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Lamego

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(54) **TISSUE PROFILE WELLNESS MONITOR**

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,910,701 A 10/1975 Henderson et al.
3,998,550 A 12/1976 Konishi et al.
(Continued)

FOREIGN PATENT DOCUMENTS

DE 3244695 C2 10/1985
EP 0 231 379 8/1987
(Continued)

OTHER PUBLICATIONS

US 8,845,543 B2, 09/2014, Diab et al. (withdrawn)
(Continued)

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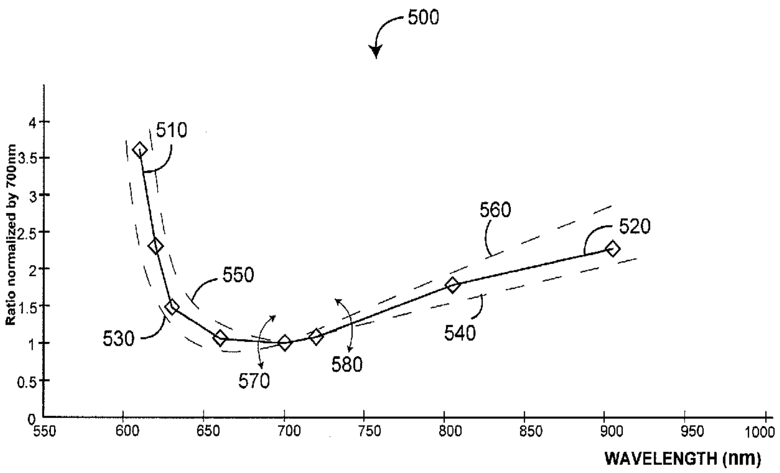
(57) **ABSTRACT**

A tissue profile wellness monitor measures a physiological parameter, generates a tissue profile, defines limits and indicates when the tissue profile exceeds the defined limits. The physiological parameter is responsive to multiple wavelengths of optical radiation after attenuation by constituents of pulsatile blood flowing within a tissue site. The tissue profile is responsive to the physiological parameter. The limits are defined for at least a portion of the tissue profile.

15 Claims, 5 Drawing Sheets



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continuation of application No. 13/764,007, filed on Feb. 11, 2013, now Pat. No. 8,965,471, which is a continuation of application No. 12/106,969, filed on Apr. 21, 2008, now Pat. No. 8,374,665.

