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(54) METHODS AND APPARATUSES FOR LOCALIZING MYOCARDIAL INFARCTION DURING CATHETERIZATION

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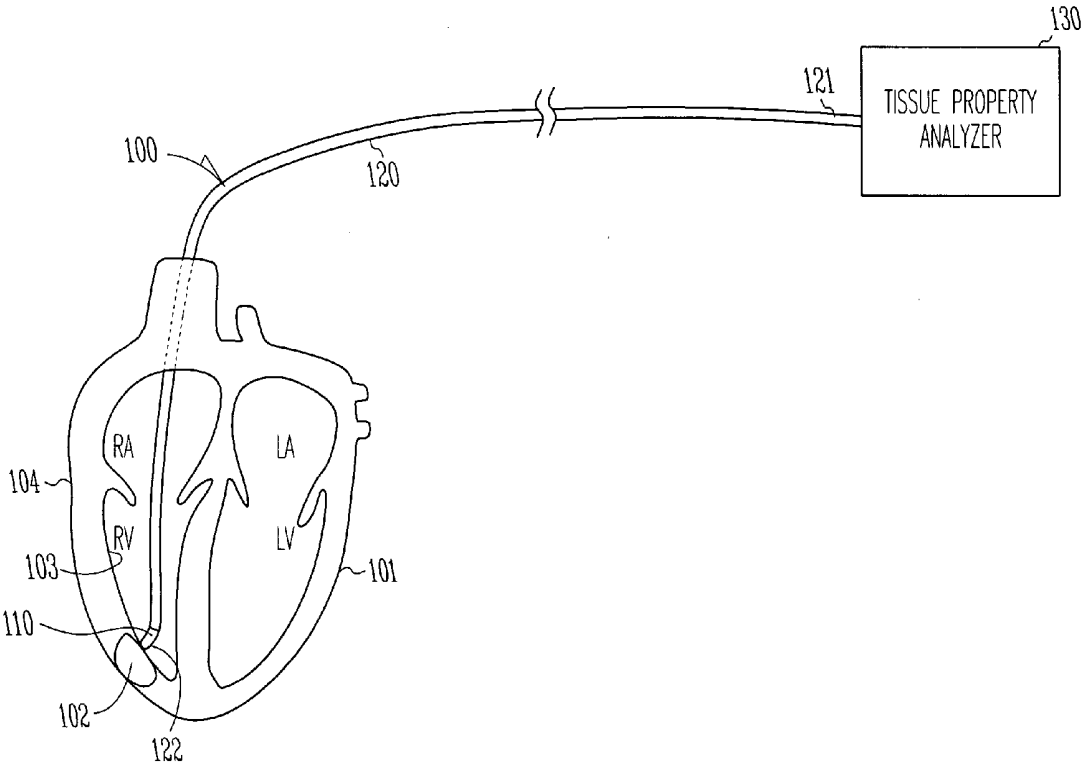
(57) ABSTRACT

A catheter with a tissue property sensor provides for localization of myocardial infarction (MI) by utilizing one or more differences between properties of infarcted myocardial tissue and properties of normal myocardial tissue. The tissue property sensor is to be placed on endocardial wall or epicardial wall during catheterization to sense at least one tissue property allowing for detection of MI. Examples of the tissue property sensor include, but are not limited to, an optical sensor, an acoustic sensor, a contractility sensor, a temperature sensor, and a drug response sensor. In one embodiment, the tissue property sensor senses a tissue property in various locations on endocardial wall or epicardial wall and detects substantial changes in the tissue property that indicate a boundary between infarcted tissue and normal tissue.



