an important object of this invention to provide improved techniques for detecting left ventricular impairment.

It is a further object of the invention to achieve the preceding object with techniques and apparatus that permit detection by relatively unskilled personnel.

SUMMARY OF THE INVENTION

According to the invention, the time derivative of the systemic arterial pulse pressure is established at a control level in the subject patient. Then the patient performs a straining manoeuvre, such as Valsalva manoeuvre, while recording the time derivative of the systemic arterial pulse pressure signal. Preferably, the systemic arterial pulse pressure, mean pressure, heart rate and left ventricular ejection time are also established and may be interpreted so that the presence or absence of impairment in the performance of the left ventricle may be detected. Specifically, the time derivative of systemic arterial pressure responds in a characteristic fashion in the presence of heart impairment; the other parameters are useful in defining the expected normal response of the time derivative of this pressure.

Numerous other features, objects and advantages of the invention will become apparent from the following specification when read in connection with the accompanying drawing in which:

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a graphical representation of stroke volume as a function of end-diastolic pressure on the left ventricle during a Valsalva maoeuvre helpful in understanding the phenomenon with which the invention is assocated;

FIG. 2 is a block diagram illustrating the logical arrangement of a system according to the invention which includes means for detecting left ventricle mechanical impairment; and

FIG. 3 is a graphical representation of time derivative of pressure waveforms helpful in understanding the operation of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

With reference now to the drawing, and more particularly FIG. 1 thereof, there is shown a graphical representation of stroke volume as a function of end-diastolic pressure at the left ventricle during a Valsalva manoeuvre. Curve **11** illustrates this relationshio for a normal left ventricle. Point **1** represents the normal stroke volume and end-diastolic pressure immediately prior to the patient holding his breath. As the patient holds his breath and makes a forceful expiratory effort without allowing air to escape from his lungs (equivalent to straining at stool), both pressure and stroke volume decrease along curve **11** to point **2** when the patient releases his breath. Stroke volume and end-diastolic pressure then begin to increase rapidly until point **3** is reached. This analysis indicates that the time derivative of the pressure signal of a healthy patient will increase significantly when he releases his breath. Since other changes occur during the Valsalva manoeuvre which may on occasion independently influence the response of stroke volume and the time derivative of pressure, the influence of such changes as heart rate and left ventricular ejection time are also measured.

Curve **12** is the curve illustrating the relationship between stroke volume and end-diastolic pressure of the left ventricle of a person having left ventricle mechanical impairment. Point **1'** is just before the patient holds his breath. He then makes a forceful expiratory effort without allowing air to escape. This initial pressure (EDP) is somewhat higher and the initial stroke volume (SV) usually somewhat lower than for a normal person, then decreases to point **2'** shortly before the breath is released. When breath is released, the blood which was prevented from returning to the heart does so at an increased rate, causing an increase in end-diastolic pressure. During the positive pressure phase, pressure generated in the chest exceeds the pressure of returning blood.

In a patient with mechanical impairment of the heart, no increase in stroke volume occurs with a rise in end-diastolic pressure (position **3'**), and this is detectable by a failure of the time derivative of the systemic arterial pulse pressure to increase. The range of changes which occur are acceptable in the individual patient depending to some extent on changes in other parameters, such as heart rate and left ventricular ejection time.

Referring to FIG. **2**, there is shown a block diagram illustrating the logical arrangement of a system according to the invention. Basically the invention senses a recovery derivative signal to indicate left ventricular impairment when this amplitude is equal to or less than a predetermined value. To this end the invention may include a number of different sources of a pressure signal. One such source may be a piezoelectric pulse pickup **11**, an impedance plethysmograph **12** or a sphygmamanometer **13** whose pressure signal is converted by transducer **14** into an electrical signal that is delivered

to amplifier means **15.** Each of these sources is pressure sensitive means noninvasive of the human body and derives a signal from contact with the skin surface near an artery. Amplifier means **15** includes means for amplifying one of the selected pressure signals and providing the amplified pressure signal to differentiator **16** that provides a differentiated pressure signal for analysis.

The apparatus also may include computer analysis control recovery means **21,** which may receive a pressure signal from amplifier means **15** and a computer analysis control recovery means **22** for responding to the time derivative pressure signal provided by differentiator **16.** Computer analysis control recovery means **21** preferably responds to heart rate, systemic arterial pulse pressure, peak systemic pressure, systemic mean pressure and left ventricular ejection time so that changes in these latter parameters may be used to more accurately define the predicted normal range for the time derivative of systemic arterial pulse and to provide a **1** signal to indicate a condition consistent with left ventricular mechanical impairment and a **2** signal to indicate a signal inconsistent with left ventricular mechanical impairment. Similarly computer analysis control recovery means **22** provides a **1** signal consistent with left ventricular failure and a **2** signal consistent with no failure. These **1** signals are applied to an AND gate **23** which provides an output to indicate left ventricular of a second AND gate **24** that provides an output to indicate no ventricular failure.

The invention may also comprise write-out means **25,** which may be a graphical recorder whose output may be manually analyzed or appear on calibrated paper that automatically displays the presence or absence of mechanical impairment.