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(56) **References Cited**

U.S. PATENT DOCUMENTS

4,014,321 A 3/1977 March
4,051,522 A 9/1977 Healy et al.
4,134,678 A 1/1979 Brown et al.
4,157,708 A 6/1979 Imura
4,163,290 A 7/1979 Sutherlin et al.
4,167,331 A 9/1979 Nielsen
4,266,554 A 5/1981 Hamaguri
4,267,844 A 5/1981 Yamanishi
4,295,475 A 10/1981 Torzala
4,305,059 A 12/1981 Benton
4,331,161 A 5/1982 Patel
4,399,824 A 8/1983 Davidson
4,446,871 A 5/1984 Imura
4,491,725 A 1/1985 Pritchard
4,531,527 A 7/1985 Reinhold, Jr. et al.
4,561,440 A 12/1985 Kubo et al.
4,586,513 A 5/1986 Hamaguri
4,603,700 A 8/1986 Nichols et al.
4,621,643 A 11/1986 New et al.
4,653,498 A 3/1987 New, Jr. et al.
4,655,225 A 4/1987 Dahne et al.
4,685,464 A 8/1987 Goldberger et al.
4,694,833 A 9/1987 Hamaguri
4,695,955 A 9/1987 Faisandier
4,700,708 A 10/1987 New et al.
4,714,341 A 12/1987 Hamaguri et al.
4,770,179 A 9/1988 New et al.
4,773,422 A 9/1988 Isaacson et al.
4,781,195 A 11/1988 Martin
4,800,885 A 1/1989 Johnson
4,805,623 A 2/1989 Jobsis
4,822,997 A 4/1989 Fuller et al.
4,832,484 A 5/1989 Aoyagi et al.
4,846,183 A 7/1989 Martin
4,854,328 A 8/1989 Pollack
4,863,265 A 9/1989 Flower et al.
4,867,571 A 9/1989 Frick et al.
4,868,476 A 9/1989 Respaut
4,869,254 A 9/1989 Stone et al.
4,890,306 A 12/1989 Noda
4,907,876 A 3/1990 Suzuki et al.
4,911,167 A 3/1990 Corenman et al.
4,934,372 A 6/1990 Corenman et al.
4,938,218 A 7/1990 Goodman et al.
4,942,877 A 7/1990 Sakai et al.
4,955,379 A 9/1990 Hall
4,960,126 A 10/1990 Conlon et al.
4,960,128 A 10/1990 Gordon et al.
4,964,010 A 10/1990 Miyasaka et al.
4,964,408 A 10/1990 Hink et al.
4,967,571 A 11/1990 Sporri
4,975,581 A 12/1990 Robinson et al.
4,975,647 A 12/1990 Downer et al.
4,986,665 A 1/1991 Yamanishi et al.
4,996,975 A 3/1991 Nakamura
4,997,769 A 3/1991 Lundsgaard
5,003,979 A 4/1991 Merickel et al.
5,025,791 A 6/1991 Niwa
RE33,643 E 7/1991 Isaacson et al.
5,028,787 A 7/1991 Rosenthal et al.
5,033,472 A 7/1991 Sato et al.
5,041,187 A 8/1991 Hink et al.
5,054,495 A 10/1991 Uemura et al.
5,058,588 A 10/1991 Kaestle et al.
5,069,213 A 12/1991 Polczynski
5,077,476 A 12/1991 Rosenthal
5,078,136 A 1/1992 Stone et al.
5,101,825 A 4/1992 Gravensetin et al.
5,137,023 A 8/1992 Mendelson et al.
5,155,697 A 10/1992 Bunsen
5,162,725 A 11/1992 Hodson et al.
5,163,438 A 11/1992 Gordon et al.
5,188,108 A 2/1993 Secker
5,189,609 A 2/1993 Tivig et al.
5,190,040 A 3/1993 Aoyagi
5,203,329 A 4/1993 Takatani et al.
5,209,230 A 5/1993 Swedlow et al.
5,226,053 A 7/1993 Cho et al.
5,226,417 A 7/1993 Swedlow et al.
5,246,002 A 9/1993 Prosser
5,247,931 A 9/1993 Norwood
5,259,381 A 11/1993 Chung
5,267,562 A 12/1993 Ukawa et al.
5,267,563 A 12/1993 Swedlow et al.
5,278,627 A 1/1994 Aoyagi
5,297,548 A 3/1994 Pologe
5,313,940 A 5/1994 Fuse et al.
5,319,355 A 6/1994 Russek
5,331,549 A 7/1994 Crawford, Jr.
5,335,659 A 8/1994 Pologe et al.
5,337,744 A 8/1994 Branigan
5,337,745 A 8/1994 Benaron
5,341,805 A 8/1994 Stavridi et al.
5,348,004 A 9/1994 Hollub
5,351,685 A 10/1994 Potratz
5,355,129 A 10/1994 Baumann
5,355,880 A 10/1994 Thomas et al.
5,355,882 A 10/1994 Ukawa et al.
5,361,758 A 11/1994 Hall et al.
5,368,041 A 11/1994 Shambroom
5,368,224 A 11/1994 Richardson et al.
D353,195 S 12/1994 Savage et al.
D353,196 S 12/1994 Savage et al.
5,370,114 A 12/1994 Wong et al.
5,372,136 A 12/1994 Steuer et al.
5,377,676 A 1/1995 Vari et al.
5,383,874 A 1/1995 Jackson et al.
5,385,143 A 1/1995 Aoyagi
5,387,122 A 2/1995 Goldberger et al.
5,392,777 A 2/1995 Swedlow et al.
5,400,267 A 3/1995 Denen et al.
5,413,101 A 5/1995 Sugiura
D359,546 S 6/1995 Savage et al.
5,421,329 A 6/1995 Casciani et al.
5,424,545 A 6/1995 Block et al.
5,425,362 A 6/1995 Siker et al.
5,425,375 A 6/1995 Chin et al.
5,427,093 A 6/1995 Ogawa et al.
5,429,128 A 7/1995 Cadell et al.
5,431,170 A 7/1995 Mathews
5,435,309 A 7/1995 Thomas et al.
D361,840 S 8/1995 Savage et al.
D362,063 S 9/1995 Savage et al.
5,452,717 A 9/1995 Branigan et al.
D363,120 S 10/1995 Savage et al.
5,456,252 A 10/1995 Vari et al.
5,469,845 A 11/1995 DeLonzor et al.
RE35,122 E 12/1995 Corenman et al.
5,479,934 A 1/1996 Imran
5,482,036 A 1/1996 Diab et al.
5,487,386 A 1/1996 Wakabayashi et al.
5,490,505 A 2/1996 Diab et al.
5,490,523 A 2/1996 Isaacson et al.
5,494,032 A 2/1996 Robinson et al.
5,494,043 A 2/1996 O'Sullivan et al.
5,503,148 A 4/1996 Pologe et al.
5,520,177 A 5/1996 Ogawa
5,528,519 A 6/1996 Ohkura et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,533,507 A 7/1996 Potratz
5,533,511 A 7/1996 Kaspari et al.
5,534,851 A 7/1996 Russek
5,551,423 A 9/1996 Sugiura
5,553,615 A 9/1996 Carim et al.
5,555,882 A 9/1996 Richardson et al.
5,561,275 A 10/1996 Savage et al.