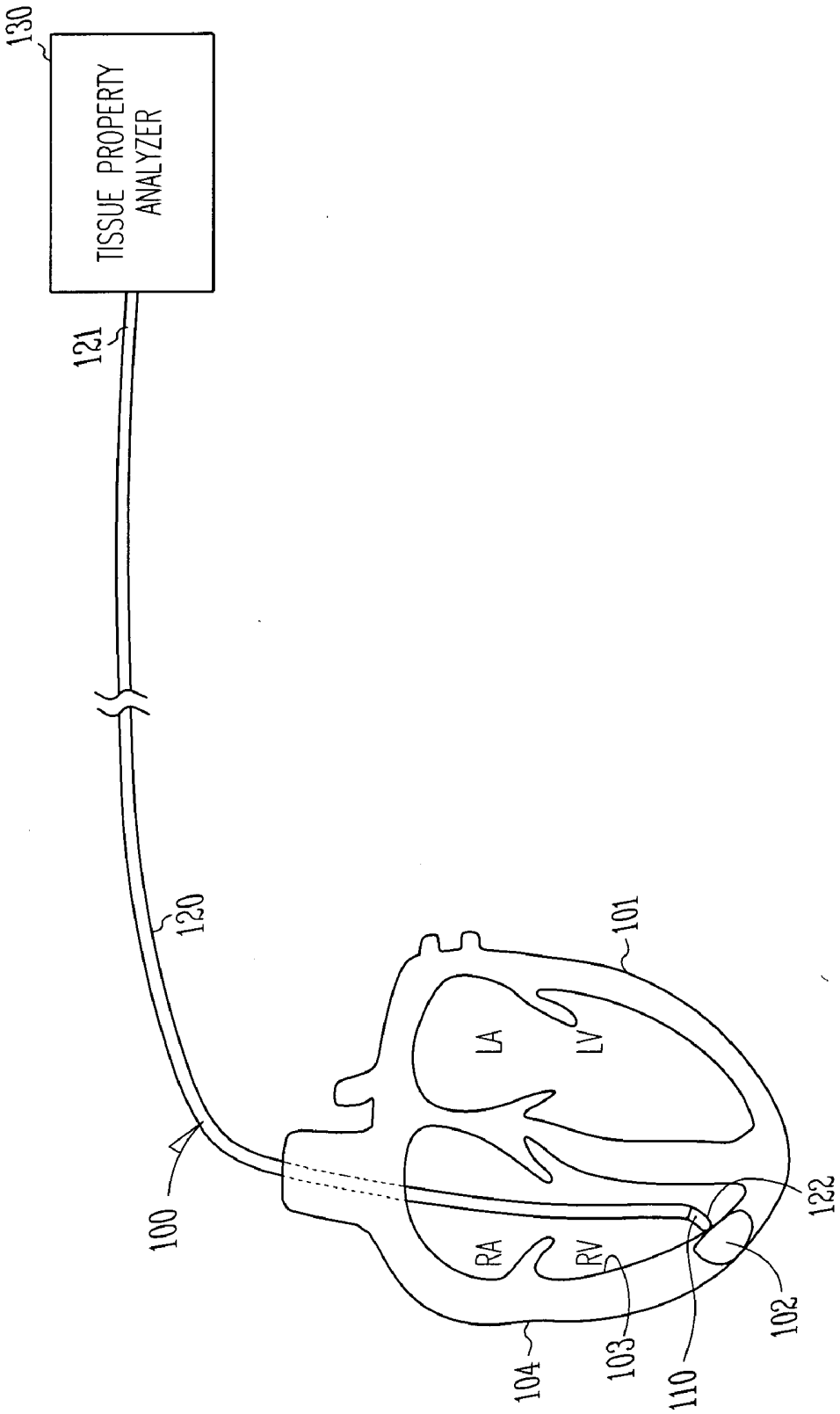

130
TISSUE PROPERTY ANALYZER
121
120
100
101
LA
LV
RA
RV
122
102
103
104
110

FIG. 1

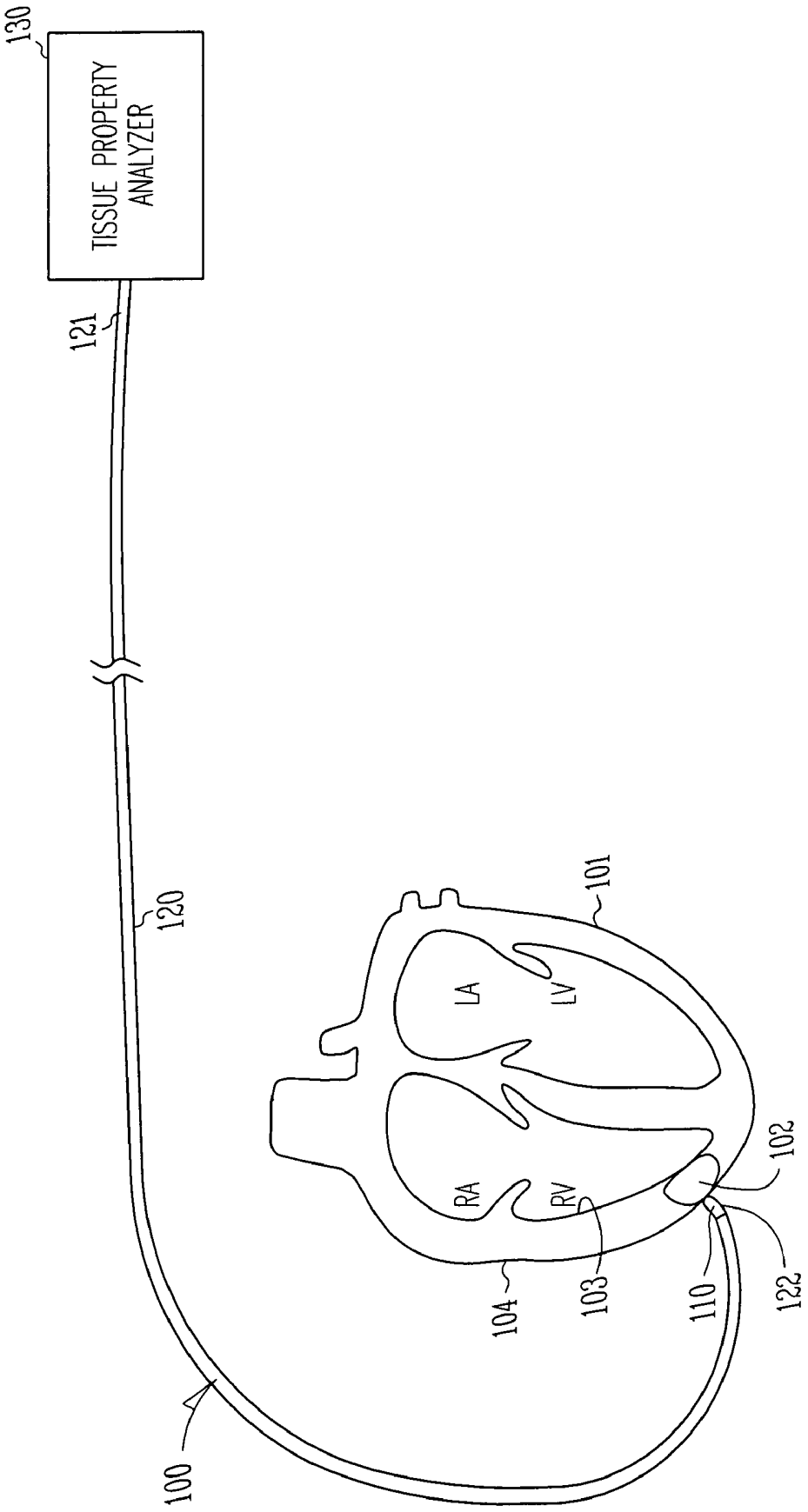

130
TISSUE PROPERTY ANALYZER
121
120
100
101
LA
LV
RA
RV
102
103
104
110
122

FIG. 2

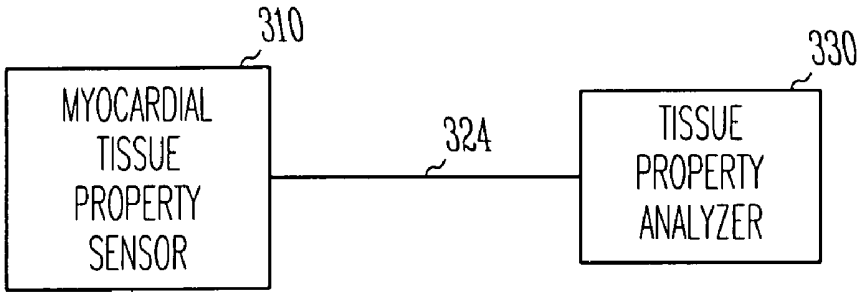

310
MYOCARDIAL TISSUE PROPERTY SENSOR
324
330
TISSUE PROPERTY ANALYZER

Fig.3

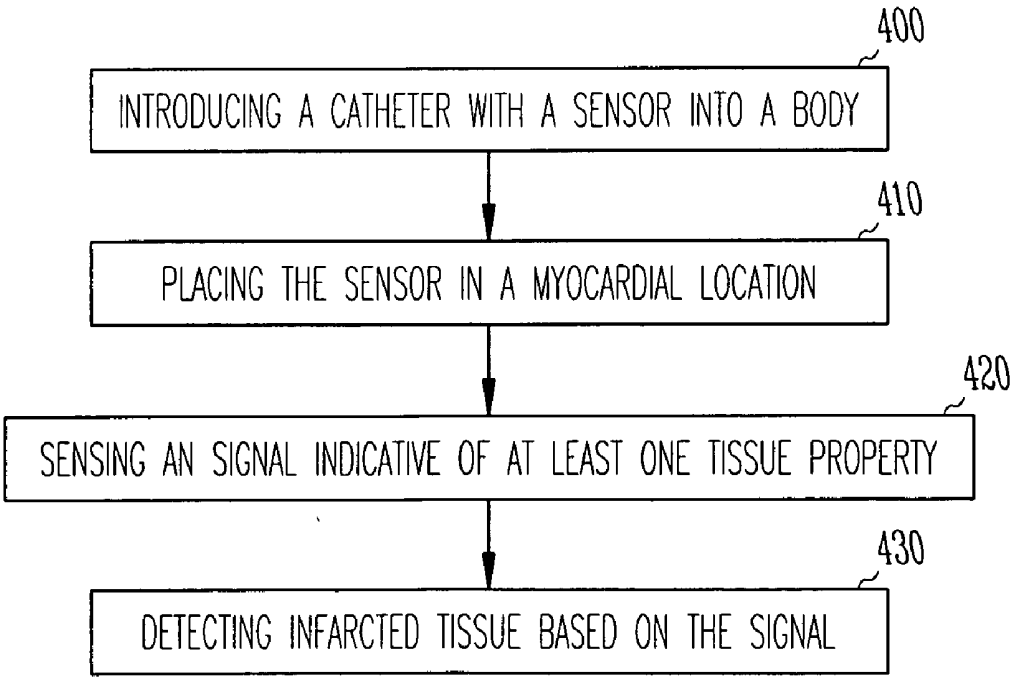

400
INTRODUCING A CATHETER WITH A SENSOR INTO A BODY
410
PLACING THE SENSOR IN A MYOCARDIAL LOCATION
420
SENSING AN SIGNAL INDICATIVE OF AT LEAST ONE TISSUE PROPERTY
430
DETECTING INFARCTED TISSUE BASED ON THE SIGNAL

Fig.4

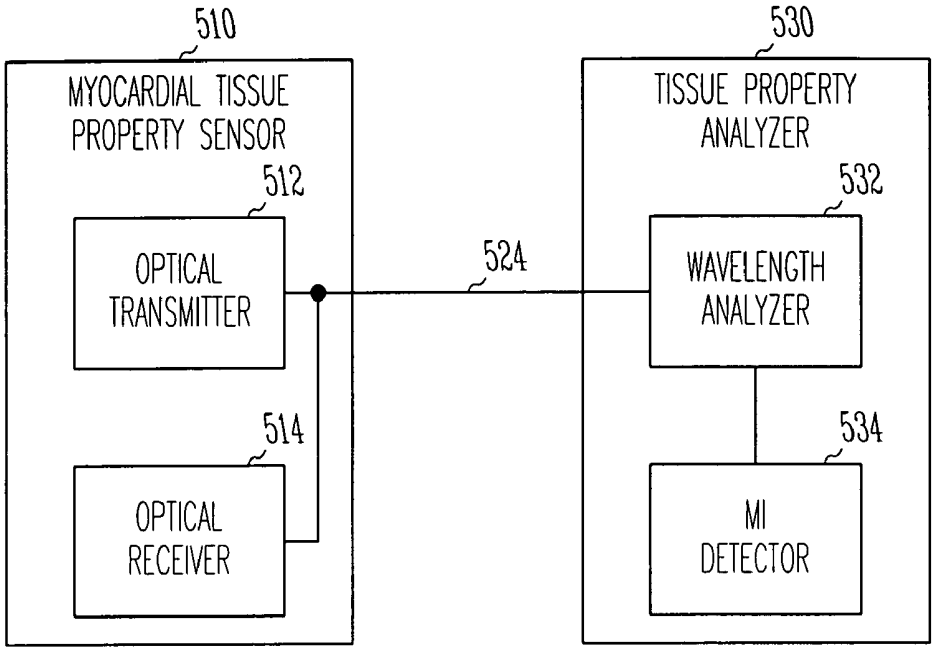

510
MYOCARDIAL TISSUE PROPERTY SENSOR
512
OPTICAL TRANSMITTER
514
OPTICAL RECEIVER
524
530
TISSUE PROPERTY ANALYZER
532
WAVELENGTH ANALYZER
534
MI DETECTOR

Fig.5

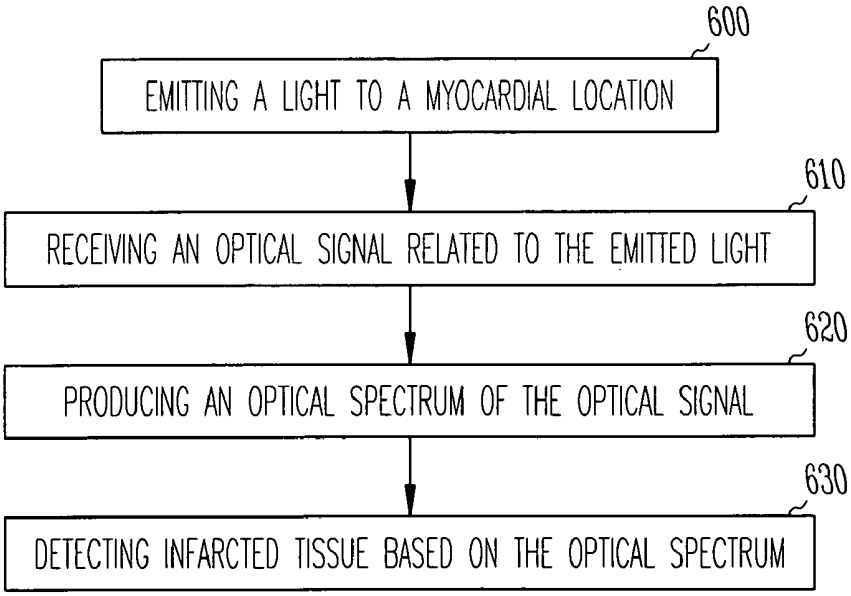

600
EMITTING A LIGHT TO A MYOCARDIAL LOCATION
610
RECEIVING AN OPTICAL SIGNAL RELATED TO THE EMITTED LIGHT
620
PRODUCING AN OPTICAL SPECTRUM OF THE OPTICAL SIGNAL
630
DETECTING INFARCTED TISSUE BASED ON THE OPTICAL SPECTRUM

Fig.6

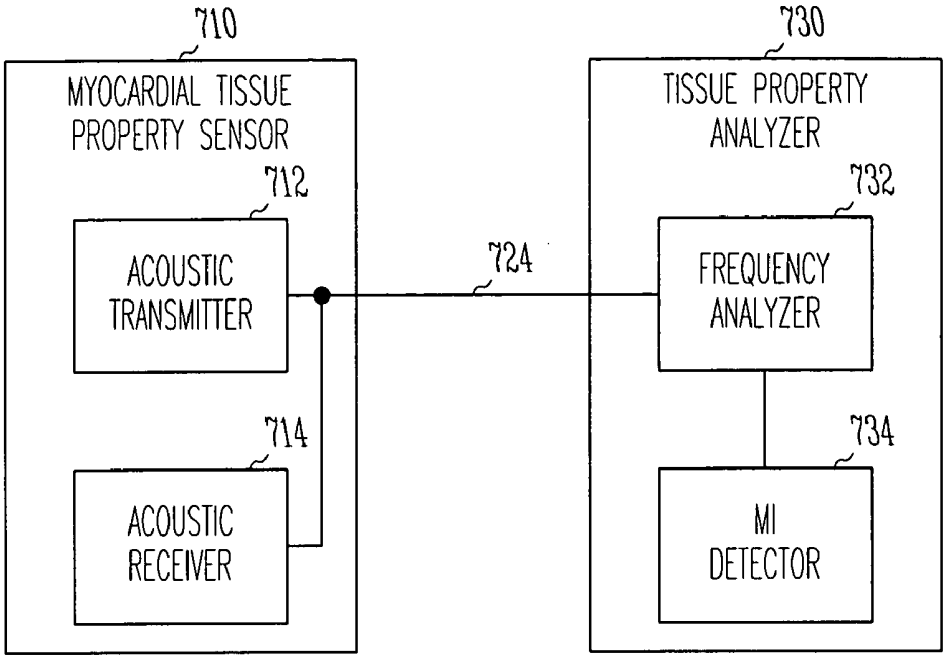

710
MYOCARDIAL TISSUE PROPERTY SENSOR
712
ACOUSTIC TRANSMITTER
714
ACOUSTIC RECEIVER
724
730
TISSUE PROPERTY ANALYZER
732
FREQUENCY ANALYZER
734
MI DETECTOR

Fig.7

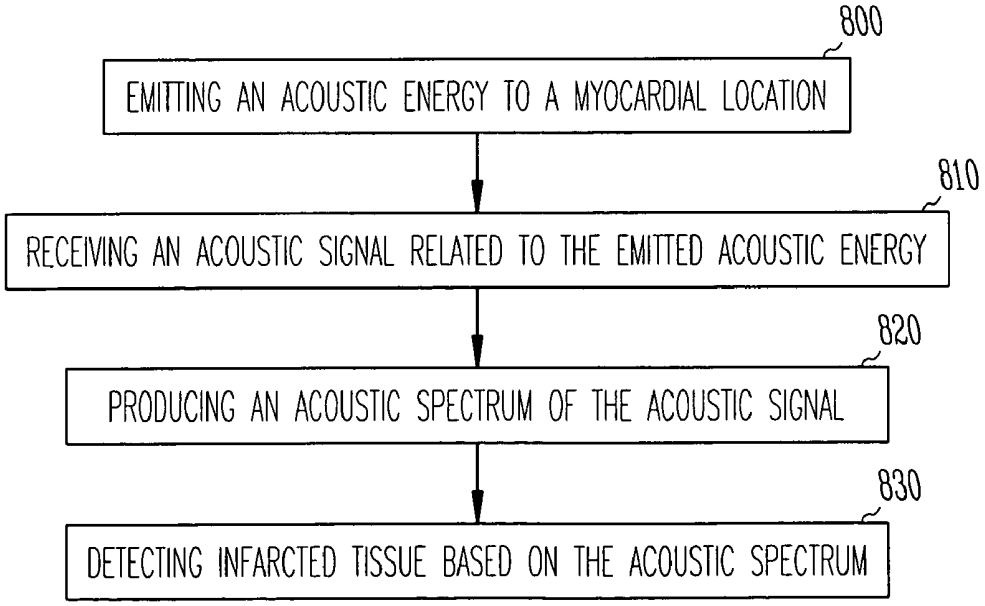

800
EMITTING AN ACOUSTIC ENERGY TO A MYOCARDIAL LOCATION
810
RECEIVING AN ACOUSTIC SIGNAL RELATED TO THE EMITTED ACOUSTIC ENERGY
820
PRODUCING AN ACOUSTIC SPECTRUM OF THE ACOUSTIC SIGNAL
830
DETECTING INFARCTED TISSUE BASED ON THE ACOUSTIC SPECTRUM

