(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 April 2010 (29.04.2010)

PCT

(10) International Publication Number
WO 2010/047678 A1

(51) International Patent Classification:
A61B 8/00 (2006.01) *A61B 18/00* (2006.01)
A61B 8/02 (2006.01)

(21) International Application Number:
PCT/US2008/012110

(22) International Filing Date:
23 October 2008 (23.10.2008)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **BLACKTOE MEDICAL III, INC.** [US/US]; 2222 NW Lovejoy Street, Suite 512, Portland, OR 97210 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **SCHUTZ, Ronald, W.** [US/US]; 3011 NW Luray Circus, Portland, OR 97210 (US). **CORBETT, Scott, S.** [US/US]; 11720 SW 28th Place, Portland, OR 97219 (US). **BATES, Kenneth, N.** [US/US]; 15580 SW Burntwood Court, Beaverton, OR 97007 (US). **MCDONOUGH, William** [US/US]; 10994 NW Claire Court, Portland, OR 97229 (US). **KRAUSE, Albert, H., Jr.** [US/US]; 11111 SE 18th Street, Vancouver, WA 98664 (US).

(74) Agents: **LEGAARD, Brenna, K.** et al.; Chernoff Vilhauer McClung & Stenzel, LLP, 601 S.W. Second Avenue, Suite 1600, Portland, OR 97204 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) **Title**: A VERSATILE ULTRASOUND PROBE AND METHOD FOR ITS USE

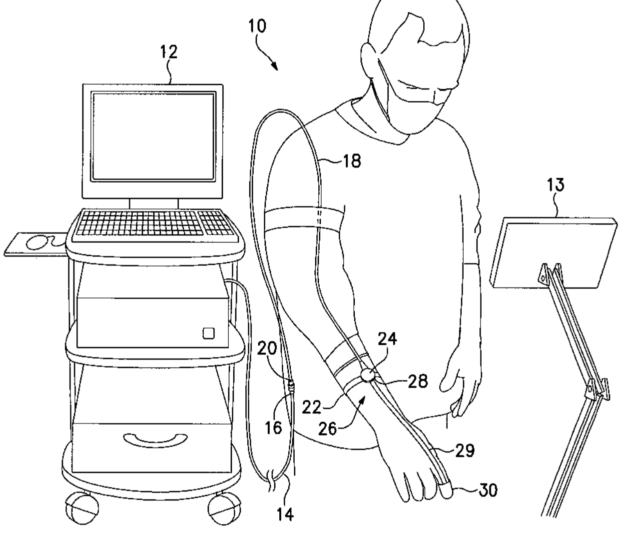

FIG.1

(57) Abstract: An ultrasound imaging assembly (10) having an ultrasound probe (30), adapted to be mounted on a finger, and a flexible multi-conductor cable (29), attached to the ultrasound probe. In addition, an arm-mounted unit is connected to the multi-conductor cable and includes a mechanical connector (22) to bind the arm-mounted unit to a user's forearm. The arm- mounted unit and the multi-conductor cable (29) may include respective connector-halves (24,26), so that the ultrasound probe (30) and the multi-conductor cable (29) can be separated from the arm-mounted unit. The ultrasound probe (30) is small and light in weight so that it can be used within body cavities and can be inserted into small surgically created spaces. Ultrasound images may be transmitted to a display station (12) by cable or by an RF communicating link (32). Additional sensors (72, 260, 280, 282, 286) and control devices (290) may be mounted on or closely associated with the ultrasound probe (30).

WO 2010/047678 A1

A VERSATILE ULTRASOUND PROBE AND METHOD FOR ITS USE

TECHNICAL FIELD

[0001] The present disclosure relates to an ultrasound probe for medical use, and relates more particularly to such a probe that can be manipulated periodically at the location of a procedure being carried out in a sterile surgical field.

BACKGROUND ART

[0002] During a surgical procedure the timely acquisition of ultrasound imagery can mean the difference between life and death for the patient. Many devices and techniques have been developed or suggested to facilitate the speedy acquisition of ultrasound data, including laparoscopic ultrasound probes, finger-mounted probes and hand-held probes having the ability to wirelessly transmit image data. Unfortunately, a number of problems continue to hamper medical personnel in the use of these devices.

[0003] For a hand-held probe, users must take an extra mental step to remember and account for the distance between the position of the sensor head and the position of the user's hand. Frequently, the user is required to perform many mental tasks simultaneously, such as reviewing imagery; manipulating the probe to effect delicate changes in the probe pressure and angle; and accessing a bank of medical knowledge in an effort to diagnose a medical problem. During the stress of a medical procedure the task of mentally calculating the probe position and orientation, based on knowledge of the probe geometry, is an extra task that taxes the already highly-taxed mental resources of the medical professional. In addition, the extra displacement of the hand from the target probe head position reduces the ability to utilize muscle memory for probe positioning.

[0004] Another problem is the disassociation, both in time and location, of the tactile input that a medical professional receives from his fingers, during a procedure, and the ultrasound imagery data. For example, for situations in which a medical procedure must be interrupted for imaging to occur, it may be quite difficult for the surgeon to match the tactile information that he notes with the imagery previously acquired. In diagnostic procedures, it may be impossible for the medical professional to gain both tactile information and image information simultaneously. The task of remembering and piecing together the two types of data presents an additional challenge to the medical professional.

[0005] Yet another problem encountered by users of currently available probes is the difficulty in fitting a probe into a small area in order to reduce the length of an ultrasound transmission path through tissue that may obscure an area of greatest interest. The human body is largely composed of delicate tissue, and the object of the medical professional is often to address a localized medical problem while disturbing surrounding or intervening tissue as little as possible. For example, one type of desired imagery that is currently very difficult to acquire is imagery from the posterior of the heart. Hand-held probes and/or probes having a large cross-section present a particular difficulty when it is desirable to move the probe head through body tissue in order to obtain imagery of interest.

[0006] Still another issue presented by currently available probes is the awkwardness of use, as the probe is typically tethered, by a multi-conductor coaxial cable that is one to three meters long, to an imaging station. It is typically difficult to twist this cable, so rotating the probe about its longitudinal axis may prove difficult. In addition, the heavy weight of the cable and the need to grip the probe handle have the potential to create repetitive motion injuries to sonographers and physicians who use the ultrasound probe.

[0007] Moreover, many of the tools available for imaging the internal regions of the human body may be unavailable in a particular case, due to special conditions. For example, although trans-esophageal imaging is an extremely valuable tool for cardiac surgeons, there are instances in which the esophagus is diseased, making it potentially harmful to insert a probe into the esophagus. In these situations, having some other method of imaging would be invaluable.

[0008] A problem faced specifically by cardiothoracic surgeons is that of assessing plaque deposits in a portion of the aortal arch and ascending aorta prior to accessing that portion of the aorta surgically. If there are plaque deposits in a part of the aorta being accessed, the deposit or a portion of it may break off, travel through the blood stream and lodge in a blood vessel, causing great damage to tissue that is dependent on the vessel for its blood supply. Although Doppler ultrasound probes are currently used for the assessment of plaque deposits in the aortal arch and ascending aorta, currently available intra-operative probes for accessing interior portions of the body are about 10 cm long and rigid. Although this form is potentially useful in some situations, it greatly complicates the task of successfully placing the probe for imaging a blood vessel and for many other intra-operative situations, while permitting the user to maintain a correct sense for the orientation and position of the probe transducer.

[0009] Another issue faced by cardiothoracic surgeons is that of finding coronary arteries in a difficult-to-assess patient. Although in many patients the coronary arteries run close to or on the surface of the heart, in perhaps 10% of patients one or more coronary arteries are buried in cardiac tissue. This can create a serious problem for a cardiothoracic surgeon attempting to perform a bypass operation, in finding the correct artery. In a few unfortunate cases, an artery has been misidentified, leading to negative surgical results.

[0010] Moreover, the previously known configuration of a permanently attached ultrasound probe connected to a cable presents sterility issues. The cable typically could be autoclaved, but the ultrasound transducer is too delicate. The entire sensor and cable assembly, however, is rather bulky for fitting into a bath of disinfecting liquid, and the connector is typically not designed to be immersed in disinfectant. As a result, achieving satisfactory sterility of the probe and cable assembly can present a challenge to hospital personnel.

[0011] Moreover, changing the mode of operation of an ultrasound probe, for example increasing or decreasing power, or changing the field of view of the scan or the frequency transmitted for typical current systems requires an adjustment at the imaging station, which is awkward for a medical professional to accomplish in the middle of a procedure.

[0012] Although finger-mounted probes are currently known, they are typically either bulky and inflexible or they do not form desirably precise images.

[0013] What is desired then are improved ultrasound probes and methods for their use.

Summary Disclosure of the Invention

[0014] The aforementioned needs and shortcomings of the prior art are addressed by the following disclosures and the invention defined by the following claims. The following embodiments and aspects thereof are described and illustrated in conjunction with apparatus and methods which are meant to be exemplary and illustrative, not limiting in scope. In various embodiments of the apparatus and methods, one or more of the above-described problems has been reduced or eliminated, while other embodiments are directed to other improvements.

[0015] In one embodiment of the present apparatus a finger-mounted ultrasound probe assembly includes an ultrasound probe adapted to be mounted on a finger and a flexible multi-conductor cable attached to the ultrasound probe.

[0016] In one embodiment the ultrasound probe may include transducer elements capable of providing therapeutic ultrasound transmission.

[0017] In one embodiment an arm unit is connected to the multi-conductor cable and includes a mounting to bind the arm unit to a user's arm. Also, the ultrasound probe and the arm unit are adapted to mate with each other so that the ultrasound probe may be engaged to and retained by the forearm unit, to stow the ultrasound probe when not in immediate use.

[0018] As a separate aspect, an image sensor assembly includes an imaging station assembly, including an imaging station and a station multi-conductor cable assembly connected to the imaging station and terminating in a station-side probe connector-half. Also, a probe assembly has an image-sensor probe and a probe multi-conductor cable assembly, terminating on a first end in a probe-side probe connector-half adapted to mate to the station-side probe connector-half.

[0019] According to one version of a method disclosed, the station multi-conductor cable assembly is connected to a forearm of the user and the probe-side probe connector-half is connected to the station-side probe connector-half. The probe is then used to examine a subject.

[0020] As another aspect of the apparatus, the finger-mounted probe is small, light in weight, and shaped to be moved easily through small surgically created openings or in naturally occurring bodily orifices.

[0021] As another separate aspect, an embodiment of the disclosed apparatus may include a finger-mounted sensor assembly having a finger-mounted sensor and an electrical connective assembly adapted to connect the finger sensor to a display station. Also, an arm mount unit is adapted to be mounted on a user's forearm, and an electrical connective subassembly extends from the arm mount unit to the sensor. The electrical connective subassembly in one embodiment is ribbon-like and no thicker than 2.5 mm.

[0022] As yet another separate aspect, one embodiment of the disclosed apparatus may include a finger-mounted sensor assembly that includes a piece of flex circuit having a first end and a second end and that is more than 5 cm long from the first end to the second end. An ultrasound transducer may be located on the two centimeters of the piece of flex circuit nearest the first end and electrical conductors for the ultrasound transducer may reside in the flex circuit and extend toward the second end.

[0023] In various other embodiments optical sensors may be associated with the ultrasound probe so as to provide additional information to a medical professional, or tools may be associated with the ultrasound probe so that use of such tools may be guided using images developed by the ultrasound probe.

[0024] In addition to the exemplary aspects and embodiments described above, further aspects, embodiments and features of the invention will be more readily understood upon consideration of the following detailed description of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] FIG. 1 is a perspective view of an ultrasound imaging assembly embodying the present invention, shown in its environment, with a probe assembly attached to a medical professional and ready for use.