5,562,002 A 10/1996 Lalin
5,575,284 A 11/1996 Athan et al.
5,577,500 A 11/1996 Potratz
5,584,299 A 12/1996 Sakai et al.
5,588,427 A 12/1996 Tien
5,590,649 A 1/1997 Caro et al.
5,590,652 A 1/1997 Inai
5,595,176 A 1/1997 Yamaura
5,596,992 A 1/1997 Haaland et al.
5,602,924 A 2/1997 Durand et al.
5,603,323 A 2/1997 Pflugrath et al.
5,603,623 A 2/1997 Nishikawa et al.
3,316,395 A 4/1997 Lavin
3,316,396 A 4/1997 Lavin
5,615,672 A 4/1997 Braig et al.
5,617,857 A 4/1997 Chader et al.
5,630,413 A 5/1997 Thomas et al.
5,632,272 A 5/1997 Diab et al.
5,638,816 A 6/1997 Kiani-Azarbayjany et al.
5,638,818 A 6/1997 Diab et al.
5,645,059 A 7/1997 Fein et al.
5,645,060 A 7/1997 Yorkey
5,645,440 A 7/1997 Tobler et al.
5,651,780 A 7/1997 Jackson et al.
5,658,248 A 8/1997 Klein et al.
5,660,567 A 8/1997 Nierlich et al.
5,662,106 A 9/1997 Swedlow et al.
5,676,139 A 10/1997 Goldberger et al.
5,676,141 A 10/1997 Hollub
5,678,544 A 10/1997 Delonzor et al.
5,685,299 A 11/1997 Diab et al.
5,685,301 A 11/1997 Klomhaus
5,687,719 A 11/1997 Sato et al.
5,687,722 A 11/1997 Tien et al.
5,690,104 A 11/1997 Kanemoto et al.
5,692,503 A 12/1997 Kuenstner
5,697,371 A 12/1997 Aoyagi
5,713,355 A 2/1998 Richardson et al.
5,719,589 A 2/1998 Norman et al.
5,720,284 A 2/1998 Aoyagi et al.
5,720,293 A 2/1998 Quinn et al.
5,730,125 A 3/1998 Prutchi et al.
D393,830 S 4/1998 Tobler et al.
5,742,718 A 4/1998 Harman et al.
5,743,262 A 4/1998 Lepper, Jr. et al.
5,743,263 A 4/1998 Baker, Jr.
5,746,206 A 5/1998 Mannheimer
5,746,697 A 5/1998 Swedlow et al.
5,752,914 A 5/1998 Delonzor et al.
5,755,226 A 5/1998 Carim et al.
5,758,644 A 6/1998 Diab et al.
5,760,910 A 6/1998 Lepper, Jr. et al.
5,769,785 A 6/1998 Diab et al.
5,772,587 A 6/1998 Gratton et al.
5,779,630 A 7/1998 Fein et al.
5,782,237 A 7/1998 Casciani et al.
5,782,756 A 7/1998 Mannheimer
5,782,757 A 7/1998 Diab et al.
5,785,659 A 7/1998 Caro et al.
5,790,729 A 8/1998 Pologe et al.
5,791,347 A 8/1998 Flaherty et al.
5,792,052 A 8/1998 Isaacson et al.
5,793,485 A 8/1998 Gourley
5,800,348 A 9/1998 Kaestle et al.
5,800,349 A 9/1998 Isaacson et al.
5,803,910 A 9/1998 Potratz
5,807,246 A 9/1998 Sakaguchi et al.
5,807,247 A 9/1998 Merchant et al.
5,810,723 A 9/1998 Aldrich
5,810,724 A 9/1998 Gronvall
5,810,734 A 9/1998 Caro et al.
5,817,010 A 10/1998 Hibl
5,818,985 A 10/1998 Merchant et al.
5,823,950 A 10/1998 Diab et al.
5,823,952 A 10/1998 Levinson et al.
5,827,182 A 10/1998 Raley et al.
5,830,121 A 11/1998 Enomoto et al.
5,830,131 A 11/1998 Caro et al.
5,830,137 A 11/1998 Sharf
5,833,602 A 11/1998 Osemwota
5,833,618 A 11/1998 Caro et al.
5,839,439 A 11/1998 Nierlich et al.
RE36,000 E 12/1998 Swedlow et al.
5,842,979 A 12/1998 Jarman
5,846,190 A 12/1998 Woehrle
5,850,443 A 12/1998 Van Oorschot et al.
5,851,178 A 12/1998 Aronow
5,851,179 A 12/1998 Ritson et al.
5,853,364 A 12/1998 Baker, Jr. et al.
5,857,462 A 1/1999 Thomas et al.
5,860,099 A 1/1999 Milios et al.
5,860,919 A 1/1999 Kiani-Azarbayjany et al.
5,865,736 A 2/1999 Baker, Jr. et al.
5,876,348 A 3/1999 Sugo
5,885,213 A 3/1999 Richardson et al.
5,890,929 A 4/1999 Mills et al.
5,891,022 A 4/1999 Pologe
5,891,024 A 4/1999 Jarman et al.
5,900,632 A 5/1999 Sterling et al.
5,904,654 A 5/1999 Wohltmann et al.
5,910,108 A 6/1999 Solenberger
5,916,154 A 6/1999 Hobbs et al.
5,919,133 A 7/1999 Taylor
5,919,134 A 7/1999 Diab
5,921,921 A 7/1999 Potratz et al.
5,924,979 A 7/1999 Swedlow
5,934,277 A 8/1999 Mortz
5,934,925 A 8/1999 Tobler et al.
5,939,609 A 8/1999 Knapp et al.
5,940,182 A 8/1999 Lepper, Jr. et al.
5,954,644 A 9/1999 Dettling
5,976,466 A 11/1999 Ratner et al.
5,978,691 A 11/1999 Mills
5,983,122 A 11/1999 Jarman et al.
5,987,343 A 11/1999 Kinast
5,991,355 A 11/1999 Dahlke
5,995,855 A 11/1999 Kiani et al.
5,995,856 A 11/1999 Mannheimer et al.
5,995,859 A 11/1999 Takahashi
5,997,343 A 12/1999 Mills et al.
5,999,841 A 12/1999 Aoyagi et al.
6,002,952 A 12/1999 Diab et al.
6,006,119 A 12/1999 Soller et al.
6,011,986 A 1/2000 Diab et al.
6,014,576 A 1/2000 Raley
6,018,673 A 1/2000 Chin et al.
6,018,674 A 1/2000 Aronow
6,023,541 A 2/2000 Merchant et al.
6,027,452 A 2/2000 Flaherty et al.
6,035,223 A 3/2000 Baker, Jr.
6,036,642 A 3/2000 Diab et al.
6,045,509 A 4/2000 Caro et al.
6,064,898 A 5/2000 Aldrich
6,067,462 A 5/2000 Diab et al.
6,068,594 A 5/2000 Schloemer et al.
6,073,037 A 6/2000 Alam et al.
6,081,735 A 6/2000 Diab et al.
6,083,172 A 7/2000 Baker, Jr. et al.
6,088,607 A 7/2000 Diab et al.
6,094,592 A 7/2000 Yorkey et al.
6,104,938 A 8/2000 Huiku
6,110,522 A 8/2000 Lepper, Jr. et al.
6,112,107 A 8/2000 Hannula
6,122,042 A 9/2000 Wunderman et al.
6,124,597 A 9/2000 Shehada et al.
6,128,521 A 10/2000 Marro et al.
6,129,675 A 10/2000 Jay

