State of the Market

A Review of Ambulatory Blood Pressure Monitoring Devices

Eoin O'Brien, Neil Atkins, Jan Staessen

Abstract The introduction of 24-hour ambulatory blood pressure measurement into clinical practice created a large market for ambulatory blood pressure measurement devices. Forty-three such devices from 31 manufacturers or suppliers are now available to satisfy a market demand that is likely to increase. The aim of this article is to identify the devices available and then to examine critically any validation studies assessing accuracy and performance. Of the 43 devices available 18 have been validated according to the protocols of the Association for the Advancement of Medical Instrumentation (AAMI) or the British Hypertension Society (BHS) in 25 reported studies. In 9 of these studies the protocol was not adhered to, and the results, which are therefore questionable, are noted but not considered further. Fourteen devices were evaluated according to the accuracy criteria of both protocols, and of these 9 fulfilled the requirements. From this review of 43 devices on the market it may be concluded that, at the time of writing, there is published evidence for only 9 devices meeting the generally accepted AAMI and BHS criteria for accuracy and performance; these are the A&D TM-2420 models 6 and 7 and TM-2421, CH-Druck, Nissei ABPM DS-240, Profilomat, QuietTrak, and SpaceLabs SL-90202 and SL-90207. (***Hypertension.* 1995;26:835-842.**)

Key Words • blood pressure monitoring, ambulatory • equipment design • evaluation studies • durable medical equipment

When the technique of blood pressure measurement was introduced to clinical medicine in the early years of the 20th century the importance of accuracy and the limitations of the technique were well recognized.[1] However the standards called for by the clinicians and scientists who pioneered the technique were relaxed as the 20th century progressed. Now once again the methodology of measurement in both clinical practice and research in hypertension is recognized as a cause for concern.[2] The first serious approach to device validation was that of Halls Dally,[3] who in 1926 called in the help of The National Physics Laboratory to endorse the claim of the manufacturer regarding the accuracy of the then-new Baumanometer. Since the 1930s various national bodies such as the American Heart Association, the British Cardiac Society, and the World Health Organization have endorsed the importance of the accuracy of devices, but none have stated how this was to be achieved.[4-12] Likewise national standards institutions have emphasized the issue but usually do not have the authority to impose minimal accuracy standards.[13-15] The importance of accurate devices recently has been voiced more strongly by individuals involved in hypertension research, as is evident from the growing number of publications on this subject.[16]

In the 1960s and 1970s individual groups, frustrated by the failure of manufacturers to produce evidence to match their claims, began to validate measuring systems according to a variety of protocols and so illustrated the need for independent device validation.[17-25] Several of these ad hoc protocols have been applied to the evaluation of some of the more expensive ABPM systems.[26-31] However well intentioned such protocols may be, they have the serious disadvantage of not permitting comparison between devices because of the differing methods of validation in these protocols.[32]

In 1987 the AAMI published the *American National Standard for Electronic or Automated Sphygmomanometers,* which included a protocol for the evaluation of device accuracy,[33] and publication of this protocol was followed in 1990 by publication of the protocol of the BHS.[34] These protocols, which differed in detail, had a common objective, namely to standardize validation methods and thus to establish minimum standards of accuracy and performance as well as facilitate comparison between devices.[35,36] Both protocols have been revised recently.[37-40] Although other countries such as Germany and Australia have included recommendations for testing the accuracy of ABPM devices in their national standards, validation studies have not been published for these protocols, which therefore will not be considered further in this review. Ng and Small[41,42] have reviewed the differences between national protocols for validation in considerable detail.