Fig.8

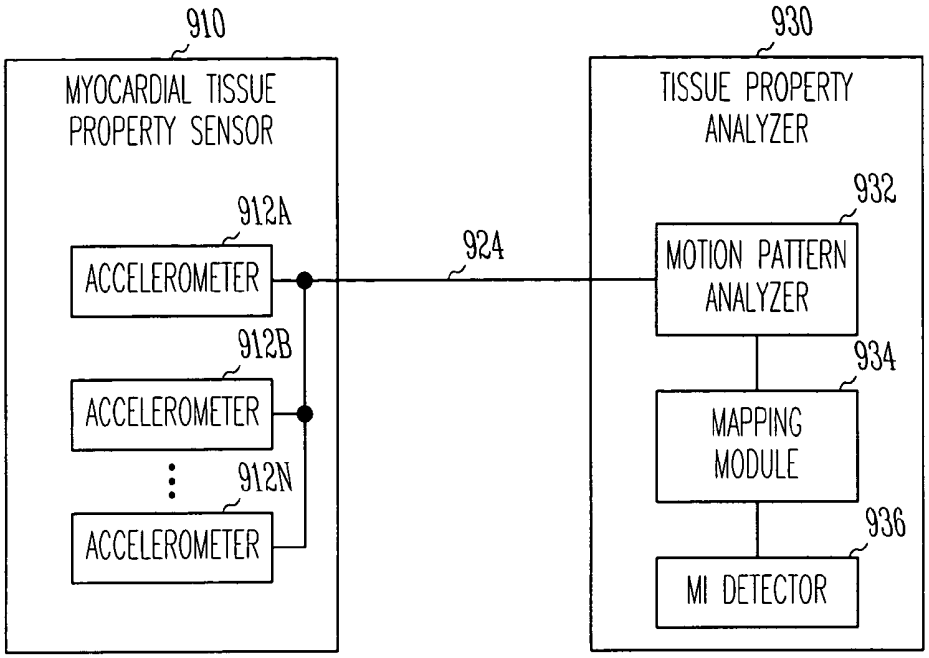

910
MYOCARDIAL TISSUE PROPERTY SENSOR
912A
ACCELEROMETER
912B
ACCELEROMETER
912N
ACCELEROMETER
924
930
TISSUE PROPERTY ANALYZER
932
MOTION PATTERN ANALYZER
934
MAPPING MODULE
936
MI DETECTOR

Fig.9

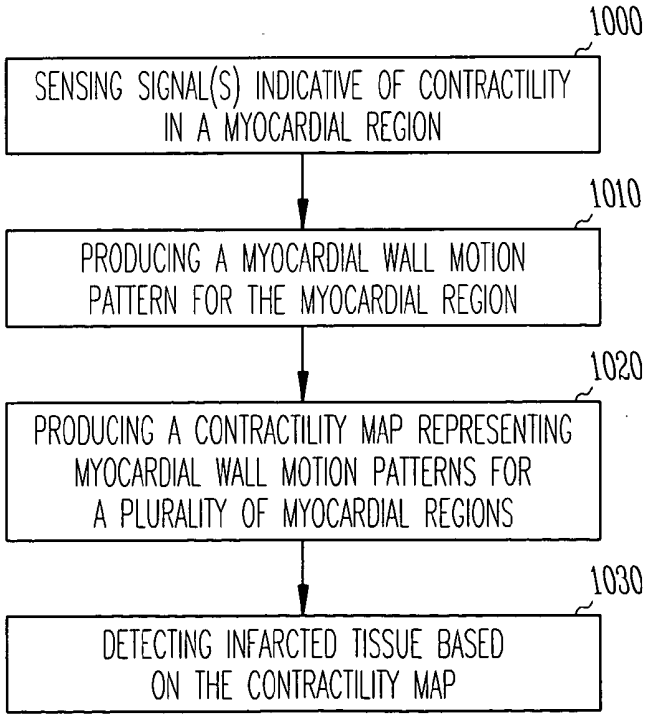

1000
SENSING SIGNAL(S) INDICATIVE OF CONTRACTILITY IN A MYOCARDIAL REGION
1010
PRODUCING A MYOCARDIAL WALL MOTION PATTERN FOR THE MYOCARDIAL REGION
1020
PRODUCING A CONTRACTILITY MAP REPRESENTING MYOCARDIAL WALL MOTION PATTERNS FOR A PLURALITY OF MYOCARDIAL REGIONS
1030
DETECTING INFARCTED TISSUE BASED ON THE CONTRACTILITY MAP

Fig.10

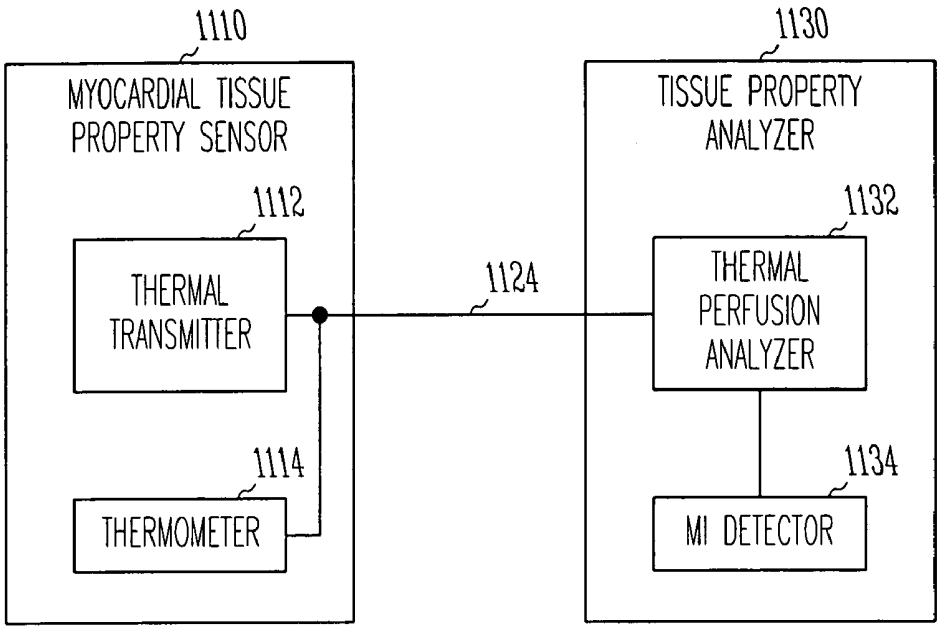

1110
MYOCARDIAL TISSUE PROPERTY SENSOR
1112
THERMAL TRANSMITTER
1114
THERMOMETER
1124
1130
TISSUE PROPERTY ANALYZER
1132
THERMAL PERFUSION ANALYZER
1134
MI DETECTOR

Fig.11

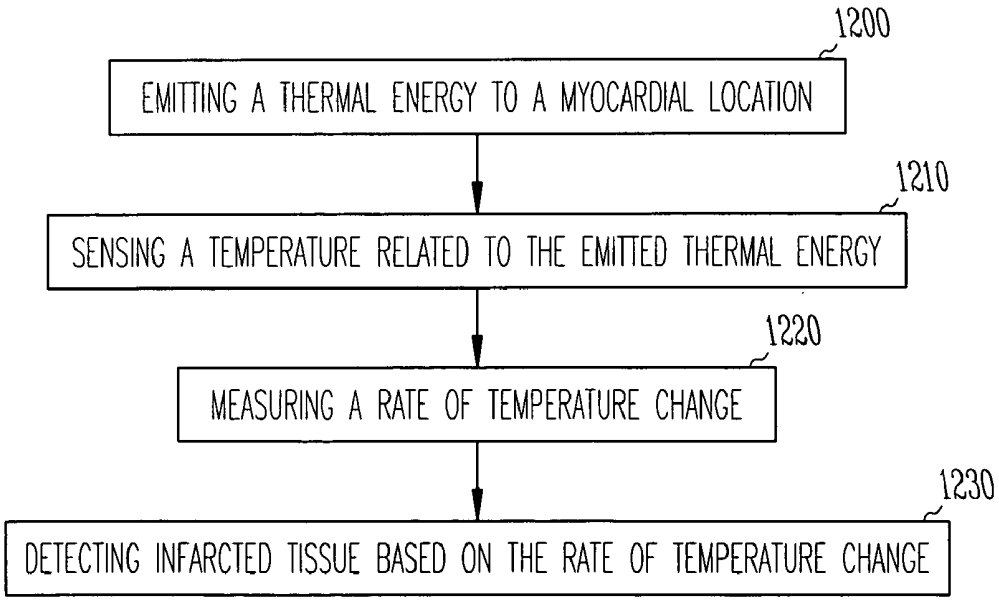

1200
EMITTING A THERMAL ENERGY TO A MYOCARDIAL LOCATION
1210
SENSING A TEMPERATURE RELATED TO THE EMITTED THERMAL ENERGY
1220
MEASURING A RATE OF TEMPERATURE CHANGE
1230
DETECTING INFARCTED TISSUE BASED ON THE RATE OF TEMPERATURE CHANGE

Fig.12

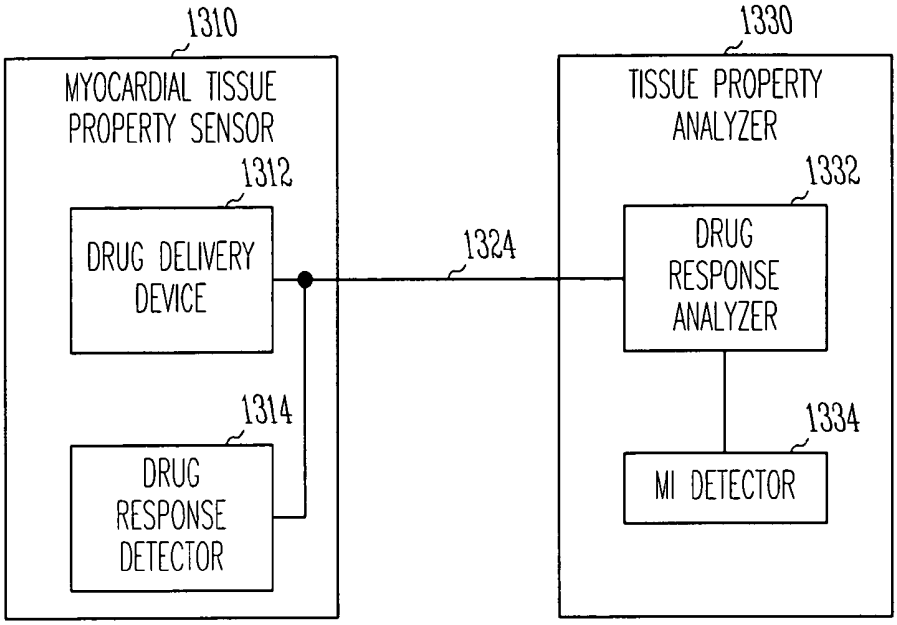

1310
MYOCARDIAL TISSUE PROPERTY SENSOR
1312
DRUG DELIVERY DEVICE
1314
DRUG RESPONSE DETECTOR
1324
1330
TISSUE PROPERTY ANALYZER
1332
DRUG RESPONSE ANALYZER
1334
MI DETECTOR

Fig.13

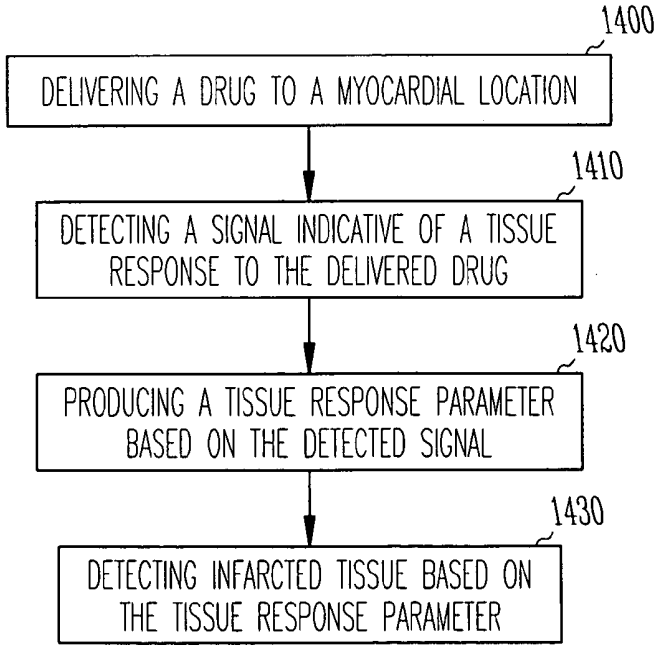

1400
DELIVERING A DRUG TO A MYOCARDIAL LOCATION
1410
DETECTING A SIGNAL INDICATIVE OF A TISSUE RESPONSE TO THE DELIVERED DRUG
1420
PRODUCING A TISSUE RESPONSE PARAMETER BASED ON THE DETECTED SIGNAL
1430
DETECTING INFARCTED TISSUE BASED ON THE TISSUE RESPONSE PARAMETER

Fig.14

METHODS AND APPARATUSES FOR LOCALIZING MYOCARDIAL INFARCTION DURING CATHETERIZATION

FIELD OF THE INVENTION

[0001] This document generally relates to cardiac rhythm management systems and particularly, but not by way of limitation, to a system for localizing infarcted tissue in a heart having suffered myocardial infarction based on tissue properties that distinguish the infarcted tissue from normal myocardial tissue.

