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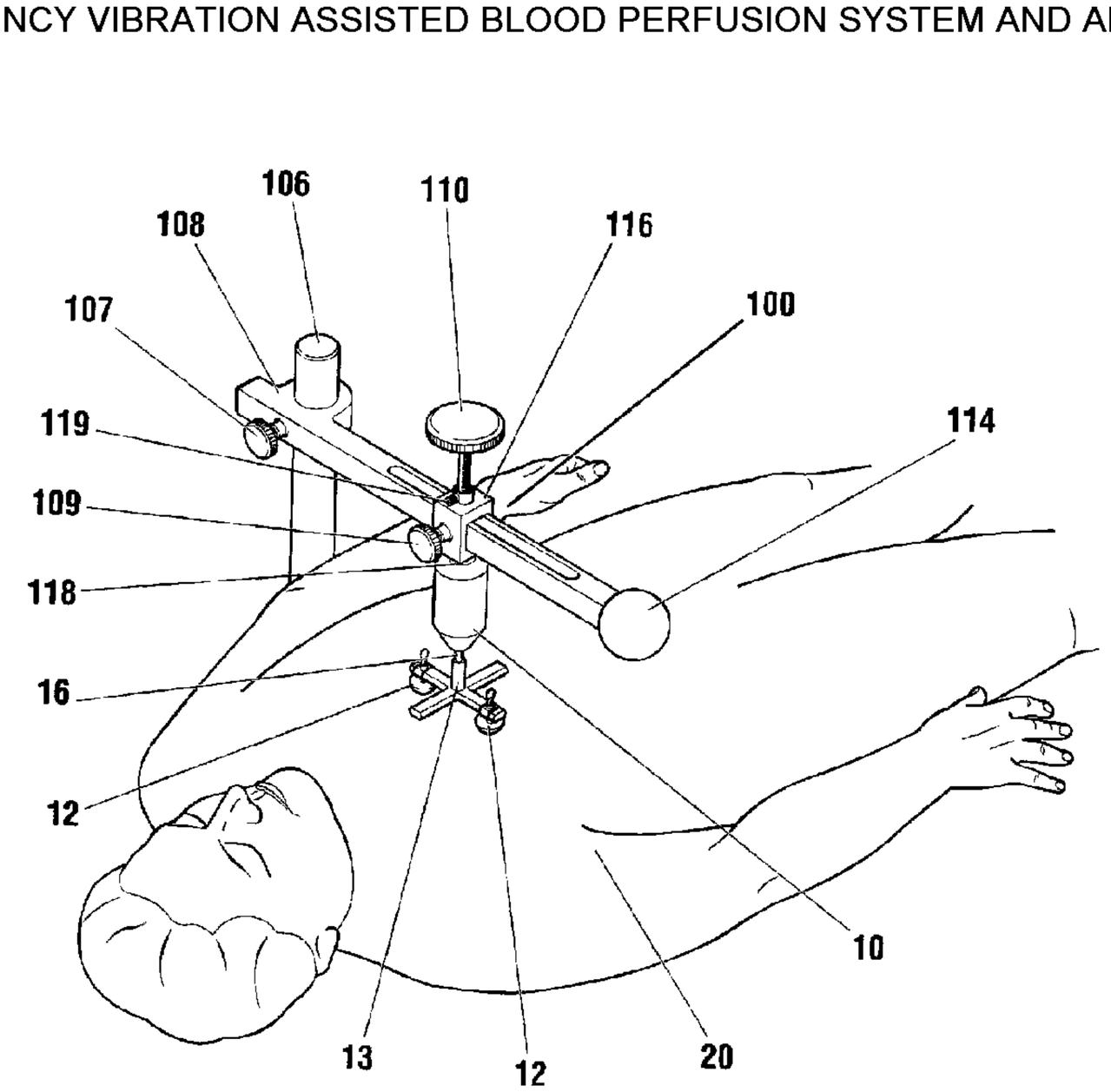
(54) Title: LOW FREQUENCY VIBRATION ASSISTED BLOOD PERFUSION SYSTEM AND APPARATUS



(57) Abrégé/Abstract:
An emergency system for the treatment of a patient (20) experiencing an acute thrombotic vascular occlusion, comprising a non-invasive, vibration device (10), in conjunction with pharmacological agents, for disrupting and lysing thrombosis, relieving spasm (if associated), and thereby restoring blood perfusion. The vibration device (10) is operable to deliver vibration within the 1-1000 Hz range, at a selectable displacement amplitude of 0.1-10 mm. For acute myocardial infarction cases, an operator places an attachment interface comprising a pair of contacts (12), to bridge the sternum of the patient at the fourth intercostal space. Vibration is initiated at 50 Hz (or any frequency, preferably within the 40 - 120 Hz range), and adjusts vibration to a maximal displacement amplitude deemed tolerable and safe to the patient (20), concurrently with the administration of thrombolytic agents, or any other form of medical therapy. A synergistic effect is achieved between vibration and medical agents to facilitate the disruption of thrombosis, and restore blood perfusion.

ABSTRACT

An emergency system for the treatment of a patient (20) experiencing an acute thrombotic vascular occlusion, comprising a non-invasive, vibration device (10), in conjunction with pharmacological agents, for disrupting and lysing thrombosis, relieving spasm (if associated), and thereby restoring blood perfusion. The vibration device (10) is operable to deliver vibration within the 1-1000 Hz range, at a selectable displacement amplitude of 0.1-10 mm. For acute myocardial infarction cases, an operator places an attachment interface comprising a pair of contacts (12), to bridge the sternum of the patient at the fourth intercostal space. Vibration is initiated at 50 Hz (or any frequency, preferably within the 40 - 120 Hz range), and adjusts vibration to a maximal displacement amplitude deemed tolerable and safe to the patient (20), concurrently with the administration of thrombolytic agents, or any other form of medical therapy. A synergistic effect is achieved between vibration and medical agents to facilitate the disruption of thrombosis, and restore blood perfusion.

LOW FREQUENCY VIBRATION ASSISTED BLOOD PERFUSION SYSTEM AND APPARATUS

1. TECHNICAL FIELD

This invention relates to noninvasive medical systems and apparatus for imparting transcutaneously applied low frequency mechanical vibrational energy to the human body, to improve first line emergency treatment of acute thrombotic vascular occlusions.

2. BACKGROUND OF THE INVENTION

Acute vascular thromboses, ischemia and infarction are common medical concerns. Acute Myocardial Infarction ("AMI") subsequent to a coronary thrombosis in particular is one of the leading causes of death in North America. Current first line treatment of thromboses in the acute phase when the patient reaches professional care is typically by intravenous introduction of thrombolytics, or a combination of drugs such as heparin, aspirin and/or GP 2b 3a platelet inhibitors to dissolve the blood clot. Intravenous and oral nitrates may also be introduced in order to dilate the culprit coronary or other vessel.

Thrombolytic drug treatment does not, however, have a high success rate. The success of systemically delivered IV drug therapy in increasing reperfusion rates in the treatment of ST elevation AMI is discussed in the following publications:

American Heart Association, Satellite Symposium 73rd Scientific Session, St. Michael's Review, New Orleans, Louisiana; Nov 11, 2000.

1Francis W M.D., "Ultrasound - Enhanced Thrombolysis. " Echocardiography: A. Jrnl. of CV Ultrasound & Allied Tech. Vol. 18, No. 3, 2001. pp 239 - 246.

Sanborn T et. al., "Impact of Thrombolysis Intra-aortic Balloon Pump Counter pulsation and their Combination in Cardiogenic Shock Complicating Acute Myocardial Infarction.", SHOCK REGISTRY JACC, 36 (3) Suppl. A. 2000, 1123 - 9.

The American Heart Association, Satellite Symposium 73rd Scientific Session, St. Michael's Review reported reperfusion rates (ie. TIMI 3 flow @ 60 - 90 minutes) with standard thrombolytic therapy varying between 50 and 63%.

Francis reported that lytic therapy fails to achieve any reperfusion (at all) in up to 20% of patients.

Success with drug based reperfusion treatment and in-hospital survival declines markedly when the patient becomes hemodynamically unstable or enters cardiogenic shock, which is the leading cause of in-hospital deaths from MI in North America. Sanborn et. al. report a 63% in-hospital mortality despite the use of thrombolytic therapy.

In the case of ST elevation Acute Myocardial Infarction, when noninvasive drug treatment (i.e. systemically introduced IV thrombolysis) to achieve reperfusion fails, invasive catheter based

techniques such as Percutaneous Coronary Intervention ("PCI") are employed. Sometimes, PCI is chosen as a direct measure, whereby a coordination of the immediate use of lytics or other agents may be first established in the field while enroute to a cardiac catheterization laboratory where intervention can be performed. A disadvantage of invasive treatment for thromboses (while very successful) is the infrastructure required, particularly the cardiac "cath lab" requiring substantial equipment and staff. Such infrastructure is not readily accessible in hospitals world wide, and even when available, there is a significant time requirement to coordinate and set up equipment and personnel. Due to the lack of immediate availability of cathlabs, patients, often unstable, must be transported and/or wait for the cathlab team to assemble. These difficulties result in a delay in treatment increasing myocardial necrosis, and reducing the likelihood of a successful and timely reperfusion.

Treatment systems utilizing noninvasive vibration in the low frequency ultrasonic range ("LFUS" e.g. 20 kHz - 100 kHz) have been employed as an adjunct to systemically delivered IV thrombolysis including coronary thrombolysis, in attempting to overcome these disadvantages. The LFUS wave form provides mechanical agitation via cavitation and acoustic streaming to the blood within the culprit vasculature wherein a blood clot resides, thereby encouraging disruption of the clot and increased permeation of the drug into the clot to accelerate reperfusion.

LFUS to disrupt thromboses and assist thrombolysis, has however, only shown effectiveness in research applications (ie. animal studies), for the treatment of relatively superficial thromboses, where the exact, fixed location of the blood clot was already known to the investigator. LFUS wave forms (which deliver micro displacement amplitudes which are imperceptible to a patient) offer no assurance of significant ultrasonic penetration to reach a blood clot within a human body in a practical application, without, for example, the establishment of a viable acoustic energy delivery window and targeting via direction of an application probe (ie. as in ultrasonographic imaging), which takes intelligible application of force and angulation of the probe against a patient's skin via a skilled operator. The need for high skill to direct a LFUS application makes such a therapy a poor candidate for the disruptive treatment of thrombosis in emergency cases where a skilled treatment operator would rarely be available. A non-directed LFUS treatment (without a skilled imaging approach) in particular, is poorly suited towards human coronary applications as the human heart is a relatively deep structure, is located variably within the thoracic cavity, and the blood clot is a hidden, moving target located beneath highly attenuating anatomic structures such as lung, fat and dense intercostal muscle which does not transmit ultrasound.

Thompson, T. et al in US Patent App. 20020049395 - 2002, disclose the emergency application of non-directed LFUS treatment in conjunction with thrombolytic therapy in response to Acute MI in humans, wherein LFUS is delivered in a nonspecific manner to a patients skin surface through a liquid cooling medium without intelligible force or angulation of the ultrasonic source through a confirmed ultrasonic penetrating window. As stated this method is sub-optimal as it does not insure adequate penetration of the therapeutic signal, and no proof is provided that this style of technique will show a clinical benefit in humans. Further examples of this kind of noninvasive LFUS treatment for vascular thrombosis are disclosed in US Pat. Nos. 5509896, 5713831, 5879314, 6126619, and 6398772; as well as in US Pat. Appl. Nos. 20020082529, 20020107473, 20020072691, 20020055693, 200200726690 and 20020091339.

Non-invasively delivered ultrasonic treatment systems, to disrupt an undesirable target with a body taken together with skilled medical imaging techniques have been disclosed. US Pat. No. 5,207,214 to Romano, for example, discloses a plurality of externally placed "reciprocal transducers" that when accompanied by an imaging modality such as an MRI or CAT scan, can permit precise focusing and spatial manipulation of "sound" intensity (a property of sound waves effectively at ultrasonic frequency), such as to target a specific volume or region of convergence within an "elastodynamic medium". This method is requiring of skill, advanced imaging, calculations, and is awkward, complicated, and time consuming hence unsuitable to emergency thrombolysis situations where time is of the essence, and first line of therapy is delivered in an ambulance or in the Emergency Room.

Similarly, U.S. Pat. No. 5,725,482 to Bishop et. al. discloses a plurality of externally placed vibration sources operational in the sonic to ultrasonic ranges (ie. 150 Hz to 25 kHz), to cause a focused, converging disruptive action within a body, wherein the body could be "organic" or "inorganic" in nature. In this system, multiples of two transducers are placed in direct opposition to one another, and are designed to converge (as per a calculated "phase angle") and constructively interfere at a target sample depth or volume in a relatively homogenous medium. This method for focusing sound intensity, (again only practically enabled in ultrasound applications), is ineffective for treating "organic" tissue targets such as thromboses while in the lower frequency ranges (ie. frequencies of < or = to 1000 Hz), as the wave lengths at such lower frequencies are too great to permit depth specific constructive interference within a human body, and the wave forms at low frequency are too divergent to permit a significant convergence and focusing of sound intensity within a human body. Furthermore, like in Romano's disclosure, this system requires precise attachment and angulation of the vibration sources to provide convergence on a target which require calculations and an imaging modality, and thus is awkward, complicated and time consuming hence again fundamentally unsuitable to emergency applications where time is of the essence and the potential operators (i.e. nurses, paramedics etc.) are equipped only with general (non-specialized) medical/technical knowledge and skill.

Ultrasonographic imaging via a skilled technique to ensure penetration and targeting of a combined external LFUS treatment to peripheral thrombosis was discussed by Dr. Siegel in US Pat. No. 5,695,460, although a highly skilled invasive technique requiring the application of cavitating micro-bubbles placed proximate the clot was required to yield effectiveness of the externally applied LFUS waveform. Also, ultrasonographic imaging and LFUS taken together as a noninvasive "Integrated Function", has also been mentioned as a possibility by Thompson T et. al. in US patent App. No's 20020072691 and 20020072690, as well as by Suorsa et. al. in US patent App. No. 20020082529. No details were disclosed about an apparatus or method to achieve this integrative function technique.

A low frequency vibration treatment system has been considered as an adjunct to thrombolytic therapy in the invasive treatment of thromboses. In U.S. Pat. No. 6,287,271 Dubrul et. al. discloses a low-frequency (1-1000 Hz) vibrating catheter drug delivery system resulting in 68% lysing when placed proximally to an artificial clot in a test tube with the drug Urokinase, versus 4.5% lysing with Urokinase treatment alone. As stated above, this method is invasive and requiring great, specialized skill to introduce a catheter directly to the thrombosis site, and thus has no utility in the field or in emergency room cases.

Generally, non-invasively delivered low frequency vibration has received little focus in the field of compromised blood circulation treatment and the treatment of thrombosis, and has instead been largely utilized in the field of physiotherapy (ie. massage) and also in the field of respiratory therapy to relieve pulmonary congestions. The most powerful massage vibrators commercially available enable displacement amplitudes of up to 6 mm, and power outputs of up to 1/25 hp. (eg. such as the Mini- Pro Thumper TM), which enable a moderate intensity, safe, therapeutic treatment, with no substantial risk to skin injury. The massage vibrators of the prior art have thereby limited power output capability, hence they are not optimally suited for emergency applications wherein a potential bruise to the skin would be an acceptable consequence when weighted against the disruption of the thrombosis and the re-establishment of blood flow to a vital organ for example. Furthermore, prior art massage vibrators do not have appropriately designed contact interfaces to enable effective and safe transmission of high amplitude vibration through the chest wall and thereby to the mediasteinal cavity, to optimally vibrate the internal organs and thrombosis potentially residing within the mediasteinal cavity. Engagement means for chest vibration for clearing of lung secretions in the field of treatment of cystic fibrosis are known to the prior art, and consist of garments (eg. vests) housing a vibration means enabling application to a patient's thorax, primarily directed laterally and posteriorly over the lungs of the patients. Disclosure of such vibration devices and vest engagement systems are described in US patents; 6193677, 4838263, 5569170, and 6036662. Prior art cystic fibrosis vibrators and vibration engagement devices are not adapted to provide and support high amplitude vibration respectively and the prior art engagement means have not specifically provided a focused attachment over the mediasteinal area of the chest wall to prospectively enable the emergency treatment of vascular occlusions residing in the mediasteinal cavity, wherein the heart and coronary arteries are situated.

Cardio Pulmonary Resuscitation ("CPR"), which is essentially high displacement amplitude compressional wave energy of 1.5 Hz (ie. very low frequency vibration), was used successfully in conjunction with coronary thrombolysis in cases of known acute myocardial infarction which had deteriorated and a poor outcome was otherwise imminent. These cases were reported by Tiffany et. al. in "Bolus Thrombolytic Infusions During CPR for Patients With Refractory Arrest Rhythms: Outcome of a Case Series" (Annals of Emergency Medicine, 31:1, Jan 1998, 134 - 136). This medical method is limited to cardiac arrest situations, and the manual nature of the application of high displacement amplitude, infrasonic mechanical energy by human hand would be labor intensive, potentially tiresome to an operator, and would eventually cause undue harm to a patient when delivered for sustained periods.

Cossone, A. et. al [PCT patent WO 02/0782 A2] discloses a water-bath vibrating palliative, therapeutic system, with an optimal frequency of 600 Hz to generally improve coronary artery circulation in chronic cases. This "whole body" water bath method is impractical to impart both for the field and prospectively in heart attack or acute cases, and water to skin vibrational energy couplings are energy transmission inefficient, of low amplitude, and do not enable focusing of treatment to key area's upon the chest wall which would confer maximum benefit.

Nagy in European Pat. No. 0429109 B1 and US Pat. No. 5,291,894 discloses a preferred loudspeaker acoustic (or sound) delivery system, capable of emitting audible sound waves through air in the 1 - 1000 Hz range and 20 Hz - 20 kHz range (respectively), to be applied externally to a human body to generally improve states of "disturbed blood circulation" in peripheral vasculature applications. Nagy also mentions optional potential use of a mechanical vibration source such as a piezoelectric

element, which may be alternatively placed in direct contact against the body part to be treated. Directing sound waves through air to a body surface is a highly inefficient means for delivering mechanical energy to the human body (ie. the actual mechanical forces which would reach the treatment skin surface would be negligible), and there is no evidence that this style of therapy would improve blood circulation. Also, "piezoelectric elements" as sited by Nagy (which are generally suited to microdisplacement ultrasonic applications) are by nature severely displacement amplitude limiting, and are thus also poorly suited to provide significant agitative external force and displacement amplitudes to ensure a deep penetration of mechanical energy to the internal organs and vascular regions of a human body wherein the treatment sites of vascular thrombosis (such as in the heart) may reside.

Jap. Pat. No. JP 8,089,549 ("549") to Koiwa and Honda discloses a noninvasive 50 Hz diastolic timed chest wall vibrator treatment system via a singular mechanical probe to skin coupling interface to treat cardiac ischemia. The '549 patent increases coronary blood flow to stable patients with known coronary artery narrowings, through a prescribed method of applying vibration specifically timed to the diastolic phase of the cardiac cycle via a hand held unit applied to the chest wall in a relatively low amplitude, comfortable manner (i.e. such that the patient "experiences no pain"). Koiwa teaches that diastolic timed vibration relaxes the myocardium (which is particularly stiff in ischemic states), allowing it to perfuse more efficiently and thereby assist blood perfusion to the ischemic heart.

The '549 patent is not directed to the treatment of acute, emergent, coronary incidents or vascular thromboses, hence there are inherent limitations to the disclosed system. For example, the disclosed single probe to skin coupling is a sub-optimal means of vibration to chest wall transmission and penetration, the system is not prescribed to deliver high amplitude vibration , and the timed application of vibration limits its effectiveness as there is no vibration during systole. The comfort level of the patient, and timing of vibration specific to diastole, is of lesser importance (and in fact limiting) when the key point of the therapy is to agitate and disrupt a thrombus, as well as to encourage the mixing of drugs into the thrombus. Furthermore, complex monitoring and processing means via an electrocardiographic trigger are required to effect cardiac phase controlled varying vibration, thus the treatment system is somewhat awkward and difficult to use prospectively in emergency cases.

As can be seen from above, there is an ongoing need to optimize a noninvasive system for the treatment of vascular ischemia and infarction by drug therapy and / or transcutaneously delivered mechanically therapeutic techniques. The prior art has failed to provide a simple to use, noninvasive mechanical method and apparatus that reliably ensures sufficient penetration to the culprit vessels and sites of vascular thrombosis (in particular to the deeply situated vessels within the mediasteinal cavity such as the coronary arteries) to ensure an adequate agitative and disruptive therapeutic effect in emergency cases. Furthermore, none of the prior arts have successfully integrated an engagement means and / or a systemically delivered drug therapy system to properly enable such an apparatus.

3. SUMMARY OF THE INVENTION

The present invention relates to a noninvasive, first line, emergent response system for the treatment of acute thrombotic vascular obstructions via the high amplitude application of low frequency vibration in the 1 - 1000 Hz range utilized as an adjunct to systemically administered drug therapy. The present invention is based on the intuition that external, transcutaneously imparted high

displacement amplitude low frequency vibration can penetrate deeply within the human body and into the vasculature, without a requirement of undue skill and imaging techniques, and provide synergistic support to systemically delivered drug therapy to improve localized drug effectiveness.

The preferred embodiment relates to a noninvasive medical system designed to facilitate and improve the emergency treatment of ST elevation, acute myocardial infarction, by externally imparting sonic to infrasonic mechanical energy to the chest wall of a patient as an adjunct to standard systemically delivered drug therapy. A medical apparatus comprising a specially designed noninvasive vibrator and contact interface enables high amplitude low frequency vibration to optimally penetrate to the heart, without the requirement of a skilled technique, and thereby synergistically facilitate the action of systemically directed drug therapy by providing an agitative response to the culprit coronary circulation. Agitation of the epimyocardium by vibration stimuli, and hence the coronary arteries, will improve (by way of sonic streaming, sheer forces and cavitation) the mixing of systemically introduced drugs down an otherwise zero flow, or low flow vascular system. Mechanically delivered vibration further induces disruption of clots which leads to increased permeation of drugs into the clots, and also low frequency vibration independently results in a localized coronary vasodilatory response to the culprit circulation which often has a degree of spasm associated.