Some workers have protested protocol standardization, however, being of the view that innovative methods of device evaluation might be discouraged.[43] In particular, the BHS reservations concerning comparison of noninvasive devices with direct intra-arterial measurement have been questioned.[43,44] These reservations not only were based on the ethical issue of performing intra-arterial measurement in healthy volunteers but also arose because intra-arterial techniques give different blood pressures than those obtained by noninvasive methods.[40] Nevertheless, the revised BHS protocol recognized that centers with expertise in intra-arterial mea-

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Selected Abbreviations and Acronyms
AAMI = Association for the Advancement of Medical Instrumentation
ABPM = ambulatory blood pressure measurement
BHS = British Hypertension Society

surement might be able to provide valuable information on performance of devices in ambulatory conditions, which otherwise might not be obtained.[40]

It is therefore possible to identify five different approaches to categorizing ABPM devices for the development of validation procedures: (1) devices that have not been validated independently; (2) devices that have been validated by ad hoc protocols; (3) devices that have been validated according to the AAMI protocol alone; (4) devices that have been validated according to the BHS and AAMI protocols; and (5) devices that have been validated by use of intra-arterial comparison methods. The first four approaches are the subject of this review. Intra-arterial comparisons are difficult to evaluate because of differing methodologies, and their main function has been to provide information on performance during exertion.[45-53]

ABPM Devices Not Subjected to Validation According to AAMI or BHS Protocols

In a recent review of more than 400 automated noninvasive blood pressure monitors Ng and Small[54,55] reviewed the methods of ABPM devices currently available. By combining data from the report of Ng and Small with our research we have identified 43 ABPM systems (from 31 suppliers and manufacturers; see "Appendix") that have been marketed in recent years and that could be in clinical use at the time of writing (Table 1). We estimate that 10 of these systems have been superseded by later models but may still be in clinical use.

The BHS protocol recommends that the results of validation studies be published in peer-reviewed journals, and a search of the literature shows that of the 43 systems identified only 18 have been subjected to independent validation with either the BHS or AAMI protocol. Put another way only 9 of the 31 suppliers and manufacturers have had their products validated (Table 1). Our listing of those devices that have not been independently validated does not carry any implications as to their accuracy but merely informs readers that to date such validations have not been performed or if they have the results have not been published in the indexed medical journals. We also acknowledge that many of the ABPM devices now available have been produced only recently, and procedures for validations may be planned or under way.

ABPM Devices Validated by Ad Hoc Protocols

Validations according to various ad hoc protocols were the first step in evaluation of ABPM and other blood pressure measurement systems.[17-31] Although many useful observations were made in these studies they are now of historical interest rather than being applicable to contemporary practice because most of the devices so validated have been replaced by newer models. However, these studies formed the foundation on which the AAMI and BHS built their standardized protocols.[38,39]

ABPM Devices Validated According to the AAMI Protocol Alone

The ABPM systems of three manufacturers have been validated according to the first AAMI protocol[33]: the Accutracker, the Medilog, and the TM-2420 (Table 2). Nine validation studies were performed on various models of these devices, but all nine studies failed to adhere strictly to the AAMI protocol recommendations.[52,56-63] An important protocol violation that occurred in eight studies was substitution of the Hawksley random-zero sphygmomanometer for the mercury sphygmomanometer recommended in the protocol[52,56-59,61-63] to reduce observer bias, but the Hawksley device subsequently was shown to underestimate blood pressure[64]; we previously presented the consequences that this may have on validation studies.[65] In a further study we compared a database of paired blood pressure measurements made with the Hawksley random-zero sphygmomanometer and a standard mercury sphygmomanometer with a database of paired measurements made with a SpaceLabs SL-90202 ambulatory recorder and a standard sphygmomanometer to determine how the SL-90202 recorder would have fared if it had been assessed against the Hawksley random-zero sphygmomanometer instead of a standard sphygmomanometer. Replacing the standard with the Hawksley sphygmomanometer reversed the direction of the average measurement error found and demoted the SL-90202 recorder measurement from BHS grades C and B, for systolic and diastolic accuracy, respectively, to grade D overall, the lowest rating of accuracy in the BHS grading system.[66] Thus the conclusions of the eight validation studies in which the Hawksley device was substituted for the standard sphygmomanometer are questionable[52,56-59,61-63] because we do not know how the results of these studies were affected by the use of the Hawksley sphygmomanometer.