[0026] FIG. 2 is a perspective view of the probe assembly shown in FIG. 1, in use on a patient.

[0027] FIG. 3 is a perspective view of an alternative embodiment of the probe assembly shown in FIG. 1, showing a wireless link to an imaging station.

[0028] FIG. 4 is a perspective view of the assembly of FIG. 1, showing a probe retaining clasp in use.

[0029] FIG. 5A is a perspective view of a work piece representing a first step in a process for manufacturing the finger-mounted probe that is part of the assembly shown in FIG. 1.

[0030] FIG. 5B is a perspective view of a work piece representing a second step in a process for manufacturing the finger-mounted probe that is part of the assembly shown in FIG. 1.

[0031] FIG. 5C is a perspective view of a work piece representing a further step in a process for manufacturing the finger-mounted probe that is part of the assembly shown in FIG. 1.

[0032] FIG. 5D is an exploded perspective view showing the manner of assembling a finger-mounted probe having an alternative structure.

[0033] FIG. 6 is a perspective view of a finger-mounted probe similar to that shown in FIG. 1, showing navigational elements.

[0034] FIG. 7 is a perspective view of an alternative finger-mounted probe having a hypodermic needle attached to it.

[0035] FIG. 8 is a perspective view of another alternative finger-mounted probe having an electric camera attached to it.

[0036] FIG. 9 is a perspective view of a further alternative finger-mounted probe having a set of sensors attached to it.

[0037] FIG. 10 is a perspective view of an alternative finger-mounted probe including an attached set of controls.

[0038] FIG. 11 is a side view of another finger-mounted probe, showing relevant features of its shape.

[0039] FIG. 12 is a front view of the probe shown in FIG. 11.

DETAILED DESCRIPTION OF MODES FOR CARRYING OUT THE INVENTION

[0040] In a first embodiment shown in FIG. 1, an ultrasound imaging assembly 10 includes an imaging station 12, which can include an auxiliary display 13 for the user's convenience. Also, a first multi-conductor electrical cable or display station cable 14 is electrically attached to the imaging station and terminates at a distal connector-half 16. A second, or intermediate, multi-conductor cable 18 extends from a connector-half 20, which may be waist-mounted as shown in FIG. 1, or shoulder-mounted as shown in FIG. 2, and which mates to the distal connector-half

16. The intermediate cable 18 terminates at an arm mount unit such as a forearm band 22 that supports a forearm-mounted connector-half 24. The forearm band 22 may be designed to be mounted where it is most convenient, including on the user's wrist, if desired, but will usually be most convenient and least likely to interfere if located between the wrist and the elbow, and somewhat closer to the elbow. In the embodiment shown in the drawings a finger probe sub-assembly 26 includes a finger probe sub-assembly connector-half 28 that mates releasably with the forearm mounted connector-half 24 and may be reconnected easily when desired. A flexible cable 29 in the form of a ribbon extends from connector-half 28 to a finger-mounted probe 30. Alternatively, the forearm mounted connector-half 24 and the finger probe subassembly connector-half 28 may be permanently connected at the arm mount unit. As yet another alternative structure, the flexible cable 29 may be an extension of the intermediate cable 18, without connector-halves 24 and 28, and the arm mount unit such as the forearm band 22 may be attached to the cable at a convenient location that would define the extent of the finger probe subassembly. The flexible cable portion 29 may then be interconnected with the finger-mounted probe 30 by a suitable fixed electrical and mechanical interconnection closely adjacent to or within the probe 30.

[0041] In use, surgery may begin with the surgeon wearing the forearm band 22, which retains the connector-half 24 and intermediate multi-conductor cable 18, which includes the shoulder or waist-mounted connector 20. At this stage it is possible that no finger probe sub-assembly 26 would be attached to the multi-conductor cable 18 and that no station cable 14 would be connected to assembly 18, so that the user would be free to move about freely. This would also permit the surgeon full use of his hands while making an initial incision and performing further preliminary surgical cutting. When the area of interest in the patient's body has been accessed, the surgeon can take a finger-mounted probe sub-assembly 26, that has been kept ready for use, attach it to connector-half 24 and also have the intermediate multi-conductor cable 18 connected to imaging station 12, by way of cable 14 and connector-halves 16 and 20. This procedure might destroy the sterility of the performing person's hands, so it is advisable that a person not otherwise participating in the surgery connect cable 18 to cable 14. Alternatively, a person having sterile hands could briefly don sterile gloves to effect the connection and then doff the gloves after finishing. In yet another possibility, the cable 14 might be equipped with a sheath which is sterile within and which can be broken away to leave the cable 14 in a sterile condition.

[0042] The surgeon can then introduce his hand, with the finger-mounted probe 30 attached, into the patient in order to gather ultrasound imagery, as shown in FIG. 2. After the imagery is gathered, yielding an enhanced knowledge of the problem being surgically addressed, the finger-mounted probe sub-assembly 26 can be removed from the surgeon's hand and detached from the connector-half 24, to free the surgeon to continue his procedure. Later on, when further imagery is required, either the same sub-assembly 26 may be reattached or another sub-assembly 26, previously maintained in sterility, can be attached to the connector-half 24 and used to perform the further imaging.

[0043] Various probe configurations are desirably kept at the ready, to provide the surgeon with a variety of image gathering options. This set of finger-mounted probes could vary in transmit frequency, so that a first probe permits detailed imaging of fine structures by using a relatively high frequency (circa 10-20 MHz), and a second, lower resolution, probe permits imaging of deeper structures using a lower ultrasound frequency (circa 2-10 MHz). Probes including transducers of various shapes and architectures are also desirably made available to permit varying fields of view. For example a curved linear array with relatively small radius of curvature permits imaging in the near field of the probe over a wide field of view. A phased array transducer permits imaging over a wide field of view at some distance from the array, while allowing imaging through a narrow access. A linear array permits imaging over a narrower field of view but provides good imaging of structures near the surface of the transducer array. This is frequently the type of imagery that is highly desirable in surgical situations.

[0044] The use of a linear array of transducer elements in a finger-mounted probe can be particularly advantageous. The probe can be configured so that the linear array images a scan plane that is parallel to the length dimension of the finger, or in another configuration, transverse to the finger. For the parallel configuration a portion of the scan looks forward from the finger, so that if the user directs his finger to point at the body surface, the probe will image a scan plane into the body. The user can then rotate the image plane by twisting his wrist, something that is quite easy for most users to do.

[0045] In the case of a curved linear array, the curved surface permits a user to rock the probe on the body or organ surface in order to view tissue over a variety of contact angles. This is particularly easy to do using a finger-mounted probe, as the index finger has a good freedom of movement in several axes. The transversely oriented probe has the advantage that it permits a physician to begin his examination with his hand transverse to the length of the patient's torso, which is a more natural position than parallel to the length of the patient's torso. A straight linear array or a phased array, however, has the advantage that the probe head profile can potentially be minimized, which is very important in accessing body portions.

[0046] The probe assembly 10 is also very useful in non-surgical procedures, for example, examination of a patient by imaging through the body surface, at the same time the physician is gathering tactile information. For example, the physician may wish to examine a bump or discolored area on the patient's skin and could by use of assembly 10 gather imagery at the same time he touches the abnormal area to diagnose the nature of the problem. Additionally, the user can make a fuller use of his muscle memory and positional awareness to return the probe head to the same location used in a recent probe use.

[0047] Imaging assembly 10 may also be used for exploration of body cavities, such as the vagina, rectum or mouth. Again, the user could gain tactile information about an organ such as the prostate gland at the same time also gaining ultrasound image information.

[0048] A physician may use the imaging assembly 10 to view difficult-to-access areas within the body, during surgery. For example during open heart surgery, the surgeon could move the probe 30 around to the posterior of the heart to gain imagery of heart features, such as valves that are difficult to otherwise image. This would be extremely difficult with a rigid probe that is poorly shaped for moving through tissue. A probe without advantageous physical characteristics could easily injure a patient during this type of use.

[0049] Referring to FIG. 2, in an additional example, an imaging assembly 10 can be used in a military field hospital to assist a surgeon in the task of removing shrapnel from a wounded soldier. Although an initial evaluation of the shrapnel locations could be made by an assessment of the entry wounds and pre-surgical imaging, a great deal might still not be known about the specific locations and dimensions of the individual pieces of shrapnel. After making an initial incision near an entry wound, the surgeon attaches a probe sub-assembly 26 to connector-half 24 and introduces the finger-mounted probe 30 into the incision, to gain a further indication of the shrapnel positions. After gaining this information, the surgeon can quickly remove the probe sub-assembly 26 from his finger, so that he can have the full use of both hands in the task of removing pieces of shrapnel identified by the imaging. Later on during the same surgery, the surgeon may wish to take further images and may reattach the probe sub-assembly 26, or some other probe sub-assembly 26, either for the sake of sterility or for the sake of having different imaging characteristics.

[0050] In another possible application, the low profile of probe 30 lends itself to imaging a premature infant in a neo natal incubator, by reaching through the small entry orifice of the incubator. This action is difficult to perform using previously available ultrasound probes.

[0051] The ultrasound imaging system 10 described generally above, having cables 14, 18, and probe sub-assembly 26, has advantages both in providing a broad range of connectivity and in easing the task of maintaining a sterile operating theater. In a preferred embodiment, the second, or intermediate multi-conductor cable 18 may be sterilized in an autoclave without being damaged. Cable 14 is typically far enough removed from the sterile area so that it need only be wiped down with disinfectant between instances of use. Probe sub-assembly 26 can be submerged in disinfectant fluid for sterilization.

[0052] In an alternative embodiment, the intermediate multi-conductor cable 18 may be protected by a sterile sheath, which can be removed when a physician who is wearing cable 18 needs to move to a different imaging station 12 and use a different probe sub-assembly 26. In another alternative, the flexible cable 29 of the probe sub-assembly 26 is longer, so that the intermediate cable 18 does not have to extend as far toward probe 30, thereby making it more likely for cable 18 to avoid contamination from body fluids.

[0053] Also, cable 18 may be a universal unit, compatible with a broad range of probe makes, by having the connector-half 24 include a super-set of pins, not all of which are used for any particular finger probe sub-assembly 26. An adapter may be provided that would be interposed between cable 18 and imaging station 12, either where cable 18 connects to cable 14, where cable 14 connects to station 12, or as part of cable 14, to accommodate different types of imaging station 12. It should be noted that this feature of imaging assembly 10 can also be used for ultrasound probes that are not finger probes.

[0054] Referring to FIG. 3, in an alternative embodiment of the imaging assembly 10 a wireless communication link is established between sub-assembly 26 and imaging station 12. A data signal processing and transmission unit 32 receives raw electrical signals from the transducer of the probe 30 and extracts the imagery, thereby greatly reducing the volume of data to be transmitted further. The processed image signal data is transmitted, typically by RF, to imaging station 12 and/or to heads-up display goggles 34, which superimpose the imagery on the user's field of view. In one embodiment the data processing and transmission unit 32 may be located directly on the forearm band 22.

[0055] Referring to FIG. 4, in a preferred embodiment a catch 38 may be provided on the forearm band 22, for the purpose of retaining the probe 30, so that it can be folded back, out of the way of the user's hand, when the probe 30 is not in use. In one embodiment, the catch 38 may include a system of magnets, with mutually attractive magnets (not shown) on the wrist or arm band 22 and associated with the probe 30.