A practical, first line non-invasive response treatment system, employing a specialized, external, chest wall low frequency mechanical vibrating apparatus, employable in conjunction with systemically delivered drug therapy, and operational in the low frequency ranges (i.e. <= 1000 Hz range), which is specifically designed and suited to assist the localized process of coronary thrombotic disruption and thrombolysis (and relief of coronary spasm if associated), in the particular emergency treatment of Acute Myocardial Infarction is disclosed.

The provided system is further adaptable to assist systemically delivered drug therapy and effectiveness localized to other body regions experiencing an acute state of low blood perfusion, such as in acute thrombotic vascular blockages to the cerebral, pulmonary and peripheral vasculature.

It is accordingly an object of this present invention to define a utility for externally placed low frequency vibration to the chest wall, as a synergistic adjunct to systemically delivered drug therapy, in a cardiological treatment application associated with acute myocardial infarction and acute ischemia.

It is a further object of the present invention to provide a first line, noninvasive , emergency response treatment system whereby 1-1000 Hz, or more exactly as a prescription 40 - 120 Hz sinusoidal compressional waves are applied externally at high displacement amplitude to the chest wall, to act to as an adjunct to systemically introduced drug therapy in the treatment of ST elevation acute myocardial infarction.

It is further still an object of the present invention to provide a first line, noninvasive emergency response treatment system which is adaptable to provide externally imparted, high amplitude low frequency vibration to improve drug therapy and localized drug effectiveness to a variety of body regions suffering from an acute, emergent state of low blood perfusion, such as the body regions of the brain, lung and the periphery.

It is further still yet another object of the present invention to provide a vibration method and apparatus which enables a simple and easy to use system without a skill requirement beyond what a nurse or paramedic could typically provide.

It is further still yet another particular object of the present invention to employ a higher powered external vibrator with higher displacement amplitude potential for body surfaces than what has been described in the prior art, in recognition that a potential degree of overlying soft tissue injury such as a bruise is of small consequence relative to the gains of an improved thrombolysis in an emergency situation to restore vessel flow to a major infarcting internal organ such as the heart.

It is still yet an even further particular object of the present invention to provide an adjustable, active skin contact interface to a vibrator which is specifically suited to optimize transmission of vibration energy from the vibrator to the chest wall and thereby to the heart and coronary arteries of a patient, wherein a skilled imaging technique is not employed.

It is still yet an even further object of the present invention to provide mechanical and adjustable engagement means comprising a clamp, wherein the clamp is adapted to bedside or stretcher use to hold the vibrator against a patient's body surface, so an operator need not hold the vibrator in place by hand throughout the course of drug therapy.

It is still yet an even further object of the present invention to provide mechanical and adjustable engagement means comprising a belt system, wherein the belt system is adapted to encircle a patient's chest wall and thorax and hold the vibrator against a patient's chest wall so an operator need not hold the vibrator by hand, and so that the patient may sit up or even ambulate.

It is still yet an even further object of the present invention to provide a vibration apparatus with a system for enabling cardiac phase controlled time and optionally frequency varying vibration delivery, to enable the selection of vibration timing algorithms designed to optimize vibration of the heart and coronary arteries (and thereby drug treatment), in particular for cases of acute myocardial infarction which have deteriorated into cardiogenic shock wherein vibration timed exclusively to the diastolic cardiac phase provides a positive inotropic effect in addition to mechanical agitation of the coronary arteries and thereby improved systemically delivered drug effectiveness.

It is still yet again an even further object of the present invention to provide a variant vibration contact head which, in addition to supplying the means of transmitting low frequency vibration from the vibration apparatus to a patient, is additionally enabled to provide ultrasonographic imaging such that an operator may optimize penetration and target therapeutic vibration to a culprit vascular region while concurrently imaging the target.

It is still yet an even further object of the present invention to provide a variant vibration contact head which, in addition to transmitting low frequency vibration from the vibration apparatus to a patient, is additionally enabled to emit an oscillative treatment wave form within the low frequency ultrasonic range such as to provide a pair of treatment oscillating wave forms (ie. low frequency vibration plus low frequency ultrasound) in concert.

It is still yet an even further object of the present invention to provide a variant contact head, which is not only enabled to transmit low frequency vibration from the vibration apparatus and

concurrently emit a low frequency ultrasonic treatment wave form (ie. as above), but is additionally enabled to provide ultrasonographic imaging such that an operator may optimize penetration and target therapeutic low frequency vibration and therapeutic low frequency ultrasonic emissions to a culprit vascular region while concurrently imaging the target.

It is yet still a further object of the present invention is to provide a low frequency vibration apparatus which has a broad range of selectable frequency, wave form and intensity parameters, such to enable the apparatus to an effective research tool.

It is a primary object of the present invention, to provide a self-contained, mobile, emergency, first line response kit for treatment of acute, emergent thrombotic and / or vasospastic vascular occlusions, wherein the first line response kit comprises: a vibration means, a drug delivery means, a plurality of useful drugs to be delivered, an engagement means to enable application of the vibration means, a variety of contact heads including those which enable ultrasonic imaging and low frequency ultrasonic oscillative treatment emissions, a connector enabling an adjustable, active skin contact interface to enable effective transmission of vibration to rib spaces of the chest wall of a patient, and a cardiac phase dependent vibration delivery system to optimize vibration delivery for cardiac applications; such as to enable the first line treatment for emergent acute low blood perfusion in the field by trained medical professionals.

It is a final object of the present invention, to provide an emergency portable, vibration treatment kit employable to an outpatient in the community for self treatment of chest pain refractory to anti-anginal therapy (eg. nitro spray, or pill), wherein an acute coronary event such as an acute coronary thrombosis cannot be ruled out.

4. BRIEF DESCRIPTION OF THE DRAWINGS

The apparatus and method of the present invention will now be described with reference to the accompanying drawing figures, in which:

Figure **1** is a perspective view of a supine patient receiving treatment from a clamped vibration device according to the invention.
Figure **2** is a perspective view of a bifurcated connector with a pair of support arms, each support arm having a single contact head according to the invention.
Figure **3** is a perspective view of a variant bifurcated connector having a plurality of support arms according to the invention.
Figure **4** is a schematic diagram of the simple vibration treatment method for thromboses according to the invention.
Figure **5** is a schematic diagram of the advanced cardiac phase modulated vibration treatment method for thromboses according to the invention.
Figure **6** is a perspective view of a variation of the vibration device incorporating ultrasonographic imaging with treatment vibration via a hand held technique according to the invention.
Figure **7** is a perspective view of a variation of the clamp mechanism according to the invention.
Figure **8** is a perspective view of a patient in fowler's position receiving treatment from a belt vibration device according to the invention.

5. DETAILED DESCRIPTION AND PREFERRED EMBODIMENT

The present invention is a first line response system and apparatus for pre-hospital or initial in-hospital treatment of patients experiencing an acute to sub-acute thrombotic vascular occlusion and/or associated vessel spasm. The emergency application of noninvasive, transcutaneously imparted low frequency vibration as a synergistic adjunct to systemically delivered drug therapy, with or without concomitant ultrasonic imaging, for lysing and vasodilating vascular thrombotic occlusions, relieving spasm (if associated), and thereby restoring blood perfusion is disclosed. The invention is particularly effective against thromboses in the thoracic / mediasteinal cavity.

Low frequency vibration shortens the onset and accelerates the effectiveness of thrombolytics. Due to the urgency to treat heart attacks, strokes, pulmonary emboli, or acute peripheral arterial occlusions to major vessels, as cell death is directly proportional to time, it is of utmost importance to enhance the onset and accelerate the effectiveness of the imparted drug treatment in lysing or clearing vascular occlusions. The noninvasive application of low frequency vibration, in addition to its potential immediate availability to expedite emergency treatment, has the further advantage of not causing undue heating of the overlying tissue superficial to the site of vascular occlusions. Furthermore, the localized biophysical nature of low frequency vibration treatment is advantageous in that as it is not a drug, it will not cause adverse systemic biochemical effects, which can otherwise be difficult to reverse such as hemorrhage.

The preferred embodiment of the treatment system, or "Vibrinolytic Therapy", involves the application of external, noninvasive mechanical vibration at a frequency of 1-1000 Hz, preferably 40 - 120 Hz, and optimally 50 Hz to the chest wall as an adjunct to thrombolytic therapy in the treatment of acute myocardial infarction ("AMI"). A maximized source output displacement amplitude ranging from 0.1 up to 10 mm (as judged safe and tolerable to the patient) is selectively provided in the 1 - 200 Hz range. The treatment system is not complicated and can be applied by a minimally trained paramedic or nurse without the need for special skilled imaging guidance or targeting. The treatment system facilitates the action of pharmacological agents such as: thrombolytics (e.g. ACTIVASE™ (Alteplase), TNKase™ (Tenecteplase), RETAVASE™ (Reteplase), Abbokinase™ (Urokinase), Kabikinase™ (Streptokinase with water), Streptase™ (Streptokinase with 0.9% NcCl solution), and Lanoteplase); GP 2b 3a platelet inhibitors (e.g. ReoPro™ (Abciximab), AGGRASTAT™ (Tirofiban hydrochloride), and Integrelin™ (Eptifibatide)); calcium channel blockers (e.g. ISOPTIN™ SR (Verapamil HCl), ADALAT™XL™ (Nifedipine), Cardizem™ (Diltiazem), and NORVASC™ (Amlodipine besylate)); Nitrates (e.g. Nitroglycerine (spray, pill or patch), isosorbide dinitrates (Isordil™ and Sorbitrate™), and Nipride™ (Nitroprusside)); Oral anti-platelets (e.g. Acetylsalicylic Acid (Aspirin), Plavix™ (Clopidogrel), and TICLID™ (Ticlopidine hydrochloride)); Anti-coagulants such as heparin, and other blood thinning and coronary vasodilatory medication. Non-pharmacological agents such as echo contrast agents (ie. micro bubble solutions which lower the cavitational threshold of a medium) may also be considered as a further adjunct to the pharmacological agents in conjunction with vibration therapy. Examples of micro bubble solutions include: EchoGen™ (Dodecafluoropentane emulsion), Albunex™ (5% human albumin), LEVOVIST™ (Galactose-Palmitic Acid ultrasound contrast agent), Air containing albumin microcapsules (Quantison™ and Myomap™), SonoVue™ (Sulfurhexafluoride) and Perfluorocarbon -containing microbubbles (Perfluorocarbon exposed sonicated dextrose albumin PESDA).

The low frequency vibration is imparted to the chest wall, and thereby by transmission the epimyocardium of the heart and coronary arteries. The preferred embodiment (ie. vibration

adjunctive to thrombolytic therapy) is particularly effective for the treatment of an acute ST elevation myocardial infarction. Vibration therapy can, with drug delivery, also be utilized for other forms of acute coronary syndromes such as Non Q wave (ie. "Non ST elevation") MI or Unstable Angina where symptoms are refractory to medical management. A lower displacement amplitude may be considered for Non ST elevation coronary syndromes (ie. to prevent bruising to the chest wall), wherein the amplitude is gradually titrated upwards until a relief of symptoms is realized.

Vibrinolytic therapy is effective as a first line medically adjunctive mechanical treatment to coronary thrombolysis. During cardiogenic shock, lytic therapy alone, especially without the immediate availability of a cardiac cathlab, has a low rate of success, yet often remains the only realistic chance for reperfusion and in-hospital survival in centers without the option of emergency rescue Percutaneous Coronary Intervention ("PCI"). Vibration therapy may be employed in conjunction with a lower dosage of thrombolytic drugs, independently, or in conjunction with other forms of medications when thrombolytic therapy is either contraindicated (e.g. because of a risk of bleeding), or not prescribed (eg. non-ST elevation MI or unstable angina refractory to rest and medical management).

There are three primary effects of Vibrinolytic Therapy. First, thromboses or clots are disrupted as the mechanical agitation creates sheer stresses due to cavitation and sonic streaming and thereby loosens or breaks apart the clot, resulting in increased fibrin binding sites, and improved lytic penetration. Second, sonic streaming (unidirectional motion of fluid in a vibration field) and convection currents aid the diffusion process and promotes mixing of intravenous drugs from the systemic circulation to the occluded, zero flow culprit vessel. Third, coronary vasodilatation within the culprit circulation is achieved as the smooth muscle within the thrombosed, often spasming coronary artery wall is relaxed by vibration (due to a vibration induced decoupling of the actin - myosin filaments of the sarcomere). Secondary therapeutic effects include a localized endogenous release of tissue plasminogen activator, an improved left ventricular ("LV") myocardial relaxation with a lowering of LV diastolic pressures (and thus potential improvements to diastolic, transmural coronary flow), the potential for a positive inotropic effect (leading to an increased lytic filtration pressure which is particularly useful in cardiogenic shock cases), the potential decrease in myocardial oxygen demand for equal contractility and an improvement of lung / gas oxygen exchange (to provide additional oxygen to the heart and help relieve ischemic burden).

Referring to Figure 1, a patient 20 undergoing Vibrinolytic Therapy according to the preferred embodiment is shown (IVs, drugs, nasal prongs and monitoring equipment etc. not shown). The preferred engagement means, a clamp 100, for applying low-frequency vibration to the patient 20 is shown. The chest wall of the patient 20 may be shaved. The contact head(s) 12 of the vibration device 10 are placed at the treatment site upon the chest wall of the patient 20. Treatment is then commenced by administering IV systemic thrombolytic therapy, plus any other helpful drug which is designed to effect clot dissolution and/or vasodilate the culprit coronary vessel. Thrombolytics may be continuously administered intravenously, and/or by bolus as prescribed by the physician.

In acute myocardial infarction cases treated in an Emergency Room, preparation of the patient should include sedation in similar manner to that of a cardiac cathlab PCI treatment where the patient is expected to remain flat (supine) and relatively still for a period of time despite an anticipated uncomfortable procedure. The recommended treatment duration is half an hour to an hour, or until clinical signs of reperfusion become manifest. An intravenous line is established for

introduction of thrombolytic therapy, and any other IV therapy. Sedatives and anti-nausea medication and a foley catheter may be administered to avoid interruptions of treatment. A superficial administration of lidocaine to the skin of the chest wall application site may be considered. Oxygen should be administered to assist breathing. Intubation may be required with congestive heart failure cases in order to maintain oxygen saturation and patient positioning in a near supine position. When treatment commences in the field (as in an ambulance enroute to hospital) a less extravagant preparation may be considered, and simply reclining a patient onto a stretcher with the establishment of an intravenous line would suffice is most situations.

For use of the vibration device 10, the patient 20 is placed supine, although two pillows behind the head may be allowable when the patient 20 is short of breath. The base (not shown) of the clamp 100 is placed under the back or under the mattress of the patient 20. A vertical bar 106 extends substantially vertically at a right angle from the base. A horizontal arm 108 is slide-ably (ie. in the vertical direction) and rotatably (i.e. in the horizontal plane) attached to arm 106 and extends at substantially 90 degrees from the vertical bar 106, whereby the horizontal arm 108 will overhang the patient's 20 torso. The horizontal arm 108 is lockable to the vertical arm 106 by a locking knob 107. The vibration device 10 is attached to the arm 108 via a slide-able sleeve 116. The sleeve 116 is of a rectangular box shape, and is horizontally slide-able and disposed in the horizontal direction along the horizontal arm 108. The sleeve 116 contains a central, threaded, vertical hole defining an internal threaded screw column (not shown), with a matching engagement screw 110 disposed and attached within the screw column. The sleeve 116 further includes a locking knob 109, which tightens clockwise to lock the vibration device 10 in place along the horizontal arm 108. The vibration device 10 is selectively lowered and raised with the engagement screw 110, which has threads that engage the interior surface of the threaded screw column. The lower or active end of the engagement screw 110 attaches the non-active end of the vibration device 10. A setscrew 119 is mounted horizontally through the top portion of the sleeve 116 and abuts the engagement screw 110 thereby locking it in place during operation. A rotatable circular piece 118 disposed at the surface within the non-active end of the vibrator housing 14 is provided such that the vibrator housing 14 may remain stationary while the engagement screw 110 screws the vibration device 10 up or down. The vibrator shaft 16 extends from the lower or active end of the vibration device 10. A cross-shaped support connector 13 with bifurcated support arms (described later) is remove ably attached to the vibrator shaft 16. A pair of contact heads 12, preferably of silicone rubber, are attached to two of the arms of the support connector 13, and provide the interface with the patient 20. The preferred default placement of the center of each contact head 12 (ie. the default placement) is the fourth intercostal space, about 2 cm rightward and leftward to the sternal margins (ie. so the edge of the contact heads 12 contact surface roughly abuts the sternal margins). An inertial weight 114 is optionally added to horizontal arm 108 to dampen the movement of the horizontal arm 108 during treatment.

Alternatively, the bifurcated support connector 13 is oriented obliquely to the sternum of the patient 20 such that the contact heads 12 are placed to the anatomic left fourth intercostal space and anatomic right fifth intercostal space, or as a further alternate, the anatomic left third intercostal space and anatomic right fourth intercostal space in order to better localize the source of vibration therapy to the plane of the base of the heart wherein the coronary arteries arise from the aorta, and are therein substantially distributed.

Referring now to Figure 2, the preferred attachment interface according to the preferred embodiment of the bifurcated connector 13 is shown. The connector 13 is comprised of a cross shaped base consisting of two support arms 22, and an upper vertical cylinder, into which the vibrator shaft 16 is inserted and is retained by means of friction, or optionally any other known attachment means. The operator slides the contact heads 12 along the support arms 22, so as to accommodate various chest wall sizes and sternum sizes of patients 20. Each contact head 12 is attached to a sleeve 25 with locking screw 21, placed slide ably and lock ably upon each of the support arms 22 of the connector 13.

The choice of connector and resultant number of contact heads 12 utilized comprises a risk /-benefit decision where the risk is patient bruising and the benefit is superior chest wall penetration of vibration thereby improving thrombolysis. The use of more contact heads 12 will result in relatively more bruising.

In reference to Figure 3, an alternate means of chest wall attachment comprises a variant bifurcated connector 13 further incorporating a substantially columnar piece 24 adapted to receive a plurality of slide-able sleeves 23, each sleeve 23 comprising a pair of support arms 22 to enable the attachment of a pair of contact heads 12 to bridge the sternum at the level of multiple intercostal space levels, namely the 3rd, 4th and 5th intercostal space. Sleeves 23 are lockable to centerpiece 24 by locking screws 26. To even further optimize the treatment, a further contact head is optionally placed more laterally to the 4th intercostal space mid clavicular line (attachment not shown), such as to approximate the location of the mid Left Anterior Descending Artery in Acute Anterior MI.

In further reference to Figure 3, a modified chest wall attachment of the variant connector 13 and support arms 22 may optionally be utilized to provide attachment for contact heads 12 to the anatomic left 3rd, 4th and 5th intercostal space at the level of the anatomic left mid-clavicular line. This is accomplished by simply moving the vibration device 10 (and thereby variant connector 13 with support arms 22) to the anatomic left of the patient 20, such that the contact heads 12 seat against the left sternal margin as well as within the left mid-clavicular line (i.e. as opposed to bridging the sternum). This modified chest wall attachment optimizes therapy directed specifically to the Left Anterior Descending Artery ("LAD"), where the diagnosis of acute anterior myocardial infarction has been made and the LAD, or any significant, large, leftward, coronary vessel is presumed the culprit. Alternatively, separate engagement means and a vibration device 10 running in phase with any pre-established vibration device 10 may be utilized to provide additional therapy along the anatomical left mid-clavicular line and thereby the LAD distribution of the patient 20. It should be noted that vibration therapy may be contraindicated to the left 5th intercostal space (and lower intercostal spaces) at the level of the mid-clavicular line to the lateral margin of the chest wall (i.e. the apical window in standard 2D echocardiography) due to the remote possibility of intra-ventricular, apical early clot formation. While intra-ventricular thrombus formation is not generally considered a significant risk factor in the hyper-acute phase of an evolving acute myocardial infarction (i.e. period of time where thrombolytics are given), caution is warranted in certain cases. Such cases include patients who present "late" and who have the development of significant Q waves to the precordium on their initial 12 lead ECG. In these cases (and in reference again to Figure 3) the contact head 12 of the support arm 22 which is otherwise directed to the 5th intercostal space of the mid-clavicular line should be removed. Alternatively, an expedited 2D echocardiographic inspection of the patient's 20 apex to rule out clot formation (good images supplying apical endocardial resolution in a non-foreshortened view as judged by an experienced

echocardiographer must be obtained) would identify a low-risk group and thereby vibration therapy to the apex may commence as per the judgment of the attending physician.

To reduce the risk of bruising, the preferred bifurcated support connector 13 giving rise to a duality of contact heads 12 (as described) may be chosen.

Alternatively, to further minimize the extent of chest wall bruising to the patient, a solitary contact head 12, attached to another variant, non-bifurcated support connector 13 (not shown), with a single attachment site for a single contact head 12 is provided and can be located over a solitary target site on the patient which by default is the 4th intercostal space, with the placement of the center of the contact head 12 about 2 cm anatomically leftward and lateral to the left sternal margin (again where the edge of the vibrator head 12 abuts the left sternal margin).

In a further variation, a single contact head 12 may be adapted to be placed by friction directly on the vibration device 10 shaft 16, without the use of a connector 13. This variant technique (ie. use of a solitary contact head 12), is allowable, regardless of bleeding and or bruising risks, in the special cases of Anterior, Antero-Septal, or Antero-Lateral AMI, where the leftward coronary circulation is presumed the culprit and whereby the contact head 12 is placed anatomically leftward to the sternum of the patient 20. To improve efficiency and penetration of this alternative technique, the patient 20 may be rotated from the supine position onto his or her left side slightly (eg. up to around 20 degrees from the plane of the bed) and supported for example by pillows or a wedge, as this position drops the heart and left coronary circulation further leftward from under the sternum bringing the culprit vessels (ie. the Left Main, Left Anterior Descending and Left Circumflex) in closer proximity to the solitary vibrating source which has been placed leftward the sternum. To maintain correct orientation and a perpendicular alignment between the contact head 12 and the patient's 20 chest wall, a rotating, pivoting and locking universal joint (not shown) is optionally incorporated at the juncture of the lower aspect of an engagement means (which comprises the lower aspect of the engagement screw 110), and the non-active end of the vibrator housing 14 of the vibration device 10. Alternatively a by hand or belt engagement means may be utilized (described later).