Another serious protocol violation, which occurred in two studies, was that the numbers of subjects recruited were well below that stipulated in the AAMI and BHS protocols, and thus the results also must be regarded as questionable.[57,60]

Another confounding issue apart from the importance of adhering strictly to protocols in conducting validation studies is the lack of information as to which device model is being validated. The BHS protocols emphasize the importance of having the manufacturer indicate any modifications made to ABPM devices by changing the model number.[34,40] The importance of this stricture is well illustrated by the conflicting reports from several laboratories on the accuracy of the Takeda TM-2420 (A&D).[52,60-63,67,68] The results of individual studies on this device, which have been reviewed in detail elsewhere,[69] show that apparent differences between laboratories can be accounted for by the manufacturers submitting a different model for validation without indicating whether the original device was modified. We hope this trend has passed, and it is perhaps significant that recent reports on the A&D systems stipulate which model is being used.[49,70,71]

ABPM Devices Validated According to AAMI and BHS Protocols

Thirteen ABPM systems[70-84] have been evaluated according to both the original BHS[34] and AAMI crite-

TABLE 1. Forty-three ABPM Systems Currently on the Market

Device	Mechanism	Validation Reference
A&D Engineering Co, Ltd		
TM-2420		
Models 1-5	A	52,60-63,71,72
Model 6	A	49
Model 7	A	70
TM-2421	O/A	71
BioAnalogics Systems Inc		
ABP Monitor	A	...
Biotrac Inc		
Auto-Cuff ABP-1001	O	...
Circadian Inc		
BP Mate	O	...
Colin Medical Instruments Corp		
ABPM 630	O	...
Del Mar Avionics		
Pressurometer IV	A/E (optional)	76
Disetronic Medical Systems AG		
CH-DRUCK (PressureScan in Germany)	A	77
Profilomat	A	78
GH Medical Inc		
ABP 901	O	...
Healthcare Technology Ltd		
Pulse Time BP-10 monitor/watch	P	...
BP-50 monitor	P	...
Hill-Med Corp		
Revelation system	O	...
IDT France		
Nissei DS-240	A/O/E (optional)	79
I.E.M. Electromedicina, S.L.		
ACP 2200	O	...
Adis II	O	...
I.E.M. GmBH		
Mobil-O-Graph	O	...
Imex Medical Systems Inc		
ABP 9000	A	...
Instromedix Inc		
BARO-GRAF 24	A	...
Kontron Instruments		
AM 5200 Micro Recorder	O/E	...
AM 5600 Micro Recorder	O	...
Novacor		
DIASYS 200	A/E (optional)	75
Oxford Medical, Ltd		
Medilog ABP	A/E	58,59
PAR Medizintechnik GmBH		
PAR-PHYSIO-PORT III (TONOPORT II, in Germany)	A/E	...
PAR-PHYSIO-PORT IIIA (TONOPORT III, in Germany)	O	...
Pilger Medizin-Elektronik		
Custo Screen	O	...
PulseTrend Inc		
PulseTrend ABP	O	...
Save 33 Electronique Medicale		
Mapa 33	O	...
Schiller AG		
Schiller BR-102	A/O	...
SpaceLabs Medical Inc		
SL-90202	O	73
SL-90207	O	74,83,84
First Medic 310	O	...
Stuart Medical Inc		
SmartLINK ABP 310	A/O/E/R	...
Suntech Medical Instruments Inc		
Accutracker II	A/E	56,57
Accutracker II (version 20-23)	A/E	80
Accutracker Dx	A/E	...
Suzuken Co Ltd		
Kenz-BPM AM-200 recorder	O/A	...
TNO Biomedical Instrumentation		
Portapres Model-2	F/V	...
Tycos Instruments Inc		
QuietTrak (TENSO24 in Germany)	A/E (optional)	81,82
Zewa AG		
Delwa-Star 24	O/A/E (optional)	...
Zymed Inc		
Multitrak-Plus ABP/ECG	A/E/R	...

For "Device," device names and models, in some cases, are listed under the name of the supplier or manufacturer. Contact information on suppliers and manufacturers is listed in the "Appendix."

Mechanism codes are as follows: O indicates oscillometric; A, auscultatory; E, ECG gating; P, pulse-wave velocity; R, ECG recording; F, finger occlusion; and V, vascular unloading.