BACKGROUND

[0002] The heart is the center of a person's circulatory system. It includes an electro-mechanical system performing two major pumping functions. The heart includes four chambers: right atrium (RA), right ventricle (RV), left atrium (LA), and left ventricle (LV). The left portions of the heart, including LA and LV, draw oxygenated blood from the lungs and pump it to the organs of the body to provide the organs with their metabolic needs for oxygen. The right portions of the heart, including RA and RV, draw deoxygenated blood from the body organs and pump it to the lungs where the blood gets oxygenated. The efficiency of the pumping functions, indicative whether the heart is normal and healthy, is indicated by measures of hemodynamic performance, such as parameters related to intracardiac blood pressures and cardiac output.

[0003] In a normal heart, the sinoatrial node, the heart's natural pacemaker, generates electrical impulses, called action potentials, that propagate through an electrical conduction system to various regions of the heart to excite the myocardial tissues of these regions. Coordinated delays in the propagations of the action potentials in a normal electrical conduction system cause the various portions of the heart to contract in synchrony to result in efficient pumping functions indicated by a normal hemodynamic performance. A blocked or otherwise abnormal electrical conduction and/or deteriorated myocardial tissue cause dysynchronous contraction of the heart, resulting in poor hemodynamic performance, including a diminished blood supply to the heart and the rest of the body. The condition where the heart fails to pump enough blood to meet the body's metabolic needs is known as heart failure.

[0004] Myocardial infarction (MI) is the necrosis of portions of the myocardial tissue resulted from cardiac ischemia, a condition in which the myocardium is deprived of adequate oxygen and metabolite removal due to an interruption in blood supply. The necrotic tissue, known as infarcted tissue, loses the contractile properties of the normal, healthy myocardial tissue. Consequently, the overall contractility of the myocardium is weakened, resulting in decreased cardiac output. As a physiological compensatory mechanism that acts to increase cardiac output in response to MI, the LV diastolic filling pressure increases as the pulmonary and venous blood volume increases. This increases the LV preload (stress on the LV wall before its contracts to eject blood). One consequence is the progressive change of the LV shape and size, a processes referred to as remodeling. Remodeling is initiated in response to a redistribution of cardiac stress and strain caused by the impairment of contractile function in the infarcted tissue as well as in nearby and/or interspersed viable myocardial tissue with lessened contractility due to the infarct. The remodeling starts with expansion of the region of the infarcted tissue and progresses to a chronic, global expansion in the size and change in the shape of the entire LV. Although the process is initiated by the compensatory mechanism that increases cardiac output, the remodeling ultimately leads to further deterioration and dysfunction of the myocardium. Consequently, post MI patients experience impaired hemodynamic performance and have a significantly increased risk of developing heart failure.

[0005] For effectively and/or efficiently applying surgical or any other treatments to control the remodeling process, there is a need for localizing the infarcted tissue in a heart having suffered MI.

SUMMARY

[0006] A catheter with a tissue property sensor provides for localization of myocardial infarction (MI) by utilizing one or more differences between properties of infarcted myocardial tissue and properties of normal myocardial tissue. The tissue property sensor is to be placed on a cardiac wall during catheterization to sense at least one tissue property allowing for detection of MI.

[0007] In one embodiment, a system for localizing MI includes a catheter, a myocardial tissue property sensor, and a tissue property analyzer. The catheter includes a distal end configured for placement in a location on the cardiac wall. The myocardial tissue property sensor is incorporated into the distal end of the catheter to be placed in a myocardial location to sense a signal indicative of at least one tissue property. The tissue property analyzer includes an input to receive the sensed signal and an output indicative of whether the sensed signal indicates infarcted tissue.

[0008] Examples of the myocardial tissue property sensor include, but are not limited to, an optical sensor, an acoustic sensor, a contractility sensor, a temperature sensor, and a drug response sensor. The optical sensor includes an optical transmitter to emit a light and an optical receiver to receive an optical signal related to the emitted light. The acoustic sensor includes an acoustic transmitter to emit an acoustic energy and an acoustic receiver to receive an acoustic signal related to the emitted acoustic energy. The contractility sensor includes an accelerometer array with a plurality of accelerometers to sense acceleration signals related to displacement of the cardiac wall. The temperature sensor includes a thermal transmitter to emit a thermal energy and a thermometer to sense a temperature signal related to the emitted thermal energy. The drug response sensor includes a drug delivery device to deliver a drug and a drug response detector to detect a drug response signal. The optical signal, acoustic signal, acceleration signals, temperature signal, and drug response signal each indicates a tissue property allowing for detection of infracted tissue.

[0009] In one embodiment, the tissue property analyzer includes a parameter generator and a comparator. The parameter generator produces a parameter based on the sensed signal. The comparator compares the parameter to a predetermined threshold and indicates a detection of infarcted tissue based on the comparison.

[0010] In one embodiment, the myocardial tissue property sensor is incorporated into the distal end of the catheter to be

placed in a plurality of myocardial locations, one at a time, over a portion of the cardiac wall to sense signals each indicative of the tissue property for one of the myocardial locations. The tissue property analyzer includes a tissue property mapping module that produces a tissue property map presenting a measure of the tissue property over the portion of the cardiac wall based on the sensed signals.

[0011] In one embodiment, methods for localizing MI are provided. A sensor is placed in a myocardial location. A signal is sensed using to sensor to indicate at least one tissue property in the myocardial location. Infarcted tissue is detected based on the signal. Examples of the signal include, but are not limited to, an optical signal, an acoustic signal, a signal indicative of myocardial contractility, a temperature signal, and a signal indicative of a myocardial tissue response to a drug delivery. These signals each indicates a tissue property allowing for detection of the infracted tissue.

[0012] This Summary is an overview of some of the teachings of the present application and not intended to be an exclusive or exhaustive treatment of the present subject matter. Further details about the present subject matter are found in the detailed description and appended claims. Other aspects of the invention will be apparent to persons skilled in the art upon reading and understanding the following detailed description and viewing the drawings that form a part thereof, each of which are not to be taken in a limiting sense. The scope of the present invention is defined by the appended claims and their equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The drawings illustrate generally, by way of example, but not by way of limitation, various embodiments discussed in the present document. The drawing are for illustrative purposes only and not to scale nor anatomically accurate.

[0014] **FIG. 1** is an illustration of one embodiment of a system providing for localization of MI during cardiac catheterization, in which the system is used for an endocardial application, and portions of an environment in which the system is used.

[0015] **FIG. 2** is an illustration of another embodiment of the system providing for localization of MI during cardiac catheterization, in which the system is used for an epicardial application, and portions of an environment in which the system is used.

[0016] **FIG. 3** is block diagram illustrating one embodiment of a circuit of the system providing for localization of MI during cardiac catheterization.

[0017] **FIG. 4** is a flow chart illustrating one embodiment of a method for localizing MI during cardiac catheterization.

[0018] **FIG. 5** is block diagram illustrating one specific embodiment of the circuit of the system providing for localization of MI in which an optical sensor is used.

[0019] **FIG. 6** is a flow chart illustrating one specific embodiment of the method for localizing MI in which an optical signal is sensed.

[0020] **FIG. 7** is block diagram illustrating another specific embodiment of the circuit of the system providing for localization of MI in which an acoustic sensor is used.

[0021] **FIG. 8** is a flow chart illustrating another specific embodiment of the method for localizing MI in which an acoustic signal is sensed.

[0022] **FIG. 9** is block diagram illustrating another specific embodiment of the circuit of the system providing for localization of MI in which a contractility sensor is used.

[0023] **FIG. 10** is a flow chart illustrating another specific embodiment of the method for localizing MI in which a signal indicative of a myocardial contractility is sensed.

[0024] **FIG. 11** is block diagram illustrating another specific embodiment of the circuit of the system providing for localization of MI in which a temperature sensor is used.

[0025] **FIG. 12** is a flow chart illustrating another specific embodiment of the method for localizing MI in which a signal indicative of temperature is sensed.

[0026] **FIG. 13** is block diagram illustrating another specific embodiment of the circuit of the system providing for localization of MI in which a drug response sensor is used.

[0027] **FIG. 14** is a flow chart illustrating another specific embodiment of the method for localizing MI in which a signal indicative of a myocardial tissue response to a drug delivery is sensed.

DETAILED DESCRIPTION

[0028] In the following detailed description, reference is made to the accompanying drawings which form a part hereof, and in which is shown by way of illustration specific embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that the embodiments may be combined, or that other embodiments may be utilized and that structural, logical and electrical changes may be made without departing from the spirit and scope of the present invention. The following detailed description provides examples, and the scope of the present invention is defined by the appended claims and their equivalents.

[0029] It should be noted that references to "an", "one", or "various" embodiments in this disclosure are not necessarily to the same embodiment, and such references contemplate more than one embodiment.

[0030] This document discusses, among other things, a method and system for localizing MI (i.e., identifying regions of infarcted tissue) based on myocardial tissue properties. After MI, various properties of the infarcted tissue change during the scar formation process. By sensing one or more tissue properties across a portion of the cardiac wall, infarcted regions are localized as areas where the one or more tissue properties are determined to be associated with infarcted tissue. The method and system are also useable for monitoring any effect of therapies delivered to control the post-MI remodeling process by treating the infarcted tissue.

[0031] **FIGS. 1 and 2** illustrate two embodiments of a system **100** providing for localization of MI and portions of an environment in which system **100** is used. System **100** includes a catheter **120** that provides for localization of at least one infarcted region **102** in a heart **101** that has suffered MI. Heart **101** includes an endocardial wall **103** and an

epicardial wall **104**. Catheter **120** has a proximal end **121** and a distal end **122**. A myocardial tissue property sensor **110** is incorporated into catheter **120** at distal end **122**. In the embodiment illustrated in **FIG. 1**, myocardial tissue property sensor **110** is configured for placement in various locations or regions on endocardial surface **103**. In the embodiment illustrated in **FIG. 2**, myocardial tissue property sensor **110** is configured for placement in various locations or regions on endocardial surface **104**. Myocardial tissue property sensor **110** senses one or more signals indicative of myocardial tissue properties. Proximal end **121** is outside the body and connected to an external tissue property analyzer **130**. Tissue property analyzer **130** analyzes the one or more signals sensed by myocardial tissue property sensor **110** to detect infarcted tissue. Catheter **120** provides for electrical and/or other connections between myocardial tissue property sensor **110** and tissue property analyzer **130** to allow transmission of the one or more sensed signals.

[**0032**] Myocardial tissue property sensor **110** is configured for placement in a location or a region on endocardial wall **103** and/or epicardial wall **104**. In one embodiment, at least a portion of myocardial tissue property sensor **110** is configured for penetration into the myocardial tissue in the location or region on the cardiac wall including endocardial wall **103** and/or epicardial wall **104**. The penetration allows sensing of tissue properties that must be achieved with a sensor in the tissue and stabilization of the sensor in the location or region of the cardiac wall. Myocardial tissue property sensor **110**, including all of its embodiments discussed below, includes at least a portion configured for tissue penetration when such a penetration is considered necessary and/or adequate. In all discussions related to sensor placement below, "in a location on a cardiac wall,""in a region on a cardiac wall," and like expressions include penetration of at least a portion of myocardial tissue property sensor **110** into tissue when such a penetration is considered necessary and/or adequate. Whether such a penetration is considered necessary and/or adequate depends on the need for reliable sensing of tissue property and/or the need for stabilizing the placement of myocardial tissue property sensor **110** during sensing, as understood by any person skilled in the art of cardiac catheterization and tissue property sensing.

[**0033**] In one embodiment, catheter **120** is a catheter dedicated to MI localization by myocardial tissue property sensing. In another embodiment, myocardial tissue property sensor **110** is incorporated into a catheter used for other diagnostic and/or therapeutic purposes. Examples of catheter **120** in this embodiment include, but are not limited to, a catheter for assessment of hemodynamic function, a catheter for mapping of cardiovascular structure, a substance (such as pharmaceutical and biological agents) delivery catheter, an ablation catheter, a pacing lead, and a defibrillation lead. In one embodiment, as illustrated in **FIG. 1**, catheter **120** is configured for transvenous or transarterial catheterization with distal end **122** reaching endocardial wall **103**. In another embodiment, as illustrated in **FIG. 2**, catheter **120** is configured for intercostal catheterization with distal end **122** reaching epicardial wall **104**. In one specific embodiment, the intercostal catheterization is performed using a minimally invasive surgical technique. For example, a small incision is made on chest between two ribs. Catheter **120** is inserted through the incision into intercostal space to reach heart **101** under guidance provided with some imaging technique. In one embodiment, catheter **120** is configured to be suitable for transvenous, transarterial, and intercostal catheterization.