Next, the vibration head or heads 12 are placed against the target site or sites on the patient 20. Again in an attempt to minimize the risk of bruising, the attending physician, nurse or paramedic may confirm or optimize a choice of a single selected intercostal space, chosen from the anatomically leftward 3rd, 4th or 5th intercostal space, using a stethoscope wherein relative loudness of heart sounds suggest anatomical location of the heart, as well as optimal sonic transmissibility through the chest wall. The pair of contact heads 12 (comprising the preferred attachment means) should be placed to either side of the sternum, either perpendicularly across the sternum at the level of the chosen "optimal" intercostal space, or obliquely across the sternum whereby the anatomic rightward placement of the contact head 12 is placed one intercostal space lower than the anatomic leftward placement of the contact head wherein the leftward placement correlates to the rib space comprising the optimal site of sonic transmissibility. Alternatively, a singular contact head 12 would be placed leftward the sternum, according to the optimal rib space chosen by the operator according to the stethoscope method. The sternal margin (ie. so the center of the contact heads 12 are applied directly over the sternal margin) may be considered for large breasted women. The heart sounds should be inspected along the anatomic left sternal margin, so as to identify the optimal leftward intercostal space. Relative loudness and sustain ability of heart sounds during gently held inspiration should be evaluated by the operator (the louder the better) when judging the quality of a sonic treatment window and also inspecting for heart location which is known to vary markedly

between patients. The target intercostal space wherein heart sounds are best heard is then marked with ink and the leftward oriented contact head 12 of the vibration device 10 is placed on the mark.

In an alternative method to minimize bruising and to establish optimal transmission through the chest wall of the patient 20 to the heart, vibration therapy may be provided in conjunction with high frequency, diagnostic ultrasonography (i.e. "HFUS" around 1 - 7 MHz), in order to optimize placement of the contact heads 12 of the vibration device 10 to the patient 20, which may in this case utilize (but not be limited to) a singular contact head 12. To confirm the ideal placement of the low frequency treatment vibration source, a trained HFUS operator (such as a Cardiac Ultrasound Technologist for example) must first locate the ideal parasternal sonic window via ultrasonographic techniques, wherein the preferred sonic window provides a clear visualization of the mid to basal aspect of the heart, ideally depicting the basal aspect of the akinetic or hypo kinetic myocardial wall which represents by anatomic reference where the culprit thrombus is most likely to reside. The operator employs a conventional two-dimensional ultrasound device (not shown), so as to mark the sonic window on the chest (ie. with a pen) and place and even angle the treatment vibration device 10 accordingly. The sonographer should (while imaging) hold the imaging probe substantially perpendicular to the chest surface (ie. ideally less than a 20 to 30 degree angulation from the perpendicular axis) to ensure a treatment window, which is consistent with a perpendicular, or near perpendicular attachment of the low frequency treatment vibration device 10. Pathologies such as COPD, with increased lung size and therefore interference with ultrasound, may indicate the use of different intercostal spaces (ie. such as the 5th intercostal space) to establish the optimal sonic window. Attachment means can be by hand, clamp 100 or a variety of engagement garments (which are described later). The parasternal chest wall is preferred but other sonic windows may be utilized (note that the apical window should be used judiciously as per the methodology as stated earlier).

As a further variation, a dual function, simultaneous vibration and imaging method may be employed (apparatus described in detail later). Low frequency vibration therapy according to the present invention is employed in conjunction with high frequency ultrasonography (i.e. HFUS), where both high and low frequency waveforms are applied simultaneously via a single application probe *or* adapted variant contact head 12 (not shown). Optimally, low frequency ultrasonic treatment (LFUS) is also used in combination with low frequency treatment vibration in the 1 - 1000 Hz range. In this manner, direct HFUS imaging and targeting of the culprit vascular region may be combined with low frequency vibration in the 1-1000 Hz range (preferably 40-120 Hz for coronary applications) and also, low frequency ultrasonic energy (at around 20 - 100 kHz, preferably 27 kHz) to agitate and disrupt the culprit thrombosis. This imaging / treatment method by the operator initially involves a skilled imaging technique to direct application of the imaging / treatment probe to the ideal parasternal sonic window. The use of both hands to support and maintain the probe and treatment vibration with enough engagement force to the chest wall is suggested, or the operator can, alternatively, utilize any of the suggested attachment means according to the present invention, as long as the appropriate imaged sonic application window is visually monitored and maintained. The optional attachment of a weight to the backside of the imaging / treatment application probe may add inertia to the vibrating means to aid the operator ergonomically who may hold the probe in position by hand, with the probe substantially perpendicular or slightly angled in relation to the substantially horizontal chest wall surface of the patient 20. While the supine position for the patient is generally preferred, different patient positioning (e.g. with the patient lying to some degree on his or her left side, up to the left lateral debecutis position) and probe placement according to standard 2D echocardiographic imaging techniques could be utilized as per the judgment of the operator (in

accordance to the endorsed clinical practice as stipulated by the advocating medical institution and / or operator preference). The parasternal windows remain the preferred application site if available, however other sonic windows may be considered (note that the apical window should be used judiciously as per the methodology as stated above). Duty factor and intensity level are selectable with respect to the LFUS application such as to provide the means to avoid undue heating to the skin surface of the patient 20.

The next step in the treatment method is to apply appropriate engagement force to the chest wall with the vibration device 10, with the vibration device 10 turned off. The attending clinician lowers the vibration device 10 against the target area via rotation of the engagement screw 110 of the clamp 100. A relatively constant, firm pressure of approximately 5 - 20N, measurable at the shaft 16 of the vibration device 10 when the vibration device 10 is turned off, should be optimally obtained with optimal placement occurring during gentle held expiration of the patient 20. The engagement force should preferably not exceed 100N (again as -measurable with the vibration device turned off) during inspiration of the patient 20. A force meter (discussed later and not shown) is optionally utilized to confirm engagement force. The placement of the base of the clamp 100 (which is described later) under the mattress of the patient 20, may be advantageous in some cases, in that the mattress provides for a slight decompression when the patient 20 inhales, so as to limit the maximum engagement force on inspiration and make for a more comfortable application to the patient 20. In the optional case where the vibration device 10 is engaged by an operator's hand, the engagement force can be monitored and maintained at a near constant level, and the range of 5 - 100N should be strived for. As a rule of thumb, the engagement force should be the maximum force, which is still relatively comfortable and tolerable for the patient, and will not cause the vibration device to dampen its oscillations. Once engaged satisfactorily, the operator tightens the set screw 119 to lock the engagement screw 110 in place. Vibration therapy would then commence with the selection of the maximum displacement amplitude judged safe and tolerable applied for emergency situations. This maximal setting, will likely result in bruising to the chest wall, and an informed consent should preferably be signed by the patient 20 if feasible.

The frequency range employed is between 1-1000 Hz, preferably between 1-200 Hz, and optimally 40 - 120 Hz. It is optimal to match the resonance frequency of the heart, which falls within this latter range. The heart, receiving vibration stimulus at or near its resonance frequency will vibrate with the highest possible displacement amplitudes at the localized areas which best receive the signal. External vibration at the resonance frequency will with highest efficiency transmit the vibration signal internally throughout the ventricular chambers, thereby vibrating the entire heart effecting optimal intra ventricular transmissibility. Optimal intra ventricular transmissibility aids agitation of the entire coronary tree, including those parts of the tree, which are hidden behind lung or soft tissue which are poor transmitters of sound and therefore otherwise difficult to penetrate directly with sonic mechanical energy. The default frequency for chest wall vibration is a 50 Hz sinusoidal compressional wave, owing to this wave-forms known superior chest wall penetration, intra-ventricular transmissibility, lytic penetration, clot disruption, and arterial vasodilatation characteristics.

Higher frequencies (i.e. 200-1000 Hz), or even in the sub-ultrasonic to ultrasonic range (ie. 1-100 kHz), while optional for clot disruption and improved drug action to sites of thromboses, are generally higher than the resonance frequency of the heart and hence not readily transmissible to all areas of the coronary anatomy by intra ventricular transverse transmission means. Higher

frequency vibration also requires diminished displacement amplitude for safe clinical use, which is a further limitation to this wave-form's potential penetrating and agitative power (i.e. through the chest wall). A directed approach through an identifiable sonic window to ensure adequate penetration to target areas by the much weaker (lower displacement amplitude) signal is strongly recommended for frequencies greater than 200 Hz, again at the highest amplitudes judged tolerable to the patient in emergency situations. Concomitant high frequency ultrasound imaging (i.e. HFUS) in conjunction with lower displacement amplitude vibration therapy at frequencies of greater than 200 Hz, to target and direct a sonic penetration pathway to culprit areas (discussed later) is the optimal method for such higher vibration treatment frequencies.

Generally, a range of frequencies selectively chosen between 1 - 1000 Hz, with the selection of multiple wave-forms is disclosed. The present invention provides a broad range of frequencies and wave-forms which are advantageous, as the apparatus and system is optionally employed both as a treatment system and a research tool.

Treatment continues during and / or post the administration of the preferred drug agent(s) wherein stated agents may be selected solely or in any combination from the group of thrombolytics, GP 2b 3a platelet inhibitors, anticoagulants, oral anti-platelets, vasodilators and cavitating micro bubble solutions, concentrated oxygen, and the oxygen of ambient air. Vibration treatment ends once clinical signs of reperfusion are identified or until emergency invasive treatment (ie. PCI and/or emergency revascularization surgery) is established.

The preferred, "simple" method for deliverance of vibration therapy is represented diagrammatically in Figure 4, where an operator (not shown) provides input to a processor 34 via a controller 50. The controller 50 comprises a set of control knobs. The processor 34 in turn controls the vibration device 10, delivering the prescribed frequency, amplitude and optionally selectable wave form of continuously applied vibration to the target site on the patient 20. Preferably, in this "simple method", the controller 50 is located at the surface of the vibrator housing 14, however, other variant controlling means such as an electronic touch pad or key board are optionally provided. The processor 34 is located within the vibrator housing 14 of the vibration device 10, and comprises a programmable logic control of known type. The simple method is particularly appropriate for first line treatment such as in emergency rooms and -ambulances during transport, where in both cases non-experts are operating the device. The preferred embodiment is designed to provide a simple and reliable first line response to AMI incidents, which can be operated with minimal training and easily applied in the field or emergency room setting.

Referring now to Figure 5, in some cases, it may be preferable to accompany drug therapy with an "advanced method" comprising physiological and mechanical monitoring or sensing equipment and varying timing and optionally frequency algorithms for vibration delivery. With varying algorithms, cardiac phase dependent time and frequency varied vibration therapy via a variant cardiac phase controlled vibration device 10 (ie. "variant 1"), adapted to receive and respond to more advanced commands from a processor 34 input, may be selected by the operator if it is best suited to the clinical situation, thereby optimizing the vibration therapy. For example, in cases of hemodynamically stable acute ST elevation myocardial infarction, the optimal vibration therapy involves continuous vibration which is cardiac phase controlled whereby approximately 50 Hz is imparted during ventricular diastole, and approximately 100 Hz during ventricular systole. Any known phase monitoring means (see below) may be used to determine the timing of the cardiac

phase, and this is firstly determined automatically via the processor 34, and is then further fine-tuned by a manual adjustment made by the operator. Also, cases of complicating cardiogenic shock or unmanageable congestive heart failure with acute ST elevation myocardial infarction and severe forms of ischemia dictate diastolic only timed vibration. Vibration timed specifically to the diastolic phase of the cardiac cycle provides for a form of ventricular assist with a positive inotropic effect, and, as the diastolic myocardium is particularly stiff in times of profound ischemia, the vibration signal exhibits excellent intra ventricular transmissibility (i.e. transversely propagated internal vibration) characteristics to ensure an agitative treatment response to all areas of the coronary circulation. It is significant that the conventional treatment of acute MI with the complication of cardiogenic shock with thrombolytics only (i.e. with no adjunctive mechanical treatment) is extremely ineffective, with a low likelihood of reperfusion and a 63% in house mortality reported.

In the advanced variation, additional physiological monitoring equipment is provided to make possible the input of special vibration timing algorithms according to cardiac phase. Such physiological monitors include; an electrocardiogram ("ECG") 36, an impedance plethysmography system 40 (optional), a phonocardiography system 42 (optional), and a noninvasive blood pressure apparatus 44 (optional). The monitoring and sensing equipment, all of commercially known types, are interfaced with the patient 20. An transesophageal accelerometer 38 (optional) placed on a transesophageal lead is of optional use, to confirm and monitor maximal sonic penetration to the esophagus, which represents the posterior aspect of the heart. Through use of this device (ie. the transesophageal accelerometer 38), maximal penetration amplitudes can be ascertained and adjustment to the placement of the external variant cardiac phase controlled vibration device 10 can be made to thereby achieve optimal penetration. An external accelerometer 39 is also provided, which is necessarily placed on the vibrator shaft 16, to assist in monitoring vibration therapy in real time, and to confirm the functioning (ie. frequency and amplitude) of the adapted vibration device 10. The monitored output then interfaces with the processor 34, which comprises a circuit board with a micro processing chip, however any other form of known programmable logic control may optionally be used. The operator, based on the monitored output displayed on a display monitor 52, (which receives input from the processor 34), may select and modulate programmed timing and frequency algorithms designed to optimize therapy by entering a selection on the controller 50 which interfaces with the processor 34. For example, specifically timed sinusoidal phase controlled vibration at 50 Hz in ventricular diastole and 100 Hz in ventricular systole, at maximum safe intensity (ie. displacement amplitude), is prescribed for use with the advanced system in the treatment of hemodynamically stable ST elevation infarcts. Vibration timed exclusively to the diastolic phase of the cardiac cycle at 50 Hz (known to produce a positive inotropic effect), is prescribed for hemodynamically unstable ST elevation infarcts, (eg. with associated cardiogenic shock). The ECG 36 output is essential to provide a timing differentiation means between the diastolic and systolic phase of the cardiac cycle. The processor 34 will interpret the QRS deflection as the onset of systole, and will assign a preprogrammed default rate related time delay to dictate the onset of diastole. The default time delay may be monitored and adjusted by the operator, based on what physiological signals are viewed on the display monitor 52. ECG 36 monitoring can additionally provide information to heart rhythm and reperfusion which is represented by a sudden decrease in ST segment elevation.

The display monitor 52 comprises a TV monitoring screen enabling real time output wave form display, digital read outs and annotations where all necessary information for an operator to make judgments is displayed. The controller 50, in this case (ie. "advanced method") comprises an

electronic control touch-pad, to allow for selection and modification of: vibration displacement amplitude, displacement amplitude according to cardiac phase, wave form selection, ECG 36 monitoring selection, and timing and frequency algorithms. The processor 34 is adapted to receive and process input from the controller 50, and through analysis of the physiological information delivered from the monitoring equipment, control the variant cardiac phase controlled vibration device 10 to cause vibration at the selected time period, frequency, amplitude and wave form. The ECG 36 employs a standard monitoring system to represent inferior (II, III, avF), anterior (V lead) and lateral (V5, I, avL) electrocardiographic information, but may be of other configurations. The accelerometer 38 has a transesophageal lead, and the external accelerometer 39 is attached on the vibrator shaft 16. The accelerometers are utilized to measure and confirm vibration force delivered to chest wall and the heart respectively. The impedance plethysmograph 40 comprises a commercially known impedance plethysmography system enabling a relative comparison in real time changes in intra thoracic blood pressure. The impedance plethysmograph 40 will further relays the timing of the dichrotic notch (signifying the onset of diastole) to the monitor 52 and thereby the operator, making manual adjustments to the timing of the onset of diastolic vibration more accurate (however in the absence of an impedance plethysmograph 40 system, the onset of diastole may be judged at the termination of the T wave of the ECG 36 displayed wave form). The termination of diastolic vibration is triggered automatically by processor 34 in accordance with the deflection of the QRS complex provided by the ECG 36 monitoring means. It is therefore important to achieve a good "tall" QRS complex on the chosen ECG 36 monitoring lead without a great deal of muscle artifact. A low pass ECG 36 filter (filter not shown) is included to minimize such artifact. The phonocardiographic means 42 of known type- is optionally included as it also provides information as to the timing of the onset of diastole (ie. by the initial deflection of the "S2" heart sound), and thereby provides additional information to assist in the manual adjustment for diastolic only vibration.

The optional noninvasive blood pressure monitor 44 is a noninvasive real time blood pressure monitor -provided by Arterial Tonometry, which non-invasively senses the pressure of the radial artery by way of an external pressure transducer to provide a real time arterial blood pressure wave form (eg. Pilot Arterial Tonometry by Colin), but may alternatively be of any commercially known type, which quantifies the blood pressure of the patient 20. For example, alternatively, an automatic noninvasive blood pressure cuff system could be utilized with periodic digital readouts sent to the processor 34 and thereby to the monitor 52. An electronic strain gauge force meter (not shown) is optionally employed to monitor the engagement force and loading force of the contact head 12 of the variant cardiac phase controlled vibration device 10 ("variant 1") on the chest of the patient 20. Alternatively, any commercially known gauge such as a weight scale may be used to determine the contact force. The accelerometer 39, placed on the vibrating shaft 16 of the cardiac variant phase adapted vibration device 10 is utilized to confirm function of the vibrating means (ie. to ensure the device is not damping against the chest wall from too high an engagement force), and to provide a real time comparison of treatment vibration application versus the ECG 36 and optionally the impedance plethysmography system 40, and the phonocardiography system 42 wave form trace.

Regardless of method employed (ie. "simple" or "advanced"), the patient 20 must be monitored by at least one clinician or nurse during the course of vibration therapy for of acute ST elevation myocardial infarction. Pain and nausea may require an adjustment in the amplitude of vibration or a cessation of treatment. The operator can readily adjust or remove the vibration device 10 as required. Particularly using the advanced method, the operator or clinician may adjust the treatment

to suit patient 20 physiological status which is displayed on the monitor 52. For instance a sudden drop in blood pressure, usually indicating deterioration into cardiogenic shock, would be registered by the plethysmograph 40 or noninvasive arterial blood pressure wave form via arterial tonometry 44. The operator may decide to discontinue continuous vibration therapy (ie. with a 100 % duty factor), which may have a negative inotropic effect on heart failure, and switch to diastolic only vibration, which has a positive inotropic effect. If hemodynamic compromise is borderline, the operator may optionally limit or reduce the displacement amplitude of vibration selectively during the time period of ventricular systole.

The above methods may be used for several pathologies and in different settings. Six examples of treatment, illustrated in reference to the heart, in various in-hospital or pre-hospital settings are as follows:

First, the present invention may be employed in an emergency room or ambulance as first line treatment of ST elevation acute myocardial infarction, adjunctive to thrombolytics, or any other form of medical therapy.

Second, also in an emergency room or ambulance as first line treatment, vibration therapy may be employed to reduce the required dosage of thrombolytics and or anti-platelet agents (ie. for those patients where thrombolytic therapy and or anti-platelet therapy is relatively contraindicated due to increased bleeding risks) for the treatment of acute ST elevation MI.

Third, vibration therapy may be employed in the in-hospital or pre-hospital setting for treatment of Non-Q MI or acute coronary insufficiency such as anginal pain with ST/T wave ECG changes (Non-ST elevation) as an adjunct to drugs such as IV nitroglycerin, GP 2b-3a platelet inhibitors, and heparin for example. Lytics are not indicated in such cases. Diastolic only vibration (ie. via the "advanced method") which is known to increase coronary flow in ischemic, non occlusive states, may be preferable in these cases as a first measure to limit vibration therapy and thereby limit bruising to the patient 20 who will usually be anti coagulated. This treatment (ie. diastolic vibration) should start at a very gentle intensity, for example 0.1 mm displacement, then increasing incrementally. If diastolic only vibration does not relieve the chest pain (or if not available), continuous vibration should be selected, which is more effective for cases of myocardial ischemia when the mechanisms are either or both of coronary artery spasm and coronary thrombosis formation at an initial stage. Continuous vibration should also be applied at incrementally increasing amplitudes until the symptoms are relieved. This gentle method of progression of phase modulation and displacement amplitude in Non-ST elevation ischemia and infarction is important as the patient will likely be (as previously stated) anti-coagulated and will bruise easily.

Fourth, vibration therapy may be employed in sub acute cases in the step down telemetry unit or CCU for example, adjunctive to nitro spray, for patients with episodes of angina without significant ECG changes (i.e. non-infarction ischemia), which is otherwise refractory to nitro spray without vibration therapy, and whereby an acute coronary event at early stage cannot be ruled out. A hand held vibration device 10 with the preferred bifurcated connector 13 and pair of contact heads 12 quickly applied at moderate intensity to the parasternal chest wall (i.e. at the fourth intercostal space by default, such as to bridge the sternum) is the most appropriate in this case, as the coronary syndrome is not typically severe, and the chest pain should be resolved quickly once nitroglycerine spray in conjunction with continuous vibration therapy optimally at 50 Hz, has been applied.

Fifth, vibration therapy may be applied to the chest wall in the cardiac cathlab as an adjunct to drugs such as nitroglycerine, nipride, verapamil, GP 2b 3a platelet inhibitors, and thrombolytics, for acute to sub-acute procedures prior to, during, or after percutaneous coronary intervention (PCI), where there may be significant clotting in the artery at the onset of or immediately following the procedure. Vibration therapy could for example be utilized pre procedure, as an adjunct to GP 2b 3a platelet inhibitors +/- thrombolytics while the patient 20 is enroute to the cathlab for emergency PCI. Post procedure, vibration therapy may for example be appropriate in "no-reflow" or "slow-flow" situations following or during an intervention, for instance when clots and/or micro emboli dislodge and affix themselves to the distal, arteriolar circulation to cause very poor flow, chest pain and injury. Note however that if chest wall vibration therapy is imparted during a PCI procedure, it is important to withdraw the guide catheter from the ostia of the selected coronary artery prior to initiation of the vibration therapy in order to avoid shear forces and resulting dissection to the ostia of the coronary.