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,132,363 A 10/2000 Freed et al.
6,144,868 A 11/2000 Parker
6,149,588 A 11/2000 Noda et al.
6,151,516 A 11/2000 Kiani-Azarbayjany et al.
6,151,518 A 11/2000 Hayashi
6,152,754 A 11/2000 Gerhardt et al.
6,154,667 A 11/2000 Miura et al.
6,157,041 A 12/2000 Thomas et al.
6,157,850 A 12/2000 Diab et al.
6,163,715 A 12/2000 Larsen et al.
6,165,005 A 12/2000 Mills et al.
6,165,173 A 12/2000 Kamdar et al.
6,174,283 B1 1/2001 Nevo et al.
6,175,752 B1 1/2001 Say et al.
6,184,521 B1 2/2001 Coffin, IV et al.
6,192,261 B1 2/2001 Gratton et al.
6,206,830 B1 3/2001 Diab et al.
6,226,539 B1 5/2001 Potratz
6,229,856 B1 5/2001 Diab et al.
6,230,035 B1 5/2001 Aoyagi et al.
6,232,609 B1 5/2001 Snyder et al.
6,236,872 B1 5/2001 Diab et al.
6,237,604 B1 5/2001 Burnside et al.
6,241,683 B1 6/2001 Macklem et al.
6,248,083 B1 6/2001 Smith et al.
6,253,097 B1 6/2001 Aronow et al.
6,256,523 B1 7/2001 Diab et al.
6,262,698 B1 7/2001 Blum
6,263,222 B1 7/2001 Diab et al.
6,266,551 B1 7/2001 Osadchy et al.
6,272,363 B1 8/2001 Casciani et al.
6,278,522 B1 8/2001 Lepper, Jr. et al.
6,280,213 B1 8/2001 Tobler et al.
6,285,895 B1 9/2001 Ristolainen et al.
6,285,896 B1 9/2001 Tobler et al.
6,295,330 B1 9/2001 Skog et al.
6,298,252 B1 10/2001 Kovach et al.
6,298,255 B1 10/2001 Cordero et al.
6,301,493 B1 10/2001 Marro et al.
6,304,675 B1 10/2001 Osbourn et al.
6,304,767 B1 10/2001 Soller et al.
6,308,089 B1 10/2001 von der Ruhr
6,317,627 B1 11/2001 Ennen et al.
6,321,100 B1 11/2001 Parker
6,325,761 B1 12/2001 Jay
6,330,468 B1 12/2001 Scharf
6,334,065 B1 12/2001 Al-Ali et al.
6,336,900 B1 1/2002 Alleckson et al.
6,339,715 B1 1/2002 Bahr et al.
6,341,257 B1 1/2002 Haaland
6,343,224 B1 1/2002 Parker
6,356,774 B1 1/2002 Bernstein et al.
6,349,228 B1 2/2002 Kiani et al.
6,351,658 B1 2/2002 Middleman et al.
6,360,113 B1 3/2002 Dettling
6,360,114 B1 3/2002 Diab et al.
6,363,269 B1 3/2002 Hanna et al.
6,368,283 B1 4/2002 Xu et al.
6,371,921 B1 4/2002 Caro et al.
6,374,129 B1 4/2002 Chin et al.
6,377,828 B1 4/2002 Chaiken et al.
6,377,829 B1 4/2002 Al-Ali
6,388,240 B2 5/2002 Schulz et al.
6,393,310 B1 5/2002 Kuenstner
6,397,091 B2 5/2002 Diab et al.
6,397,092 B1 5/2002 Norris et al.
6,397,093 B1 5/2002 Aldrich
6,402,690 B1 6/2002 Rhee et al.
6,408,198 B1 6/2002 Hanna et al.
6,411,833 B1 6/2002 Baker, Jr. et al.
6,415,166 B1 7/2002 Van Hoy et al.
6,415,233 B1 7/2002 Haaland
6,415,236 B2 7/2002 Kobayashi et al.
6,421,549 B1 7/2002 Jacques
6,430,437 B1 8/2002 Marro
6,430,525 B1 8/2002 Weber et al.
6,434,408 B1 8/2002 Heckel
6,441,388 B1 8/2002 Thomas et al.
6,453,184 B1 9/2002 Hyogo et al.
6,455,340 B1 9/2002 Chua et al.
6,463,310 B1 10/2002 Swedlow et al.
6,463,311 B1 10/2002 Diab
6,466,824 B1 10/2002 Struble
6,470,199 B1 10/2002 Kopotic et al.
6,480,729 B2 11/2002 Stone
6,490,466 B1 12/2002 Fein et al.
6,490,684 B1 12/2002 Fenstemaker et al.
6,497,659 B1 12/2002 Rafert
6,501,974 B2 12/2002 Huiku
6,501,975 B2 12/2002 Diab et al.
6,504,943 B1 1/2003 Sweatt et al.
6,505,059 B1 1/2003 Kollias et al.
6,505,060 B1 1/2003 Norris
6,505,061 B2 1/2003 Larson
6,505,133 B1 1/2003 Hanna
6,510,329 B2 1/2003 Heckel
6,515,273 B2 2/2003 Al-Ali
6,519,486 B1 2/2003 Edgar, Jr. et al.
6,519,487 B1 2/2003 Parker
6,522,398 B2 2/2003 Cadell et al.
6,525,386 B1 2/2003 Mills et al.
6,526,300 B1 2/2003 Kiani et al.
6,526,301 B2 2/2003 Larsen et al.
6,528,809 B1 3/2003 Thomas et al.
6,537,225 B1 3/2003 Mills
6,541,756 B2 4/2003 Schulz et al.
6,542,763 B1 4/2003 Yamashita et al.
6,542,764 B1 4/2003 Al-Ali et al.
6,545,652 B1 4/2003 Tsuji
6,546,267 B1 4/2003 Sugiura
6,553,241 B2 4/2003 Mannheimer et al.
6,564,077 B2 5/2003 Mortara
6,571,113 B1 5/2003 Fein et al.
6,580,086 B1 6/2003 Schulz et al.
6,582,964 B1 6/2003 Samsoondar et al.
6,584,336 B1 6/2003 Ali et al.
6,584,413 B1 6/2003 Keenan et al.
6,591,123 B2 7/2003 Fein et al.
6,594,511 B2 7/2003 Stone et al.
6,594,518 B1 7/2003 Benaron et al.
6,595,316 B2 7/2003 Cybulski et al.
6,597,932 B2 7/2003 Tian et al.
6,597,933 B2 7/2003 Kiani et al.
6,600,940 B1 7/2003 Fein et al.
6,606,509 B2 8/2003 Schmitt
6,606,510 B2 8/2003 Swedlow et al.
6,606,511 B1 8/2003 Ali et al.
6,609,016 B1 8/2003 Lynn
6,611,698 B1 8/2003 Yamashita et al.
6,614,521 B2 9/2003 Samsoondar et al.
6,615,064 B1 9/2003 Aldrich
6,615,151 B1 9/2003 Scecina et al.
6,618,602 B2 9/2003 Levin