[**0034**] For all descriptions below, the term "myocardial" includes "endocardial" and "epicardial," and the term "cardiac wall" includes "endocardial wall" and "epicardial wall." For example, any "myocardial tissue property sensor" is configured as an "endocardial tissue property sensor" for endocardial placement over a portion of the myocardium in one embodiment, as illustrated in **FIG. 1**, and an "epicardial tissue property sensor" for epicardial placement over a portion of the myocardium in another embodiment, as illustrated in **FIG. 2**. A "myocardial location" includes a location on endocardial wall **103** or epicardial wall **104** or locations in myocardial tissue accessible through endocardial wall **103** or epicardial wall **104**.

[**0035**] **FIG. 3** illustrates one embodiment of a circuit of system **100**. The circuit includes a myocardial tissue property sensor **310** and a tissue property analyzer **330**. Myocardial tissue property sensor **310** represents one embodiment of myocardial tissue property sensor **110**. Tissue property analyzer **330** represents one embodiment of tissue property analyzer **130**. A sensor link **324**, which couples myocardial tissue property sensor **310** and tissue property analyzer **330** via electrical and/or other connections, is included in catheter **120** and extends from proximal end **121** to distal end **122**.

[**0036**] Myocardial tissue property sensor **310** includes a sensor that senses at least one signal indicative of a tissue property that changes as a result of MI. Examples of myocardial tissue property sensor **310** include, but are not limited to, an optical sensor, an acoustic sensor, a temperature sensor, a contractility sensor, and a drug response sensor. These examples are discussed below with reference to **FIGS. 5, 7, 9, 11**, and **13**. Tissue property analyzer **330** includes an input coupled to myocardial tissue property sensor **220** through sensor link **324** and an output indicating detection of infarcted tissue. In one embodiment, tissue property analyzer **330** includes a parameter generator and an MI detector. The parameter generator produces at least one parameter representative of the tissue property indicated by the sensed signal. The MI detector includes a comparator with a signal input receiving the parameter, a threshold input receiving a predetermined threshold, and an output indicating a detection of the infarcted tissue based on a comparison between the signal and the threshold. In a specific embodiment, the threshold is determined based on a study evaluating a patient population. In another embodiment, tissue property analyzer **330** includes a tissue property mapping module to produce a tissue property map presenting a measure of at least one tissue property over at least a portion of the cardiac wall. In a further embodiment, tissue property analyzer **330** includes an MI detector to detect one or more infarcted regions based on the tissue property map.

[**0037**] **FIG. 4** is a flow chart illustrating one embodiment of a method for localizing MI during cardiac catheterization. In one specific embodiment, the method is performed with system **100** including the circuit of **FIG. 3**.

[**0038**] A catheter is introduced into a body to provide for access to the heart at **400**. The catheter includes a sensor at its end portion. The sensor is placed in a location on the

cardiac wall at **410**. A signal indicative of at least one tissue property of the tissue in that myocardial location is sensed at **420**. The tissue property indicated by the sensed signal is a tissue property that changes as a result of MI and provides for distinction between normal and infarcted tissues. Examples of the sensed signal include, but are not limited to an optical signal, an acoustic signal, a signal indicative of myocardial contractility, a temperature signal, and a signal indicative of a myocardial tissue response to a drug delivery. These examples are further discussed below with reference to **FIGS. 6, 8, 10, 12**, and **14**. The infarcted tissue is detected based on the sensed signal at **430**. The detection indicates that the tissue in the myocardial location where the sensor is placed is infarcted tissue.

[**0039**] In one embodiment, the sensor is moved to and placed in a plurality of myocardial locations, one at a time, within at least a portion of the cardiac wall to sense the signal at each of these locations. The signal sensed at each location indicates whether the tissue in that location is infarcted tissue. In one embodiment, a parameter representative of the tissue property for each location is produced and compared to a predetermined threshold value. Infarcted tissue is detected for each location based on an outcome of the comparison. In another embodiment, a tissue property map is produced to present a measure of the at least one tissue property over the at least the portion of the cardiac wall. Boundaries of one or more infarcted regions are identified based on the tissue property map.

EXAMPLE 1

System with Optical Sensor

[**0040**] **FIG. 5** illustrates one specific embodiment of the circuit of system **100**. The circuit provides for localization of MI using an optical sensor. This circuit includes a myocardial tissue property sensor **510**, which is a specific embodiment of myocardial tissue property sensor **310**, and a tissue property analyzer **530**, which is a specific embodiment of tissue property analyzer **330**. A sensor link **524**, which is a specific embodiment of sensor link **324**, couples myocardial tissue property sensor **510** and tissue property analyzer **530**.

[**0041**] Myocardial tissue property sensor **510** is an optical sensor including an optical transmitter **512** and an optical receiver **514**. Optical transmitter **512** emits a light into tissue in a myocardial location where myocardial tissue property sensor **510** is placed. The light includes a visible light, an infrared light, an ultraviolet light, or a combination of such lights. Optical receiver **514** receives an optical signal related to the emitted light while the light is being emitted. The optical signal includes fluorescence generated from myocardial tissue in response to the emitted light. The fluorescence has an optical spectrum including wavelengths (colors) being a function of the tissue property. Thus, the fluorescence generated from infarcted tissue includes wavelengths that are different from the wavelengths of the fluorescence generated from normal tissue. In one embodiment, to increase the signal-to-noise ratio of the optical signal including the fluorescence, a fluorescent dye sensitive to transmembrane potentials is injected through catheter **120**. In one specific embodiment, myocardial tissue property sensor **510** includes an injection device allowing the injection of the fluorescent dye. Catheter **120** includes a lumen allowing passage of the fluorescent dye through the catheter. In a further embodiment, to further increase the signal-to-noise ratio, subthreshold electrical stimuli, such as subthreshold pacing pulses, are delivered to the heart. The subthreshold electrical stimuli are electrical stimuli each having a stimulation amplitude that is below the threshold for myocardial tissue excitation. Myocardial tissue property sensor **510** includes at least one electrode allowing delivery of the electrical stimuli. In one specific embodiment, catheter **120** includes an electrical conductor allowing delivery of the electrical stimuli through the catheter.

[**0042**] Tissue property analyzer **530** includes a wavelength analyzer **532** and an MI detector **534**. Wavelength analyzer **532** produces an optical spectrum of the optical signal received by optical receiver **514**. MI detector **534** detects infarcted tissue based on the optical spectrum. In one embodiment, MI detector **534** detects the infarcted tissue when the optical spectrum differs from a template spectrum associated with normal tissue by a predetermined margin. In an alternative embodiment, MI detector **534** detects the infarcted tissue when the optical spectrum matches a template spectrum associated with known infarcted tissue within a predetermined margin. For example, NADH (the reduced form of Nicotinamide Adenine Dinucleotide) is a product of metabolism associated with myocardial ischemia. A template spectrum is thus obtained from an optical signal including fluorescence generated from tissue with elevated level of NADH. In these embodiments, the template spectrum and the predetermined margin are each determined based on a study evaluating a patient population. In another embodiment, MI detector **534** detects the infarcted tissue based on a substantial change in the optical spectrum when the optical sensor moves from one myocardial location to another myocardial location. A quantitative standard for the substantiality of the change is determined based on a study evaluating a patient population.

[**0043**] **FIG. 6** is a flow chart illustrating one specific embodiment of the method for localizing MI. As a specific embodiment of steps **420** and **430** of **FIG. 3**, infarcted tissue is detected by sensing an optical signal.

[**0044**] A light is emitted to a myocardial location in a heart at **600**. In one embodiment, a fluorescent dye sensitive to transmembrane potentials is also released to the myocardial location. In a further embodiment, electrical stimuli, such as pacing pulses, are delivered to the heart. An optical signal related to the emitted light is received at **610**, while the light is being emitted. An optical spectrum of the received optical signal is produced at **620**. Infarcted tissue is detected for the myocardial location based on the optical spectrum at **630**. In one embodiment, the infarcted tissue is detected when the optical spectrum differs from a template spectrum associated with normal tissue by a predetermined margin. In an alternative embodiment, the infarcted tissue is detected when the optical spectrum matches a template spectrum associated with known infarcted tissue within a predetermined margin. In one embodiment, steps **600** through **620** are repeated for a plurality of myocardial locations. The infarcted tissue is detected based on the optical spectra produced all the myocardial locations. An infarcted tissue region includes one or more myocardial locations where the optical spectra for the adjacent myocardial locations are substantially different from the optical spectra for the one or more myocardial locations.

EXAMPLE 2

System with Acoustic Sensor

[0045] **FIG. 7** illustrates another specific embodiment of the circuit of system **100**. The circuit provides for localization of MI using an acoustic sensor. This circuit includes a myocardial tissue property sensor **710**, which is another specific embodiment of myocardial tissue property sensor **310**, and a tissue property analyzer **730**, which is another specific embodiment of tissue property analyzer **330**. A sensor link **724**, which is another specific embodiment of sensor link **324**, couples myocardial tissue property sensor **710** and tissue property analyzer **730**.

[0046] Myocardial tissue property sensor **710** is an acoustic sensor including an acoustic transmitter **712** and an acoustic receiver **714**. Acoustic transmitter **712** emits an acoustic energy into tissue in a myocardial location where myocardial tissue property sensor **710** is placed. In one embodiment, acoustic transmitter **712** includes a speaker to transmit an audible sound pulse. In another embodiment, acoustic transmitter **712** includes an ultrasound transmitter to transmit an ultrasound pulse. In one embodiment, acoustic transmitter **712** includes a piezoelectric crystal. Acoustic receiver **714** receives an acoustic signal related to the emitted acoustic energy. The acoustic signal includes echoes of the audible sound pulse or the ultrasound pulse. As a result of the scar formation process, infarcted tissue is stiffer than normal tissue. The echoes from infarcted tissue have a pitch distinguishable from the pitch associated of normal tissue.

[0047] Tissue property analyzer **730** includes a frequency analyzer **732** and an MI detector **734**. Frequency analyzer **732** produces an acoustic spectrum of the received acoustic signal. MI detector **734** detects infarcted tissue based on the acoustic spectrum. In one embodiment, MI detector **734** detects the infarcted tissue when the acoustic spectrum differs from a template spectrum associated with normal tissue by a predetermined margin. In an alternative embodiment, MI detector **534** detects the infarcted tissue when the acoustic spectrum matches a template spectrum associated with known infarcted tissue within a predetermined margin. In these embodiments, the template spectrum and the predetermined margin are each determined based on a study evaluating a patient population. In another embodiment, MI detector **734** detects the infarcted tissue based on a substantial change in the acoustic spectrum when the acoustic sensor moves from one myocardial location to another myocardial location. A quantitative standard for the substantiality of the change is determined based on a study evaluating a patient population.

[0048] **FIG. 8** is a flow chart illustrating another specific embodiment of the method for localizing MI. As another specific embodiment of steps **420** and **430** of **FIG. 3**, infarcted tissue is detected by sensing an acoustic signal.

[0049] An acoustic energy is emitted to a myocardial location at **800**. In one embodiment, the acoustic energy is in a form of an audible sound. In another embodiment, the acoustic energy is in a form of an ultrasound. An acoustic signal related to the emitted acoustic energy is received at **810**. The acoustic signal includes echoes of the audible sound or ultrasound. An acoustic spectrum of the received acoustic signal is produced at **820**. Infarcted tissue is detected based on the acoustic spectrum at **830**. In one embodiment, the infarcted tissue is detected when the acoustic spectrum differs from a template spectrum associated with normal tissue by a predetermined margin. In an alternative embodiment, the infarcted tissue is detected when the acoustic spectrum matches a template spectrum associated with known infarcted tissue within a predetermined margin. In another embodiment, steps **800** through **820** are repeated for a plurality of myocardial locations. The infarcted tissue is detected based on the acoustic spectra produced for the plurality of myocardial locations. An infarcted tissue region includes one or more myocardial locations where the acoustic spectra for the adjacent myocardial locations are substantially different from the acoustic spectra for the one or more myocardial locations.

EXAMPLE 3

System with Contractility Sensor

[0050] **FIG. 9** illustrates another specific embodiment of the circuit of system **100**. The circuit provides for localization of MI using a contractility sensor. This circuit includes a myocardial tissue property sensor **910**, which is another specific embodiment of myocardial tissue property sensor **310**, and a tissue property analyzer **930**, which is another specific embodiment of tissue property analyzer **330**. A sensor link **924**, which is another specific embodiment of sensor link **324**, couples myocardial tissue property sensor **910** and tissue property analyzer **930**.