Sixth, vibration therapy may be employed in the community for acute states of coronary insufficiency resulting in symptoms of angina pectoris refractory to nitroglycerine treatment in the patient 20. Every bout of "angina" that a patient 20 in the community experiences might represent an acute coronary event wherein a plaque has ruptured and a blood clot has formed. In these cases, the patient 20 will typically have tried nitro spray x 3, each dose spread 5 minutes apart, and still have no relief of chest pain which may be quite severe. The patient 20 will then proceed to dial "911" wherein the diagnosis of an acute coronary thrombosis leading to an acute MI cannot be ruled out until the outpatient receives professional care. Hyper acute early clot formation (while a major killer), ironically comprises a soft aggregation of platelets, which are easily mobilized (ie. prior to the deposition of fibrin), hence coronary thrombotic vascular obstructions at early stage are particularly amenable to dissolution via mechanical agitation. High amplitude chest wall vibration therapy in these instances provides such agitation, and is therefore an extremely important first line emergency tool, to capture the window of susceptibility of a newly formed blood clot and ameliorate it before it has a chance to grow and harden, and cause damage to the myocardium, and even death to the patient 20. The vibration device 10 or alternatively a variant "light weight" vibration device 10 (ie. "variant 3" - described later), is placed to the anterior chest wall at the level of the fourth intercostal space of the patient 20. The vibration device 10 to chest wall interface is accomplished via the connector 13 equipped with preferably a pair or optionally a plurality beyond a pair of pre-sized contact heads 12, wherein the contact heads 12 have been pre adjusted in location on the connector's 13 support arms 22 to optimally bridge the sternum and seat within the intercostal spaces of the patient 20 for maximum chest wall penetrability as per the methods and apparatus previously described. The vibration amplitude is selected as the maximum tolerable to the patient 20, who should ideally be resting in either the supine position or seated comfortably upright in a chair. The optimal frequency is selected at 50 Hz continuous wave (ie. 100% duty factor), with a sinusoidal wave form, however optionally any frequency within the 40 - 120 Hz range (ie. to match the resonance frequency of the heart) and square waves may be selected according to the preferred method. Ideally a friend or bystander should engage the vibration device 10 against the outpatient by hand until profession care arrives. Alternatively, a portable belt system with shoulder straps (described later) is utilized to engage the vibration device 10 to the chest wall of the patient 20.

Vibration therapy is effective in emergency situations where an acute thrombotic vascular occlusion has occurred and cell death or hemodynamic compromise is imminent, particularly when there is a

poor prognosis for drug therapy alone and emergency invasive intervention is delayed or not available.

Acute pulmonary emboli and in particular saddle emboli (which involves a critical life and death situation) are also good candidates for external, transcutaneous vibration therapy adjunctive to standard drug therapy (e.g. IV thrombolytics, anticoagulants etc.). Chest wall vibration to the patient's 20 vascular region of the lung (pulmonary vasculature) and pulmonary artery are readily achieved by the methods disclosed above. The underperfused body region is in this case is the patient's 20 organ and tissues of the lung and, in the case of saddle emboli, the entire body. A frequency of less than 1000 Hz, and preferably selected from the 1 - 200 Hz range at maximum tolerable amplitude is suitable for such applications. The choice of 50 Hz is preferred, as 50 Hz sinusoidal vibration can be delivered at relatively high amplitude, has excellent chest wall to thoracic cavity penetrability, and is also a well established frequency known to produce cavitation and acoustic streaming (to assist in thrombolytic to clot filtration), as well as vascular dilation and clot disruption. As the lungs also reside in the thoracic cavity, the present invention also functions to vibrate the vasculature of the lungs and pulmonary artery with low frequency vibration. Ultrasonic imaging means to target the pulmonary artery (ie. where saddle emboli is presumed the culprit) may be employed to target the vibration therapy. Without ultrasonic imaging, the placement of the vibration device 10 to the patient's body 20 (ie. chest wall), is attached via a singular contact head 12 to the left sternal margin of the fourth intercostal space, or alternatively via a plurality of contact heads 12 to the left sternal margin of preferably the third, fourth and fifth intercostal space. A frequency of less than 1000 Hz, preferably 1 - 200 Hz, and optimal in the 50 Hz range is then applied at maximum tolerable amplitude in conjunction with a systemically delivered drug such as a thrombolytic, anti-platelet, anticoagulant or vasodilatory drug. Low frequency vibration treatment commences with adjunctive drug therapy until signs of reperfusion or until invasive corrective measures may be established.

Vibration therapy may also be employed to treat acute Cerebral Vasculature Accidents, once determined as ischemic or embolic in origin, adjunctive to thrombolytic therapy where brain function is still arguably salvageable. Transcutaneous cranial vibration to the vascular region of the patient's 20 brain are readily achieved by the methods below. The underperfused body region is in this case is the organ and tissues of the patient's 20 brain. The vibration device 10 is attached to the patient's 20 head and cushioned to avoid bruising via a helmet attachment means (not shown). A frequency of less than 1000 Hz, preferably 1 - 200 Hz, is then applied at a selected amplitude (ie. from 0.1 mm to 6 mm displacements), in conjunction with a systemically delivered drug such as a thrombolytic, anti-platelet, anticoagulant drug, or vaso-dilatory drug. The choice of 50 Hz is preferred, as 50 Hz sinusoidal vibration can be delivered at a relatively high displacement amplitude, and is a well established frequency known to produce cavitation and acoustic streaming (to assist in thrombolytic to clot filtration), as well as vascular dilation and clot disruption. It should be noted that for the more serious natured acute ischemic strokes (ie. where there is a traumatic deficit noted), higher displacement amplitudes should be considered in keeping with an increased benefit to risk ratio (ie. benefit of improved thrombolysis to restore vital function vs. risk of cerebral bleeding).

Vibration therapy in accordance with the present invention may be further utilized to facilitate treatment of acute peripheral arterial occlusions such as those occurring in the limbs of a patient. When the occlusion (which is usually thrombo-embolic in nature, or involving acute thrombosis on a preexisting ulcerative plaque) involves a critical segment of the arterial system where the collateral

potential of blood perfusion is poor, the clinical picture is dramatic with loss of limb viability and amputation imminent if not treated effectively within six hours. Transcutaneous peripheral vibration to the vascular region of the effected peripheral body part (including all organs and tissues distal to and including the clavicles and groin region of the patient 20) are readily achieved by the methods disclosed below. A vibration frequency of less than 1000 Hz, preferably 1-200 Hz, and optimally 50 Hz, is applied transcutaneously to the presumed culprit area, with maximal tolerable and safe displacement amplitudes. Vibration therapy is used in conjunction with pharmacologically active agents such as thrombolytics, anti-platelets, vaso-dilatory or anticoagulant drugs as a first line method to restore early flow, and to also act as a bridge to emergency corrective surgery or intervention. A singular or plurality of contact heads 12 running in phase, are utilized to provide maximal agitative vibration energy imparted to the culprit area. The contact heads 12 to the periphery are provided in a variety of sizes (ie. 2 cm - 2 cm to 6 cm - 6 cm) such as to match contact surface sizes. The contact heads 12 are placed on the limb surface affected, with contact established at -the point at which distal pulses are lost. Typical attachment areas comprise the pelvis/groin area (i.e. iliac and femoral arteries), thigh (femoral artery), popliteal space (popliteal artery), lower leg (tibial artery), periosteum of the clavicle and first rib (sub-clavian artery), soft tissue area between the clavicle and trapezius muscle (sub-clavian artery), axilla (axillary artery), brachium (brachial artery), anti-cubital fossa (brachial artery), forearm (radial artery). The contact heads 12 are comprised of silicone rubber, however any commercially available material, preferably resilient and substantially non-distortable may be used to form the attachment surface of the contact points. Alternatively, the surface of specially adapted "peripheral" contact heads (not shown) are malleable to enable a more exacting vibration contact to complex, uneven and even rigid contours (such as in contours overlying a bone) of the patient's 20 body surface. The peripheral contact heads in this variation are comprised of a solid base piece, that substantially encapsulates an incompressible fluid with the semi-compliant membrane overlying the active end of the base piece and incompressible fluid. For peripheral vascular occlusion applications, the engagement means of the vibration device 10 may be by hand, by the clamp 100, or alternatively via a belt engagement system with Velcro™ strap securement (described later). Ultrasonic imaging means to target a culprit blood clot within a culprit vascular region may be employed to target the vibration therapy. Vibration treatment commences with adjunctive drug therapy until signs of reperfusion or until invasive corrective measures may be established.

Referring again to Figures 1, 2 and 3, the preferred embodiment of the vibration device 10 (i.e. in the emergency treatment of ST elevation MI) is provided with a clamp 100 attachment means and removable vibration device 10 with the patient 20 lying substantially in the supine position. The vibration device 10 is -operable in the 1 - 200 Hz range (which is preferred for clinical treatment applications), with an optional second variant "research" vibration device 10 (ie.- "variant 2"), adapted to operate at higher frequencies, above 200 Hz (which is designed primarily for research applications). The preferred vibration device 10 comprises a high powered electric motor, with a horsepower of 1/18 hp, enabled to select-ably emit sinusoidal and square wave forms, and a selection of displacement amplitudes ranging from 0.1 to 10 mm. The research variant vibration device 10 ("variant 2") is provided, enabling selection of a broad frequency range of 1-1000 Hz, with a selection of sinusoidal, square and exponential wave forms. The transducer of the research variant vibration device ("variant 2") is preferably an electromagnet, however a piezoelectric may serve as an alternate. The amplitude displacement (or intensity) in the 1 - 200 Hz range is adjustable between 0.1 and 10 mm, although another "light weight" variant vibration device 10 (ie. "variant 3")

assembly is also provided (described later), and enables maximum amplitudes of up to only 6.5 mm displacements.

The maximum power availability of the preferred vibration device 10 generally provides for non-dampening oscillations against a chest wall interface given a total engagement force (defined as the load applied to the surface of the vibrator shaft 16, with the vibration device 10 placed against the chest wall of the patient 20 while turned off) of up to 100 N. Yet another variant "heavy duty" vibration device 10 (i.e. "variant 4") of higher power (ie. 1/12 hp - described later) is provided for obese patients and is equipped to not dampen its oscillations with engagement forces of significantly greater than 100 N. The preferred vibration device 10 comprises an electric motor, however, any other transducer such as an electromagnet, solenoid, piezoelectric crystal, or pneumatic device, is optional. In some cases, higher fidelity transducers offering superior waveform control (ie. such as piezoelectric crystals and electromagnetic coils) are preferable, especially in the higher frequency, lower displacement amplitude applications (i.e. above 200 Hz) and where selectable wave forms beyond sinusoidal and square waves are required.

The present invention provides a preferred vibration motor with a horsepower of 1/18 hp with a vibration device 10 weight of approximately 15 lbs (7 kgs). The preferred vibration device 10 is well suited for clamp 100 engagement, belt engagement (described later) or engagement by hand via a double-handed technique. Optionally, the variant lightweight vibration device 10 ("variant 3") provides a motor of 1/30 hp, with a weight of approximately 8 lbs (3.6 kgs)- suited to single hand engagement. The variant heavy duty vibration device 10 ("variant 4") provides a motor of 1/12 hp, with a weight of approximately 35 lbs (16 kgs) - more suited to clamp 100 engagement. The later variant heavy-duty vibration device 10 ("variant 4") is well suited for use with obese patients where higher displacement amplitudes and engagement force may be required.

The electrical transducer (or electric motor) of the vibration device 10 (including variants) runs on AC power, and is supplied by an AC power cord. Portability of the vibration device 10 (preferred and "variant 4") is made possible through the use of a high-powered portable external DC battery unit (not shown) with a compatible DC - AC adapter of a known type (not shown).

A DMS Power Pack (24V, 27kg) by DMS Technologies Inc. is suitable, however any known high-powered portable DC battery unit may be used. The lightweight variant vibration device 10 ("variant 3") is enabled for battery operation wherein the storage of the batteries are housed within the variant vibration device's 10 housing 14. The vibrator housing 14 of the vibration device 10 is made of ABS Cycolac (TM) material, however any alternative durable and lightweight material is optional.

The vibration device 10 is powered by battery or power cord at a range of voltages (eg. North America - 110, 120 V, Europe - 220V, Japan 95, 105 V, Australia 240 V) and is operable both by battery and power cord for emergency settings. The vibration device 10 (all variants), cumulatively provides a selection means for a range of frequencies in increments of 1, 5, 10, 20, 40, 50, 60, 70, 80, 90, 100, 110, 120, 200, 300, 400, 500, 600, 700, 800, 900 and 1000 Hz (although other variations in frequency selection are optional), which is selected by a controller 50 comprising a control knob (not shown) on the vibration device 10 housing in the preferred "simple method" embodiment (described earlier), or optionally an electronic touch pad provided as a separate unit, as in the "advanced method". The control means 50 also provides for selection of displacement amplitude, from 0.1-10 mm to be placed in conjunction with the prescribed frequency setting, with

an amplitude selection of 0.1 - 6.5 mm provided in the variant light weight vibration device 10 ("variant 3"). Frequency settings above 200 Hz and up to 1000 Hz have limited displacement amplitude availability in keeping with patient safety and due to limitations of the mechanical transducing nature of the research variant vibration device 10 ("variant 2"). The engagement force, with a contact head(s) 12 of the vibration device 10 resting against the body of the patient with the vibration device 10 turned off, is preferably between 5 - 100 N , and optimally around 50N (depending on the tolerance and comfort level of the patient). The engagement force should preferably not exceed 100N, to avoid dampening of oscillations of the vibration device 10.

Detachable contact heads 12 are provided in a plurality of sizes, (i.e. small medium and large), and made substantially of silicone rubber, however any resilient yet non-obtrusive material, to allow comfortable application against the patient's body 20 is optional. The attachment heads are sized to make contact with an intercostal space of the human body, and rest evenly against the upper and lower rib, as well as the sternal margin, with an outward dome shaped convexity to ensure soft tissue contact. Standard head 12 sizes range in size and shape according to operator preference. The preferred contact head 12, comprises a semi spherical dome shape, with a flat planar circular base (the base being of similar size to the head of a stethoscope), wherein the base ranges in size between 2 cm, 3 cm and 4 cm diameter. Optionally, a variety of contact heads 12 comprising suction cups (not shown) are provided to provide an additional active retraction force, provided the patient is not significantly diaphoretic. A soft sponge like lining over the engagement surface of the contact head 12 in conjunction with the choice of a broader surface area contact is optional for extremely tender skinned females with fleshy breast tissue who often are very sensitive to pressure applications to the chest wall.

The preferred embodiment comprises a pair of contact heads 12, divided by a support connector 13 with a bifurcated pair of support arms 22 which is attached to the vibrator shaft 16, to provide therapy to either side of the sternum at the selected intercostal space as per the prescribed methodology. Alternatively, to avoid unnecessary bruising of the chest wall, a solitary contact head 12 placed leftward the sternum can be utilized, this method particularly suitable in cases of known Anterior or Lateral AMI (ie. wherein leftward coronary involvement is diagnosed), without the need of the bifurcated support connector 13, as per the methodology described earlier. In a further variation, to optimize sonic penetrability to the heart, a plurality of contact heads 12 are represented. In this case, the connector 13 further comprises a center piece 24 to allow for the addition of up to two slide able and lockable sleeves 23, each sleeve 23 incorporating a pair of support arms 22. Each support arm 22 has another slide able and lockable sleeve 25 disposed around it. Each pair of sleeves 25 includes a pair of contact heads 12 such as to enable bridging of the sternum of the patient 20). Placement of the contact heads 12 could be for example along the right and left sternal border, encompassing the 3rd, 4th and 5th intercostal spaces. Alternatively, if the sonic windows utilized did not occur within the same plane of body contour, separate contact heads 12 could each be placed separately with separate vibration devices 10 and separate engagement means. To maximize sonic penetrability to the heart, further contact heads 12 could be placed more laterally along the mid clavicular line, via a separate engagement means (not shown) to provide more directive therapy to the Left Anterior Descending Artery distribution of the coronary artery system.

An engagement screw 110 allows the vibration device 10 and contact heads 12 to be lowered or raised by the operator via rotation of the upper end of the engagement screw 110 via a turning knob

disposed on the upper end. The vibration device 10 may be detached from the clamp 100 for hand held use.

As an option, the vibration device 10 will emit a range of vibratory wave form characteristics, such as sinusoidal, square, saw tooth or exponential waves as selected by the operator via the control means 50.

Referring again to Figure 5, peripheral devices to the vibration device 10 are required for the advanced variation of the invention. The advanced variation is specifically designed for cardiac use, to enable cardiac phase controlled vibration therapy (timed in accordance to the cardiac cycle) and the use of frequency algorithms to optimize the system.

A display monitor 52 receives output from the variant controller 50, and peripheral physiologic sensors (as specified below) via the processor 34. The display monitor 52 displays: ECG 36 and heart rate (at least three leads, V lead (anterior), Lead II (inferior) and V5 (lateral)); external accelerometer 39 output comprising the delivered surface vibration amplitude on the 'y' axis in displacement (mm) or other measurement; and a real time display moving right to left at 25 mm/second to match the ECG in real time, on the 'x' axis; optional impedance plethysmography system 40 output also moving in real time to match the ECG (to monitor relative real time blood pressure, and inspect for timing of diastolic therapy; optional phonocardiography system 42 signal trace; the chosen frequency and mode of delivery (written annotations); the chosen intensity of the therapy (written annotation); and optionally a noninvasive blood pressure wave form also moving in real time to match the ECG via arterial tonometry 44 output to support an absolute value to the otherwise unit-less plethysmography wave form analogue. A noninvasive automatic blood pressure cuff output apparatus output is alternatively utilized (to arterial tonometry) wherein a periodic digital readout is displayed on the monitor 52.

A variant controller 50 comprises an electronic control touch pad (ie. for the "advanced method"), but can optionally comprise a series of rotating knobs to the vibration device 10 housing 14 (ie. such as in the preferred "simple method"), such as to receive input from the operator (not shown) and interface with a processor 34. The control means 50 is adapted to receive and transmit information relating to: the mode of vibration to be delivered (ie. continuous, or diastolic only vibration); the displacement amplitude of vibration (0.1 -10 mm displacements); the displacement amplitude of vibration according to cardiac phase (0.1-10 mm displacements) treatment frequency (1 - 1000 Hz); the wave form type (ie. sinusoidal, square or exponential); the preferred ECG 36 lead to be utilized for determining or "tracking" the QRS complex via the processor 34; and an electrocardiographic frequency filter suitable for eliminating muscle tremor and vibrational artifact from the resultant ECG trace prior to processing via the processor 34.

A processor 34 receives information from the physiological monitoring and sensing equipment and the controller 50, and provides output to the display monitor 52 and vibration device 10. A preprogrammed, default rate related time delay following tracking of the deflection of the QRS complex (used to signify and electronically trigger the onset of diastolic vibration) is provided by the processor 34 programmable control. The processor 34 thereby is enabled to determine systolic and diastolic phases based on ECG output. The beginning of the diastolic phase of vibration is further adjustable by the operator according to an additional operator input to the controller 50, based on information gained by physiological timing parameters as viewed on the display monitor 52. These timing parameters are represented by; the accelerometer 39 on the vibration device shaft 16 (which

defines the timing and amplitude of the treatment vibration), the ECG 36 (which defines the beginning of systole via the onset of the QRS complex), and the plethysmograph 40 (which defines the beginning of diastole via the dichrotic notch of the arterial wave form analogue). Optionally, the phonocardiogram 42 is used to define with more exacting precision the onset of diastole (i.e. via the initial split of the "S2" heart sound signifying closure of the Aortic Valve). The phonocardiogram 42 however is not useful in continuous mode vibration therapy because of the treatment vibration noise, which contaminates the signal. In the case where an impedance plethysmography system 40 and a phonocardiography system 42 is not employed, the onset of diastole can be approximated as the termination of the T wave as seen on the ECG 36 wave form trace. The processor 34, upon receiving input from the controller 50, and upon receiving information from the physiological monitoring and sensing equipment, will place a judgment to provide output to the vibration device 10, which applies the selected timing, mode, wave form, frequency and amplitude of vibration therapy.

An ECG 36 comprises a six electrode system, with a left arm, left leg, right arm, right leg (ground) and an anterior pre cordial lead (modified V lead placed on the sternum) and a lateral pre cordial lead (V5). Output from at least leads II, V1 and V5 are preferably displayed on the display monitor 52.

An impedance plethysmograph 40 requires the placement of two electrodes on the arm of the patient 20 and the application of a minimal current in order to monitor relative changes of blood pressure in real time, checking for example for any beneficial inotropic effects with diastolic only vibration in cardiogenic shock patients, or sudden deterioration of blood pressure during treatment in an otherwise hemodynamically stable case of, evolving myocardial infarction. The present invention employs the Tektronix™ type 3C66 impedance plethysmograph 40 system, however any known impedance plethysmography system may be used. The plethysmograph 40 is also employed to check the timing of the closure of the aortic valve and therefore the beginning of diastole, and is useful to confirm or to facilitate a manual adjustment of the default time delay set after sensing of the QRS complex to ensure that diastole is captured properly in the timing algorithms. Alternatively, a variant photo plethysmograph 40 (such as the Tektronix™ Plethysmography Pulse Sensor) with output to the display monitor 52 represented as a wave form signal (important to inspect for inotropic changes) using finger or forehead plethysmography may be employed. The impedance plethysmograph 40 is preferable as it -yields a closer analogue trace of a central arterial wave form (ie. yielding an closer approximation of the true timing of Aortic Valve closure via the dichrotic notch) than the variant photo plethysmograph 40 which incorporates an analogue trace of a peripheral arterial wave form.