6,622,095 B2 9/2003 Kobayashi et al.
6,628,975 B1 9/2003 Fein et al.
6,631,281 B1 10/2003 Kastle
6,632,181 B2 10/2003 Flaherty et al.
6,639,668 B1 10/2003 Trepagnier
6,640,116 B2 10/2003 Diab
6,643,530 B2 11/2003 Diab et al.
6,645,142 B2 11/2003 Braig et al.
6,650,917 B2 11/2003 Diab et al.
6,654,623 B1 11/2003 Kastle
6,654,624 B2 11/2003 Diab et al.
6,657,717 B2 12/2003 Cadell et al.
6,658,276 B2 12/2003 Kianl et al.
6,658,277 B2 12/2003 Wasserman
6,661,161 B1 12/2003 Lanzo et al.
6,662,033 B2 12/2003 Casciani et al.
6,665,551 B1 12/2003 Suzuki
6,668,183 B2 12/2003 Hicks et al.
6,671,526 B1 12/2003 Aoyagi et al.
6,671,531 B2 12/2003 Al-Ali et al.
6,675,031 B1 1/2004 Porges et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,675,106	B1	1/2004	Keenan et al.
6,676,600	B1	1/2004	Conero et al.
6,678,543	B2	1/2004	Diab et al.
6,681,126	B2	1/2004	Solenberger
6,684,090	B2	1/2004	Ali et al.
6,684,091	B2	1/2004	Parker
6,687,620	B1	2/2004	Haaland et al.
6,690,466	B2	2/2004	Miller et al.
6,694,157	B1	2/2004	Stone et al.
6,697,655	B2	2/2004	Sueppel et al.
6,697,656	B1	2/2004	Al-Ali
6,697,657	B1	2/2004	Shehada et al.
6,697,658	B2	2/2004	Al-Ali
RE38,476	E	3/2004	Diab et al.
6,699,194	B1	3/2004	Diab et al.
6,701,170	B2	3/2004	Stetson
6,708,049	B1	3/2004	Berson et al.
6,711,503	B2	3/2004	Haaland
6,714,803	B1	3/2004	Mortz
6,714,804	B2	3/2004	Al-Ali et al.
6,714,805	B2	3/2004	Jeon et al.
RE38,492	E	4/2004	Diab et al.
6,719,705	B2	4/2004	Mills
6,720,734	B2	4/2004	Norris
6,721,582	B2	4/2004	Trepagnier et al.
6,721,584	B2	4/2004	Baker, Jr. et al.
6,721,585	B1	4/2004	Parker
6,725,074	B1	4/2004	Kastle
6,725,075	B2	4/2004	Al-Ali
6,726,634	B2	4/2004	Freeman
6,728,560	B2	4/2004	Kollias et al.
6,735,459	B2	5/2004	Parker
6,741,875	B1	5/2004	Pawluczyk et al.
6,741,876	B1	5/2004	Scecina et al.
6,743,172	B1	6/2004	Blike
6,745,060	B2	6/2004	Diab et al.
6,745,061	B1	6/2004	Hicks et al.
6,748,253	B2	6/2004	Norris et al.
6,748,254	B2	6/2004	O'Neil et al.
6,754,515	B1	6/2004	Pologe
6,754,516	B2	6/2004	Mannheimer
6,760,607	B2	7/2004	Al-Ali
6,760,609	B2	7/2004	Jacques
6,770,028	B1	8/2004	Ali et al.
6,771,994	B2	8/2004	Kiani et al.
6,773,397	B2	8/2004	Kelly
6,778,923	B2	8/2004	Norris et al.
6,780,158	B2	8/2004	Yarita
6,788,849	B1	9/2004	Pawluczyk
6,792,300	B1	9/2004	Diab et al.
6,800,373	B2	10/2004	Corczyca
6,801,797	B2	10/2004	Mannheimer et al.
6,801,799	B2	10/2004	Mendelson
6,810,277	B2	10/2004	Edgar, Jr. et al.
6,813,511	B2	11/2004	Diab et al.
6,816,741	B2	11/2004	Diab
6,819,950	B2	11/2004	Mills
6,822,564	B2	11/2004	Al-Ali
6,825,619	B2	11/2004	Norris
6,826,419	B2	11/2004	Diab et al.
6,829,496	B2	12/2004	Nagai et al.
6,829,501	B2	12/2004	Nielsen et al.
6,830,711	B2	12/2004	Mills et al.
6,836,679	B2	12/2004	Baker, Jr. et al.
6,839,579	B1	1/2005	Chin
6,839,580	B2	1/2005	Zonios et al.
6,839,582	B2	1/2005	Heckel
6,842,702	B2	1/2005	Haaland et al.
6,845,256	B2	1/2005	Chin et al.
6,847,835	B1	1/2005	Yamanishi
6,850,787	B2	2/2005	Weber et al.
6,850,788	B2	2/2005	Al-Ali
6,852,083	B2	2/2005	Caro et al.
6,861,639	B2	3/2005	Al-Ali
6,861,641	B1	3/2005	Adams
6,869,402	B2	3/2005	Arnold
6,882,874	B2	4/2005	Huiku
6,898,452	B2	5/2005	Al-Ali et al.
6,912,049	B2	6/2005	Pawluczyk et al.
6,917,422	B2	7/2005	Samsoondar et al.
6,919,566	B1	7/2005	Cadell
6,920,345	B2	7/2005	Al-Ali et al.
6,921,367	B2	7/2005	Mills
6,922,645	B2	7/2005	Haaland et al.
6,928,311	B1	8/2005	Pawluczyk et al.
6,931,268	B1	8/2005	Kiani-Azarbayjany et al.
6,931,269	B2	8/2005	Terry
6,934,570	B2	8/2005	Kiani et al.
6,939,305	B2	9/2005	Flaherty et al.
6,943,348	B1	9/2005	Coffin, IV
6,944,487	B2	9/2005	Maynard et al.
6,950,687	B2	9/2005	Al-Ali
6,956,572	B2	10/2005	Zaleski
6,961,598	B2	11/2005	Diab
6,970,792	B1	11/2005	Diab
6,975,891	B2	12/2005	Pawluczyk
6,979,812	B2	12/2005	Al-Ali
6,985,764	B2	1/2006	Mason et al.
6,987,994	B1	1/2006	Mortz
6,993,371	B2	1/2006	Kiani et al.
6,996,427	B2	2/2006	Ali et al.
6,999,904	B2	2/2006	Weber et al.
7,001,337	B2	2/2006	Dekker
7,003,338	B2	2/2006	Weber et al.
7,003,339	B2	2/2006	Diab et al.
7,006,856	B2	2/2006	Baker, Jr. et al.
7,015,451	B2	3/2006	Dalke et al.
7,024,233	B2	4/2006	Ali et al.
7,027,849	B2	4/2006	Al-Ali
7,030,749	B2	4/2006	Al-Ali
7,039,449	B2	5/2006	Al-Ali
7,041,060	B2	5/2006	Flaherty et al.
7,044,918	B2	5/2006	Diab
7,067,893	B2	6/2006	Mills et al.
7,096,052	B2	8/2006	Mason et al.
7,096,054	B2	8/2006	Abdul-Hafiz et al.