This list was compiled in January 1995 and includes ABPM systems either currently on the market or recently available and still in use. Much of the data were modified with permission from Ng and Small.[54]

ria,[33] and more recently the revised AAMI protocol was used for validation (Table 3).[81] These studies, unlike the earlier studies mentioned above in which only the AAMI protocol was used, complied generally with BHS and AAMI protocol requirements. Moreover, two validation studies in which both protocols were used have been performed with pregnant women.[83,84]

Expert committees[38,40] and steering committees of some studies[85-87] have recommended independent validation of devices for clinical practice and research. Of the many ABPM devices available, only nine fulfill both the BHS and AAMI criteria in that they achieved at least a grade of B/B for both systolic and diastolic pressures,[40] and the mean difference between the ambulatory device and a mercury standard was less than 5 mm Hg with a standard deviation of less than 8 mm Hg.[38] These devices are the CH-Druck, Nissei ABPM DS-240, Profilomat, QuietTrak, SpaceLabs SL-90202 and SL-90207, and A&D Takeda TM-2420 models 6 and 7 and TM-2421. Moreover, the SpaceLabs SL-90207 fulfilled the criteria of both protocols in pregnant women[83,84] (Table 4).

Two devices, the Novacor DIASYS 200 R[75] and the Accutracker II (version 30/23),[80] fulfilled the AAMI criteria for systolic and diastolic pressures and satisfied the BHS criteria for systolic but not diastolic pressure. The early A&D TM-2420 models[72] and the Del Mar Avionics Pressurometer IV[76] failed to fulfill the criteria of either protocol.

Discussion

ABPM is now recognized to be a useful procedure in clinical practice, an occurrence that has created a large market with many ABPM device manufacturers. The potential purchaser faced with attractive advertising brochures and persuasive sales talk may have difficulty

TABLE 2. Results of Nine Validation Studies Performed With the AAMI Protocol Alone

Device	Study	Compliance With Accuracy Criteria	Comments
A&D TM-2420*‡	Jamieson et al[60]	Pass	Few subjects, protocol violation
	Clark et al[61]	Pass	HRZS, protocol violation
	Clark et al[62]	Pass	In pregnant women, HRZS, protocol violation
	Clark et al[63]	Pass	In elderly, HRZS, protocol violation
	Hoegholm et al[52]	Pass	HRZS, protocol violation
Accutracker*	Jyothinagaram et al[57]	Fail	HRZS, protocol violation
Accutracker II	O'Brien et al[56]	Fail	HRZS, protocol violation
Medilog*	Hope et al[59]	Pass	HRZS, protocol violation
	Radaelli et al[58]	Pass	HRZS, after exercise, protocol violation

HRZS indicates testing with Hawksley random-zero sphygmomanometer.
*Model number not denoted.
‡Early models of this device were known as the Takeda Medical TM-2420.

determining the accuracy of any given ABPM device. Two national bodies, the AAMI[38] and the BHS,[40] have recommended that all blood pressure measuring devices be validated carefully before being introduced into clinical practice. This review was undertaken to examine the published evidence for the accuracy and performance of all known ambulatory systems on the market.

We identified 43 ABPM devices from 31 suppliers and manufacturers. Three devices had been validated by the AAMI protocol alone in nine studies, but the protocol had been violated in all instances. The results are therefore questionable, and we did not consider these devices in the final assessment. Fourteen ABPM devices have been evaluated according to both protocols. Of these, nine fulfilled both the BHS and AAMI criteria in that they achieved at least a grade of B/B for systolic and diastolic pressures and the mean difference between the ambulatory device and a mercury standard was less than 5 mm Hg with a standard deviation less than 8 mm Hg.[38,40]

TABLE 3. ABPM Systems Subjected to Validation According to the BHS and AAMI Protocols

Device	Study	AAMI	BHS
Accutracker II (version 30/23)	Taylor et al[80]	Pass	A/C
CH-DRUCK*	O'Brien et al[77]	Pass	A/A
DIASYS 200	O'Brien et al[75]	Pass	C/C
Nissei DS-240	Mee et al[79]	Pass	B/A
Pressurometer IV	O'Brien et al[76]	Fail	C/D
Profilomat*	O'Brien et al[78]	Pass	B/A
QuietTrak*	White et al[81]	Pass	B/B
SpaceLabs			
SL-90202	O'Brien et al[73]	Pass	B/B
SL-90207	O'Brien et al[74]	Pass	B/B
	O'Brien et al[84]	Pass	A/C, Pregnancy
	Shennan et al[83]	Pass	B/C, Pregnancy
A&D			
TM-2420*	O'Brien et al[72]	Fail	D/D
TM-2420 model 5	Imai et al[71]	Pass	C/C
TM-2420 model 6	White et al[49]	Pass	B/B
TM-2420 model 7	Palatini et al[70]	Pass	B/B
TM-2421	Imai et al[71]	Pass	B/A