A phonocardiogram 42 of commercially known type consists of a small microphone placed on the chest wall and provides output to the display monitor 52 representing the heart sounds in time with the ECG 36, plethysmograph 40 and accelerometer 39 signals. The heart sound "S1" represents the onset of systole, and the initial component (or "split") of the heart sound "S2" represents the onset of diastole. The phonocardiogram can with extreme precision provide the timing of aortic valve closure marking the onset of diastole, however the device is limited to diastolic only mode vibration therapy as continuous mode vibration contaminates the audio trace.

The blood pressure monitor 44 comprises a modern state of the art arterial tonometry noninvasive blood pressure monitoring means, (ie. Pilot arterial tonometry device manufactured by Colin

Medical Instruments Corp.) Optionally, a variant noninvasive blood pressure monitor 44, comprising a blood pressure cuff system which takes a periodic blood pressure reading from the arm of the patient and displays the information on the display monitor 52, is provided. Vibration therapy may be programmed to temporarily cease during the measurements to avoid interference with the blood pressure monitor 44, in the case of a blood pressure cuff monitoring means.

An external miniature accelerometer 39 placed on the shaft of the vibrator 16 (ie. Shin Nipon Sokki C. Ltd Emic 540) is utilized to monitor the timing, frequency and amplitude of delivered vibration from the vibration device 10. Optionally, a miniature transesophageal accelerometer 38 (ie. Shin Nipon Sokki Co. Ltd Emic 540M) placed on a transesophageal lead is used to monitor chest wall penetration of sound to behind the heart. Alternatively, any commercially available miniature accelerometers can be used.

A strain gauge force transducer (not shown) or optionally a weight scale to indicate the engagement force of the contact heads 12 against the patient's 20 chest is also provided.

Referring now to Figure 6, a perspective view of a variation of the preferred embodiment, a hand held dual function imaging vibration device 15 and method as applied to a patient 20 is shown. This dual function imaging system option employs both low frequency treatment vibration and high frequency ultrasonographic imaging (HFUS) taken together in concert via the hand held variant dual function imaging vibration device 15. The variant dual function imaging vibration device 15 contains a piezoelectric phased array transducer adapted to emit and receive HFUS for imaging (whereby an ultrasonic image 18 can be viewed on the ultrasonographic 2-D display monitor 17), and a vibration source to emit the low frequency vibration for thrombosis disruption and improved systemically delivered drug therapy effectiveness localized to the thrombosis site. An optional weight added to the handle of the variant dual function imaging vibration device 15 (weight not shown) adds inertia to the system to assist in the hand held placement of the treatment probe. An example of a useful ultrasonic image 18 (in this case an image of the heart is depicted), is shown on the ultrasonographic 2-D display 17.

A simply adapted ultrasonographic imaging transducer system (not shown), readily incorporated for use with the vibration device 10 of the present invention is provided. This variant dual function imaging system comprises a variant "ultrasonographic imaging" contact head 12 (not shown), wherein a semi spherical silicone dome attaches and substantially encapsulates a distal active end of a pediatric HFUS transducer imaging probe of known type. A flat, 1.5 cm by 1.1 cm rectangular slit is centered at the silicone dome's otherwise curved distal, active contact surface to provide for a minimal protrusion (approximately 1.5 mm) of the imaging contact surface of the HFUS transducer imaging probe. This arrangement enables stable contact of both the active distal contact surface of the HFUS transducer imaging probe (i.e. for imaging) and the distal, active contact surface of the semi spherical silicone dome (i.e. for the transmission of low frequency vibration treatment) to the chest wall of the patient 20. The non-active, proximal end of the variant ultrasonographic imaging contact head 12 comprises a flat planar base, and stemming from the base, a housing to the electronic components of HFUS transducer, such that the distal, active end of the housing is centered at the base, and the proximal, non-active end of the housing projects away from the base for a length of approximately 6 cm. A hollow connecting column is attached to the proximal, non-active end of the HFUS transducer housing, which enables removable attachment (by friction) to the shaft 16 of the vibration device 10. In this variant dual multifunction imaging system the vibration shaft 16

once activated vibrates the HFUS transducer's housing which in turn vibrates the attached silicone dome and the attached HFUS transducer's imaging probes distal, active end, which taken together comprises the variant ultrasonographic imaging contact head 12. An electronic cord (measuring 0.5 cm in diameter - not shown) of the HFUS transducer imaging probe protrudes through a hole in the proximal, non-active end of the HFUS transducer housing, and then is removably secured to the exterior surface of the housing 14 of the vibration device 10. The proximal, non-active end of the electronic cord is attached to an ultrasound imaging apparatus of known type, however any commercially available ultrasonic apparatus, could be utilized.

A multifunction ultrasonographic imaging system is also provided, which in addition to providing a means of transmission for low frequency treatment vibration (ie. as above in the dual function imaging systems), further enables a LFUS treatment wave form emission. A variant "ultrasonographic imaging and LFUS treatment" contact head 12 with low frequency ultrasonic treatment capabilities as well as high frequency ultrasonic imaging capabilities, comprises an ultrasonic phased array imaging transducer of a known type, mounted upon and acoustically coupled to the active surface of a low frequency ultrasonic transducer which is also of known type, such as to enable transmission of the LFUS treatment wave form emission through the active components of the ultrasonic phased array imaging transducer, and thereby to the patient 20. This variant ultrasonographic imaging and LFUS treatment contact head 12 optionally comprises a semi spherical silicone dome which attaches and substantially encapsulates a distal, active end of an ultrasonic phased array imaging transducer of a known type (like in the dual function imaging systems as above). A flat rectangular slit is centered at the silicone dome's otherwise curved active contact surface to provide for a minimal protrusion of the imaging contact surface of the ultrasonic phased array imaging transducer. This arrangement enables stable contact of the active distal contact surface of the ultrasonic phased array imaging transducer (i.e. for imaging), while concurrently enabling a fitted contact to the rib spaces of the chest wall of the patient 20. The low frequency ultrasonic transducer component of the multifunction ultrasonograhic imaging system is operation at 27 kHz, however other frequencies of LFUS treatment are optionally provided via use of a selection of differing and interchangeable low frequency ultrasonic transducers, and a range of between 20 kHz and 100 kHz is provided. The LFUS transducer and phased array transducer assembly work together simultaneously and nondestructively, to supply continuous high resolution imaging with HFUS and simultaneous treatment with a LFUS wave form. The variant ultrasonographic imaging and LFUS treatment contact head 12, like the variant ultrasonographic imaging contact head 12, is also coupled to the low frequency vibration device's 10 shaft 16 by friction via a hollow connector (not shown), wherein the hollow connector is attached in this case to the non-active end of the low frequency ultrasonic transducer electronic housing. An- electronic cord joins the variant ultrasonographic imaging and LFUS treatment contact head 12 to a an ultrasonic imaging device, and a separate electronic cord joins the variant ultrasonographic imaging and LFUS treatment contact head 12 to a LFUS control apparatus to enable an operator to control the function of the LFUS component of the multifunction ultrasonographic imaging system. A selectable duty between 1% -and 100%, plus a selectable intensity level of between 0.5 W/cm 2 and 9 W/cm 2 is provided to the operator via the control means. The preferred LFUS treatment wave-form comprises a frequency of 27 kHz, with a continuous (ie. 100% duty factor) emission at maximum intensity (ie. 9 W/cm 2). A temperature probe is optionally attached to the periphery of the active surface of the ultrasonic phased array imaging transducer such as to supply a digital readout on a display apparatus, such that the operator can adjust the duty factor and intensity levels of the LFUS treatment when the temperature of the active surface of the variant phased array transducer rises to an unacceptable level

to avoid burning of the skin of the patient 20. Alternatively, the variant ultrasonographic imaging and LFUS treatment contact head 12 may be exchanged, with the application skin surface cooled down by a wash cloth or ice bag in between variant ultrasonographic imaging and LFUS treatment contact head 12 exchanges. Noninvasive low frequency treatment vibration, low frequency treatment ultrasound, and high frequency imaging are utilized nondestructively in concert to provide an optimized therapy system for low blood perfusion as an adjunct to systemically delivered drug therapy, to improve localized drug effectiveness.

As a variant means of supplying low frequency treatment ultrasound for the multifunction ultrasonic imaging system, an electromagnetic transducer is provided as an alternative to the above described piezoelectric crystal assembly. The electromagnetic transducer uniquely enables a selection of broad range frequencies in the sonic, subsonic and ultrasonic ranges, as well as selectable complex waveform control (including the simultaneous delivery of multiple wave forms at multiple frequency levels). To provide the imaging components of this variant "electromagnetic transducer multifunction ultrasonic imaging system", the active elements of the ultrasonic phased array transducer are mounted and acoustically coupled to the active emission surface of the electromagnetic transducer. While the electromagnetic transducer is enabled to deliver a low frequency sonic wave form, the electromagnetic transducer is displacement amplitude limiting, hence to provide the necessary high amplitudes needed for effective treatment (i.e. in the 6 mm and beyond amplitude range), it is still preferable to treat the electromagnetic transducer as a variant "contact head" 12 of the vibration device 10, whereby the proximal, non-active end of the electromagnetic transducer assembly is attached to the shaft 16 of the vibration device 10. The coupling of the high powered electric motor of the vibration device 10 (for high amplitude delivery of low frequency vibration) and the high fidelity, more versatile electromagnetic transducer (for low amplitude delivery of higher frequency vibration) is thereby achieved to best advantage.

Regardless of transducer chosen, noninvasive low frequency treatment vibration, low frequency treatment ultrasound, and high frequency imaging are utilized simultaneously and non-destructively in concert to provide an optimized agitative therapy system for low blood perfusion as a synergistic adjunct to systemically delivered drug therapy, to improve localized drug effectiveness.

As the cost of incorporation of a high frequency ultrasonic phased array transducer to enable ultrasonic imaging to a variant contact head 12 may be prohibitive in some medical centers, a more cost effective LFUS plus low frequency vibration treatment system enabling LFUS treatment concurrently with the transmission of low frequency vibration therapy (ie. a "dual therapy"), without ultrasonographic imaging capabilities is provided. This LFUS plus low frequency vibration treatment system comprises a variant "LFUS treatment" contact head 12 (not shown), wherein a semi spherical silicone dome attaches and substantially encapsulates a distal, active end of a commercially known low frequency ultrasound transducer which is operational at 27 kHz. Other variant low frequency ultrasound transducer's operational at a variety of low frequency ultrasonic frequencies may optionally be utilized, and a range within 20 - 100 kHz is provided. A flat, rectangular slit is centered at the semi spherical silicone dome's otherwise curved active contact surface to provide for a minimal protrusion of the distal, active surface of the low frequency ultrasound transducer's distal, active end. This arrangement enables stable contact of both the distal, active, flat surface of the low frequency ultrasound transducer and the distal, active treatment end of the silicone dome, such as to enable optimal seating in a selected rib space of the patient 20. Optionally, the distal, active, surface of the low frequency ultrasound transducer is curved in a

convex manner, such as to seat uniformly within a selected rib space of the patient 20, and thus eliminating the need of an accompanying silicone dome, which serves only to optimize transmission of the low frequency vibration aspect of the dual therapy. The non-active end of the variant LFUS treatment contact head 12 comprises a flat planar base, and extending from the base protrudes a housing to the electronic components of the low frequency ultrasound transducer, such that the distal, active end of the housing is centered at the base and the proximal, non-active end of the housing extends away from the base. A hollow connecting column is attached to the proximal, non-active end of the low frequency ultrasound transducer housing, which enables removable attachment to the shaft 16 of the vibration device 10. In this LFUS plus low frequency vibration treatment system the vibration shaft 16 once activated vibrates the low frequency ultrasound transducer's housing which in turn vibrates the attached distal, active surface of the low frequency ultrasound transducer and the attached silicone dome, which taken together, comprises the variant LFUS treatment contact head 12. The simultaneous delivery of low frequency ultrasonic treatment and low frequency vibration treatment via a single application surface is thus enabled. Alternatively, in a variant assembly, at least a pair of LFUS treatment contact head's 12 are removably, slide ably and lock ably mounted along the length of at least a pair of variant support arms 22 (not shown) of the bifurcated support connector 13, such as to enable a pair of "dual therapy" treatment sites across the sternum of the patient 20. In this variant assembly, the LFUS treatment contact head 12 is attached to a variant support arm 22 which is adapted to include a vertically transversing slit, wherein the slit is centrally located along the length of the variant support arm 22. A slid able and lock able variant sleeve 25 (also not shown) being of a rectangular box shape, is horizontally slide able and disposed in the horizontal direction along the variant support arm 22. The variant sleeve 25 contains a centrally placed hole defining a vertically located internal column, wherein the internal column attaches the low frequency ultrasound transducer's housing. The internal column of the variant sleeve 25 vertically transverses through the central slit of the variant support arm 22, such that the low frequency ultrasound transducer's housing vertically transverses the slit of the variant support arm 22, and is thereby horizontally slide ably and lock ably enabled along the length of the slit of the variant support arm 22. The variant sleeve 25 further includes a locking knob, which tightens clockwise to lock the variant sleeve 25, and thereby the LFUS treatment contact head 12 in place along the variant support arm 22. An electronic cord of the low frequency ultrasound transducer protrudes through a hole in the proximal, non-active end of the low frequency ultrasound transducer's housing, projects away from the low frequency ultrasound transducer's housing, and then is removably secured to the exterior surface of the housing 14 of the vibration device 10. The proximal, non-active end of the electronic cord is attached to a control apparatus to enable an operator to control the function of the LFUS plus low frequency vibration treatment system. A selectable duty factor of between 1%- and 100%, -and selectable intensity level of between 0.5 W/cm 2 and 9 W/cm 2, is provided to the operator via the control apparatus. A temperature probe placed at the periphery of the active surface of the low frequency ultrasound transducer (ie. wherein the active surface interfaces with the skin of the patient 20) is optionally provided with a digital readout, such that the operator can adjust the duty factor and intensity levels when the temperature of the active surface of the low frequency ultrasound transducer rises to an unacceptable level to avoid burning of the skin of the patient 20. Alternatively, the variant LFUS treatment contact head 12 may be exchanged, with the application skin surface cooled down by a cool wash cloth or ice in-between variant LFUS treatment contact head 12 exchanges. Low frequency treatment vibration and low frequency treatment ultrasound (without high frequency imaging) are utilized nondestructively in concert to provide an optimized therapy system for low blood perfusion as an adjunct to systemically delivered drug therapy, and improved localized drug effectiveness.

It should be understood that the use of the fore mentioned electromagnetic transducer to provide low frequency ultrasonic therapy is optional to the use of the above stated low frequency ultrasonic piezoelectric transducer.

In the preferred embodiment, (which utilizes low frequency vibration solely in the sonic to infrasonic ranges), the vibration device 10 is secured to the patient 20 with the clamp 100. Referring now to Figure 7, a perspective view of- a variation of the clamp 100, namely "clamp 101" is shown. The clamp 101 is used to attach the vibration device 10 to the chest wall for cardiac applications or for any body part. The clamp 101 is made of steel, and may be optionally aluminum or other material, which provides a stable platform. The clamp 101 optionally comes with a rectangular or oval board 104, which can slide underneath a supine patient's back. A base 102 is placed on top of the board 104. A vertical bar 106 extends at substantially 90 degrees from the base 102. A moveable arm 108 extends horizontally from the vertical bar 106, and can be moved up and down the bar 106 to accommodate patients 20 of different sizes. The arm 108 may be locked in place to arm 106, with a locking knob 107, or other mechanism such as a clip or notch. The arm 108- in this variation is non-rotatable about the longitudinal axis of the vertical bar 106 to provide a more stable platform for vibration therapy. A weight 114 is placed on the arm 108 to add inertia to the clamp 101.

A vibrator sleeve 116, which articulates with and supports the vibration device 10 is slide-able along the horizontal arm 108. The sleeve 116 includes a locking knob 109, which tightens to lock the vibration device 10 in place along the arm 108. The vibrator device 10 is selectively lowered and raised with the engagement screw 110, which articulates with and vertically transverses the vibrator sleeve 116 via a vertical screw column (not shown). The engagement screw 110 comprises an upper end disposing a turning knob, and a lower end that attaches the proximal, non-active end of the housing 14 of the vibration device 10. A set screw 119 is optionally provided to abut against the engagement screw 110 thereby locking it in place during operation. A rotatable circular piece 118 in articulation with the lower end of the engagement screw 110 and disposed at the surface within the non-active end of the vibrator housing 14 is provided such that the vibrator housing 14 may remain stationary while the engagement screw 110 screws the vibrator 10 up or down. The exact dimensions of the components of the clamp are not critical, as the height of the vertical support of the vibrator device 10 and the horizontal distance of the vibrating device 10 along the horizontal support arm 108 is made adjustable.

The force of engagement of the vibrator device 10 is optionally evaluated by a strain gauge force meter (not shown) or in a variation a weight scale (not shown). Optionally, a pivoting, rotating and locking universal joint (not shown), located at the juncture between the non-active end of the vibrator housing 14 and the lower end of the engagement screw 110, allows for the adjustment of the correct angulation and orientation of the vibration device 10 relative to the engagement screw 110, to ensure a perpendicular contact between the attachment point of the contact head(s) 12 and the chest wall, where the patient 20 may not always rest perfectly supine or lying flat. Universal joint adjustments comprising angulations of less than or equal to 20 degrees (ie. from the axis of the engagement screw 110) are recommended to ensure structural stability of the clamp 100 engagement of the vibration device 10 to the selected body treatment surface of the patient 20.

An emergency quick release system comprising a mechanical lever (not shown) disposed to the vibrator sleeve's 116 underside is provided such that the screw column which is internalized within the vibrator sleeve 116, can be quickly disengaged by the mechanical lever from the engagement screw 110, thus (once quickly releasing the set screw 119) liberating the vibration device 10 from the patient 20. Alternatively, a quick unlocking and detachment means of the vertical arm 106 and the horizontal arm 108 (not shown) may be provided to allow an alternative means of quick release. An electrical shutoff switch or button (not shown) is provided in case of emergency.

Referring now to Figure 8, a belt 130 variation of attachment means to the chest wall of the patient 20 is shown in use on a patient wherein the patient is sitting upright in Fowler's position (emergency use of IV's, nasal prongs and monitoring equipment is not shown). The belt 130 is comprised of semi-flexible poly-carbonate plastic, selectable in various curves to accommodate the chest of varying sized patient's 20. The polycarbonate material may optionally be transparent. Alternatively, the belt 130 is comprised of a variant flexible resilient material, which is highly resistant to longitudinal strain (such as reinforced leather, nylon or vinyl). The belt 130 is adapted to overly a substantially flat central panel 132, which is made of durable, lightweight aircraft aluminum (however any commercially available, substantially rigid and non-deform able material such as stainless steel or reinforced poly carbonate plastic may serve as an alternate). The central panel 132 is located to match an area on the patient's chest over the sternum. The central panel 132 is provided in various sizes to accommodate different patients 20, and will optimally cover the 2nd to 6th intercostal spaces of the patient 20. The distal, active end of the vibrator housing 14 of the vibration device 10 is attached and stabilized through a slit 133 within the central panel 132, having sides defined by a series of holes with semicircular edges, such that the vibrating attachment surfaces of the contact heads 12 of the vibration device 10 make contact with the target sites on the patient 20. The slit 133 to the central panel 132 has beveled edges (not shown) which taper inwards towards the patient 20 to match the beveled surface of the conical head of the vibrator housing 14 of the distal, active end of the vibration device 10. The central panel 132, by means of the operator selecting the appropriate location in the slit 133, will allow for variable placement of the vibrator housing 14 of the vibration device 10 and contact heads 12 to differing intercostal spaces according to the optimal placement established by the operator (according to the methods described earlier). The belt 130 covers the central panel 132 and partially encircles the patient's 20 torso such that the ends of the belt 130 extend up to and not beyond the front side of the mid-axial line of the patient 20 (i.e. up to and not beyond the anterior half of the patient's 20 Anterior-Posterior torso diameter measurable from the anterior most aspect of the chest wall). In the flexible belt 130 variation, the belt 130 is longer and is adapted to substantially encircle the patient's 20 torso. The central panel 132 further includes a securing means comprising slide able and insert able bolts (not shown) adapted to snap into corresponding slots (not shown) located at the distal, active end of the vibrator housing 14 and thereby be locked in place. The belt 130 further comprises a matching (but slightly larger) belt slit 135 to the slit 133 in the central panel 132 to further cradle the distal active end of the vibrator housing 14 of the vibration device 10, such that the proximal, non active end of the vibrator housing 14 of the vibration device 10 projects away from the patient 20. The securement means of the belt 130 to the patient's backside is enabled through utilization of a single bungee cord (not shown), which is selectable in varying lengths and diameters. The provided bungee cords have ends comprising metal hooks, which are made securable to reinforced holes placed near the ends of the belt 130. Optionally, any highly elastic material which allows for an appropriate degree of strain and recoil under load is acceptable, in order to allow for expansion of the patient's 20 chest during inspiration while still maintaining adequate tension to the belt 130 and thereby maintaining adequate

engagement force (i.e. 5-100N) to the central panel 132 (and thereby the contact heads 12) to enable the application of the vibration device 10 regardless of phase of respiration of the patient 20. Fine tuning of the engagement force to the chest wall of the patient 20 is provided to the operator by an inflatable bladder (not shown) which is removably placed (while deflated) to the underside of the securement bungee cord, to the hollow between the shoulder blades of the patient 20 once the bungee cord securement is secured in place. The operator incrementally inflates (or deflates) the inflatable bladder until the desired engagement force of the vibration device 10 to the patient's 20 chest wall is achieved (ie. 5 - 20N in expiration, and less than or equal to 100N in inspiration). Suppliers of bungee shock cords, which are readily adaptable to the present invention, include Reef Scuba Accessories, Inc.; American Home and Habitat Inc.; and VER SALES, Inc.