7,132,641	B2	11/2006	Schulz et al.
7,142,901	B2	11/2006	Kiani et al.
7,149,561	B2	12/2006	Diab
7,186,966	B2	3/2007	Al-Ali
7,190,261	B2	3/2007	Al-Ali
7,215,984	B2	5/2007	Diab et al.
7,215,986	B2	5/2007	Diab et al.
7,221,971	B2	5/2007	Diab et al.
7,225,006	B2	5/2007	Al-Ali et al.
7,225,007	B2	5/2007	Al-Ali et al.
RE39,672	E	6/2007	Shehada et al.
7,239,905	B2	7/2007	Kiani-Azarbayjany et al.
7,245,953	B1	7/2007	Parker
7,254,429	B2	8/2007	Schurman et al.
7,254,431	B2	8/2007	Al-Ali et al.
7,254,433	B2	8/2007	Diab et al.
7,254,434	B2	8/2007	Schulz et al.
7,272,425	B2	9/2007	Al-Ali
7,274,955	B2	9/2007	Kiani et al.
D554,263	S	10/2007	Al-Ali
7,280,858	B2	10/2007	Al-Ali et al.
7,289,835	B2	10/2007	Mansfield et al.
7,292,883	B2	11/2007	De Felice et al.
7,295,866	B2	11/2007	Al-Ali
7,299,080	B2	11/2007	Acosta et al.
7,328,053	B1	2/2008	Diab et al.
7,332,784	B2	2/2008	Mills et al.
7,340,287	B2	3/2008	Mason et al.
7,341,559	B2	3/2008	Schulz et al.
7,343,186	B2	3/2008	Lamego et al.
D566,282	S	4/2008	Al-Ali et al.
7,355,512	B1	4/2008	Al-Ali
7,356,365	B2	4/2008	Schurman
7,371,981	B2	5/2008	Abdul-Hafiz
7,373,193	B2	5/2008	Al-Ali et al.
7,373,194	B2	5/2008	Weber et al.
7,376,453	B1	5/2008	Diab et al.
7,377,794	B2	5/2008	Al-Ali et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,377,899 B2 5/2008 Weber et al.
7,383,070 B2 6/2008 Diab et al.
7,415,297 B2 8/2008 Al-Ali et al.
7,428,432 B2 9/2008 Ali et al.
7,438,683 B2 10/2008 Al-Ali et al.
7,440,787 B2 10/2008 Diab
7,454,240 B2 11/2008 Diab et al.
7,457,652 B2 11/2008 Porges et al.
7,467,002 B2 12/2008 Weber et al.
7,469,157 B2 12/2008 Diab et al.
7,471,969 B2 12/2008 Diab et al.
7,471,971 B2 12/2008 Diab et al.
7,483,729 B2 1/2009 Al-Ali et al.
7,483,730 B2 1/2009 Diab et al.
7,489,958 B2 2/2009 Diab et al.
7,496,391 B2 2/2009 Diab et al.
7,496,393 B2 2/2009 Diab et al.
D587,657 S 3/2009 Al-Ali et al.
7,499,741 B2 3/2009 Diab et al.
7,499,835 B2 3/2009 Weber et al.
7,500,950 B2 3/2009 Al-Ali et al.
7,509,154 B2 3/2009 Diab et al.
7,509,494 B2 3/2009 Al-Ali
7,510,849 B2 3/2009 Schurman et al.
7,526,328 B2 4/2009 Diab et al.
7,530,942 B1 5/2009 Diab
7,530,949 B2 5/2009 Al-Ali et al.
7,530,955 B2 5/2009 Diab et al.
7,563,110 B2 7/2009 Al-Ali et al.
7,596,398 B2 9/2009 Al-Ali et al.
7,606,861 B2 10/2009 Killcommons et al.
7,618,375 B2 11/2009 Flaherty et al.
D606,659 S 12/2009 Flaherty et al.
7,647,083 B2 1/2010 Al-Ali et al.
D609,193 S 2/2010 Al-Ali et al.
7,670,726 B2 3/2010 Lu
7,679,519 B2 3/2010 Lindner et al.
D614,305 S 4/2010 Al-Ali et al.
RE41,317 E 5/2010 Parker
7,729,733 B2 6/2010 Al-Ali et al.
7,734,320 B2 6/2010 Al-Ali
7,761,127 B2 7/2010 Al-Ali et al.
7,761,128 B2 7/2010 Al-Ali et al.
7,764,982 B2 7/2010 Dalke et al.
D621,516 S 8/2010 Kiani et al.
7,791,155 B2 9/2010 Diab
7,801,581 B2 9/2010 Diab
7,822,452 B2 10/2010 Schurman et al.
RE41,912 E 11/2010 Parker
7,844,313 B2 11/2010 Kiani et al.
7,844,314 B2 11/2010 Al-Ali
7,844,315 B2 11/2010 Al-Ali
7,865,222 B2 1/2011 Weber et al.
7,873,497 B2 1/2011 Weber et al.
7,880,606 B2 2/2011 Al-Ali
7,880,626 B2 2/2011 Al-Ali et al.
7,891,355 B2 2/2011 Al-Ali et al.
7,894,868 B2 2/2011 Al-Ali et al.
7,899,507 B2 3/2011 Al-Ali et al.
7,899,518 B2 3/2011 Trepagnier et al.
7,904,132 B2 3/2011 Weber et al.
7,909,772 B2 3/2011 Popov et al.
7,910,875 B2 3/2011 Al-Ali
7,919,713 B2 4/2011 Al-Ali et al.
7,937,128 B2 5/2011 Al-Ali
7,937,129 B2 5/2011 Mason et al.
7,937,130 B2 5/2011 Diab et al.
7,941,199 B2 5/2011 Kiani
7,951,086 B2 5/2011 Flaherty et al.
7,957,780 B2 6/2011 Lamego et al.
7,962,188 B2 6/2011 Kiani et al.
7,962,190 B1 6/2011 Diab et al.
7,976,472 B2 7/2011 Kiani
7,988,637 B2 8/2011 Diab
7,990,382 B2 8/2011 Kiani
7,991,446 B2 8/2011 Ali et al.
8,000,761 B2 8/2011 Al-Ali
8,008,088 B2 8/2011 Bellott et al.
RE42,753 E 9/2011 Kiani-Azarbayjany et al.
8,019,400 B2 9/2011 Diab et al.
8,028,701 B2 10/2011 Al-Ali et al.
8,029,765 B2 10/2011 Bellott et al.
8,036,727 B2 10/2011 Schurman et al.
8,036,728 B2 10/2011 Diab et al.
8,046,040 B2 10/2011 Ali et al.
8,046,041 B2 10/2011 Diab et al.
8,046,042 B2 10/2011 Diab et al.
8,048,040 B2 11/2011 Kiani
8,050,728 B2 11/2011 Al-Ali et al.
RE43,169 E 2/2012 Parker
8,118,620 B2 2/2012 Al-Ali et al.
8,126,528 B2 2/2012 Diab et al.
8,128,572 B2 3/2012 Diab et al.
8,130,105 B2 3/2012 Al-Ali et al.
8,145,287 B2 3/2012 Diab et al.
8,150,487 B2 4/2012 Diab et al.