[0051] Myocardial tissue property sensor **910** is a contractility sensor that senses one or more signals indicative of myocardial contractility in a myocardial region. In one embodiment, the contractility sensor includes an accelerometer array including a plurality of accelerometers **912**A, **912**B, . . . , and **912**N to sense acceleration signals from a plurality of locations constituting the myocardial region.

[0052] Tissue property analyzer **930** includes a motion pattern analyzer **932**, a mapping module **934**, and an MI detector **936**. Motion pattern analyzer **932** produces a cardiac wall motion pattern for the myocardial region based on the sensed one or more signals indicative of myocardial contractility in the myocardial region. Mapping module **932** produces a contractility map presenting cardiac wall motion patterns for a plurality of myocardial regions within at least a portion of a cardiac wall. MI detector **936** detects infarcted tissue based on the contractility map. Infarcted tissue regions are detected by identifying dyskinetic and/or hypokinetic regions on the contractility map.

[0053] **FIG. 10** is a flow chart illustrating another specific embodiment of the method for localizing MI. As another specific embodiment of steps **420** and **430** of **FIG. 3**, infarcted tissue is detected by sensing a signal indicative of a myocardial contractility.

[0054] One or more signals indicative of myocardial contractility in a myocardial region is sensed at **1000**. In one embodiment, this includes sensing a plurality of acceleration signals from the myocardial region. A cardiac wall motion pattern for the myocardial region is produced based on the sensed one or more signals at **1010**. Steps **1000** and **1010** are repeated for a plurality of myocardial regions, and a contractility map presenting cardiac wall motion patterns for the plurality of myocardial regions is produced at **1020**. Inf-

arcted tissue is detected based on the contractility map at **1030**. In one embodiment, the infarcted tissue is detected by identifying dyskinetic and/or hypokinetic regions on the contractility map. In one embodiment, infarcted tissue is detected by identifying myocardial regions associated with cardiac wall displacements that are substantially smaller than the cardiac wall displacements of other myocardial regions.

EXAMPLE 4

System with Temperature Sensor

[**0055**] **FIG. 11** illustrates one specific embodiment of the circuit of system **100**. The circuit provides for localization of MI using a temperature sensor. This circuit includes a myocardial tissue property sensor **1110**, which is another specific embodiment of myocardial tissue property sensor **310**, and a tissue property analyzer **1130**, which is another specific embodiment of tissue property analyzer **330**. A sensor link **1124**, which is another specific embodiment of sensor link **324**, couples myocardial tissue property sensor **1110** and tissue property analyzer **1130**.

[**0056**] Myocardial tissue property sensor **1110** is a temperature sensor including a thermal transmitter **1112** and a thermometer **1114**. Thermal transmitter **1112** emits a thermal energy into tissue in a myocardial location where myocardial tissue property sensor **1110** is placed. In one embodiment, the thermal energy raises the temperature at the myocardial location. In another embodiment, the thermal energy lowers the temperature at the cardiac wall location. In one embodiment, myocardial tissue property sensor **1110** includes an injection device allowing injection of a thermal dilution liquid. In one specific embodiment, catheter **120** includes a lumen allowing passage of thermal dilution liquid. Thermometer **1114** senses a temperature related to the emitted thermal energy.

[**0057**] Tissue property analyzer **1130** includes a thermal perfusion analyzer **1132** and an MI detector **1134**. Thermal perfusion analyzer **1132** produces a rate of temperature change (or thermal perfusion rate) being a change in the sensed temperature over a predetermined period of time. Infarcted tissue includes tissue properties related to thermal perfusion that are distinguishable from those of normal tissue. MI detector **1134** detects infarcted tissue based on the rate of temperature change. In one embodiment, MI detector **1134** detects the infarcted tissue when the rate of temperature change differs from a template rate associated with normal tissue by a predetermined margin. In an alternative embodiment, MI detector **1134** detects the infarcted tissue when the rate of temperature change matches a template spectrum associated with known infarcted tissue within a predetermined margin. In these embodiments, the template rate and the predetermined margin are each determined based on a study evaluating a patient population. In another embodiment, MI detector **1134** detects the infarcted tissue based on a substantial change in the rate of temperature change when the acoustic sensor moves from one myocardial location to another myocardial location. A quantitative standard for the substantiality of the change is determined based on a study evaluating a patient population.

[**0058**] **FIG. 12** is a flow chart illustrating another specific embodiment of the method for localizing MI. As another specific embodiment of steps **420** and **430** of **FIG. 3**, infarcted tissue is detected by sensing a signal indicative of temperature.

[**0059**] A thermal energy is emitted to a myocardial location at **1200**. In one embodiment, the thermal energy is emitted to heat the tissue in the myocardial location. In another embodiment, the thermal energy is emitted to cool the tissue in the myocardial location. In one embodiment, a thermal dilution liquid is released to the myocardial location. A temperature related to the emitted thermal energy is sensed at **1210**, following the emission of the thermal energy. A rate of temperature change, or thermal perfusion rate, which is a change in the sensed temperature over a predetermined period of time, is measured for the myocardial location at **1220**. Infarcted tissue is detected based on the rate of temperature change at **1230**. In one embodiment, the infarcted tissue is detected when the rate of temperature change differs from a template rate associated with normal tissue by a predetermined margin. In an alternative embodiment, the infarcted tissue is detected when the rate of temperature change matches a template rate associated with known infarcted tissue within a predetermined margin. In another embodiment, steps **1200** through **1220** are repeated for a plurality of myocardial locations. The infarcted tissue is detected based on the rates of temperature change measured for the plurality of myocardial locations. An infarcted tissue region includes one or more myocardial locations where the rates of temperature change for the adjacent myocardial locations are substantially different from the rates of temperature change for the one or more myocardial locations.

EXAMPLE 5

System with Drug Response Sensor

[**0060**] **FIG. 13** illustrates another specific embodiment of the circuit of system **100**. The circuit provides for localization of MI using a drug response sensor. This circuit includes a myocardial tissue property sensor **1310**, which is another specific embodiment of myocardial tissue property sensor **310**, and a tissue property analyzer **1330**, which is another specific embodiment of tissue property analyzer **330**. A sensor link **1324**, which is another specific embodiment of sensor link **324**, couples myocardial tissue property sensor **1310** and tissue property analyzer **1330**.

[**0061**] Myocardial tissue property sensor **1310** is a drug response sensor including a drug delivery device **1312** and a drug response detector **1314**. Drug delivery device **1312** releases a drug from a myocardial location where myocardial tissue property sensor **1310** is placed. The drug is of a type that causes a reaction from infarcted tissue that is distinguishable form a reaction from normal tissue. Examples of the drug include, but are not limited to, isoproterenol, dobutamine, nitroglycerin, and brain natriuretic peptide (BNP). In one embodiment, catheter **120** includes a lumen allowing passage of the drug from proximal end **121** to drug delivery device **1312**. Drug response detector **1314** detects a signal indicative of a tissue response the delivered drug.

[**0062**] Tissue property analyzer **1330** includes a drug response analyzer **1332** and an MI detector **1334**. Drug response analyzer **1332** produces a tissue response param-

eter as a tissue response parameter to the delivered drug based on the signal detected by drug response detector **1314**. MI detector **1334** detects infarcted tissue based on the tissue response parameter to the delivered drug. In one embodiment, MI detector **1334** detects the infarcted tissue when the tissue response parameter differs from a template tissue response parameter associated with normal tissue by a predetermined margin. In an alternative embodiment, MI detector **1334** detects the infarcted tissue when the tissue response parameter matches a template tissue response parameter associated with known infarcted tissue within a predetermined margin. In these embodiments, the template tissue response parameter and the predetermined margin are each determined based on a study evaluating a patient population. In another embodiment, MI detector **1334** detects the infarcted tissue based on a substantial change in the tissue response parameter when the acoustic sensor moves from one myocardial location to another myocardial location. A quantitative standard for the substantiality of the change is determined based on a study evaluating a patient population.

[**0063**] In one specific embodiment, the drug includes an agent changing the contractility of myocardial tissue, such as isoproterenol. Drug response detector **1314** includes a contractility sensor to sense a signal indicative of myocardial contractility, such as an accelerometer. Drug response analyzer **1332** produces a parameter indicative of the myocardial contractility. In one embodiment, drug response analyzer **1332** includes a displacement analyzer to produce a parameter indicative of a cardiac wall displacement based on the acceleration signal sensed by the accelerometer. MI detector **1334** detects infarcted tissue based on the myocardial contractility, such as indicated by the parameter indicative of the cardiac wall displacement.

[**0064**] In another specific embodiment, the drug includes an agent known to produce a rapid, even perfusion in tissue, such as nitroglycerin. Drug response detector **1314** includes a drug concentration sensor. Drug response analyzer **1332** includes a drug perfusion analyzer that produces a rate of drug perfusion, which is a change in the sensed drug concentration over a predetermined period of time. MI detector **1334** detects the infarcted tissue based on the rate of drug perfusion.

[**0065**] **FIG. 14** is a flow chart illustrating another specific embodiment of the method for localizing MI. As another specific embodiment of steps **420** and **430** of **FIG. 3**, infarcted tissue is detected by sensing a signal indicative of a myocardial tissue response to a drug delivery.

[**0066**] A drug is delivered to a myocardial location at **1400**. The drug provides for detection of infarcted tissue by examining a tissue property that is sensitive to the drug. Examples of the drug include, but are not limited to, isoproterenol, dobutamine, nitroglycerin, and BNP. A signal indicative of a tissue response to the delivered drug is detected at **1410**. A tissue response parameter is produced based on the signal indicative of the tissue response at **1420**. Infarcted tissue is detected for the myocardial region based on the tissue response parameter at **1430**. In one embodiment, the infarcted tissue is detected when the tissue response parameter differs from a template tissue response parameter associated with normal tissue by a predetermined margin. In an alternative embodiment, the infarcted tissue is detected when the tissue response parameter matches a template tissue response parameter associated with known infarcted tissue within a predetermined margin. In another embodiment, steps **1400** and **1510** are repeated for a plurality of myocardial locations. The infarcted tissue is detected based on the tissue response parameters detected for the plurality of myocardial locations. An infarcted tissue region includes one or more myocardial locations where the tissue response parameters detected from the adjacent myocardial locations are substantially different from the tissue response parameters detected from the one or more myocardial locations.

[**0067**] In one specific embodiment, the drug includes an agent changing the contractility of myocardial tissue, such as nitroglycerin. The tissue response is indicated by a signal indicative of myocardial contractility, such as an acceleration sensed from the cardiac wall. Infarcted tissue is generally less sensitive to the agent than normal tissue. That is, the agent causes a smaller change in contractility in infarcted tissue than in normal tissue. The infarcted tissue is detected based on the signal indicative of myocardial contractility.

[**0068**] In another specific embodiment, the drug includes an agent known to perfuse rapidly and evenly in tissue, such as nitroglycerin. A drug concentration is sensed following the delivery of the drug. A rate of drug perfusion, which is a change in the sensed drug concentration over a predetermined period of time, is measured. Infarcted tissue is generally more resistant to the perfusion of the agent than normal tissue. The infarcted tissue is detected based on the rate of drug perfusion.

[**0069**] In General

[**0070**] It is to be understood that the above detailed description, including Examples 1 through 5, is intended to be illustrative, and not restrictive. For example, myocardial tissue property sensor **110** includes any sensor or sensors capable of sensing a signal indicative of a myocardial tissue property that changes as a result of MI. Tissue property analyzer **130** detects infarcted tissue generally by analyzing that signal. Other embodiments, including any possible permutation of the system components discussed in this document, will be apparent to those of skill in the art upon reading and understanding the above description. The scope of the invention should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

What is claimed is:

1. A system for localizing myocardial infarction (MI) in a heart having a cardiac wall, the system comprising:

a catheter including a distal end configured for placement in a location on the cardiac wall;

a myocardial tissue property sensor incorporated into the distal end of the catheter and adapted to be placed in a myocardial location to sense a signal indicative of at least one tissue property, the myocardial tissue property sensor selected from a group consisting of an optical sensor, an acoustic sensor, a contractility sensor, a temperature sensor, and a drug response sensor; and

a tissue property analyzer including an input to receive the sensed signal and an output indicative of whether the sensed signal indicates infarcted tissue.