A force meter (not shown) is also optionally provided to determine and monitor engagement force (measurable at the tip of the shaft 16 of the vibration device 10), of the contact head 12 or heads 12 against the chest wall of the patient 20. The maximum engagement force tolerable to the patient 20 is recommended (eg. approximately 5N - 10N in expiration and up to 100 N in inspiration), so long as the vibration device 10 does not dampen its oscillations from too great an engagement force, and the patient 20 can breathe freely, and ideally feel at least "moderately" comfortable. The belt 130 once secured with adequate tension, will provide appropriate engagement force to the central panel 132, which in turn supplies appropriate engagement force to the vibration device 10, and contact heads 12 (not shown in Figure 8) to enable the application of vibration therapy to the chest wall of the patient 20. The belt 130 design is advantageous as a nauseous patient 20 may sit up or roll over.

Variant attachment, tightening and securement means of the belt 130 to the patient's 20 backside is obtained by a resilient, substantially inelastic pair of Velcro™ straps (not shown), but may as a further variant comprise a pair of like securement straps with holes connected by a tang (not shown), or as a further option a pair of securement straps connected by a tight enable friction buckle (not shown). In this variant securement system, the same bladder (which has a greater length than the securement strap's width) is removably centered to the underside of the secured inelastic straps, once the straps are fastened (again placement of the bladder is to the hollow of the patient's 20 back between the shoulder blades). In addition to the provision of a control means for engagement force, the bladder (which is made of a semi compliant material) will buckle slightly at the securement site while under load hence providing a degree of compliance to the otherwise substantially non yielding variant securement means which (unlike the preferred bungee cord rubber securement means) is highly resistant to longitudinal strain, thereby enabling the patient's 20 chest to expand and relax with respiration. The advantage to Velcro™ straps variant securement system, while less compliant and thus offering less comfort to the patient 20 during respiration, is that it provides for the most stable platform to the central panel 132 for vibration device 10 engagement to the chest wall of the patient 20.

Optionally to the preferred bladder system, once fastened (regardless of securement means chosen), engagement force to the chest wall of the patient 20 may be fine tuned by the placement of a relatively small, stiff pillow (not shown), selectable in varying sizes and similarly adapted to be wedged in between the back side of the patient 20 (i.e. to the hollow of the back in between the shoulder blades) and the above-stated overlying chosen securement means. This alternative pillow adaptation also provides for a degree of compliance to the otherwise substantially non-compliant Velcro™ strap securement system, to allow for a degree of necessary expansion and relaxation of the chest of the patient 20, while still maintaining adequate tension to the belt 130 (and thereby

engagement force to the central panel 132) to enable the application of the vibration device 10 regardless of -the phase of respiration of the patient 20.

In yet a further variation of securement, a rigid, flat, supportive platform (not shown) is placed to the back of the patient 20, wherein the platform is sized to slightly protrude past the lateral margins of the patient's 20 torso, such that the belt 130 is secured to the supportive platform by the above-stated preferred bungee cord or variant resilient Velcro™ straps. The supportive platform once secured, provides appropriate tension to the belt 130, and thereby appropriate engagement force to the central panel 132 (i.e. in the anterior-posterior direction) while allowing for lateral expansion and relaxation of the chest of the patient 20 during respiration. -Again, the above-stated bladder system located to the hollow of the patient's 20 backside, is used in this variation of the belt 130 system for fine tuning of the resultant engagement force.

Other variations such as a halter, strap, sling or vest (i.e. for sitting up or ambulation), may be adapted to the present invention by those skilled in the art of vibration garment manufacture, to enable support for the relatively high amplitude vibration means applied to the anterior chest -wall of the patient 20 while the patient 20 is in an upright position. The present invention provides a set of removable, and length adjustable shoulder straps (not shown) which connect with the belt 130 via reinforced alligator clips, such as to provide vertical support to the belt 130 engagement when the patient 20 is in the upright position. Alternatively, any other commercially available or adaptable means of shoulder strap attachment is acceptable. The garment variations allow fixation of the vibration device 10 to the target site upon anterior region of the chest wall of the patient 20, which substantially overlies -the mediasteinal cavity of the patient 20, while allowing the patient to move or even ambulate during therapy.

It should be understood that the above described belt 130 variation of attachment means can be utilized for any body part, and not just to provide engagement to the thorax of the patient 20.

Mobile, Noninvasive Emergency Response System for Paramedic Use:

For first line treatment by paramedics in an ambulance or before transportation, a self-contained, emergency, mobile, non-invasive response system for the treatment of acute, thrombotic vascular occlusions, including a selection of drugs, drug delivery supplies and a vibration device 10 is provided. The preferred treatment is for acute coronary thromboses, yielding a diagnosis of an Acute ST elevation Myocardial Infarction.

The emergency response system includes:

a) Vibration device 10 (1/18 hp, 1-200 Hz, 0.1 -10 mm, sine/square wave),
b) Portable, compartmentalized storage carrying case,
c) Drugs,
d) Drug delivery supplies,
e) Portable high powered battery and DC to AC adapter,
f) Bifurcated Connector 13, adapted to provide a pair of adjustable attachment interfaces,
g) Variant bifurcated Connector 13, adapted to provide a plurality of adjustable attachment interfaces,

h) Variant non bifurcated Connector, adapted to provide one attachment interface, and
i) Set of removable contact heads 12 with a selection of sizes (2 x 2 cm, 3 x 3 cm, 4 x 4 cm, 5 x 5 cm).

Optional provisions for the emergency response system includes:

a) Clamp 100 (engagement means),
b) Variant clamp 101 (engagement means),
c) Belt 130 system (engagement means),
d) Variant ultrasonographic imaging contact head 12, and portable untrasonic imaging device,
e) Variant LFUS treatment contact head 12 with bifurcated connector 13 with variant support arm 22 assembly,
f) Variant ultrasonographic imaging and LFUS treatment contact head 12, and portable ultrasonic imaging device,
g) Variant contact head 12 with semi malleable attachment interface,
h) Cardiac phase dependent time and frequency varying vibration delivery system comprising; Variant cardiac phase controlled vibration device 10 ("variant 1"), ECG monitoring system 36, Processor 34, Display monitor 52, Controller 50, and External accelerometer 39,
i) Variant research vibration device 10 ("variant 2"),
j) Variant light weight vibration device 10 ("variant 3"),
k) Variant heavy duty vibration device 10 ("variant 4"),
l) Larger, portable, compartmentalized storage carrying case, and
m) Set of helmet attachment means comprising helmets of various sizes.

The preferred vibration device 10 for the emergency response system provides a selectable sinusoidal and square wave form, with a selectable frequency range of 1 - 200 Hz, and a maximum displacement amplitude of 10 mm, with a power output of 1/18 hp. The vibration device 10 runs on AC power via a power cord, or alternatively runs on portable battery power via a DC to AC adapter and a high powered DC portable battery source. A research variant vibration device's 10 (ie. "variant 2") with selectable wave forms such as sinusoidal, square and exponential waves, and adapted to emit lower amplitude, higher frequencies such as in the 200 to 1000 Hz range is optionally provided. Also, a variant light weight vibration device 10 (i.e. "variant 3") with a power output of 1/30 hp, and a variant heavy duty vibration device 10 (ie. "variant 4") with a power output of 1/12 hp, is optionally provided.

The emergency response system comprises a self contained system, with a module and portable storage carrying case (not shown) which houses the materials comprising the treatment system (as above). A variant larger portable storage compartment (not shown) is adapted to additionally house optional components (as above).

The emergency response system enables systemic drug delivery, via intravenous, intra arterial, subcutaneous, oral, topical and nasal drug administration means. Drugs within the emergency response treatment system include: thrombolytic agents (e.g. ACTIVASE™ (Alteplase), TNKase™ (Tenecteplase), RETAVASE™ (Reteplase), Abbokinase™ (Urokinase), Kabikinase™ (Streptokinase with water), Streptase™ (Streptokinase with 0.9% NcCl solution), Lanoteplase); GP

2b 3a platelet inhibitors (e.g. ReoPro™ (Abciximab), AGGRASTAT™ (Tirofiban hydrochloride), Integrelin™ (Eptifibatide)); calcium channel blockers (e.g. ISOPTIN™ SR (Verapamil HCl), ADALAT XL™ (Nifedipine), Cardizem™ (Diltiazem), NORVASC™ (Amlodipine besylate); Nitrates (Nitroglycerine (spray, pill or patch), isosorbide dinitrates (Isordil™ and Sorbitrate™), Nipride™ (Nitroprusside); Oral anti-platelets (e.g. Acetylsalicylic Acid (Aspirin), Plavix™ (Clopidogrel), TICLID™ (Ticlopidine hydrochloride); Anti-coagulants such as heparin, and other blood thinning and coronary vasodilatory medication.

Non-pharmacological agents such as echo contrast agents (ie. micro bubble solutions which lower the cavitational threshold of a medium) are optionally included to enhance the agitative internal effects of externally delivered vibration therapy. Optional cavitating micro bubble solutions within the emergency response system include: EchoGen™ (Dodecafluoropentane emulsion), Albunex™ (5% human albumin), LEVOVIST™ (Galactose Palmitic Acid ultrasound contrast agent), Air containing albumin microcapsules (Quantison™ and Myomap™), SonoVue™ (Sulfurhexafluoride) and Perfluorocarbon containing microbubbles (Perfluorocarbon exposed sonicated dextrose albumin PESDA).

Drug delivery supplies within the emergency response system include: IV tubing, IV start kits, sterile IV introduction needles, tape, IV pole, 0.9 NaCl IV solution, Dextrose IV solution, Code 8 IV solution, Heparinized IV solution, IV pressure bag with pressure gauge and pressure bulb, sterile intra arterial introduction needles, guidewires, sheaths with dilators, scalpel blades, one way stopcocks, three way stop cocks, sterile drapes, sterile gowns, sterile gloves, sterile skin preparation solution, needles adapted to subcutaneous drug delivery, alcohol swabs, paper cups, straws, sublingual sprays, aerosol sprays, oxygen tank, ambubag, oxygen tubing, oxygen mask, and nasal prongs.

Options to the emergency response system include an engagement means (ie. Clamp 100 or 101, or belt 130 system) so an operator need not hold the vibration device 10 by hand throughout the course of therapy. A retractable IV stand (not shown) is optionally incorporated within and extending from the vertical arm 106 of the clamping device 100.

A variant ultrasonographic imaging contact head 12 specially adapted to provide ultrasonic imaging (with an ultrasonic imaging device) is also optionally provided so an operator can establish a viable sonic treatment window and target the culprit vascular region with low frequency treatment vibration with optimal efficiency. This variant ultrasonographic imaging contact head 12 is readily adaptable for use in all variations of vibration devices 10, including the variant research vibration device 10 (i.e. "variant 2").

A variant ultrasonographic imaging and LFUS treatment contact head 12 is also optionally provided to enable ultrasonic imaging, low frequency therapeutic vibration and low frequency therapeutic ultrasound (as a second therapeutic wave form). For cost effectiveness, a variant LFUS treatment contact head 12 enabling emissions of low frequency therapeutic ultrasound and transmission of low frequency vibration (i.e. without the use of a relatively expensive phased array imaging transducer) is also optionally provided.

A cardiac phase dependent time and frequency varying vibration treatment system is optionally included within the emergency response system for treatment of Acute Myocardial Infarction. Phase

modulated vibration allows the selection of varying frequency of vibration according to cardiac phase. It is advantageous to vibrate the myocardium at 50 Hz during ventricular diastole (approximating the diastolic resonance frequency of the myocardium) and to vibrate the myocardium at 100 Hz during ventricular systole (thereby matching the systolic resonance frequency of the myocardium which is stiffer in systole). Higher frequencies at same displacement amplitude are generally known to improve blood clot disruption and induce cavitation and the acoustic streaming, thus taking advantage of the myocardium's higher vibration resonance frequency is during the systolic period is advantageous. A cardiac phase "mode" selection is also provided in the above system, wherein "mode" defines the timing of emission of vibration therapy. The selection of vibration mode enables vibration specifically to the diastolic phase of the cardiac cycle, which is useful in cases of acute myocardial infarction which have deteriorated to cardiogenic shock as diastolic vibration, besides agitating and assisting dissolution of the culprit coronary thrombosis, is also known to provide a positive inotropic effect. For the sake of simplicity and ease of portability, the emergency response system of the present invention incorporates a variant abbreviated version of the aforementioned "advanced system", wherein an ECG 36, Processor 34, Controller 50, Display monitor 52, External Accelerometer 39, and the variant cardiac phase controlled vibration device 10 ("variant 1"), is all that is required to enable cardiac phase dependent time and frequency varying vibration. The deflection of the QRS complex from the ECG 36 monitoring system is interpreted by the processor 34 and is therein defined as the onset of "ventricular systole", and a rate related timing delay determined by the processor 34 following the QRS defines the onset of "ventricular diastole". The processor 34 is thereby enabled to respond to operator inputted cardiac phase modulated vibration algorithms and therein provide output commands to the variant cardiac phase controlled vibration device 10 ("variant 1"), to enable the delivery of cardiac phase dependent time and frequency varying vibration treatment. The operator upon viewing the ECG 36 and accelerometer 39 output on the display monitor 52 can adjust the diastolic timing of vibration via the controller 50, which in this case (as per the "advanced method") comprises an electronic touch screen. Ideally diastolic vibration should commence from the terminal end of the T wave of the QRS complex and then discontinue upon the onset of the deflection of the QRS complex as visualized by the provided ECG 36 wave form. The use of this variant abbreviated version of the aforementioned "advanced system" is of significant importance when a patient 20 is suffering from an acute coronary thrombotic vascular occlusion wherein the patient 20 has deteriorated to a state of cardiogenic shock.

A tutored paramedic or physician selects at least one drug based upon patient 20 bleeding risks, systemically administers the drug, and then transcutaneously vibrates the patient's 20 -body surface overlying the general area of a vascular occlusion at a low frequency, preferably 1 - 200 Hz, (selectively 40-120 Hz cardiac applications), or at any frequency with in the 1 - 1000 Hz range according to the preferred method. Generally, the default frequency of 50 Hz is preferred, as 50 Hz sinusoidal vibration can be delivered at a relatively high displacement amplitude, has excellent penetration characteristics through the chest wall and other body surfaces, falls within the resonance frequency of the heart, and is a well established frequency known to produce vascular dilation, and cavitation and acoustic streaming for encouraged clot disruption and increased drug permeation. Generally the maximum tolerable and judge safe displacement amplitude should be utilized in cases of acute myocardial infarction or acute vascular occlusions to the pulmonary vasculature or the peripheral vasculature. A gentle 2 mm displacement amplitude is recommended for the treatment of ischemic stroke via the helmet attachment means, however higher treatment amplitudes may be considered according to a risk / benefit weighted decision (ie. risk of cerebral hemorrhage vs. benefit

of accelerated reperfusion) made by an attending physician. The vibration treatment commences once systemic drug therapy is established, and continues until clinical signs of reperfusion are evident, or until an invasive corrective procedure such as emergency PCI (ie. in heart attack cases) is established.

Emergency Portable System for Outpatient Use:

For first line treatment of a variant patient 20 herein referred to as "out" patient 20, before the arrival of paramedics, a self-contained, emergency, portable system for the treatment of an acute coronary thrombosis at early stage is provided, including a vibration device 10 (or variant) and at least one anti anginal medication. The emergency, portable system is designed to be utilized by the out-patient 20 as an emergency tool for self treatment.

The present invention provides an outpatient emergency portable treatment kit comprising a black leather portable carrying case which is adapted to house and port: the vibration device 10, a bifurcated connector 13 (adapted to provide at least a pair of adjustable attachment interfaces for a pair of contact heads 12), a set of contact heads 12 (pre fitted to the patient 20), a set of DC batteries, an AC power cord, and at least one anti-anginal medication (such as Nitro spray, Nitro pill, Nitro patch, Isordil™, and/ or Sorbitate™), and preferably at least one oral antiplatelet medication (such as Acetysalicylic Acid, Plavix™, and/ or TICLID). A larger brown leather carrying case is adapted to additionally house and port a small oxygen canister and nasal prongs to enable the administration of concentrated oxygen to the outpatient 20, as well as the optional inclusion of the fore mentioned belt 130 engagement system (plus central panel 132), with inflatable bladder, bungee cord securement and, shoulder strap support. The use of the variant lightweight vibration device 10 ("variant 3") is optional, and may be preferable to some patients who are not themselves strong enough to hold the preferred vibration device 10 effectively.

Vibration therapy is, in this case, employed for acute states of coronary insufficiency resulting in angina pectoris refractory to nitroglycerine treatment in the out patient 20, wherein an acute coronary thrombosis (ie. "Heart Attack") cannot be ruled out. Every bout of "angina" that the out patient 20 in the community experiences might infact be an acute coronary event wherein a plaque has ruptured and a blood clot has formed. In these cases, the out patient 20 will try an anti-anginal medication such as nitro spray x 3 (ie. with each dose spread 5 minutes apart), and upon recognition of no relief of chest discomfort (which may be quite severe), the out patient 20 will proceed to dial "911" wherein the diagnosis of an acute coronary thrombosis leading to an acute MI cannot be ruled out until the outpatient receives a professional diagnosis. As described earlier, hyper acute early clot formation at early stage is extremely amenable to dissolution, hence a mechanically disruptive, agitative technique such as high amplitude chest wall vibration therapy in these instances, is an extremely effective and important emergency method. The out patient 20 will rest and preferably administer an oral antiplatelet medication (as above) as prescribed by a family physician or Cardiologist of the out patient 20. The out patient 20 should articulate the potential medical problem of a potential "heart attack" to bystanders such that the out patient 20 is not alone while waiting for the arrival of an ambulance and professional care (ie. in the case of cardiac arrest).

The preferred vibration device 10 or alternatively the variant light weight vibration device ("variant 3"), is placed to the anterior chest wall at the default level of the fourth intercostal space of the out patient 20. Alternatively, the variant cardiac phase controlled vibration device 10 ("variant 1"), equipped with an ECG monitoring system such as to enable the application of vibration restricted to

the diastolic phase of the cardiac cycle of the patient 20 is optionally provided, wherein it may be considered useful to provide a therapy which ensures a positive inotropic effect whereby the blood pressure and hemodynamic status of the patient 20 will be unknown until professional care arrives.

The vibration device 10 to chest wall interface is accomplished via the bifurcated connector 13 equipped with preferably a pair or optionally a plurality beyond a pair of pre fitted contact heads 12, wherein the contact heads 12 have been pre adjusted in location on the connector's 13 support arms 22 to optimally bridge the sternum and seat within the intercostal spaces of the outpatient for maximum chest wall penetrability as per the methods and apparatus previously described. The vibration amplitude is selected as the maximum tolerable to the patient, who should ideally be resting in either the supine position or seated comfortably upright in a chair. The optimal frequency is selected at 50 Hz continuous wave (ie. 100% duty factor), with a sinusoidal wave form, however optionally any frequency within the 40 - 120 Hz range (ie. to match the resonance frequency of the heart) and square waves may be selected according to the preferred method. Ideally a friend or bystander should engage the vibration device 10 against the out patient 20 by hand until profession care arrives. Alternatively, the portable belt 130 system with shoulder straps (as described earlier) is utilized to engage the vibration device 10 to the chest wall of the out patient 20, such that the out patient 20 need not exert any effort to hold the vibration device 10 in place. The out patient 20 will administer a dose of anti anginal medication such as nitro spray 0.4 mg SL (and optionally an oral anti platelet agent), and then proceed to administer adjunctive vibration therapy (as per the methods disclosed earlier) such as to provide a synergistic treatment system to assist localized drug effectiveness to the coronary vasculature.

It is significant that acute coronary thrombosis in the outpatient is one of, if not the greatest killer of North Americans today.

As will be apparent to those skilled in the art in the light of the foregoing disclosure, many alterations and modifications are possible in the practice of this invention without departing from the spirit or scope thereof. Accordingly, the scope of the invention is to be construed in accordance with the substance defined by the following claims.

I claim:

1. A non-invasive, transcutaneously applied low frequency vibration apparatus for the emergency treatment of an acute vascular obstruction in a patient, said vibration apparatus comprising an electrically powered vibrator adapted to vibrate at a frequency within the range of 1 - 1000 Hz, such as to enable an adjunctive system of externally applied vibration and a drug therapy towards remediation of said acute vascular obstruction.

2. The apparatus of Claim 1, wherein said vibrator is adapted to operate within a frequency range of 40 - 120 Hz, thereby matching the resonance frequency of the heart in coronary applications.

3. The apparatus of Claim 1, wherein said vibrator vibrates at a displacement amplitude within the range of 0.1 and 10 mm, such as to ensure penetration of said externally applied vibration.

4. The apparatus of Claim 1, wherein said vibrator is operable to emit at least one wave form, said wave from selected from the group comprising: a sinusoidal wave, a square wave, and an exponential wave.

5. The apparatus of Claim 1 further comprising a bifurcated connector disposed on a distal active end of said vibrator, said connector attaching at least a pair of contact heads thereby enabling at least a pair of contact interfaces for application of said externally applied vibration to said patient.

6. The apparatus of Claim 5, wherein said contact heads are adjustably located along a distal active end of said connector.

7. The apparatus of Claim 1, wherein a contact head of said vibrator, further comprises an ultrasonic imaging transducer, such as to enable ultrasonic imaging to an operator during application of said externally applied vibration.

8. The apparatus of Claim 1, wherein a contact head of said vibrator, further comprises a low frequency ultrasonic transducer, such as to enable the application of low frequency ultrasound concurrently with said externally applied vibration.

9. The apparatus of Claim 1 further comprising an engagement means to said vibrator, said engagement means selected from a clamp and a belt.

10. A non-invasive, mobile, emergency first line response system utilized for applying vibration to a patient experiencing an acute vascular obstruction, said response system comprising at least one electrically powered vibrator adapted to operate within the range of 1 - 1000 Hz , and a portable storage kit providing storage and portability for at least one member of the group comprising:

a) At least one said vibrator for transcutaneously agitating said vascular obstruction,

b) At least one drug to treat said vascular obstruction,

c) At least one drug delivery means to enable the delivery of a drug to treat said vascular obstruction,

d) A bifurcated connector attaching at least a pair of contact heads, thereby enabling at least a pair of contact interfaces for application of said vibration to said patient

e) A belt engagement apparatus to enable engagement of said vibrator to an external body surface of said patient,

f) A clamp engagement apparatus to enable engagement of said vibrator to an external body surface of said patient,

g) A contact head adapted to enable ultrasonic imaging to an operator during application of said vibration, such as to enable targeting of said acute vascular obstruction, and

h) A contact head adapted to emit a low frequency ultrasonic wave form, such as to enable the application of low frequency ultrasound during the application of said vibration.