[0056] The finger-mounted probe sub-assembly 26 may be made primarily of molded light weight plastics materials and in one embodiment has a mass of less than 70 grams. Depending on the mass of the probe 30, the length and the number of conductors included in the multi-conductor cable 29, and the specifics of the structure of the finger-mounted probe sub-assembly connector-half 28, the mass of the finger-mounted probe sub-assembly 26 is preferably no more than 280 grams, more desirably not more than 140 grams, and even more desirably not more than 80 or 100 grams. The distal 3 cm of finger-mounted probe 30, which includes the ultrasound transducer 56 and absorptive backing 54, and possibly a lens 63, in a housing 62, desirably has a mass of not more than about 100 grams, although, depending on the factors including the number of transducer elements 58, the transmission frequency and the type of transducer materials the mass may advantageously be as little as 50 grams, 30 grams, 20 grams, 15 grams, or even 11 grams. This low mass is very convenient in enabling a user to easily maneuver the finger-mounted probe 30.

[0057] Applicant notes, in connection with the immediately following discussion, that flex circuit is a term of art in the electronic device industry, referring to an electrically connective element made of a sheet of flexible polymeric dielectric material having conductive traces formed on it by, for example, photolithographic techniques. A flex circuit may be sealed with an additional sheet of polymeric material, so that the conductive traces are interposed and sealed between two flexible sheets.

[0058] In one embodiment construction of the finger-mounted probe sub-assembly 26 begins with the creation of a T-shaped piece of flex circuit 40, shown in a simplified form in FIGS. 5A, 5B, and 5C. In an alternative embodiment, as shown in FIG. 5D, two or more L-shaped pieces such as pieces 41a, 41b, 41c, and 41d are overlapped or placed side-to-side to form a T shape. The length 46 between a proximal end 42 and a distal end 43, of flex circuit 40 may be, for example, 25 cm. The length 48 of the T-shape top bar at distal end 43 may conveniently be about 7.0 cm. The distal end T-shaped top bar includes a first branch 44 and a second branch 45. Each of several conductive traces 50 turns at the T-junction and extends from proximal end 42 to the end of either branch 44 or 45. While for illustrative clarity only 7 conductive traces 50 are shown in each branch 44 or 45, a larger number, such as 32 separate parallel traces 50 may be included in a layer of the flex circuit 40, and more than one layer, for example 4 layers, as shown in FIG. 5D, or as many as 8 layers, may be included. A set of bare trace ends 53 are formed at the free ends of branches 44 and 45 by removing the end of the plastic of flex circuit 40 from about traces 50, typically by laser ablation. Each of several flex circuit layers may typically have a thickness of only 0.3 mm, so a cable 29 of 8 flex circuit layers can still be conveniently flexible and have a small thickness 57 of no more than about 2.5 mm. The ribbon-like cable 29 may have a width 59, depending on the number and size of the traces 50, in the range of 1-2 cm.

[0059] An ultrasound transducer 56 is formed by connecting the trace ends 53 to respective transducer elements 58 such as pieces of piezoelectric material arrayed along side one another, shown in a reduced number for the sake of clarity in FIGS. 5C and 5D. The trace ends 53 may be interdigitated and connected to alternately located elements 58 from the two sides of the transducer 56. After connection of the trace ends 53 to the piezoelectric elements 58 a high performance acoustically absorptive backing material 54 is affixed behind the piezoelectric transducer, so that trace ends 53 are encapsulated between backing material 54 and piezoelectric material. Backing material 54 may be as disclosed in U.S. Patent 4,779,244, issued October 18, 1988, which is incorporated herein by reference as if fully set forth herein. In that patent a backing material having an acoustic absorbance equal to or greater than 60 db/MHz/cm is disclosed. Using such a material and given the need to attenuate a typical 5 MHz ultrasound signal emitted from the back of the array by approximately 150 dB, over a two-way trip through the backing material (so as not to interfere with a desired ultrasound image), the array backing would need to have a thickness 55 of approximately 150dB ÷ [(2)(5Mhz) (60dB/MHz/cm)] = 2.5 mm, which allows a very low profile for a transducer 56 intended to fit on the finger.

[0060] In instances where a high absorptive backing material is not available, such as for a pre-existing probe retrofit, such a probe could be modified by creating a toothed pattern, such as that found on the sides of an anechoic chamber, in the surface of the backing material that faces away from the ultrasound array. This causes the sound waves reflecting off the rear of the ultrasound array stack to scatter.

[0061] The elements 58 of piezoelectric material 56 of the ultrasound transducer may be arrayed, as shown in a simplified view in FIG. 5C, with each transducer element 58 being connected to a unique trace 53 and to a common ground plane bus (not shown). In one contemplated embodiment a conveniently located set of ultrasound elements 58 may be connected to trace ends 53 of branch 44, while another set of transducer elements 58 are connected to trace ends 53 of branch 45.

[0062] Skilled persons will appreciate that the alternative construction noted above, in which L-shaped pieces 41a and 41b of flex circuit 40 are used, rather than a single T-shaped piece, permits the step of connecting bare traces 53 to piezoelectric transducer elements 58 to be performed with the L-shaped pieces 41a and 41b of flex circuit laying flat, as shown in FIG. 5D, thereby greatly easing this connective task. The lateral branches 44 and 45, respectively, of L-shaped pieces 41a and 41b may then be curled up and the longitudinal portions may be interleaved and overlapped at the top, thereby forming an annulus that fits about the finger at the end of a multi-layer flex circuit cable 29.

[0063] Referring to FIG. 5C, the branches 44 and 45 are flexed arcuately to form a ring 60 that can fit about a user's finger, so that ultrasound transducer array faces downwardly, or outwardly, with the piezoelectric elements 58 arranged and oriented conveniently to sweep forward or backward relative to the finger. A housing 62, possibly including an ultrasound lens 63, may be molded about the ring 60 that is formed by flex circuit branches 44 and 45, legs 41a and 41b, and materials 54 and 56, to arrive at a final configuration of a finger-mounted probe 30, various possible versions of which are shown in FIGS. 7-10. The housing 62 may be made by molding materials such as room temperature curing plastics such as epoxies. A protective coating may also be added to the medial portion 64 of flex circuit 40.

[0064] As shown in FIGS. 11 and 12, a probe 30 constructed according to the preferred methods described herein may have a distance 312, from the interior surface 324 of the finger mount to the furthest protrusion of the transducer and lens, of about 1.2 cm, greatly facilitating a user in passing the probe 30 through small passages in the body. In another embodiment distance 312 may equal about 1.5 cm.

[0065] Moreover probe 30 is made, in one embodiment of the finger probe sub-assembly 26, so that the ultrasound transducer 30 protrudes outwardly with its front and rear end tapered from the middle, defining an angle 314 between a probe surface that extends parallel to the user's finger and the sloped surface of the front of the probe as it begins to protrude outwardly. Angle 314 is ideally about 70° at its maximum. In an alternative preferred embodiment, angle 314 is about 60° at its maximum and in yet another preferred embodiment, this angle is about 50° at its maximum. In yet another preferred embodiment, angle 314 is about 40°. An additional angle 316 may be defined as the angle between a probe surface that extends parallel to the user's finger and the surface of the rear of the probe as it begins to extend outwardly, going from rear to front. It is also desirable to minimize angle 316, so that as the probe is being removed back through tissue, it disturbs the tissue as little as possible. In a preferred embodiment this angle is about 40°. In other embodiments this angle ranges from 40° to 70°.

[0066] A finger cot 320 may be used both to isolate the front of the user's finger from a patient's tissue, and to provide a rounded surface, at the front of the finger, which can be pushed through tissue with less chance of causing damage. A probe unit 310 having a fixed inner diameter 324 can accommodate a range of finger thicknesses, by being used with cots having a range of different thicknesses. It is desirable to minimize the distance 318 between finger cot 320 and probe surface 322. Although this distance 318 is shown as being on the order of 2 mm, in another embodiment distance 318 is zero, with the finger cot 320 being flush with the probe surface.

[0067] This low and sloping profile and gradual protrusion greatly facilitates a probe user in inserting the probe into small body cavities and avoiding damage to delicate tissues. Along these lines it is beneficial to have a "bullet shaped" probe that comes to a point forward of the finger and smoothly expands to the area where the transponder is located. This can be accomplished by equipping the probe with a forward section that terminates distal to the finger tip in a single point and expands transversely outwardly approximately equally and smoothly in each direction, to yield the bullet shape.

[0068] In one preferred embodiment a 128-element probe is constructed and in an alternative preferred embodiment a 256-element probe is constructed. Skilled persons will recognize that although a linear array is shown, a curved linear array could be constructed just as easily, using the techniques shown, simply by curving the array of piezoelectric elements 58. In an alternative method of construction, a separately formed ultrasound transducer is connected to flex circuit 40 by way of a flex circuit connective tab.

[0069] The use of a high absorptive backing material 54, incorporated into the array, as well as the flex circuit construction that obviates the need for connecting the flex circuit to a cable in the probe head permits the formation of a lower profile probe head. As mentioned above, this low profile can be critical in permitting a user to locate the probe in small spaces internal to the human body without damaging body tissue.

[0070] The benefit of this innovation may also be utilized in other probes. For example, flex circuit 40, rather than terminating in connector-half 24, can be terminated by connection to a multi-conductor coaxial cable, of the type that is currently standard in the ultrasound imaging industry, 5 cm or farther away from the probe, with or without a detachable connector. In the typical previously known ultrasound probe design, a generally cylindrical multi-conductor coaxial cable terminates quite close to the probe head or in the probe head, causing the finger-mounted portion to be bulky and heavy. By extending the flex circuit portion more than 5 cm from the probe itself, and preferably more than 10 cm or even 20 cm, the finger probe sub-assembly 26 is kept light and given a low profile. Accordingly, the present invention does not require inclusion of system connectors that although advantageous do not by themselves yield the low profile of the finger-mounted probe sub-assembly 26.

[0071] In an alternative preferred embodiment the traces 50 are connected a capacitive micro machined ultrasound transceiver (CMUT), using the same techniques as used for connecting them to the elements 58 of piezoelectric material 56. A CMUT transceiver tends to be thermally robust, thereby lending itself to use in a probe that may be exposed to the heat and pressure of an autoclave sterilization cycle, without being damaged.

[0072] Referring to FIGS. 5A-5C, at the proximal end 42 of the flex circuit 40, a set of electrical contact points 52 are formed by removing the flex circuit plastic down to each trace 50, in a particular spot. Conductive material may be deposited onto contacts 52, so that they are not recessed. Alternatively, a surface coating material covers flex circuit conductive traces 50 so that only connector contacts 52 are left exposed on the surface of flex circuit 40. Rigid backing material 58 may be adhered underneath the flex circuit and a metal housing (not shown) may be provided to finished connector-half 22. Alternatively, the proximal end 42 of the flex circuit 40 can be selectively rigidized by laminating a rigid circuit board material layer onto each flex circuit, and forming connections to the flex traces by laser or mechanical drilling and subsequent plating, to form a monolithic integrated connector assembly. Conventional techniques can be used to interconnect traces 50 of each of several layers of flex circuits 40 to provide an array of contacts 50 on a single plane.

[0073] Referring to FIG. 6, in a one embodiment a finger-mounted probe assembly 70 may include a set of accelerometers (not shown) and/or inductors 72 that are mounted in a mutually orthogonal pattern as part of finger-mounted probe 70 to permit determination of the orientation and location of the finger-mounted probe 70 within the body.

[0074] Referring to FIG. 7, in an additional embodiment, a hypodermic needle 200 and an attached syringe 210 are releasably mounted adjacent a finger-mounted ultrasound probe 30 in a probe assembly 74. This permits use of imagery gathered by the probe 30 to assist a health care professional in reaching a blood vessel of interest to insert the needle. Health care professionals sometime need to find a particular blood vessel, such as a jugular vein or a radial vein, in order to inject fluid or drugs as soon as possible so that a substance being injected will reach a target organ as quickly as possible. In such a procedure, known as central-line-placement, color flow ultrasound imagery, in which Doppler information drives the display of flow in blood vessels and non-Doppler information drives the display for the surrounding tissue, is particularly useful in this endeavor.