For BHS protocol, A indicates best agreement with mercury standard sphygmomanometer; D, worst agreement with mercury standard sphygmomanometer. Pregnancy indicates that the device was tested on pregnant women.
*Model number not denoted.

As noted above, of 43 ABPM devices available only 9 fulfilled AAMI and BHS criteria to ensure reasonable accuracy in clinical use (Table 4), and for 28 devices no published evidence of independent validation according to either the AAMI or BHS protocol could be found at the time this article was written. We again emphasize that the publishing process is often lengthy and that manufacturers may have conducted or may be conducting independent validation studies on many of the devices listed in this review. However we also emphasize the importance of publishing such results as recommended by the BHS protocol[40] so that device accuracy and performance occasionally can be reviewed. One might argue that it should be sufficient for the manufacturer or supplier to provide evidence of independent validation according to a standardized, albeit unpublished, protocol, but the evidence from this review demonstrating that protocol violations are common also illustrates the need for the critical peer-review process that is a prerequisite of scientific publication. One problem with this policy is that the hypertension journals have scarce space to provide for publication of somewhat repetitive, albeit important, data. The *Journal of Hypertension* facilitated the early publication of validation studies by publishing short summary reports of validation studies within the regular journal issue and then publishing the full report later in a supplement. The

TABLE 4. Nine ABPM Devices That Have Fulfilled BHS and AAMI Accuracy Criteria as of January 1995

Device	AAMI	BHS Grade
CH-DRUCK	Pass	A/A[77]
Profilomat	Pass	B/A[78]
Nissei DS-240	Pass	B/A[79]
QuietTrak	Pass	B/B[81,82]
SpaceLabs		
SL-90202	Pass	B/B[73]
SL-90207	Pass	B/B[74,83,84]
A&D		
TM-2420 model 6	Pass	B/B[49]
TM-2420 model 7	Pass	B/B[70]
TM-2421	Pass	B/A[71]

For fulfillment of BHS protocol, device must achieve at least grade B/B (where A indicates best agreement with mercury standard sphygmomanometer; D, worst agreement). For fulfillment of AAMI standard, mean difference ≤5/≤8 mm Hg (SD). References are to studies that reported validation results for these devices.

Journal of Blood Pressure Monitoring, which is to be launched soon, will provide for publication of validation studies among a number of other functions in this growing area of interest (Prof William White, The University of Connecticut Health Center, Farmington, personal communication, 1995).

We are aware of two untoward practices to which attention should be drawn. First, some manufacturers may have applied the favorable validation results of one model to another model that has not been validated. The BHS protocol clearly states that each model must be subjected to independent validation.[40] Second, some manufacturers claim to have satisfied a protocol by quoting the results of published work in which the AAMI or BHS criteria are applied to data derived from a validation study that did not adhere to the protocol requirements.

This review of the state of the market also has allowed us to look to the trends in manufacturing practice. The next generation of devices for ABPM will be smaller, quieter, and considerably cheaper than many of its predecessors. The trend is toward oscillometric rather than auscultatory measurement techniques, although many devices may combine both methods. Other methods of measurement such as pulse-wave–velocity detection, which is not dependent on cuff occlusion, may be developed.[54] The vascular unloading technique, which is used in the Finapres device[88] and which gives continuous rather than intermittent blood pressures, is confined to research laboratories at present, but a clinical role can be anticipated. ECG gating is being used less frequently, and as algorithms improve its use for conferring greater accuracy will have to be balanced against the major disadvantages of the time required for its application and the discomfort to the male subject whose chest must be shaved before use. Devices that combine ECG and ABPM techniques are likely to be used in certain clinical circumstances. The combination of a motion-logging system and ABPM would be a welcome development that would permit standardization of ABPM in relation to activity, especially when repeat ABPMs are being performed.