8,175,672 B2 5/2012 Parker
8,180,420 B2 5/2012 Diab et al.
8,182,443 B1 5/2012 Kiani
8,185,180 B2 5/2012 Diab et al.
8,190,223 B2 5/2012 Al-Ali et al.
8,190,227 B2 5/2012 Diab et al.
8,203,438 B2 6/2012 Kiani et al.
8,203,704 B2 6/2012 Merritt et al.
8,204,566 B2 6/2012 Schurman et al.
8,219,172 B2 7/2012 Schurman et al.
8,224,411 B2 7/2012 Al-Ali et al.
8,228,181 B2 7/2012 Al-Ali
8,229,532 B2 7/2012 Davis
8,229,533 B2 7/2012 Diab et al.
8,233,955 B2 7/2012 Al-Ali et al.
8,244,325 B2 8/2012 Al-Ali et al.
8,255,026 B1 8/2012 Al-Ali
8,255,027 B2 8/2012 Al-Ali et al.
8,255,028 B2 8/2012 Al-Ali et al.
8,260,577 B2 9/2012 Weber et al.
8,265,723 B1 9/2012 McHale et al.
8,274,360 B2 9/2012 Sampath et al.
8,301,217 B2 10/2012 Al-Ali et al.
8,306,596 B2 11/2012 Schurman et al.
8,310,336 B2 11/2012 Muhsin et al.
8,315,683 B2 11/2012 Al-Ali et al.
RE43,860 E 12/2012 Parker
8,337,403 B2 12/2012 Al-Ali et al.
8,346,330 B2 1/2013 Lamego
8,353,842 B2 1/2013 Al-Ali et al.
8,355,766 B2 1/2013 MacNeish, III et al.
8,359,080 B2 1/2013 Diab et al.
8,364,223 B2 1/2013 Al-Ali et al.
8,364,226 B2 1/2013 Diab et al.
8,374,665 B2 2/2013 Lamego
8,385,995 B2 2/2013 Al-Ali et al.
8,385,996 B2 2/2013 Dalke et al.
8,388,353 B2 3/2013 Kiani et al.
8,399,822 B2 3/2013 Al-Ali
8,401,602 B2 3/2013 Kiani
8,405,608 B2 3/2013 Al-Ali et al.
8,414,499 B2 4/2013 Al-Ali et al.
8,418,524 B2 4/2013 Al-Ali
8,423,106 B2 4/2013 Lamego et al.
8,428,967 B2 4/2013 Olsen et al.
8,430,817 B1 4/2013 Al-Ali et al.
8,437,825 B2 5/2013 Dalvi et al.
8,455,290 B2 6/2013 Siskavich
8,457,703 B2 6/2013 Al-Ali
8,457,707 B2 6/2013 Kiani
8,463,349 B2 6/2013 Diab et al.
8,466,286 B2 6/2013 Bellott et al.
8,471,713 B2 6/2013 Poeze et al.
8,473,020 B2 6/2013 Kiani et al.
8,483,787 B2 7/2013 Al-Ali et al.
8,489,364 B2 7/2013 Weber et al.
8,498,684 B2 7/2013 Weber et al.
8,504,128 B2 8/2013 Blank et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,509,867	B2	8/2013	Workman et al.
8,515,509	B2	8/2013	Bruinsma et al.
8,523,781	B2	9/2013	Al-Ali
8,529,301	B2	9/2013	Al-Ali et al.
8,532,727	B2	9/2013	Al-Ali et al.
8,532,728	B2	9/2013	Diab et al.
D692,145	S	10/2013	Al-Ali et al.
8,547,209	B2	10/2013	Kiani et al.
8,548,548	B2	10/2013	Al-Ali
8,548,549	B2	10/2013	Schurman et al.
8,548,550	B2	10/2013	Al-Ali et al.
8,560,032	B2	10/2013	Al-Ali et al.
8,560,034	B1	10/2013	Diab et al.
8,570,167	B2	10/2013	Al-Ali
8,570,503	B2	10/2013	Vo et al.
8,571,617	B2	10/2013	Reichgott et al.
8,571,618	B1	10/2013	Lamego et al.
8,571,619	B2	10/2013	Al-Ali et al.
8,577,431	B2	11/2013	Lamego et al.
8,581,732	B2	11/2013	Al-Ali et al.
8,584,345	B2	11/2013	Al-Ali et al.
8,588,880	B2	11/2013	Abdul-Hafiz et al.
8,600,467	B2	12/2013	Al-Ali et al.
8,606,342	B2	12/2013	Diab
8,626,255	B2	1/2014	Al-Ali et al.
8,630,691	B2	1/2014	Lamego et al.
8,634,889	B2	1/2014	Al-Ali et al.
8,641,631	B2	2/2014	Sierra et al.
8,652,060	B2	2/2014	Al-Ali
8,663,107	B2	3/2014	Kiani
8,666,468	B1	3/2014	Al-Ali
8,667,967	B2	3/2014	Al-Ali et al.
8,670,811	B2	3/2014	O'Reilly
8,670,814	B2	3/2014	Diab et al.
8,676,286	B2	3/2014	Weber et al.
8,682,407	B2	3/2014	Al-Ali
RE44,823	E	4/2014	Parker
RE44,875	E	4/2014	Kiani et al.
8,690,799	B2	4/2014	Telfort et al.
8,700,112	B2	4/2014	Kiani
8,702,627	B2	4/2014	Telfort et al.
8,706,179	B2	4/2014	Parker
8,712,494	B1	4/2014	MacNeish, III et al.
8,715,206	B2	5/2014	Telfort et al.
8,718,735	B2	5/2014	Lamego et al.
8,718,737	B2	5/2014	Diab et al.
8,718,738	B2	5/2014	Blank et al.
8,720,249	B2	5/2014	Al-Ali
8,721,541	B2	5/2014	Al-Ali et al.
8,721,542	B2	5/2014	Al-Ali et al.
8,723,677	B1	5/2014	Kiani
8,740,792	B1	6/2014	Kiani et al.
8,754,776	B2	6/2014	Poeze et al.
8,755,535	B2	6/2014	Telfort et al.
8,755,856	B2	6/2014	Diab et al.
8,755,872	B1	6/2014	Marinow
8,761,850	B2	6/2014	Lamego
8,764,671	B2	7/2014	Kiani
8,768,423	B2	7/2014	Shakespeare et al.
8,771,204	B2	7/2014	Telfort et al.
8,777,634	B2	7/2014	Kiani et al.
8,781,543	B2	7/2014	Diab et al.
8,781,544	B2	7/2014	Al-Ali et al.
8,781,549	B2	7/2014	Al-Ali et al.
8,788,003	B2	7/2014	Schurman et al.
8,790,268	B2	7/2014	Al-Ali
8,801,613	B2	8/2014	Al-Ali et al.
8,821,397	B2	9/2014	Al-Ali et al.
8,821,415	B2	9/2014	Al-Ali et al.
8,830,449	B1	9/2014	Lamego et al.
8,831,700	B2	9/2014	Schurman et al.
8,840,549	B2	9/2014	Al-Ali et al.
8,847,740	B2	9/2014	Kiani et al.
8,849,365	B2	9/2014	Smith et al.
8,852,094	B2	10/2014	Al-Ali et al.