11. An acute care, noninvasive emergency method of ameliorating an acute state of low blood perfusion employing a low frequency vibration apparatus, such as to provide an adjunctive system of externally applied vibration and a systemically delivered drug therapy for the localized improvement of said drug therapy towards remediation of said acute state of low blood perfusion; comprising the steps of:

a) Recognizing a symptom associated with said acute state of low blood perfusion such as to determine a diagnosis of said acute state of low blood perfusion,

b) Determining an underperfused body region of said patient,

c) Determining a culprit vascular region deemed responsible for said acute state of low blood perfusion to said underperfused body region,

d) Selecting and administering at least one drug for acting on said acute state of low blood perfusion in order to treat said acute state of low blood perfusion,

e) Locating at least one skin surface substantially overlying said culprit vascular region,

f) Engaging said low frequency vibration apparatus against said skin surface,

g) Selecting a characteristic of said vibration, said characteristic belonging to at least one member of the group comprising: a frequency, a displacement amplitude, and a wave form, and

h) Applying said vibration to said skin surface, by vibrating said skin surface at a low frequency within the range of 1 - 1000 Hz once the systemic delivery of at least one said drug has been established, and wherein said symptom has not dissipated;

thereby shortening the onset and enhancing the effectiveness of action of said systemically delivered drugs localized to said culprit vascular region.

12. The method of Claim 11 (c), wherein said culprit vascular region is selected from a member of the group comprising, the coronary vasculature, the pulmonary vasculature, the peripheral vasculature, and the cerebral vasculature.

13. The method of Claim 11 (d), wherein said drugs are selected and administered from at least one member from the group consisting of: a thrombolytic agent, a GP 2b 3a platelet inhibitor, an anticoagulant, an oral anti-platelet agent, a nitrate, a calcium channel blocker, a cavitating micro bubble solution, a placebo, an IV solution, concentrated oxygen and oxygen of ambient air.

14. The method of Claim 11(g), wherein said frequency is selected within the range of 40 - 120 Hz, such as to vibrate the heart according to its resonance frequency.

15. The method of Claim 11(g), wherein said displacement amplitude is selected at a value within the range of 0.1 and 10 mm.

16. The method of Claim 11(g), wherein said selected wave form is selected from a member of the group comprising: a sinusoidal wave form, a square wave form, and an exponential wave form.

17. The method of Claim 11 (h), wherein said displacement amplitude of said vibration is adjusted to maximum level, wherein said maximum level is the maximum amplitude judged tolerable and safe to a particular patient by an attending clinical practitioner.

18. The method of Claim 11 further comprising the step of selecting a connector adapted to transmit said vibration from said vibration apparatus to at least one skin surface overlying at least one intercostal space of the chest wall of said patient, wherein said connector is selected from the group comprising:

a) A connector adapted to transmit said vibration via a single contact head attachment point enabling attachment of a single contact head,

b) A connector adapted to transmit said vibration via a pair of contact head attachment points enabling attachment of a pair of contact heads, and

c) A connector adapted to transmit said vibration via a plurality greater than a pair of said contact head attachment points enabling attachment of a numerically equivalent plurality greater than a pair of contact heads;

prior to step 11 (f).

19. The method of Claim 18 (a), wherein said connector providing said single said contact head attachment point with a single said contact head attached, is selected, attached to a vibration source, and then oriented to said skin surface overlying said chest wall of said patient prior to step 11 (f), and then engaged to one solitary engagement site comprising the anatomic left 4th intercostal space, two finger breaths lateral the anatomic left sternal margin of said patient during step 11 (f).

20. The method of Claim 18 (b), wherein said connector providing said pair of said contact head attachment points with a pair of said contact heads attached, is selected, attached to a vibration source, and then oriented over a pair of said skin surfaces overlying said chest wall of said patient prior to step 11 (f), and then engaged to the left and right of the sternum at engagement sites comprising a selection of a member of the group consisting of: the anatomic left 4th and anatomic right 4th intercostal space, the anatomic left 3rd and anatomic right 4th intercostal space, and the anatomic left 4th and the anatomic right 5th intercostal space; during step 11 (f).

21. The method of Claim 18 (c), wherein said selected connector providing a plurality greater than a pair of said contact head attachment points with a full compliment of said contact heads attached, is selected, attached to a vibration source, and then oriented to said skin surfaces overlying said chest wall of said patient prior to step 11 (f), and then engaged to the left and right of the sternum along the 3rd, 4th, and 5th intercostal spaces of said patient, during step 11 (f).

22. The acute care method of Claim 11 further comprising the step of selecting a noninvasive imaging system to determine an optimal sonic treatment window to said culprit vascular region to target said culprit vascular region; said system comprising the use of an imaging contact head adapted with a phased array transducer to enable ultrasonographic imaging concurrently with the transmission of said 1 - 1000 Hz vibration via use of substantially one contact interface to said patient, said system comprising the steps of:

a) Placing said imaging contact head on a distal active end of said vibration apparatus and then placing said adapted imaging contact head to the general area overlying said culprit vascular region, and then displaying said ultrasonographic imaging output on a display monitor prior to step 11 (e),

b) Determining said skin surface of said patient's body having said optimal sonic treatment window to target said culprit vascular region supplying said acute state of low blood perfusion using said ultrasonographic imaging as in step 11 (e), while concurrently engaging said vibration apparatus as in step 11 (f), such that steps 11 (e) and 11 (f) are accomplished simultaneously, and

c) Maintaining a position of said imaging contact head on said skin surface of said optimal acoustic treatment window through continued visualization of said imaging output on said display monitor, concurrently with step 11 (h);

such that the said optimal sonic treatment window is established and maintained so as to maximize and ensure the penetration of said 1 - 1000 Hz vibration to said culprit vascular region supplying said acute state of low blood perfusion.

23. The method of Claim 22, wherein a target of step 22 (b) comprises a member of the group omprising: an imaged blood clot within said culprit vascular region, such as in cases of acute peripheral thrombotic occlusions; an imaged basal aspect of a myocardium which is substantially hypo kinetic, wherein said culprit vascular region is deemed most likely to reside by anatomical reference, such as in cases of acute coronary occlusions; and, the pulmonary artery such as in cases of acute pulmonary emboli and saddle emboli.

24. The method of Claim 11, further comprising the step of selecting and attaching at least one contact head adapted to emit a low frequency ultrasonic wave form within the range of 20 - 100 kHz prior to step 11 (f), selecting a characteristic of said low frequency ultrasonic wave form concurrently with step 11 (g), and then applying said low frequency ultrasonic wave form concurrently with said 1 - 1000 Hz vibration during step 11 (h), such as to provide a pair of oscillating wave forms in concert to said culprit vascular region.

25. The method of Claim 11 further comprising the step of using a cardiac phase dependent time varying vibration system, such as to enable the specific timing of said vibration according to the timing of the cardiac phase of said patient for coronary applications.

26. The method of Claim 25, wherein said specific timing of said vibration is restricted to the period of ventricular diastole of said patient, in cases of acute ST elevation myocardial infarction which is complicated by hemodynamic compromise.

27. The method of Claim 11 (f) wherein said engagement is by at least one hand of an operator.

28. The method of Claim 11, wherein said engagement of step 11 (f) is by a clamp apparatus adapted for bedside and stretcher use, said engagement of said clamp apparatus comprising the steps of:

a) Placing said patient substantially in the supine position,

b) Sliding a base of said clamp apparatus under the backside of the thorax of said patient,

c) Maneuvering and locking said vibration apparatus over a target area over the chest wall of said patient, wherein said clamp apparatus retains said vibration apparatus, and

d) Engaging said vibration apparatus against said target site via use of a vertically positioned screw mechanism, wherein said screw mechanism is retained by said clamp apparatus and whereby a lower end of said screw mechanism attaches said vibration apparatus, such that by screwing a top end of said screw mechanism said vibration apparatus is lowered to engage said target site, and an engagment force is controlably established by an operator via an adjustment of said top end of said screw mechanism.

29. The method of Claim 11, wherein said engagement of step 11 (f) is by a belt system adapted to encircle the thorax of said patient, said belt system engagement comprising the steps of:

a) Placing said belt system around the thorax of said patient, said belt system having a front side which attaches said vibration apparatus and a backside, such that said vibration apparatus is engaged to a target site on the chest wall of said patient, via said front side of said belt system,

b) Securing said backside of said belt system to the backside of said thorax of said patient, via a highly elastic material, said elastic material adapted to strain and recoil when placed under varying load,

c) Placing an inflatable bladder under said elastic securement material between the shoulder blades of said patient, and

d) Inflating said bladder until an optimal engagement force within the range of 5 N and 100 N is established between said vibration apparatus and said target site, wherein said engagement force does not exceed 100 N during inspiration of said patient.

30. A noninvasive, emergency, response system for treating a patient with an acute vascular obstruction with a low frequency vibration apparatus, such as to provide an adjunctive system of externally applied vibration and a systemically delivered drug therapy for the localized improvement of said drug therapy towards remediation of said acute vascular obstruction; comprising the steps of:

a) Recognizing a symptom associated with said acute vascular obstruction such as to determine a diagnosis of said acute vascular obstruction,

b) Determining an underperfused body region of said patient, whereby said underperfused body region of said patient is selected from a member of the group comprising: the heart, the lung, the brain and the periphery,

c) Determining a culprit vascular region responsible for said acute vascular obstruction to said underperfused body region,

d) Selecting and administering at least one drug for acting on said acute vascular obstruction in order to treat said acute vascular obstruction,

e) Locating at least one skin surface substantially overlying said culprit vascular region,

f) Engaging at least one contact interface comprising at least one contact head against at least one skin surface, wherein said contact head enables transmission of said externally applied vibration from said vibration apparatus,

g) Selecting a characteristic of said vibration, said characteristic belonging to at least one member of the group comprising: a frequency, a displacement amplitude, and a wave form, and

h) Applying said vibration to said skin surface, by vibrating said skin surface at a low frequency within the range of 1 - 1000 Hz once the systemic delivery of at least one said drug has been established, and wherein said symptom has not dissipated;

thereby shortening the onset and enhancing the effectiveness of action of said systemically delivered drugs localized to said culprit vascular region.

31. The method of Claim 30 wherein said noninvasive, emergency, response system is mobile, and implemented by at least one trained, mobile, medical professional; said mobile, noninvasive emergency response system further comprising the steps of: storing, porting and delivering said vibration apparatus and at least one drug to enable said drug therapy to said patient prior to step 30 (a), and then transporting said patient to a treatment facility concurrently with steps 30 (a) through 30 (h).

32. The method of Claim 30 and 31, wherein step 30 (d) comprises selection and administration of at least one said drug belonging to a member of the group comprising: Alteplase, Tenecteplase, Reteplase, Urokinase, Streptokinase, Lanoteplase, Abciximab, Tirofiban hydrochloride, Eptifibatide, Heparin, Acetylsalicylic Acid, Clopidogrel, and Ticlopidine hydrochloride.

33. The method of Claim 30 and 31, wherein step 30 (d) comprises selection and administration of at least one said drug belonging to a member of the group comprising: Nitroglycerine spray, Nitroglycerine pill, Nitroglycerine patch, Nitroprusside, Isordil™, Sorbitate™, Verapamil HCL, Nifedipine, Diltiazem, and Amlodipine besylate.

34 The noninvasive, emergency, response system of Claim 30, wherein said noninvasive, emergency response system is substantially self administered by said patient as a first line measure in the community for symptoms of chest discomfort relating to an acute coronary vascular obstruction, whereby said self administered, noninvasive, emergency, first line response system comprises the additional steps of:

a) Storing and porting said vibration apparatus and at least one said drug with said patient prior to step 30 (a),

b) Recognizing no relief of said chest discomfort by said patient after said selection and said administration of at least one said drug after step 30 (d), and

c) Calling for professional emergency assistance to assist said patient prior to the initiation of steps 30 (e) through 30 (h).

35. The self administered, noninvasive, emergency, response system of Claim 34, wherein at least one said selected drug of step 30 (d) comprises a vasodilator.