Device validations are protracted procedures requiring considerable involvement of trained personnel and careful supervision.[36] It has been estimated that the cost of performing a full validation according to the original BHS protocol is about British sterling £25 000.[36] This figure is likely to be appreciably higher for validation studies performed according to the revised protocols, particularly if both the AAMI and BHS criteria are fulfilled.[89] Likewise, ABPM systems incorporating two measurement methods, such as Korotkov sound detection and oscillometry, should be validated for both methods, an exercise that adds appreciably to the cost of validation. Future technological developments should improve device validation procedures. For example, noninvasive blood pressure simulators now being developed can be expected to reduce dependence on hypertensive subjects for validation of oscillometric devices.[41,42] The manufacture of a reliable automated device will reduce dependency on observer-measured blood pressure so that it will be possible to simplify further the validation procedure. The introduction of audiovisual methods of recording Korotkov sounds simultaneously with the use of a falling column of mercury also may be expected to reduce dependency on observers.[90] However, it must be emphasized that all such innovative techniques must be subjected to careful validation before being introduced into research methodology.

The adoption of standards by ABPM device manufacturers may not be easily effected. One of the important points to emerge from this review is the need to persuade manufacturers of the importance of having the ABPM devices validated before placing these devices on the market. In fact, this principle should apply to all blood pressure measuring devices. At present manufacturers are not obliged to guarantee the accuracy of their products, although most reputable manufacturers welcome the opportunity to have their devices evaluated independently according to a generally accepted protocol. The European community has established a working party (CEN/TC 205/WG 10 Non-invasive sphygmomanometers) to draw up a standard for all ABPM devices, and in 1996 a directive will be issued that will be legally binding on member states.[91]

The process of encouraging manufacturers of ABPM systems to have their products evaluated independently according to an approved evaluation procedure has been influenced positively by editors of general medical, clinical pharmacology, and hypertension journals seeking evidence supporting the accuracy of ABPM systems used in research studies. Health authorities and sponsoring organizations should purchase only equipment that has been evaluated adequately. The protocols of some hypertension studies, such as the Syst-Eur (Systolic Hypertension in the Elderly) study,[85] the APTH (Ambulatory Blood Pressure and Treatment of Hypertension) study,[86] and the OvA (Office Versus Ambulatory Measurement) study,[87] stipulate that no automated system can be used in the study unless it is evaluated independently by use of an accepted validation protocol.

Our concluding statement is devoted to expressing a degree of scientific disquiet. The AAMI published its protocol in 1987[33] and revised it in 1993,[38] and in 1990 the BHS constituted a Working Party that published a protocol for validation of ABPM devices[34] that was revised in 1993.[40] In spite of this we have had to write six letters in the year before publication of this article alerting researchers and potential purchasers of blood pressure measurement devices that the results of validation studies published in peer-reviewed journals were questionable or invalid because the devices being considered failed to comply with protocol requirements.[92-97] That such letters have had to be written at all is disquieting but that they may inevitably fail to influence the published statement of the original article is a cause for even greater concern.

Appendix: ABPM Device Suppliers and Manufacturers

A&D Co, Ltd, 3-23-14 Higashi-Ikeburo, Tokyo, Japan; phone, 3-5391-6123; fax, 3-5391-6148.

BioAnalogics Systems Inc, 9000 SW Gemini, Beaverton, OR 97005; phone, 800-327-7953; fax, 503-641-4031.

Biotrac Inc, 9261 130th Ave N, Largo, FL 34643-1304; phone, 813-584-9129; fax, 813-397-9893.

Circadian Inc, 3942 N First St, San Jose, CA 95134; phone, 800-669-7001; fax, 408-434-9585.

Colin Medical Instruments Corp, University Technology Park, 5850 Farinon Dr, San Antonio, TX 75249; phone, 800-829-6427; fax, 210-696-8808.

Del Mar Avionics, 1601 Alton Ave, Irvine, CA 92714-4878; phone, 800-854-0481; fax, 714-261-0529.