2. The system of claim 1, wherein the distal end of the catheter is configured for placement in a location on an endocardial wall.

3. The system of claim 1, wherein the distal end of the catheter is configured for placement in a location on an epicardial wall.

4. The system of claim 1, wherein the tissue property analyzer comprises a parameter generator to produce a parameter based on the sensed signal.

5. The system of claim 4, wherein the tissue property analyzer further comprises a comparator including a signal input receiving the parameter, a threshold input receiving a predetermined threshold, and an output indicating a detection of infarcted tissue based on a comparison between the signal and the threshold.

6. The system of claim 1, wherein the myocardial tissue property sensor is adapted to be placed in a plurality of locations, one at a time, over at least a portion of the cardiac wall to sense signals each indicative of at least one tissue property associated with one of the plurality of locations.

7. The system of claim 6, wherein the tissue property analyzer comprises a tissue property mapping module to produce a tissue property map presenting a measure of the at least one tissue property over the at least the portion of the cardiac wall based on the sensed signals.

8. The system of claim 7, wherein the tissue property analyzer further comprises a myocardial infarction detector to detect one or more infarcted regions based on the tissue property map.

9. The system of claim 1, wherein the catheter comprises a diagnostic catheter adapted for assessment of hemodynamic function.

10. The system of claim 1, wherein the catheter comprises a diagnostic catheter adapted for mapping of cardiovascular structure.

11. The system of claim 1, wherein the catheter comprises a substance-delivery catheter.

12. The system of claim 1, wherein the catheter comprises an ablation catheter.

13. The system of claim 1, wherein the catheter comprises a pacing lead.

14. The system of claim 1, wherein the catheter comprises a defibrillation lead.

15. A system for localizing myocardial infarction (MI) in a heart having a cardiac wall, the system comprising:

a catheter including a distal end configured for placement in a location on the cardiac wall;

a myocardial tissue property sensor incorporated into the distal end of the catheter and adapted to be placed in a myocardial location, the myocardial tissue property including an optical sensor including:

an optical transmitter to emit a light; and

an optical receiver to receive an optical signal related to the emitted light, the optical signal indicative of a tissue property; and

a tissue property analyzer including an input to receive the optical signal and an output indicative of whether the optical signal indicates infarcted tissue.

16. The system of claim 15, wherein the catheter comprises a lumen allowing injection of a fluorescent dye through the lumen, the fluorescent dye sensitive to transmembrane potentials.

17. The system of claim 16, wherein the catheter comprises a lead extending through at least a portion of the catheter and an electrode at or near the distal end, the electrode connected to the lead to allow delivery of electrical stimuli.

18. The system of claim 15, wherein the tissue property analyzer comprises a wavelength analyzer to produce an optical spectrum of the optical signal.

19. The system of claim 18, wherein the tissue property analyzer further comprises an MI detector to detect the infarcted tissue based on the optical spectrum.

20. The system of claim 19, wherein the MI detector is adapted to detect the infarcted tissue by comparing the optical spectrum to a template spectrum.

21. The system of claim 19, wherein the MI detector is adapted to detect the infarcted tissue based on a substantial change in the optical spectrum when the optical sensor is moved from one myocardial location to another myocardial location.

22. A system for localizing myocardial infarction (MI) in a heart having a cardiac wall, the system comprising:

a catheter including a distal end configured for placement in a location on the cardiac wall;

a myocardial tissue property sensor incorporated into the distal end of the catheter and adapted to be placed in a myocardial location, the myocardial tissue property sensor including an acoustic sensor including:

an acoustic transmitter to emit an acoustic energy; and

an acoustic receiver to receive an acoustic signal related to the emitted acoustic energy, the acoustic signal indicative of a tissue property; and

a tissue property analyzer including an input to receive the acoustic signal and an output indicative of whether the acoustic signal indicates infarcted tissue.

23. The system of claim 22, wherein the acoustic transmitter comprises a speaker to transmit an audible sound.

24. The system of claim 22, wherein the acoustic transmitter comprises an ultrasound transmitter to transmit an ultrasound.

25. The system of claim 22, wherein the acoustic transmitter comprises a piezoelectric crystal.

26. The system of claim 22, wherein the tissue property analyzer comprises a frequency analyzer to produce an acoustic spectrum of the received acoustic signal.

27. The system of claim 26, wherein the tissue property analyzer further comprise an MI detector to detect the infarcted tissue based on the acoustic spectrum.

28. The system of claim 27, wherein the MI detector is adapted to detect the infarcted tissue by comparing the acoustic spectrum to a template spectrum.

29. The system of claim 27, wherein the MI detector is adapted to detect the infarcted tissue based on a substantial change in the acoustic spectrum when the acoustic sensor moves from one myocardial location to another myocardial location.

30. A system for localizing myocardial infarction (MI) in a heart having a cardiac wall, the system comprising:

a catheter including a distal end configured for placement in a location on the cardiac wall;

a myocardial tissue property sensor incorporated into the distal end of the catheter and adapted to be placed in a

myocardial location, the myocardial tissue property sensor including a contractility sensor being an accelerometer array including a plurality of accelerometers to sense acceleration signals each indicative of a tissue property; and

a tissue property analyzer including an input to receive the acceleration signals and an output indicative of whether the acceleration signals indicate infarcted tissue.

31. The system of claim 30, wherein the contractility senor is adapted to sense the acceleration signals from a plurality of myocardial locations constituting a myocardial region.

32. The system of claim 31, wherein the tissue property analyzer comprises a motion pattern analyzer to produce a cardiac wall motion pattern for the myocardial region based on the sensed acceleration signals.

33. The system of claim 32, wherein the contractility sensor is adapted to be placed in a plurality of myocardial regions, one at a time, over at least a portion of a cardiac wall, and wherein the tissue property analyzer further comprises a mapping module to produce a contractility map presenting cardiac wall motion patterns for the at least the portion of a cardiac wall.

34. The system of claim 33, wherein the tissue property analyzer further comprises an MI detector adapted to detect the infarcted tissue based on the contractility map.

35. A system for localizing myocardial infarction (MI) in a heart having a cardiac wall, the system comprising:

a catheter including a distal end configured for placement in a location on the cardiac wall;

a myocardial tissue property sensor incorporated into the distal end of the catheter and adapted to be placed in a myocardial location, the myocardial tissue property sensor including a temperature sensor including:

a thermal transmitter to emit a thermal energy; and

a thermometer to sense a temperature signal related to the emitted thermal energy, the temperature indicative of a tissue property; and

a tissue property analyzer including an input to receive the temperature signal and an output indicative of whether the temperature signal indicates infarcted tissue.

36. The system of claim 35, wherein the catheter includes a lumen allowing injection of thermal dilution liquid through the lumen.

37. The system of claim 35, wherein the tissue property analyzer comprises a thermal perfusion analyzer to produce a rate of temperature change based on the temperature signal, the rate of temperature change being a change in a temperature over a predetermined period of time.

38. The system of claim 37, wherein the tissue property analyzer further comprises an MI detector adapted to detect the infarcted tissue based on the rate of temperature change.

39. The system of claim 38, wherein the MI detector is adapted to detect the infarcted tissue by comparing the rate of temperature change to a template rate.

40. The system of claim 38, wherein the MI detector is adapted to detect the infarcted tissue based on a substantial change in the rate of temperature change when the temperature sensor moves from one myocardial location to another myocardial location.

41. A system for localizing myocardial infarction (MI) in a heart having a cardiac wall, the system comprising:

a catheter including a distal end configured for placement in a location on the cardiac wall;

a myocardial tissue property sensor incorporated into the distal end of the catheter and adapted to be placed in a myocardial location, the myocardial tissue property sensor including a drug response sensor including:

a drug delivery device to deliver a drug; and

a drug response detector to detect a signal indicative of a tissue response to the delivered drug; and

a tissue property analyzer including an input to receive the signal and an output indicative of whether the signal indicates infarcted tissue.

42. The system of claim 41, wherein the drug comprises one of isoproterenol, dobutamine, nitroglycerin, and brain natriuretic peptide (BNP).

43. The system of claim 41, wherein the catheter comprises a lumen allowing injection of the drug through the lumen.

44. The system of claim 41, wherein the tissue property analyzer comprises a drug response analyzer to produce a tissue response parameter based on the signal indicative of the tissue response.

45. The system of claim 44, wherein the tissue property analyzer further comprises an MI detector adapted to detect the infarcted tissue based on the tissue response parameter.

46. The system of claim 45, wherein the MI detector is adapted to detect the infarcted tissue by comparing the tissue response parameter to a template tissue response parameter.

47. The system of claim 45, wherein the MI detector is adapted to detect the infarcted tissue based on a substantial change in the tissue response parameter when the drug response sensor moves from one myocardial location to another myocardial location.

48. The system of claim 41, wherein the drug comprises an agent changing contractility of myocardial tissue.

49. The system of claim 48, wherein the drug response detector comprises a contractility sensor to sense a signal indicative of the contractility of myocardial tissue.

50. The system of claim 49, wherein the contractility sensor comprises an accelerometer.

51. The system of claim 50, wherein the drug includes isoproterenol.

52. The system of claim 50, wherein the tissue property analyzer comprises a displacement analyzer to produce a parameter indicative of a cardiac wall displacement.

53. The system of claim 52, wherein the tissue property analyzer further comprises an MI detector to detect the infarcted tissue based on parameter indicative of the cardiac wall displacement.

54. The system of claim 41, wherein the drug response detector comprises a drug concentration sensor.

55. The system of claim 54, wherein the drug comprises nitroglycerin.

56. The system of claim 54, wherein the tissue property analyzer comprises a drug perfusion analyzer to produce a rate of drug perfusion being a change in the sensed drug concentration over a predetermined period of time.

57. The system of claim 56, wherein the tissue property analyzer further comprises an MI detector adapted to detect infarcted tissue based on the rate of drug perfusion.

58. A system for localizing myocardial infarction (MI), the system comprising:

a catheter including a distal end configured for myocardial placement;

a myocardial tissue property sensor incorporated into the distal end of the catheter and adapted to be placed in a myocardial location to sense a signal indicative of at least one tissue property; and

a tissue property analyzer receiving the sensed signal, the tissue property analyzer including:

a parameter generator to produce a parameter based on the sensed signal; and

a comparator including a signal input receiving the parameter, a threshold input receiving a predetermined threshold, and an output indicating a detection of infarcted tissue based on a comparison between the parameter and the threshold.

59. The system of claim 58, wherein the distal end of the catheter is configured for endocardial placement.

60. The system of claim 58, wherein the distal end of the catheter is configured for epicardial placement.

61. The system of claim 58, wherein the myocardial tissue property sensor comprises an optical sensor.

62. The system of claim 61, wherein the optical sensor comprises:

an optical transmitter to emit a light; and

an optical receiver to receive an optical signal related to the emitted light.

63. The system of claim 58, wherein the myocardial tissue property sensor comprises an acoustic sensor.

64. The system of claim 63, wherein the acoustic sensor comprises:

an acoustic transmitter to emit an acoustic energy; and

an acoustic receiver to receive an acoustic signal related to the emitted acoustic energy.

65. The system of claim 58, wherein the myocardial tissue property sensor comprises a myocardial contractility sensor.

66. The system of claim 65, wherein the contractility sensor comprises a plurality of accelerometers.

67. The system of claim 58, wherein the myocardial tissue property sensor comprises a temperature sensor.

68. The system of claim 67, wherein the temperature sensor comprises:

a thermal transmitter to emit a thermal energy; and

a thermometer to sense a temperature related to the emitted thermal energy.

69. The system of claim 58, wherein the myocardial tissue property sensor comprises a drug response sensor to sense a signal indicative of a myocardial tissue response to a drug delivery.

70. The system of claim 69, wherein the drug response sensor comprises:

a drug delivery device to deliver the drug; and

a drug response detector to detect a signal indicative of a tissue response to the delivered drug.

71. A system for localizing myocardial infarction (MI), the system comprising:

a catheter including a distal end configured for myocardial placement;

a myocardial tissue property sensor adapted to sense a signal indicative of at least one tissue property, the myocardial tissue property sensor incorporated into the distal end of the catheter and adapted to be placed in a plurality of myocardial locations, one at a time, over at least a portion of a cardiac wall to sense signals each indicative of the at least one tissue property for one of the plurality of myocardial locations;

a tissue property analyzer receiving the sensed signals, the tissue property analyzer including a tissue property mapping module adapted to produce a tissue property map presenting a measure of the at least one tissue property over the at least the portion of the cardiac wall based on the sensed signals.