[0075] In an alternative embodiment, another sort of skin broaching device, such as a canula (not shown) or a hypodermic needle 200 without the syringe 210, but connected through a tube (not shown) to a remotely located intravenous drip bag (not shown) may be mounted on the ultrasound probe 30. Guidance of the hypodermic needle associated with the finger-mounted probe 30 may also be assisted by use of commercially available guidance devices, such as a pressure sensor associated with the needle, including that available from Vascular Technologies, Ness-Ziona, Israel, which provide an additional positive indication when the needle enters a vein, through sensing a pressure change.

[0076] A probe assembly 76 which is an additional embodiment, shown in FIG. 8, is similar to the finger-mounted probe assemblies described above except that an optical link 260 and light source 262 are provided adjacent the probe 30 to permit optical viewing of body tissue. In one embodiment the optical link 260 may be in the form of a lens coupled to a fiber optic link 264 that may terminate in a video camera (not shown). Alternatively optical link 260 is in the form of a video camera (as shown) attached to the finger-mounted probe 30 and adapted to communicate electrically with the imaging station 12, or heads up display 34. In either situation it is necessary to provide light for the optical link 260. This may be accomplished either by an electrically powered light source, such as a light emitting diode 262, or a chemically powered light source (not shown), such as those available under the trade name "pin lights," from Embo-Optics of Beverly, MA.

[0077] Referring to FIG. 9, in another preferred embodiment a finger-mounted sensor assembly 78 is equipped with a sensor suite that includes a thermometer 280, an oximeter 282, a pressure sensor 284 and a glucometer 286 mounted on the finger-mounted probe 30. As an alternative embodiment element 286 may be an agent administration patch 286 that is electrically activated by a signal transmitted along a trace 50 to express the agent, thereby administering the agent to a precise location. In an alternative embodiment, a different number of sensors, or even only a single sensor may be provided.

[0078] In another embodiment, a finger-mounted sensor assembly 130 is provided that can both image tissue, using ultrasound, and also provide therapy, typically by cauterizing tissue, also using ultrasound. A transducer assembly 288 includes both an imaging array 292 and a treatment array 294. The treatment array 294 uses up to 100 watts of power and is powered by flex circuit traces 50 that are larger in cross-sectional dimension and are therefore capable of conducting more current in order to meet the greater power demands of treatment array 294.

[0079] In another embodiment of a finger-mounted ultrasound probe assembly (not shown), a single transducer array may be used for both imaging and treatment. In one variant of this embodiment, some piezoelectric transducer elements 58 are used for both imaging and treatment and others are used solely for imaging. Again, some of the elements 58 of the array must be powered by a larger input of current, and to accommodate this need, the associated flex circuit 40 must include conductor traces 50 of ample size for the transducer current needed for the treatment ultrasound elements.

[0080] A set of thumb controls 290 are provided for the transducer 288, so that the user may switch between imaging and treatment. These controls are typically in the form of small push buttons that must be pressed in a specific pattern, for example two rapid presses followed by continuous pressure during the period of time treatment is desired, in order to activate treatment mode, as any inadvertent activation could greatly harm a patient. In one embodiment associated power supply circuits could be programmed so that a warning signal is given when two rapid presses have placed the treatment probe in a "ready" state, in case some passage through tissue ever causes two rapid presses to occur. In an alternative preferred embodiment controls are placed on the wrist or forearm band 22, thereby providing easy access for a probe user.

[0081] In another embodiment (not shown), buttons 290 may be provided for a probe, such as the probe 30, in which therapeutic ultrasound is not available. The buttons 290 in such a probe may be connected so as to control or change the scan width and orientation, the transmit power and frequency, and the imaging mode, among other aspects of probe operation. The buttons 290 communicate with imaging station 12 by way of traces 50 and cables 18 and 14, or by RF transmission through the data processing and transmitting unit 32, in the embodiment of FIG. 3. The buttons 290 may also communicate or be mechanically associated with the array of transducer elements within the finger probe to allow a change in orientation of the elements to revise the orientation of the scan plane.

[0082] One use of probe 30 is for the intra-operative evaluation of plaque deposits in the aortal arch and ascending aorta, prior to invasively accessing the aorta. To perform this function a Doppler probe may be used to obtain a measurement of the speed of the blood in the aorta. In the case where the aorta has been narrowed due to plaque deposits, the blood flows more rapidly. Reaching the tissue of the aorta is greatly eased by use of a finger-mounted probe 30, as opposed to the long, stiff intra-operative probes previously available.

[0083] While a number of exemplary aspects and embodiments have been discussed above, those of skill in the art will recognize certain modifications, permutations, additions and sub-combinations thereof. It is therefore intended that the following appended claims and claims hereafter introduced are interpreted to include all such modifications, permutations, additions and sub-combinations as are within their true spirit and scope.

[0084] The terms and expressions which have been employed in the foregoing specification are used therein as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding equivalents of the features shown and described or portions thereof, it being recognized that the scope of the invention is defined and limited only by the claims which follow.

CLAIM(S)

What is claimed is:

1. A sensor assembly, comprising:

(a) a finger-mounted sensor including an ultrasound probe;

(b) an electrical connective assembly, adapted to connect said finger-mounted sensor electrically to a display station, and including:

(i) a display station multi-conductor electrical cable;

(ii) an intermediate multi-conductor cable having a first end adapted to be attached to a user's clothing and releasably connected mechanically and electrically with said display station multi-conductor cable through a connector-half; and

(iii) an arm mount unit at a second end of said intermediate multi-conductor cable, adapted to be carried on a user's arm.

2. The sensor assembly of claim 1 wherein said electrical connective assembly also includes an electrical connective subassembly interconnected electrically with said arm mount unit, the electrical connective subassembly extending from said arm mount unit to said sensor and including a multi-conductor sensor cable connected electrically with said ultrasound probe.

3. The sensor assembly of claim 2, wherein said multi-conductor cable of said electrical conductive sub-assembly has a width in the range of about 1 cm to about 2 cm.

4. The sensor assembly of claim 1, wherein the electrical connective subassembly is interconnected with the arm mount unit by a releasable and reconnectible connector.

5. The sensor assembly of claim 4, wherein said arm mount unit includes a first connector-half of said releasable and reconnectible connector and wherein said electrical connective sub-assembly includes a second connector-half of said releasable and reconnectible connector detachably mated with said first connector-half, said finger-mounted sensor thereby being connected electrically to said first connector-half to connect said finger-mounted sensor with said display station, and wherein said finger-mounted sensor and said electrical connective

sub-assembly can be disconnected electrically and mechanically from said display station by detaching said second connector-half from said first connector-half.

6. The sensor assembly of claim 2 wherein said multi-conductor sensor cable of said electrical connective subassembly is flat and has a thickness no greater than 2.5 mm.

7. The assembly of claim 2, wherein said multi-conductor sensor cable of said electrical connective sub-assembly incorporates a piece of flex circuit and wherein said piece of flex circuit extends more than 5 cm from said finger sensor toward said arm mount unit.

8. The sensor assembly of claim 2, wherein said finger-mounted sensor comprises a piece of flex circuit having a first end and a second end and having a length greater than 5 cm from said first end to said second end; an ultrasound transducer mounted on the said piece of flex circuit at said first end; and a plurality of electrical conductors resident in said flex circuit and connected electrically with said transducer and extending toward said second end.

9. The sensor assembly of claim 8, wherein said length of said piece of flex circuit is at least 10 cm.

10. The sensor assembly of claim 2, wherein said finger-mounted sensor and said electrical connective subassembly together have a mass of not more than 280 grams.

11. The sensor assembly of claim 10, wherein said finger-mounted sensor and said electrical connective subassembly together have a mass of not more than 140 grams.

12. The ultrasound probe assembly of claim 10, wherein said finger-mounted sensor and said electrical connective subassembly together have a mass of not more than 100 grams.

13. The ultrasound probe assembly of claim 10, wherein said finger-mounted sensor and said electrical connective subassembly together have a mass of not more than 80 grams.

14. The ultrasound probe assembly of claim 10, wherein a distal 3 cm portion of said finger-mounted sensor includes said ultrasound probe and has a mass of not more than 100 grams.

15. The ultrasound probe assembly of claim 14, wherein said distal 3 cm portion of said finger-mounted sensor has a mass of not more than 50 grams.

16. The ultrasound probe assembly of claim 14, wherein said distal 3 cm portion of said finger-mounted sensor has a mass of not more than 30 grams.

17. The ultrasound probe assembly of claim 14, wherein said distal 3 cm portion of said finger-mounted sensor has a mass of not more than 20 grams.

18. The ultrasound probe assembly of claim 14, wherein said distal 3 cm portion of said finger-mounted sensor has a mass of not more than 15 grams.

19. The ultrasound probe assembly of claim 14, wherein said distal 3 cm portion of said finger-mounted sensor has a mass of not more than 12 grams.

20. The sensor assembly of claim 2, wherein said ultrasound probe includes ultrasound transducer elements adapted to provide therapeutic ultrasound, and wherein said multi-conductor sensor cable of said electrical connective subassembly includes a flex circuit electrically connected to said ultrasound probe and having a plurality of electrically conductive traces of which some traces have a larger cross section than others of said traces, said traces that have a larger cross section being connected to provide electricity for said transducer elements adapted to provide therapeutic ultrasound.

21. The sensor assembly of claim 1, including a catch located on said arm mount unit and adapted to receive said ultrasound probe so that said ultrasound probe may be attached to and carried by said arm mount unit, keeping said ultrasound probe out of the way but connected and readily available for immediate use.

22. The sensor assembly of claim 1 wherein said finger-mounted sensor includes a finger-mounting device, adapted to be received on a human finger and having an interior surface adapted to be located proximate said human finger, and said an ultrasound probe is mounted on and supported by said finger-mounting device, and wherein said ultrasound probe protrudes outwardly, relative to said interior surface, by less than 1.5 cm.

23. The sensor assembly of claim 22 wherein said ultrasound probe has a front and a back and an outermost surface; and wherein said outermost surface protrudes increasingly outwardly, and said front and said back are inclined with respect to said outermost surface at an average slope of less than 50°, thereby helping to avoid tissue damage when said probe is pushed through body tissue.

24. The sensor assembly of claim 22, wherein said average slope is less than 40°.

25. The sensor assembly of claim 1 wherein said ultrasound probe includes ultrasound transducer elements adapted to provide therapeutic ultrasound.

26. A method for using an ultrasound sensor assembly, comprising:

(a) providing an ultrasound sensor assembly comprising:

(i) an imaging station assembly, including an imaging station and a station multi-conductor cable assembly connected to said imaging station and terminating in a station-side probe connector-half; and

(ii) a probe assembly having an ultrasound probe and a probe multi-conductor cable assembly, the probe multi-conductor cable assembly terminating on a first end in a probe-side probe connector-half adapted to mate with said station-side probe connector-half;

(b) attaching said station-side probe connector-half to a user;

(c) mating said probe-side probe connector-half to said station-side probe connector-half; and

(d) using said sensor probe to examine a subject; and

(e) leaving said station-side probe connector-half attached to said user, and disconnecting said probe-side probe connector-half from said station-side probe connector-half after using said sensor probe.

27. The method of claim 26, wherein said step of using said sensor probe to examine a subject includes using said probe to examine plaque in the aorta of said subject.

28. The method of claim 26, wherein said step of using said sensor probe to examine a subject includes using said probe to locate a cardiac blood vessel that is hidden in tissue.

29. The method of claim 26, including the further step of thereafter again mating said station-side probe connector-half with said probe-side probe connector-half, and again using said ultrasound probe to examine said subject.