Disetronic Medical Systems AG, Brunnmattstr 6, CH-3401 Burgdorf, Switzerland; phone 41-34-23-13-33; fax, 41-34-23-13-85.

GH Medical Inc, 2010 E Hennepin Ave, Minneapolis, MN 55413; phone, 612-623-3966; fax, 612-378-1937.

Healthcare Technology Ltd, York House, City Fields Business Park, Tangmere, West Sussex, UK; phone, 44-1243-528-800; fax, 44-1243-774-728.

Hill-Med Corp, 7215 NW 46th St, Miami, FL 33166; phone, 305-594-7474; fax, 305-477-0699.

IDT France, 15 rue Boileau, 66000 Perpignan, France; phone, 33-68-35-4620; fax, 33-68-34-0945.

I.E.M. Electromedicina, S.L, Plaça del Poble, 27, 08410 Vilanova del Vallès, Barcelona, Spain; phone, 34-3-845-61-28; fax, 34-3-845-60-12.

I.E.M. GmBH, Eifelstr 20, D-52224 Stolberg, Germany; phone, 49-2402-7-59-01; fax, 49-2402-7-28-19.

Imex Medical Systems Inc, 6355 Joyce Dr, Golden, CO 80403; phone, 800-525-2519; fax, 303-431-0429.

Instromedix Inc, One Technology Center, 7431 NE Evergreen Pkwy, Hillsboro, OR 97124-5898; phone, 800-633-3361; fax, 503-681-8230.

Kontron Instruments, Via G. Fantoli, 16/15, 20138 Milano, Italy; phone, 39-2-50721; fax, 39-2-506-0918.

Novacor, 4 passage Saint-Antoine, 92508 Rueil-Malmaison, Cedex, France; phone, 33-1-47-08-06-66; fax, 33-1-47-32-45-76.

Oxford Medical, 1 Kimber Rd, Abingdon, Oxon OX14 1BZ, UK; phone, 44-1235-533-433; fax, 44-1235-534-465.

PAR Medizintechnik GmBH, Einemstr 9, D-10787 Berlin, Germany; phone, 49-30-2-13-90-55; fax, 49-30-2-13-85-42.

Pilger Medizin-Elektronik, Speicherstr 48, 9000 St Gallen, Germany; phone, 49-71-22-30-16; fax, 49-71-22-30-04.

PulseTrend Inc, 2010 E Hennepin Ave, Suite 220, Minneapolis, MN 55413; phone, 800-584-6686; fax, 612-623-7748.

Save 33 Electronique Medicale, PO Box 25, 124 rue Emile Zola, 59860 Bruay sur Escaut, France; phone, 33-27-29-55-44; fax, 33-27-29-55-67.

Schiller AG, Altgasse 68, CH-6340 Baar, Switzerland; phone, 41-42-33-43-53; fax, 41-42-31-08-80.

SpaceLabs Medical Inc, PO Box 97013, 15220 NE 40th St, Redmond, WA 98073-9713; phone, 800-251-9910; fax, 206-885-4877.

Stuart Medical Inc, 11403 Cronhill Dr, Suite B, Owings Mills, MD 21117; phone, 800-377-5378; fax, 410-581-1513.

Suntech Medical Instruments Inc, 8608 Jersey Court, Raleigh, NC 27613; phone, 800-421-8626; fax, 919-782-9113.

Suzuken Co Ltd, 1-6-10 Shimizu, Kita-ku, Nagoya 462, Japan; phone, 81-52-971-3641; fax, 81-52-962-7440.

TNO Biomedical Instrumentation, Suite G1-111, Meibergdreef 9, 1105 AZ Amsterdam, the Netherlands; phone, 20-566-58-44; fax, 20-697-64-24.

Tycos Instruments Inc, A Welch Allyn Co, 95 Old Shoals Rd, Ardern, NC 28704; phone, 704-684-4895; fax, 704-687-1002.

Zewa AG, Seestr 7a, CH-6052 Hergiswil, Switzerland; phone, 41-36-51-88; fax, 41-36-53-36.

Zymed Inc, 20 N Aviador St, CA 93010-8302; phone, 800-235-5941; fax, 805-987-9532.

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