72. The system of claim 71, wherein the distal end of the catheter is configured for endocardial placement.

73. The system of claim 71, wherein the distal end of the catheter is configured for epicardial placement.

74. The system of claim 71, wherein the tissue property analyzer further comprises a myocardial infarction detector to detect one or more infarcted regions based on the tissue property map.

75. The system of claim 71, wherein the myocardial tissue property sensor comprises an optical sensor.

76. The system of claim 75, wherein the optical sensor comprises:

an optical transmitter to emit a light; and

an optical receiver to receive an optical signal related to the emitted light.

77. The system of claim 71, wherein the myocardial tissue property sensor comprises an acoustic sensor.

78. The system of claim 77, wherein the acoustic sensor comprises:

an acoustic transmitter to emit an acoustic energy; and

an acoustic receiver to receive an acoustic signal related to the emitted acoustic energy.

79. The system of claim 71, wherein the myocardial tissue property sensor comprises a myocardial contractility sensor.

80. The system of claim 79, wherein the contractility sensor comprises a plurality of accelerometers.

81. The system of claim 71, wherein the myocardial tissue property sensor comprises a temperature sensor.

82. The system of claim 81, wherein the temperature sensor comprises:

a thermal transmitter to emit a thermal energy; and

a thermometer to sense a temperature related to the emitted thermal energy.

83. The system of claim 71, wherein the myocardial tissue property sensor comprises a drug response sensor to sense a signal indicative of a myocardial tissue response to a drug delivery.

84. The system of claim 83, wherein the drug response sensor comprises:

a drug delivery device to deliver the drug; and

a drug response detector to detect a signal indicative of a tissue response to the delivered drug.

85. A method for localizing myocardial infarction (MI) in a heart having a cardiac wall, the method comprising:

introducing a catheter including a sensor to provide for access to the heart, placing the sensor in a myocardial location;

sensing an signal using the sensor, the signal indicative of at least one tissue property in the myocardial location, the signal selected from a group consisting of an optical signal, an acoustic signal, a signal indicative of myocardial contractility, a temperature signal, and a signal indicative of a myocardial tissue response to a drug delivery; and

detecting infarcted tissue based on the signal.

86. The method of claim 85, wherein detection the infarcted tissue comprises:

producing a parameter representative of the at least one tissue property;

comparing the parameter to a predetermined threshold value; and

determining whether tissue in the myocardial location is infarcted based on the comparing.

87. The method of claim 85, further comprising:

sensing signals in a plurality of myocardial locations within at least a portion of the cardiac wall, the signals each indicative of the at least one tissue property in one location of the plurality of myocardial locations; and

producing a parameter representative of the at least one tissue property for each location of the plurality of myocardial locations.

88. The method of claim 87, further comprising:

comparing the measure of the at least one tissue property for the each location to a predetermined threshold value; and

detecting whether tissue in the each location is infarcted based on the comparing.

89. The method of claim 87, further comprising:

producing a tissue property map presenting the measure of the at least one tissue property over the at least the portion of the cardiac wall; and

detecting one or more infarcted regions based on the tissue property map.

90. The method of claim 89, wherein detecting the one or more infarcted regions comprises identifying where substantial changes in the measure of the at least one tissue property occur on the tissue property map.

91. A method for localizing myocardial infarction (MI) in a heart, the method comprising:

placing an optical sensor in a myocardial location;

emitting a light from the optical sensor;

receiving an optical signal related to the emitted light, the optical signal indicative of a tissue property in the myocardial location; and

detecting infarcted tissue based on the optical signal.

92. The method of claim 91, further comprising injecting a fluorescent dye sensitive to transmembrane potentials to the myocardial location.

93. The method of claim 91, further comprising delivering subthreshold electrical stimuli to the myocardial location.

94. The method of claim 91, wherein detecting the infarcted tissue comprises:

producing an optical spectrum of the received optical signal; and

detecting the infarcted tissue based on the optical spectrum.

95. The method of claim 94, wherein detecting the infarcted tissue comprises detecting the infarcted tissue when the optical spectrum differs from a template spectrum by a predetermined margin.

96. The method of claim 94, wherein detecting the infarcted tissue comprises detecting the infarcted tissue when the optical spectrum matches a template spectrum within a predetermined margin.

97. The method of claim 94, further comprising repeating the emitting the light, receiving the optical signal, and producing the optical spectrum for a plurality of myocardial locations, wherein detecting the infarcted tissue comprises detecting the infarcted tissue based on the optical spectra produced for the plurality of myocardial locations.

98. The method of claim 97, wherein detecting the infarcted tissue further comprises detecting an infarcted tissue region including one or more myocardial locations of the plurality of myocardial locations when the optical spectra for the myocardial locations adjacent to the one or more myocardial locations are substantially different from the optical spectra for the one or more myocardial locations.

99. A method for localizing myocardial infarction (MI) in a heart, the method comprising:

placing an acoustic sensor in a myocardial location;

emitting an acoustic energy from the acoustic sensor;

receiving an acoustic signal related to the emitted acoustic energy, the acoustic signal indicative of a tissue property in the myocardial location; and

detecting infarcted tissue based on the acoustic signal.

100. The method of claim 99, wherein emitting the acoustic energy comprises transmitting an audible sound.

101. The method of claim 99, wherein emitting the acoustic energy comprises transmitting an ultrasound.

102. The method of claim 99, wherein detecting the infarcted tissue comprises:

producing an acoustic spectrum of the received acoustic signal; and

detecting the infarcted tissue based on the acoustic spectrum.

103. The method of claim 102, wherein detecting the infarcted tissue further comprises detecting the infarcted tissue when the acoustic spectrum differs from a template spectrum by a predetermined margin.

104. The method of claim 102, wherein detecting the infarcted tissue further comprises detecting the infarcted tissue when the acoustic spectrum matches a template spectrum within a predetermined margin.

105. The method of claim 102, further comprising repeating the emitting the acoustic energy, receiving the acoustic signal, and producing the acoustic spectrum for a plurality of myocardial locations, wherein detecting the infarcted tissue

further comprises detecting the infarcted tissue based on the acoustic spectra produced for the plurality of myocardial locations.

106. The method of claim 105, wherein detecting the infarcted tissue further comprises detecting an infarcted tissue region including one or more myocardial locations of the plurality of myocardial locations when the acoustic spectra for the myocardial locations adjacent to the one or more myocardial locations are substantially different from the acoustic spectra for the one or more myocardial locations.

107. A method for localizing myocardial infarction (MI) in a heart having a cardiac wall, the method comprising:

placing an accelerometer array on the cardiac wall;

sensing a plurality of acceleration signals indicative of myocardial contractility; and

detecting infarcted tissue on the cardiac wall based on the plurality of acceleration signals.

108. The method of claim 107, wherein sensing the plurality of acceleration signals comprises sensing the plurality of acceleration signals from a plurality of myocardial locations on the cardiac wall, the myocardial locations constituting a myocardial region.

109. The method of claim 108, wherein detecting the infarcted tissue comprises producing a cardiac wall motion pattern for the myocardial region based on the plurality of acceleration signals.

110. The method of claim 108, wherein detecting the infarcted tissue further comprises:

producing a contractility map representing cardiac wall motion patterns for a plurality of myocardial regions; and

detecting the infarcted tissue based on the contractility map.

111. The method of claim 110, wherein detecting the infarcted tissue based on the contractility map comprises identifying dyskinetic or hypokinetic regions on the contractility map.

112. The method of claim 111, wherein detecting the infarcted tissue based on the contractility map comprises identifying one or more regions of the plurality of myocardial regions associated with cardiac wall displacements that are substantially smaller than cardiac wall displacements of other regions of the of the plurality of myocardial regions.

113. A method for localizing myocardial infarction (MI) in a heart, the method comprising:

placing a thermal sensor in a myocardial location;

emitting a thermal energy from the thermal sensor;

sensing a temperature signal related to the emitted thermal energy, the temperature signal indicative of a tissue property in the myocardial location; and

detecting infarcted tissue based on the temperature signal.

114. The method of claim 113, wherein emitting the thermal energy comprises emitting a thermal energy to raise a temperature in the myocardial location.

115. The method of claim 113, wherein emitting the thermal energy comprises emitting a thermal energy to lower a temperature in the myocardial location.

116. The method of claim 113, wherein emitting the thermal energy comprises injecting the thermal dilution liquid.

117. The method of claim 116, wherein detecting the infarcted tissue comprises measuring a rate of temperature change from the temperature signal, the rate of temperature change being a change in a temperature over a predetermined period of time.

118. The method of claim 116, wherein detecting the infarcted tissue further comprises detecting the infarcted tissue when the rate of temperature change differs from a template rate by a predetermined margin.

119. The method of claim 116, wherein detecting the infarcted tissue further comprises detecting the infarcted tissue when the rate of temperature change matches a template spectrum within a predetermined margin.

120. The method of claim 116, further comprising repeating the emitting the thermal energy, sensing the temperature, and measuring the rate of temperature change for a plurality of myocardial locations, wherein detecting the infarcted tissue comprises detecting the infarcted tissue based on the rate of temperature change measured for the plurality of myocardial locations.

121. The method of claim 120, wherein detecting the infarcted tissue comprises detecting an infarcted tissue region including one or more myocardial locations of the plurality of myocardial locations when the rates of temperature change for the myocardial locations adjacent to the one or more myocardial locations are substantially different from the rates of temperature change for the one or more myocardial locations.

122. A method for localizing myocardial infarction (MI) in a heart, the method comprising:

placing a drug response sensor in a myocardial location;

delivering a drug from the drug response sensor;

detecting a signal indicative of a tissue response to the delivered drug; and

detecting infarcted tissue based on the signal indicative of the tissue response.

123. The method of claim 122, wherein delivering the drug comprises delivering one of isoproterenol, dobutamine, nitroglycerin, and brain natriuretic peptide (BNP).

124. The method of claim 122, wherein detecting the infarcted tissue comprises producing a tissue response parameter based on the signal indicative of the tissue response.

125. The method of claim 124, wherein detecting the infarcted tissue further comprises detecting the infarcted tissue when the tissue response parameter differs from a template tissue response parameter by a predetermined margin.

126. The method of claim 125, wherein detecting the infarcted tissue further comprises detecting the infarcted tissue when the tissue response parameter matches a template tissue response parameter within a predetermined margin.

127. The method of claim 125, further comprising repeating the delivering the drug, detecting the signal, and producing the tissue response parameter for a plurality of myocardial locations, wherein detecting the infarcted tissue

comprises detecting the infarcted tissue based on the tissue response parameters produced for the plurality of myocardial locations.

128. The method of claim 127, wherein detecting the infarcted tissue comprises detecting an infarcted tissue region including one or more myocardial locations of the plurality of myocardial locations when the tissue response parameters for the myocardial locations adjacent to the one or more myocardial locations are substantially different from the tissue response parameters for the one or more myocardial locations.

129. The method of claim 122, wherein delivering the drug comprises delivering an agent changing contractility of myocardial tissue, wherein detecting the tissue response comprises sensing a signal indicative of the myocardial contractility, and wherein detecting the infarcted tissue comprises detecting the infarcted tissue based on the signal indicative of the myocardial contractility.

130. The method of claim 129, wherein delivering the drug comprises delivering isoproterenol.

131. The method of claim 129, wherein sensing the signal indicative of myocardial contractility comprises sensing an acceleration.

132. The method of claim 122, wherein delivering the drug comprises delivering nitroglycerin.

133. The method of claim 132, wherein detecting the tissue response comprises sensing a drug concentration.

134. The method of claim 133, wherein detecting the infarcted tissue comprises:

producing a rate of drug perfusion being a change in the sensed drug concentration over a predetermined period of time; and

detecting the infarcted tissue based on the rate of drug perfusion.

* * * * *

专利名称(译)	用于在导管插入术中定位心肌梗塞的方法和装置		
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摘要(译)

具有组织特性传感器的导管通过利用梗塞心肌组织的特性和正常心肌组织的特性之间的一个或多个差异来提供心肌梗塞（MI）的定位。在导管插入期间将组织特性传感器放置在心内膜壁或心外膜壁上以感测至少一种允许检测MI的组织特性。组织特性传感器的示例包括但不限于光学传感器，声学传感器，收缩性传感器，温度传感器和药物响应传感器。在一个实施例中，组织特性传感器感测心内膜壁或心外膜壁上的各个位置的组织特性，并检测指示梗塞组织和正常组织之间的边界的组织特性的实质变化。