30. The method of claim 26, including the further steps of providing an additional probe assembly having a probe-side probe connector-half and mating said probe-side probe connector-half of said additional probe assembly with said station-side probe connector-half after said step of disconnecting said probe-side probe connector-half.

31. The method of claim 26, including the further steps of connecting a proximal multi-conductor cable sub-assembly including a proximal connector-half with said imaging station as a part of said station multi-conductor cable sub-assembly and interconnecting an intermediate multi-conductor sub-assembly including a medial connector-half with said proximal multi-conductor cable sub-assembly by mating said proximal connector-half separably with said medial connector-half.

32. The method of claim 31, including the further step of disconnecting said medial connector-half from said proximal connector-half, thereby leaving said probe assembly disconnected from said imaging station, after said step of using said ultrasound probe.

33. The method of claim 31, including protecting said medial multi-conductor cable by a sterile sheath, removing the sterile sheath after said step of disconnecting said medial

connector-half, and thereafter attaching the medial multi-conductor cable to a second imaging station.

34. The method of claim 26, including the step of mounting said ultrasound probe on a finger of said user.

35. An ultrasound probe assembly, comprising:

(a) a sensor unit, including:

(i) a finger-mounting device, adapted to be received on a human finger;

(ii) an ultrasound probe attached to and supported on said finger-mounting device; and

(iii) a multi-conductor cable, electrically connected to said ultrasound probe; and

(b) a processing unit adapted to be worn on a human body and including:

(i) a data signal processing unit, electrically connected to said multi-conductor cable and adapted to extract an image from an electrical signal produced by said ultrasound probe; and

(ii) an RF transmitter unit, adapted to send said extracted image to an RF receiver.

36. The assembly of claim 35, further including a separable connector between said multi-conductor cable and said processing unit, so that said multi-conductor cable can be disconnected from said processing unit.

37. The assembly of claim 35, wherein said RF transmitter unit includes a receive capability and is thereby capable of receiving instructions from another RF transmitter.

38. A method of imaging a portion of the human body, comprising:

(a) providing an ultrasound probe assembly, including:

(i) a finger-mounting device, adapted to be received on a human finger;

(ii) an ultrasound probe attached to and supported on said finger-mounting device; and

(iii) a multi-conductor cable, electrically connected to said ultrasound probe; and

(b) providing a processing unit adapted to be worn on a human body and including:

(i) a data signal processing unit, electrically connected to said multi-conductor cable and adapted to extract an image from an electrical signal produced by said ultrasound probe; and

(ii) an RF transmitter unit, adapted to send said extracted image to an RF receiver;

(c) using said finger-mounting device to mount said ultrasound probe on a user's finger; and

(d) using said ultrasound probe assembly, with said ultrasound probe mounted on said user's finger, to image a portion of the human body.

39. The method of claim 38, including using said ultrasound probe assembly to image a patient's aortal arch and ascending aorta so as to determine thereby the presence of plaque in said aortal arch or ascending aorta.

40. The method of claim 38, including using said ultrasound probe assembly to image a patient's cardiac tissue and thereby to locate cardiac arteries buried beneath said tissue.

41. The method of claim 38, including using said ultrasound probe assembly to image an anterior portion of a patient's heart.

42. An ultrasound probe assembly, comprising:

(a) a finger-mounting device, adapted to be received on a human finger;

(b) an ultrasound probe mounted on and supported by said finger-mounting device; and

(c) an additional sensor mounted on said finger-mounting device proximate said ultrasound probe.

43. The assembly of claim 42, wherein said additional sensor is a thermometer.

44. The assembly of claim 42, wherein said additional sensor is an oximeter.

45. The assembly of claim 42, wherein said additional sensor is a glucometer.

46. The assembly of claim 42, wherein said additional sensor is a pressure sensor.

47. The assembly of claim 42, wherein said additional sensor is an optical viewing device mounted on said finger-mounting device and associated with said ultrasound probe; and wherein said ultrasound probe assembly also includes a cable connected to said ultrasound probe and said optical viewing device and adapted to transmit data from said ultrasound probe and said optical viewing device to a remote device.

48. The probe assembly of claim 47, wherein said optical viewing device includes a lens connected to an optical fiber and said cable includes an optical fiber arranged to transmit data from said optical viewing device to said remote device.

49. The probe assembly of claim 47, wherein said optical viewing device includes an electrical sensing device and said cable includes an electrically conductive link for transmitting said data from said optical viewing device.

50. The probe assembly of claim 47 further including an illumination probe mounted on said finger-mounting device proximate said optical viewing device.