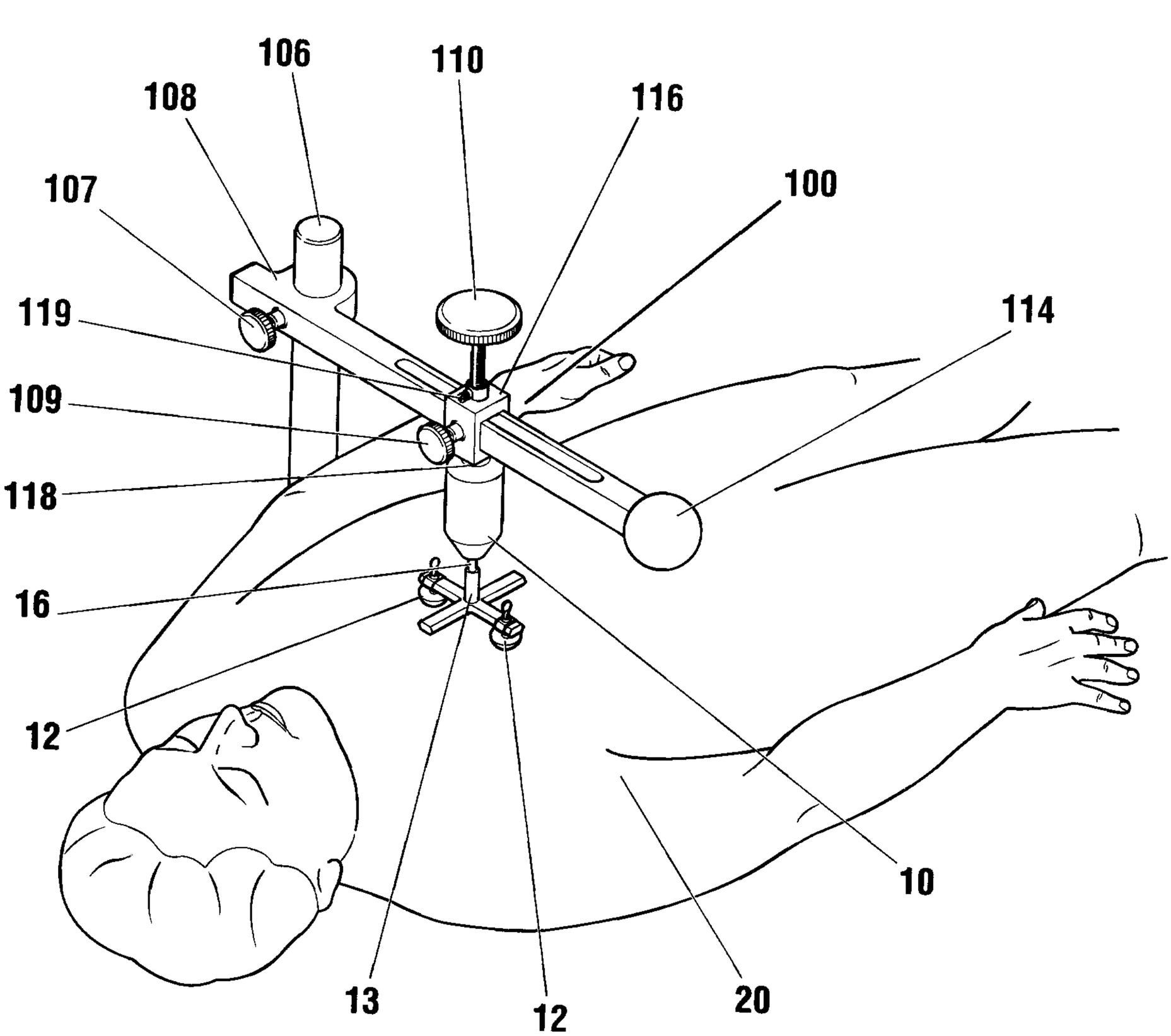


FIG. 1

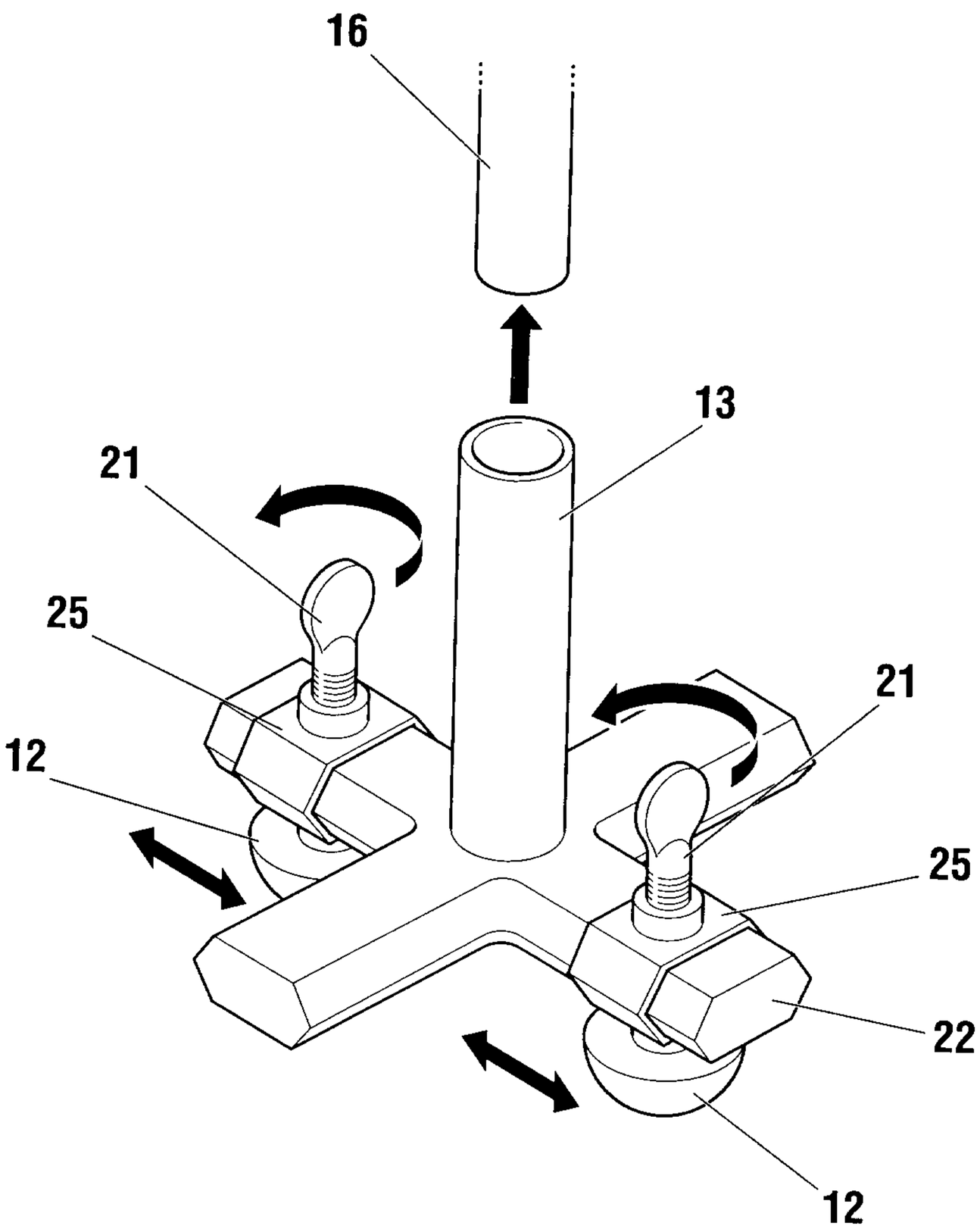


FIG. 2

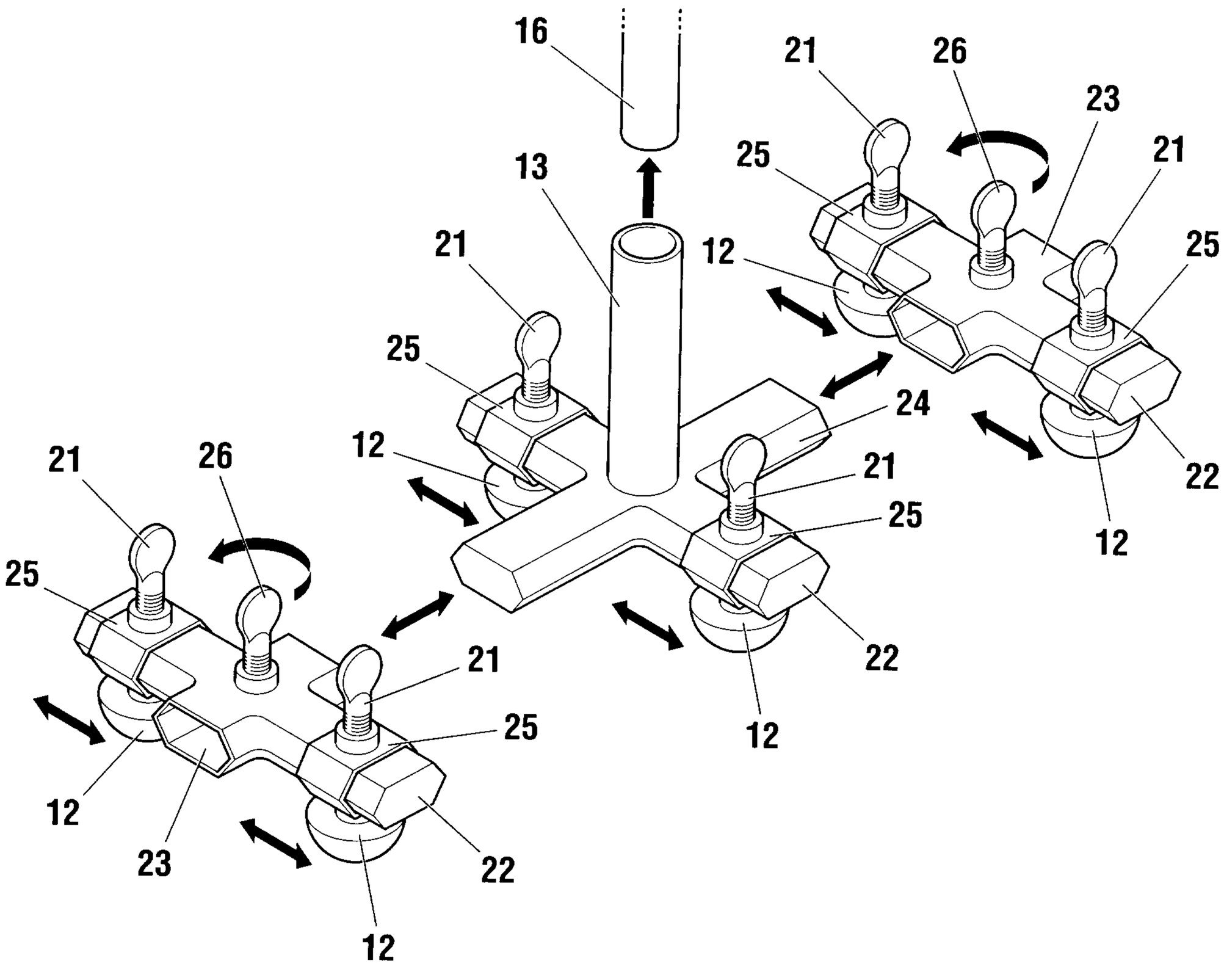


FIG. 3

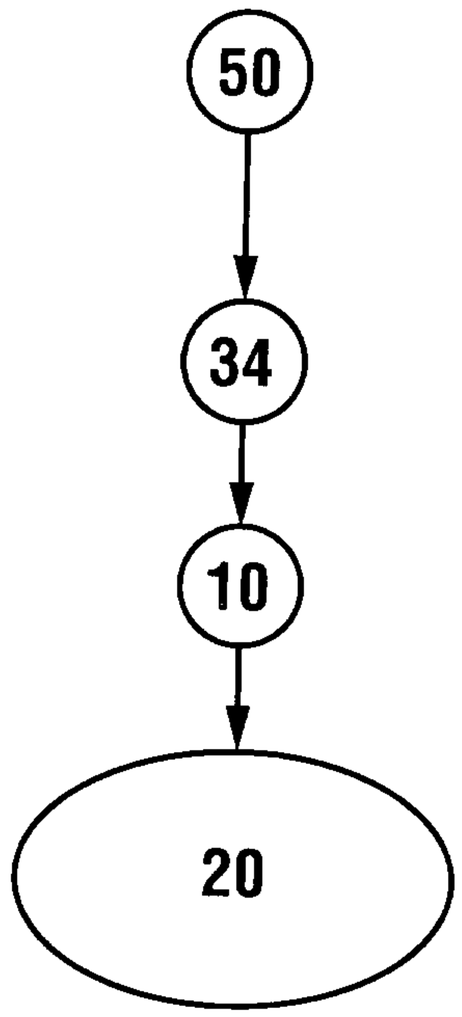


FIG. 4

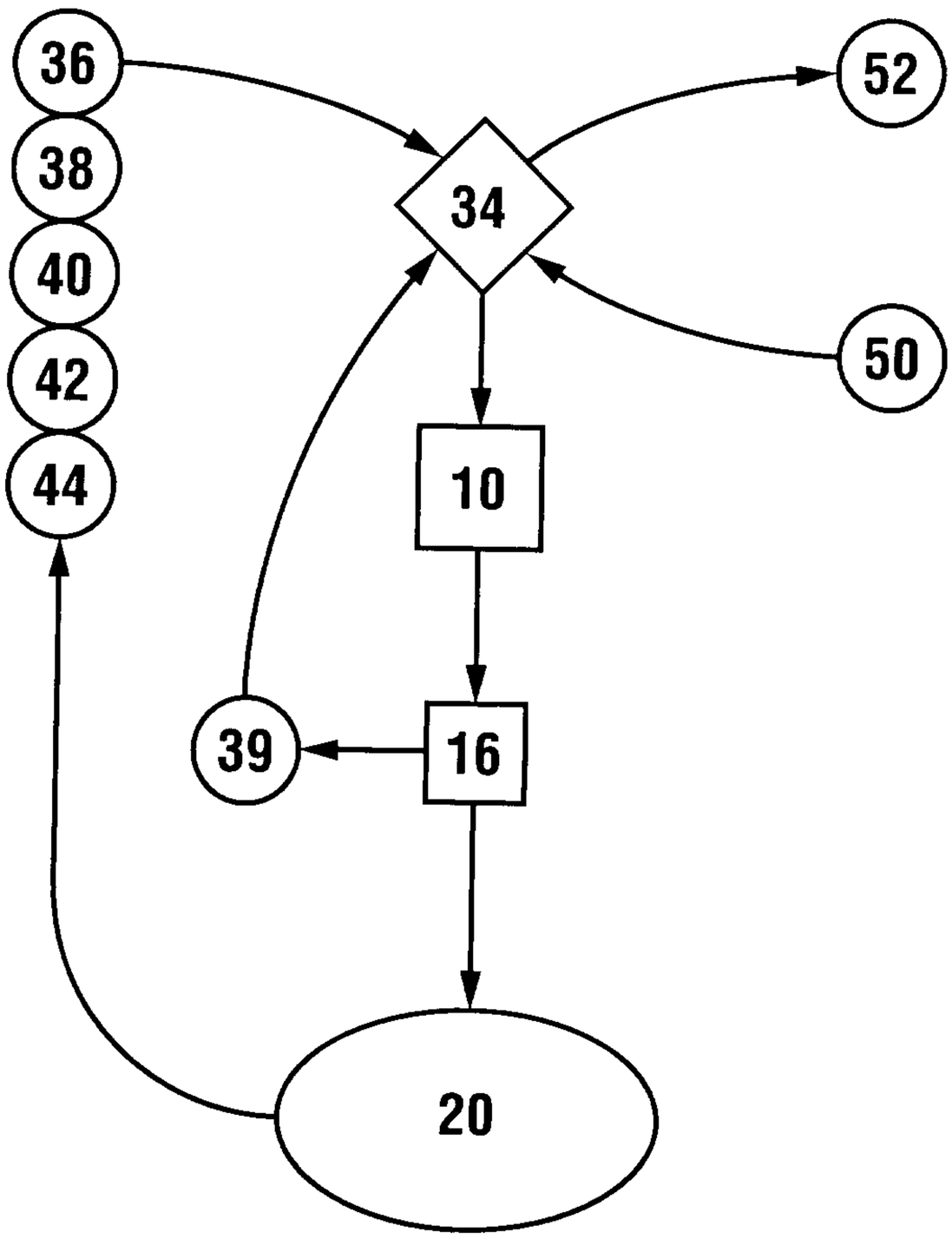


FIG. 5

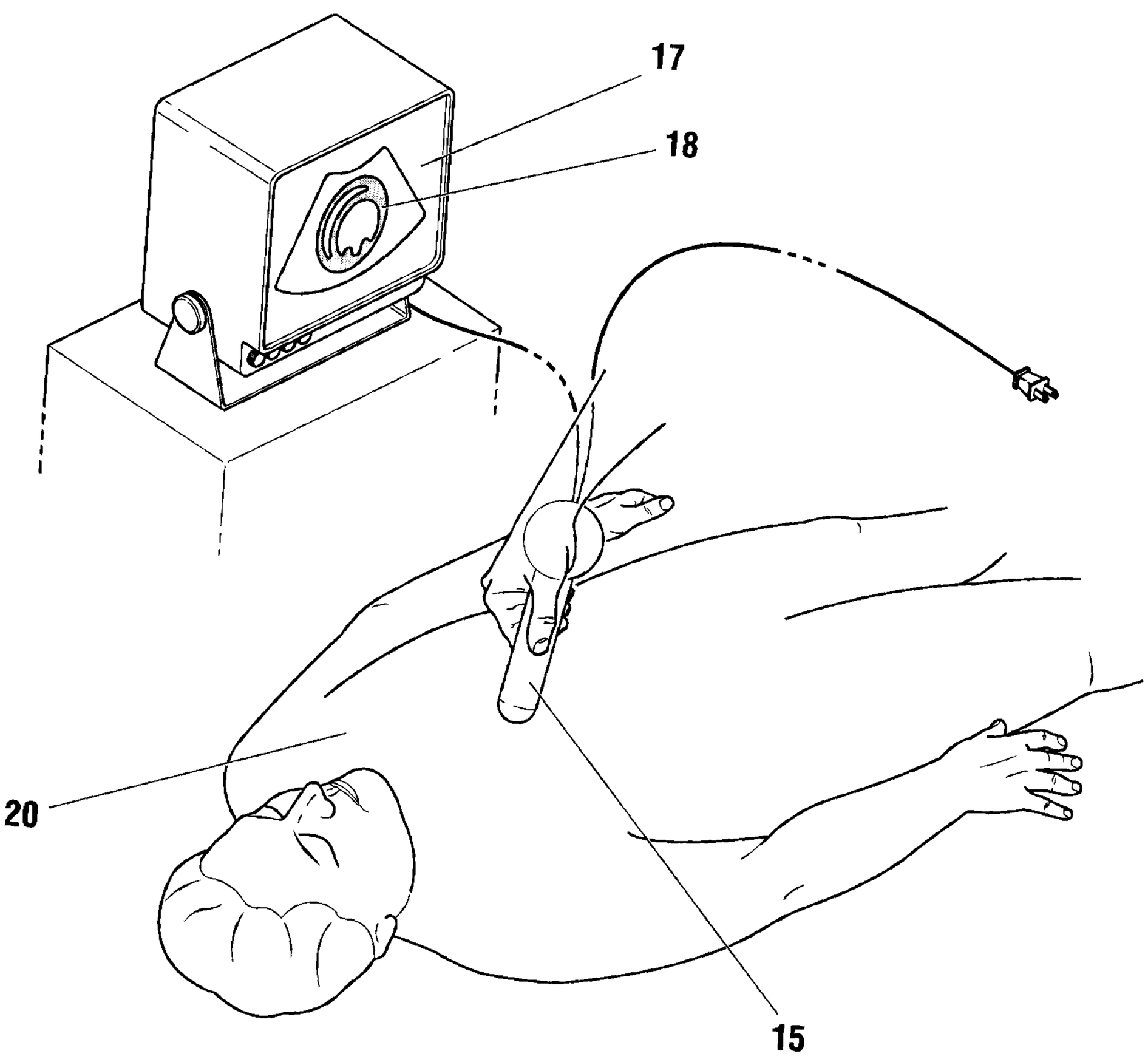


FIG. 6

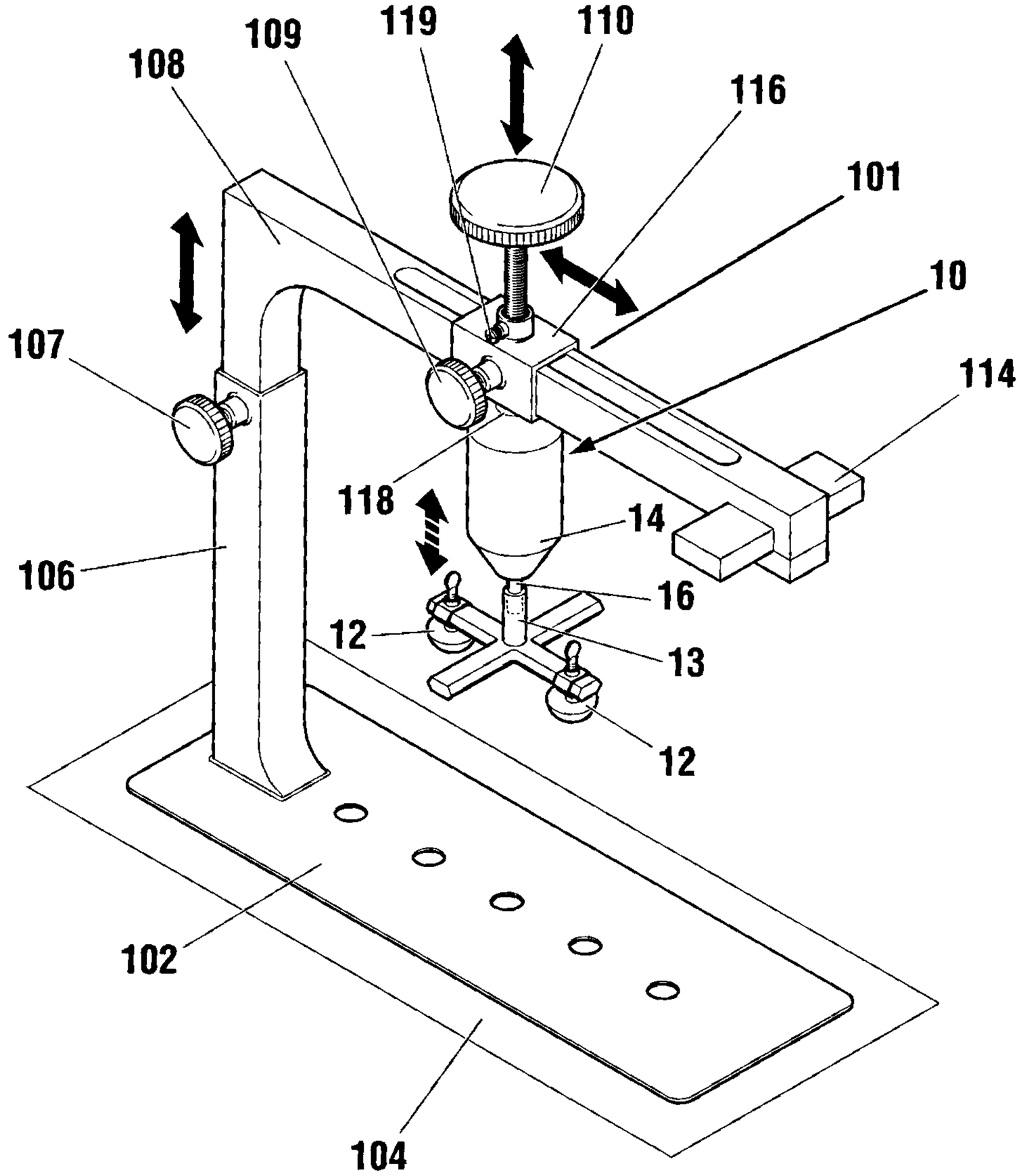


FIG. 7

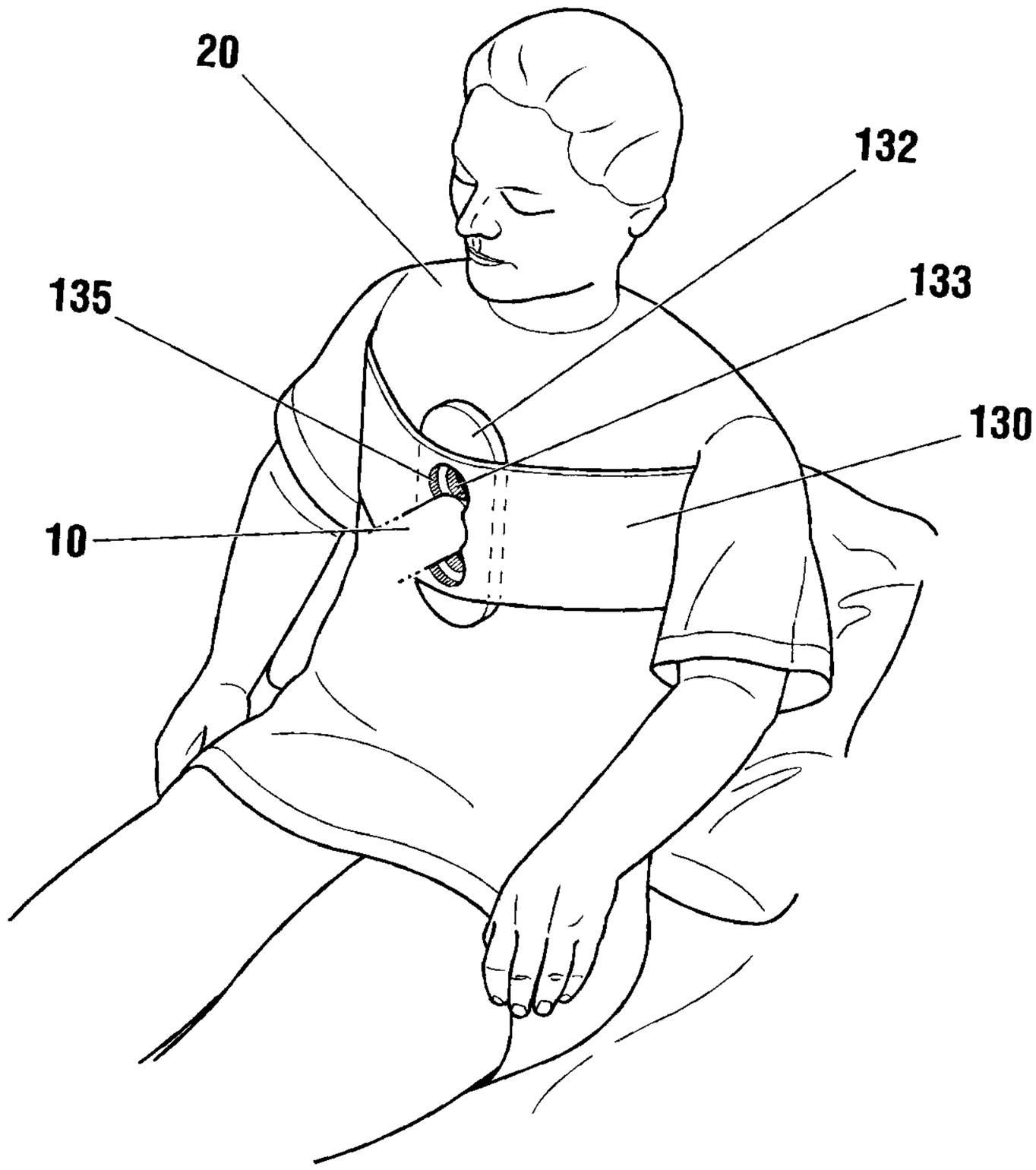
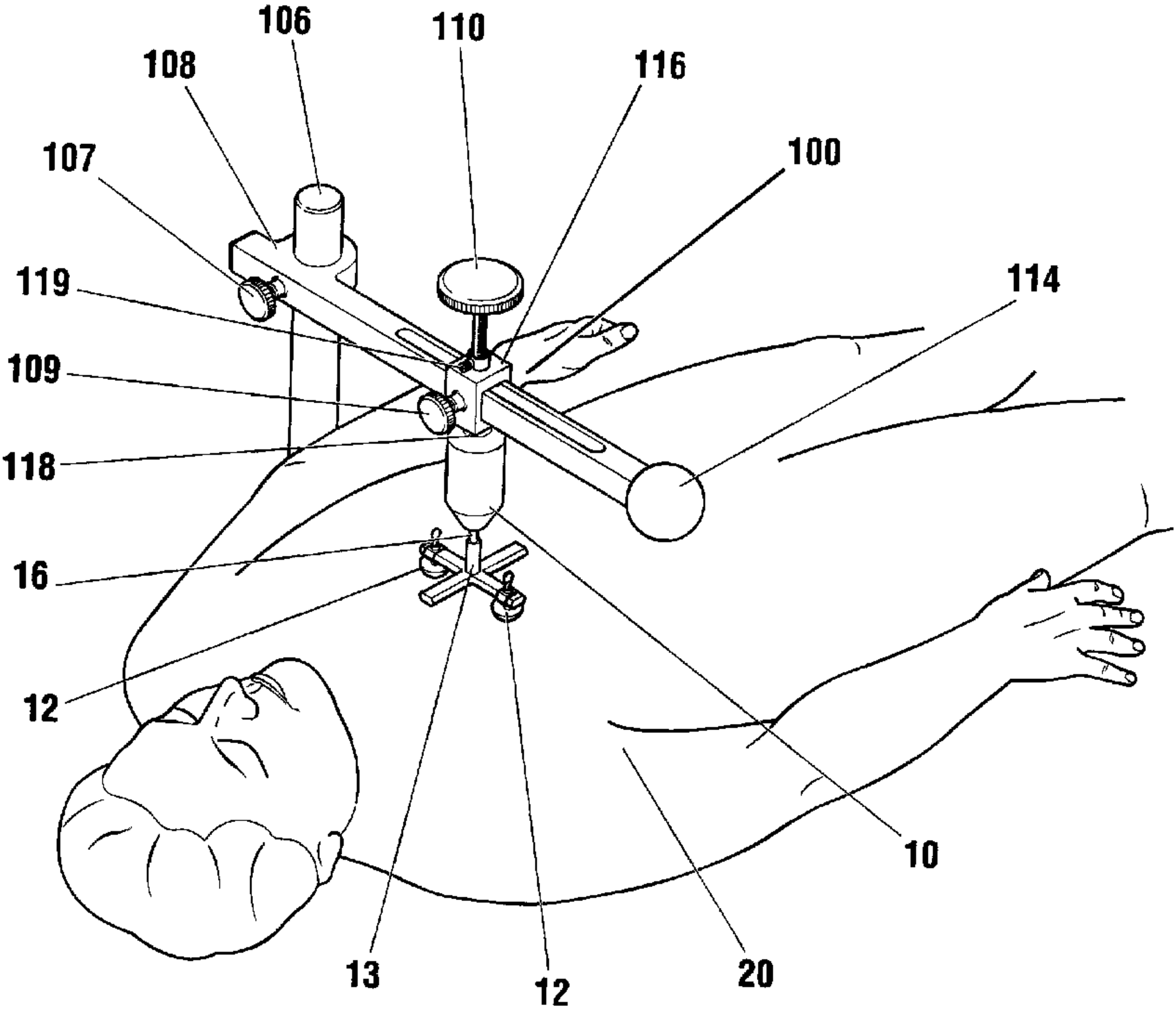


FIG. 8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