Referring to FIG. **3,** there is shown three pairs of pulses that might be recorded during the course of a Valsalva manoeuvre. The first pair of pulses **31** occurs prior to holding the breath. The gain of amplifier means **15** is then adjusted so that the peak of the time derivative pressure waveform just reached the control line **32** with baseline adjusted **31A.** After the breath is released, if the pulses have a height, such as that of pair **33,** that is less than level **34,** left ventricular mechanical impairment is probable. If they have a height greater than level **34,** such as that of pulse pair **35,** there is no left ventricular impairment.

If the height is less than level **34,** such as that of pulse pair **33,** then the heart rate signals, systemic pulse pressure signals, peak systemic pressure signals, mean systemic pressure signals and left ventricular ejection time signals are subjected to further computer analysis to determine the extent to which certain of these parameters may independently alter the time derivative signal. For example, if changes in heart rate, the systemic arterial pulse pressure, mean pressure, systolic peak pressure and left ventricular ejection time are greater than a predetermined level, a second independent reanalysis of the pressure derivative signal is provided which takes into account the possible influence of changes in the latter parameters on the time derivative of pressure. Such an analysis is unlikely to be required in routine use but will improve the accuracy of the instrument.

Details of the various elements of the system represented by the boxes have not been described to avoid obscuring the principles of this invention and because such elements are known to those having ordinary skill in the signal analysis art.

For example, heart rate is readily determined by a digital counter whose count is compared by known techniques with a predetermined reference count equal to a control heart rate. The other two pressures may be readily determined by analog comparison techniques or by first converting these signals to digital values and making the comparison digitally.

While the preferred embodiment of the invention contemplates utilizing both derivatives and other signals in sensing for mechanical impairment of the heart, the derivative signal itself provided by differentiator **16** is most significant. Those skilled in the art might also determine the derivative by analyzing the pressure signal.

An advantage of differentiating before analyzing is that shifts in d-c pressure levels are essentially removed so that the resultant output signal waveform clearly represents a manifestation of the change in rate of pressure as a function of time to facilitate diagnosing left ventricular impairment.

There has been described novel apparatus and techniques for facilitating the detection of mechanical heart impairment by relatively unskilled personnel. It is evident that those skilled in the art may now make numerous uses and modifications of and departures from the specific embodiments disclosed herein without departing from the inventive concepts. Consequently, the invention is to be construed as embracing each and every novel feature and novel combination of features present in or possessed by the apparatus and techniques herein disclosed and limited solely by the spirit and scope of the appended claims.

What is claimed is:

1. A method of detecting mechanical heart impairment which method includes the steps of,

noninvasively providing a blood pressure signal representative of blood pressure by placing pressure sensitive means in contact with the skin of a patient near an artery,

differentiating said blood pressure signal,

subjecting said patient whose blood pressure is characterized by said pressure signal to a heart straining manoeuvre,

detecting the change in the amplitude of the differentiated pressure signal after said manoeuvre from its amplitude before said manoeuvre,

and determining a probable mechanical impairment of the heart when said change is less than a predetermined value.

2. A method of detecting mechanical heart impairment in accordance with claim **1** wherein said heart straining manoeuvre is a Valsalva manoeuvre and said signal representative of blood pressure is representative of systemic arterial blood pressure.

3. A method of detecting mechanical heart impairment in accordance with claim **2** wherein said Valsalva manoeuvre is involuntarily induced in said patient.

4. A method of detecting mechanical heart impairment in accordance with claim **1** and further including the steps of providing signals representative of systemic peak pressure, systemic mean pressure, heart rate, and left ventrical ejection time both before and after said manoeuvre and sensing the differences between respective signals before and after said manoeuvre.

5. A method of detecting mechanical heart impairment in accordance with claim **1** which method includes the steps of,

recording the differentiated blood pressure signal so that its peak amplitude before said manoeuvre is between a baseline and predetermined control line and observing the amplitude of said differentiated blood pressure signal immediately after said manoeuvre relative to a predetermined normal limit line spaced from said control line to determine potential mechanical impairment when the peak amplitude after said manoeuvre is between the control line and the acceptable level line, mechanical heart impairment when then below said control line and no mechanical impairment when above said acceptable level line.

6. Apparatus for practicing the method of claim **1** comprising,

pressure sensitive means responsive to said blood pressure for providing said blood pressure signal,

means for differentiating said blood pressure signal to provide a differentiated pressure signal representative of the time derivative of said blood pressure,

means for detecting the change in the amplitude of the differentiated pressure signal after said manoeuvre from its amplitude before said manoeuvre including means for recording said differentiated pressure signal before and after said manoeuvre to provide an indication of the changes in the differentiated pressure signal before and after said manoeuvre,

and means for determining a probable mechanical impairment of the heart when said change is less than a predetermined value.

7. Apparatus in accordance with claim **6** and further comprising means responsive to said blood pressure signal for deriving signals representative of heart rate, pulse pressure and peak pressure,

and means responsive to said differentiated pressure signal, said heart rate, said pulse pressure and said peak pressure for providing an indication of mechanical heart impairment.

* * * * *