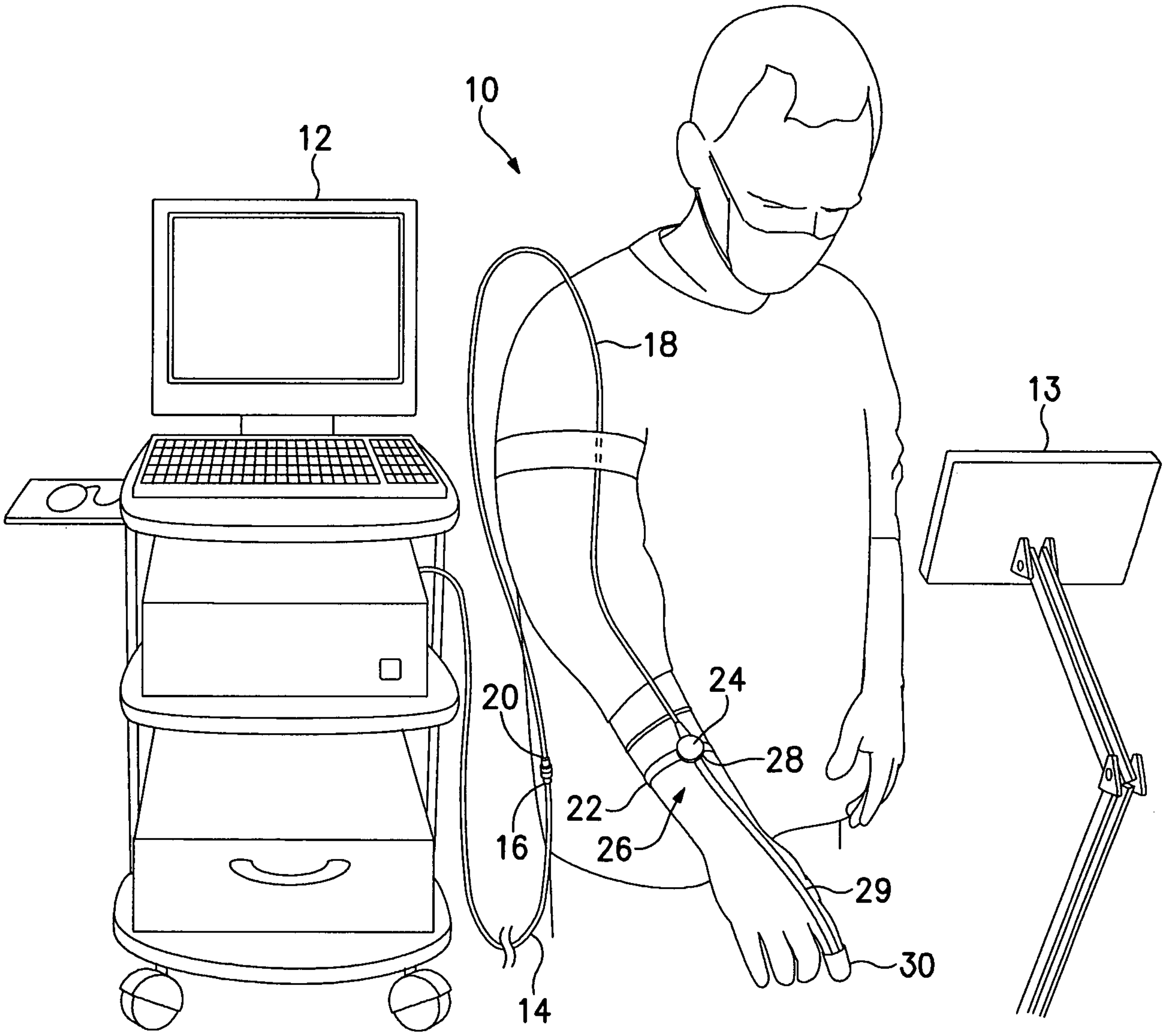

FIG.1

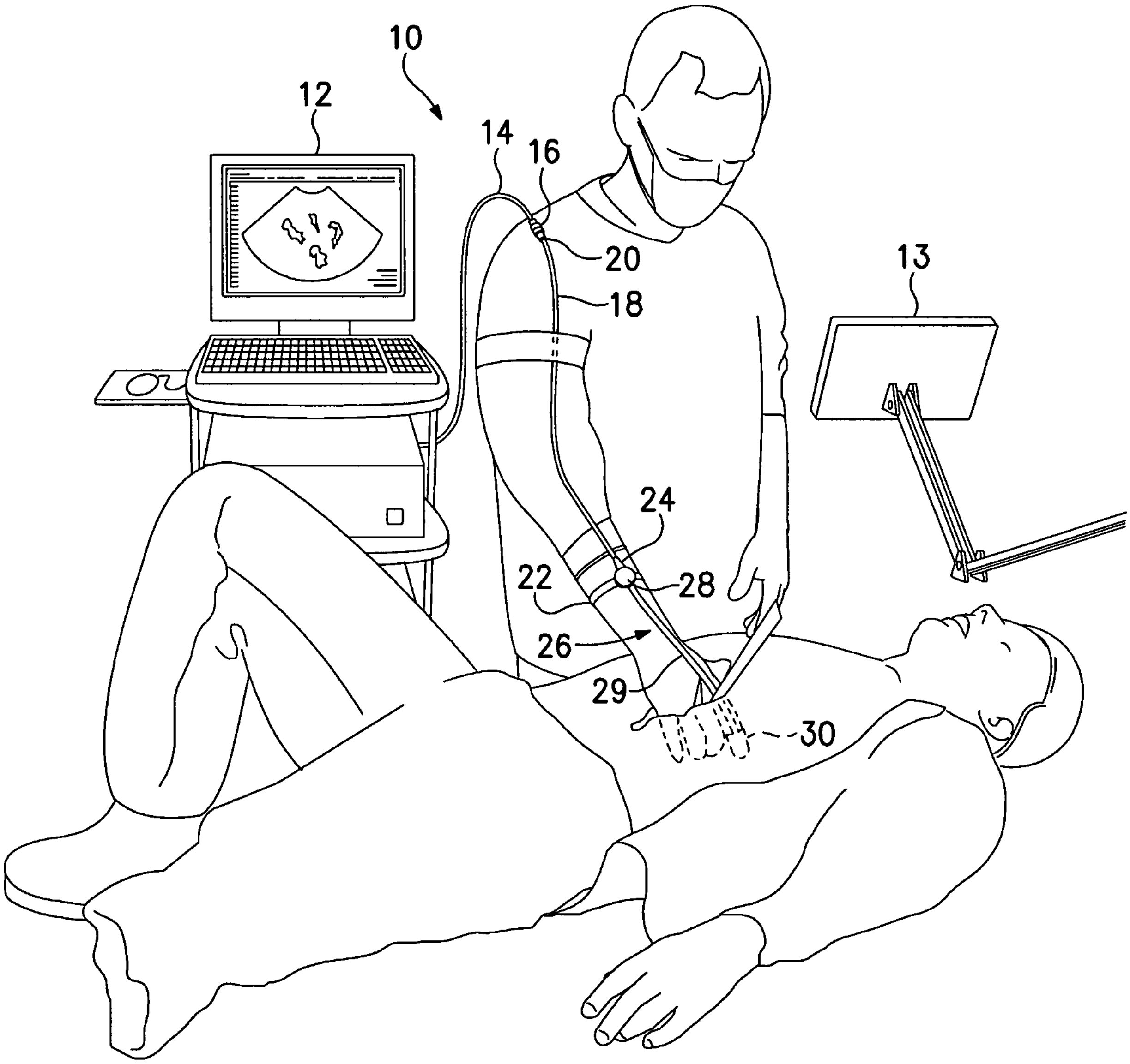

FIG.2

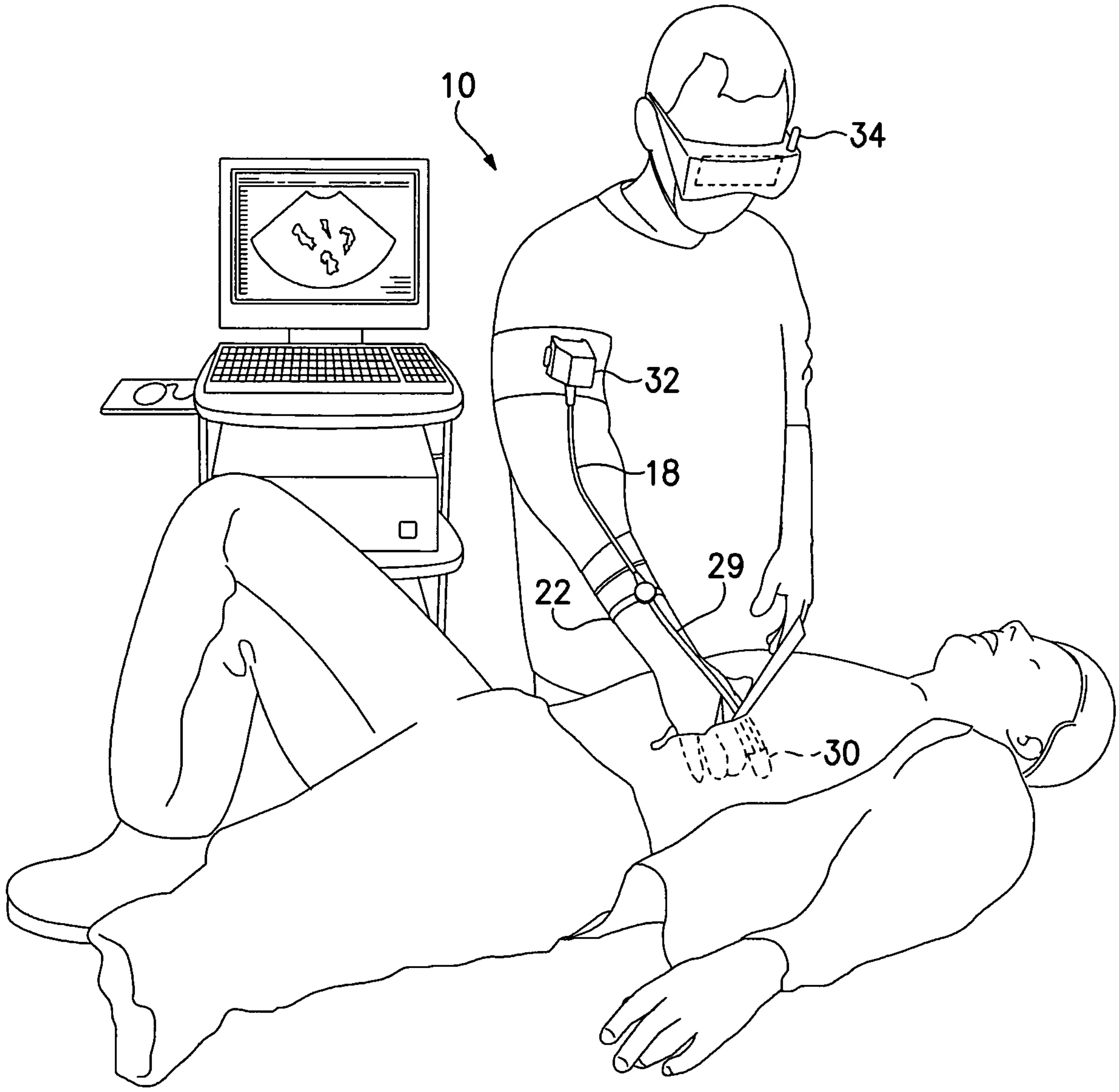

FIG.3

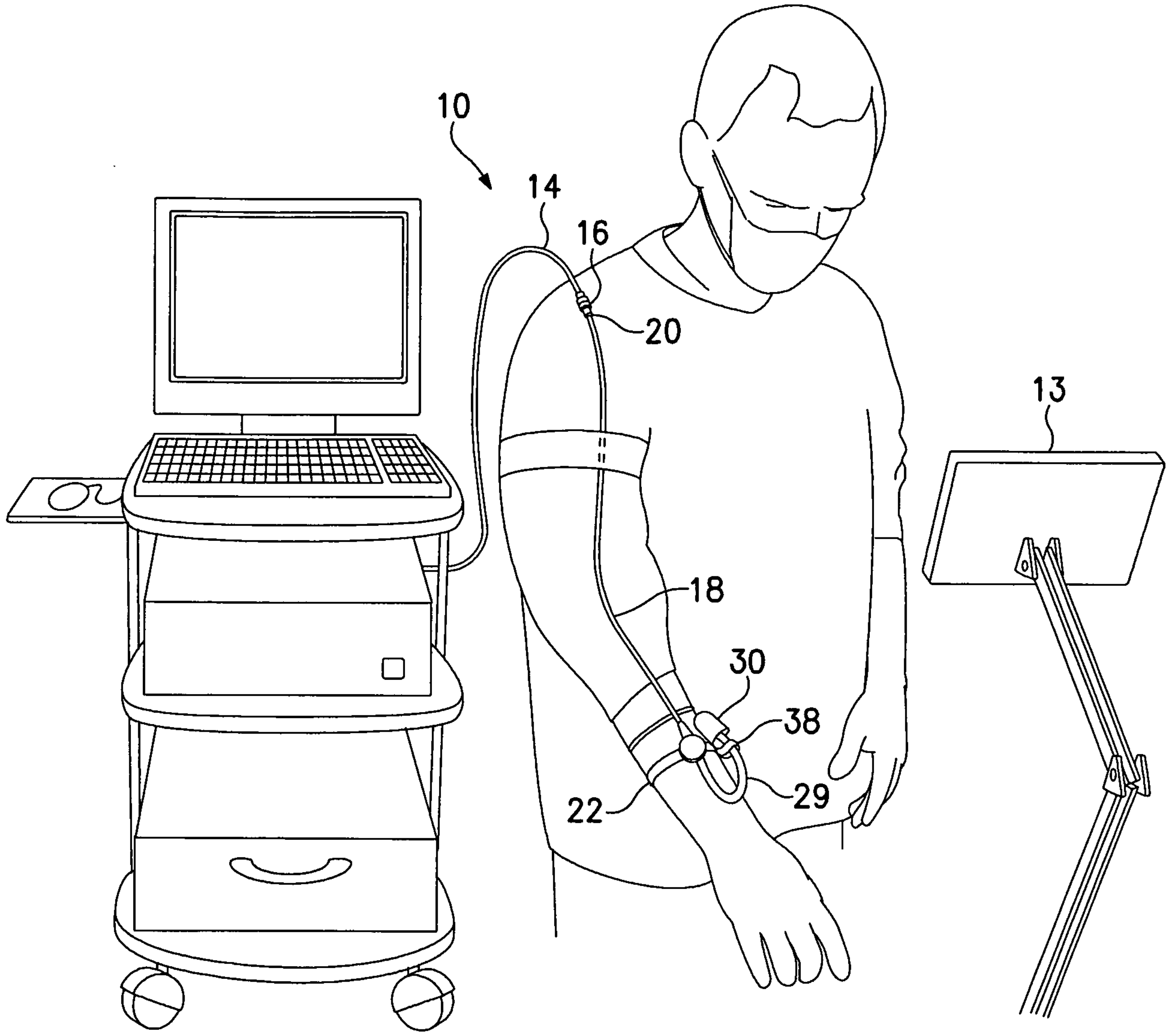

FIG.4

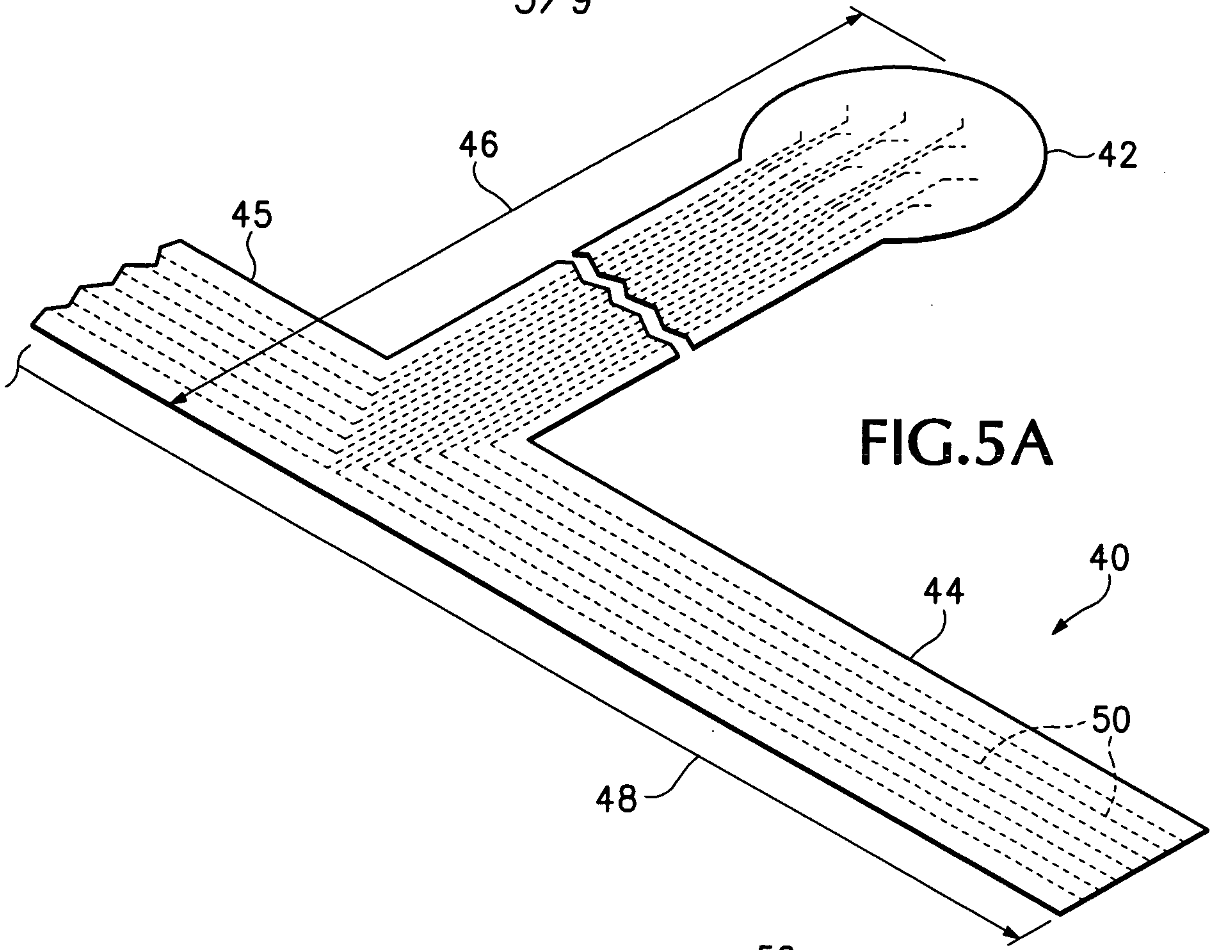

FIG.5A

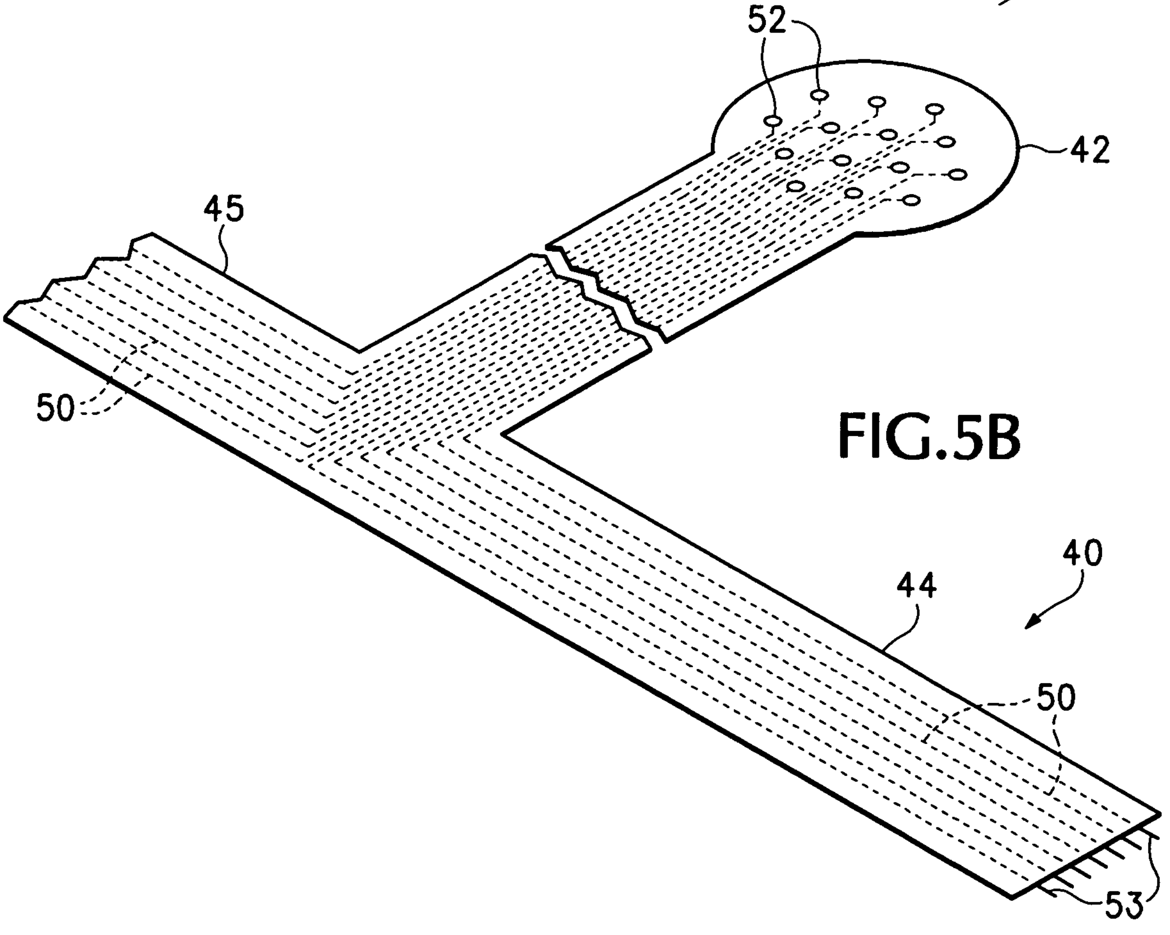

FIG.5B

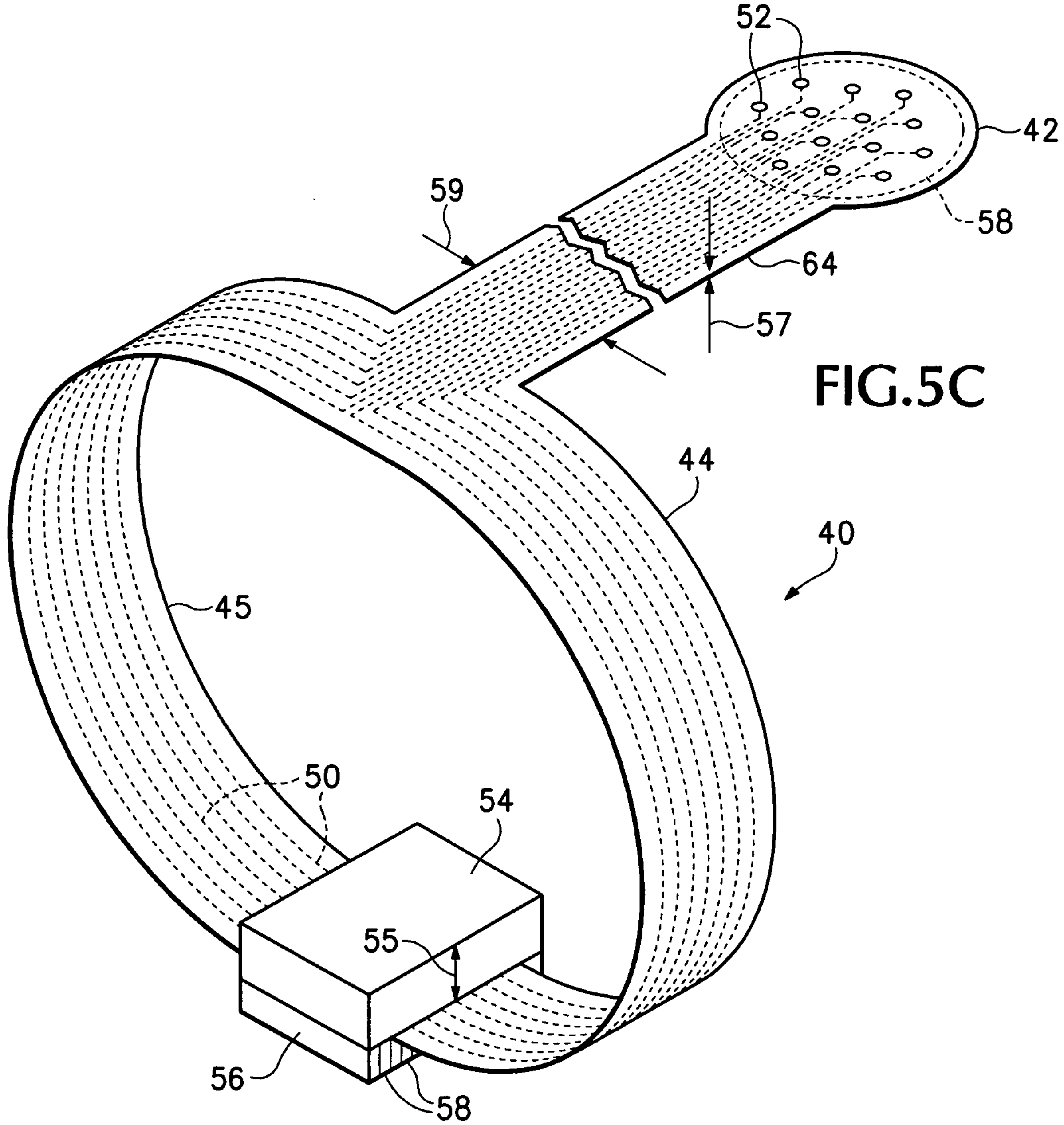

FIG.5C

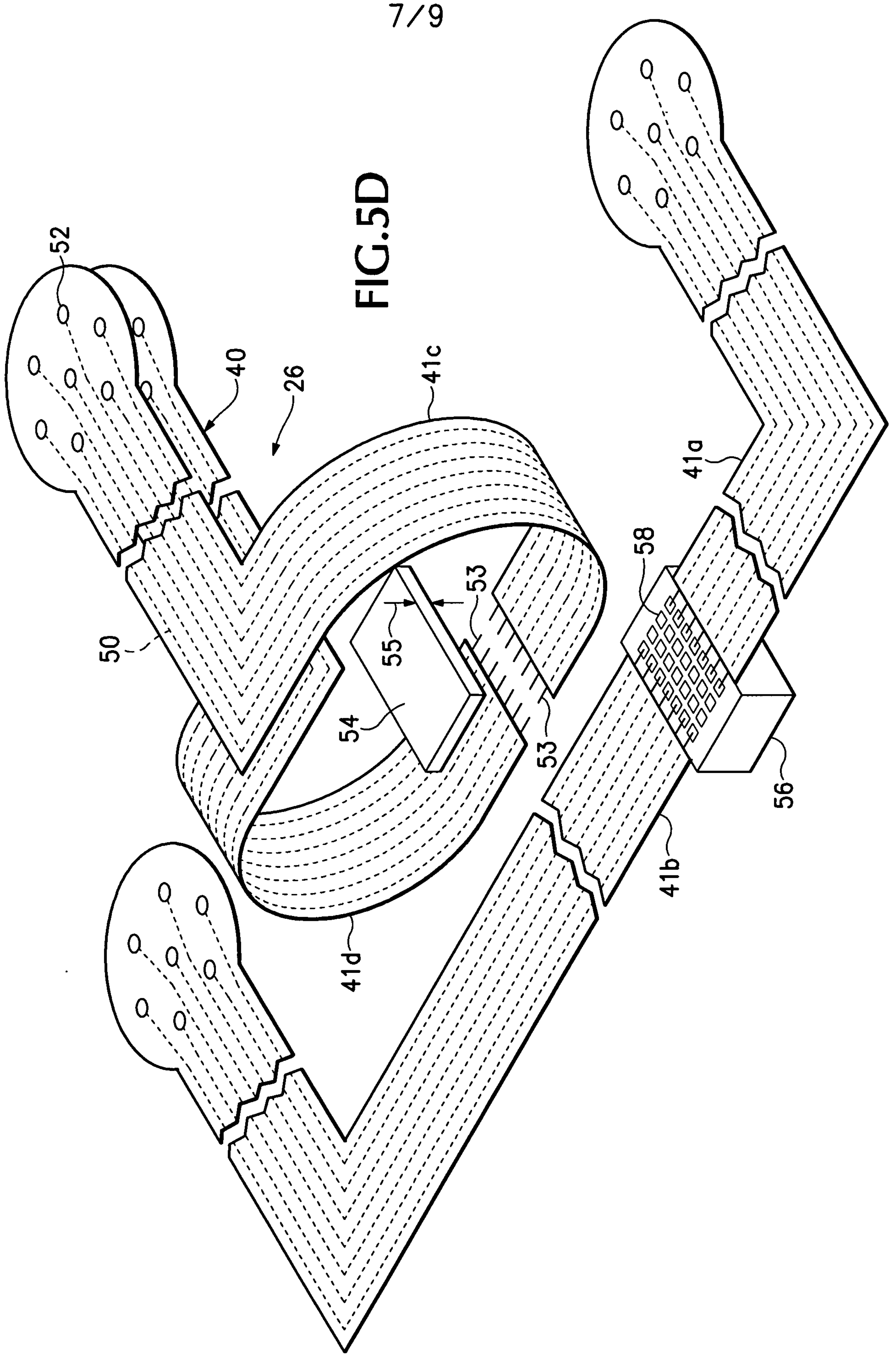

FIG.5D

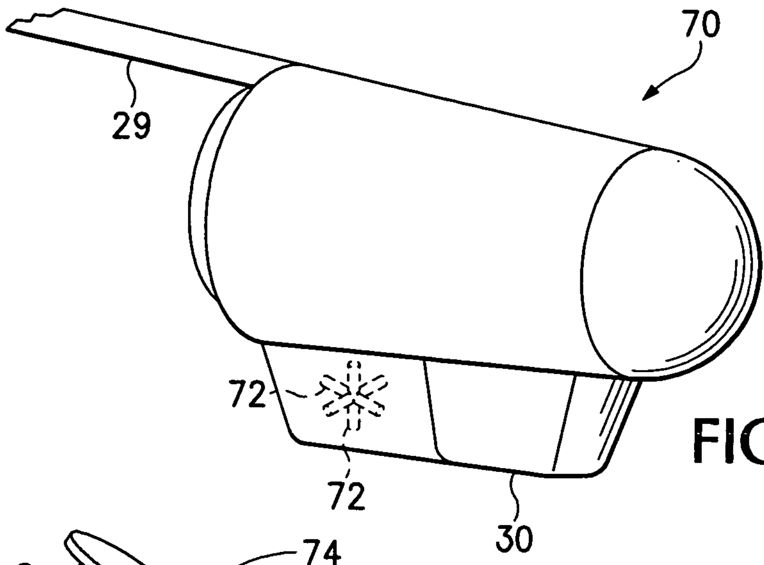

FIG.6

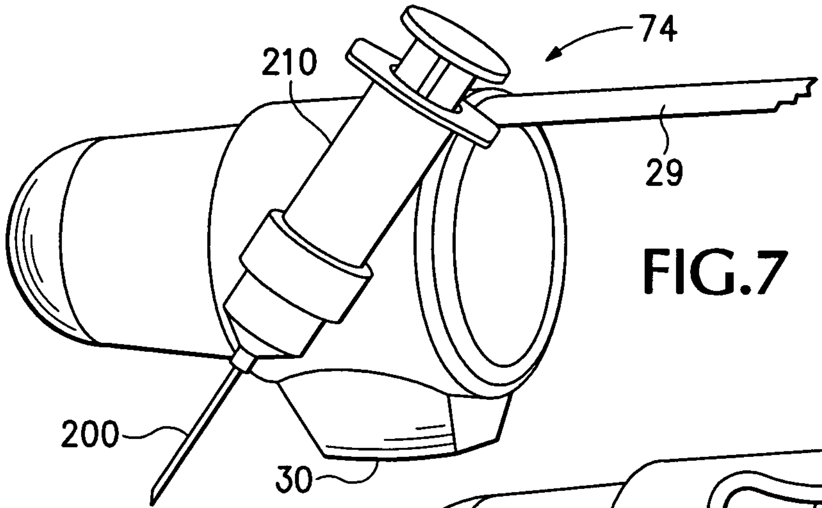

FIG.7

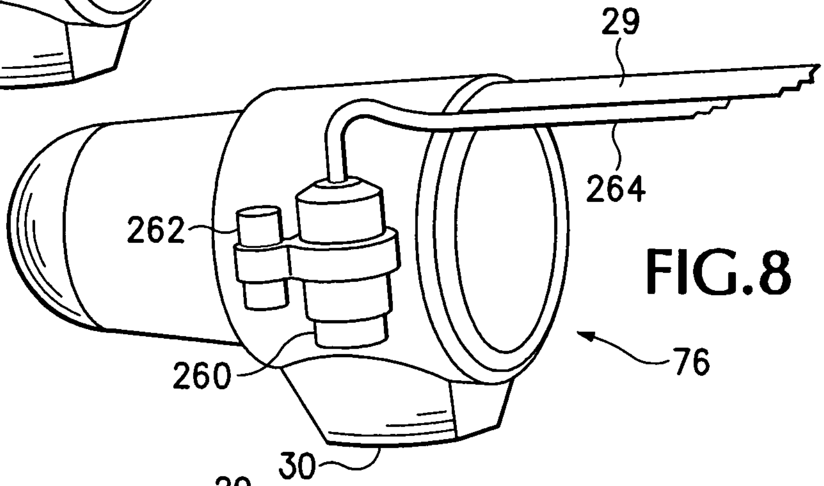

FIG.8

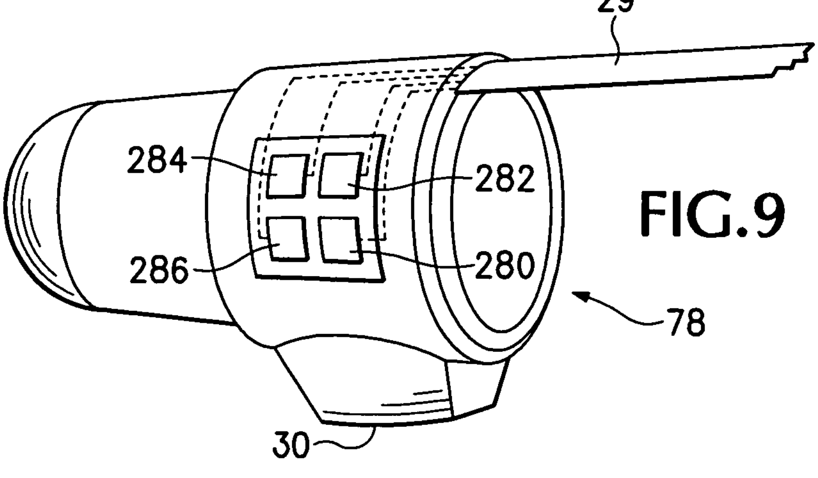

FIG.9

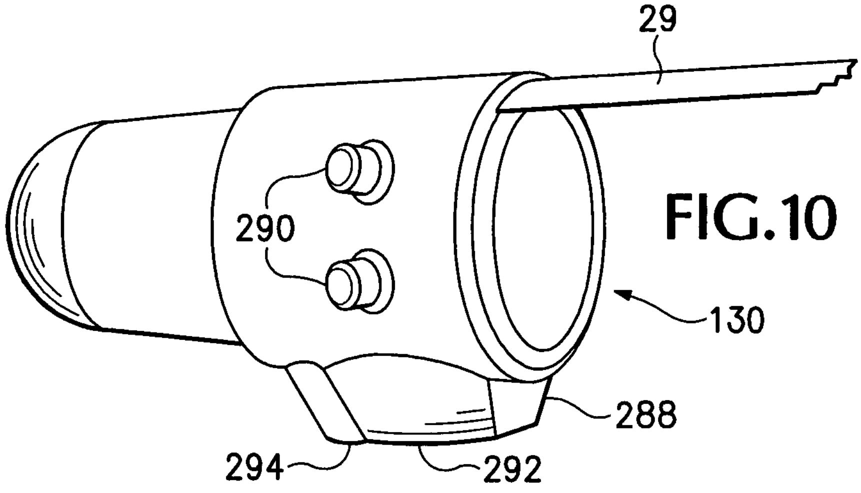

FIG.10

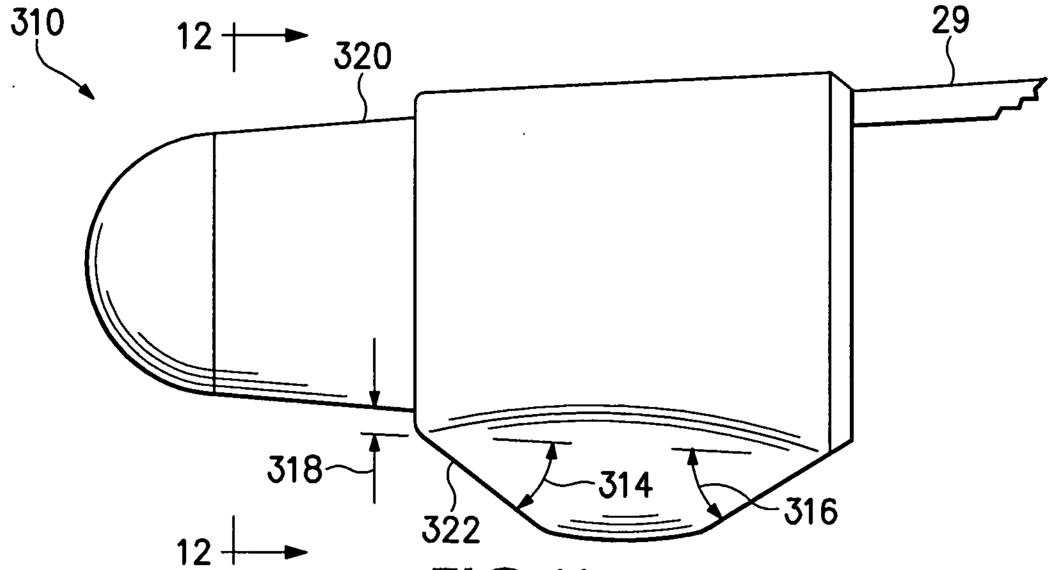

FIG.11

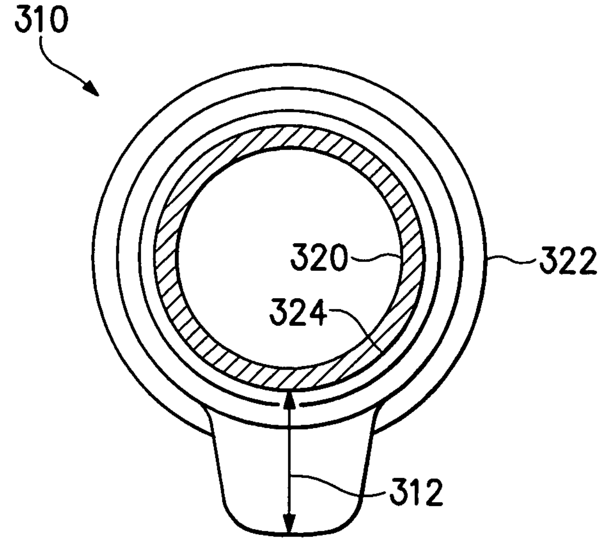

FIG.12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2008/012110

A. CLASSIFICATION OF SUBJECT MATTER

A61B 8/00(2006.01)i, A61B 8/02(2006.01)i, A61B 18/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC8 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Utility models and applications for Utility models since 1975
Japanese Utility models and applications for Utility models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) and keywords "connector, probe, ultrasound, images, finger, mount, electrical, sensor, cable, display, and similar terms"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 7,297,115 B2 (Bates et al.) 20 November 2007 See abstract, Figures 1-15 and claims 1-29	1-34 35-50
A Y	US 6,290,649 B1 (Miller et al.) 18 September 2001 See abstract, Figures 1-4 and claims 1-24	1-34 35-50
A	US 2004-0225217 A1 (Voegele et al.) 24 November 2004 See abstract, Figures 1-6 and claims 1-8	1-50

☐ Further documents are listed in the continuation of Box C.　　☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 JULY 2009 (22.07.2009)	**23 JULY 2009 (23.07.2009)**

Name and mailing address of the ISA/KR
Korean Intellectual Property Office
Government Complex-Daejeon, 139 Seonsa-ro, Seo-gu, Daejeon 302-701, Republic of Korea
Facsimile No. 82-42-472-7140

Authorized officer
KIM, Jun Hak
Telephone No. 82-42-481-5785

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2008/012110

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 07297115 B2	20.11.2007	EP 1771110 A2	11.04.2007
		JP 201-08-504944 A	21.02.2008
		US 2004-0111029 A1	10.06.2004
		US 2005-0096554 A1	05.05.2005
		WO 2005-120338 A3	22.12.2005
		WO 2005-120338 A2	22.12.2005
US 06290649 B1	18.09.2001	None	
US 2004-0225217 A1	11.11.2004	AU 2004-212940 A1	02.09.2004
		CA 2515854 A1	02.09.2004
		EP 1596717 A4	22.03.2006
		EP 1596717 A2	23.11.2005
		JP 2006-517841 A	03.08.2006
		JP 2004-009405 A	15.01.2004
		US 07073899 B2	11.07.2006
		US 2004-0004652 A1	08.01.2004
		WO 2004-073496 A2	02.09.2004