8,852,994	B2	10/2014	Wojtczuk et al.
8,868,147	B2	10/2014	Stippick et al.
8,868,150	B2	10/2014	Al-Ali et al.
8,870,792	B2	10/2014	Al-Ali et al.
8,886,271	B2	11/2014	Kiani et al.
8,888,539	B2	11/2014	Al-Ali et al.
8,888,708	B2	11/2014	Diab et al.
8,892,180	B2	11/2014	Weber et al.
8,897,847	B2	11/2014	Al-Ali
8,909,310	B2	12/2014	Lamego et al.
8,911,377	B2	12/2014	Al-Ali
8,912,909	B2	12/2014	Al-Ali et al.
8,920,317	B2	12/2014	Al-Ali et al.
8,921,699	B2	12/2014	Al-Ali et al.
8,922,382	B2	12/2014	Al-Ali et al.
8,929,964	B2	1/2015	Al-Ali et al.
8,942,777	B2	1/2015	Diab et al.
8,948,834	B2	2/2015	Diab et al.
8,948,835	B2	2/2015	Diab
8,965,471	B2	2/2015	Lamego et al.
8,983,564	B2	3/2015	Al-Ali
8,989,831	B2	3/2015	Al-Ali et al.
8,996,085	B2	3/2015	Kiani et al.
8,998,809	B2	4/2015	Kiani
9,028,429	B2	5/2015	Telfort et al.
9,037,207	B2	5/2015	Al-Ali et al.
9,060,721	B2	6/2015	Reichgott et al.
9,066,666	B2	6/2015	Kiani
9,066,680	B1	6/2015	Al-Ali et al.
9,072,474	B2	7/2015	Al-Ali et al.
9,078,560	B2	7/2015	Schurman et al.
9,084,569	B2	7/2015	Weber et al.
9,095,316	B2	8/2015	Welch et al.
9,106,038	B2	8/2015	Telfort et al.
9,107,625	B2	8/2015	Telfort et al.
9,107,626	B2	8/2015	Al-Ali et al.
9,113,831	B2	8/2015	Al-Ali
9,113,832	B2	8/2015	Al-Ali
9,119,595	B2	9/2015	Lamego
9,131,881	B2	9/2015	Diab et al.
9,131,882	B2	9/2015	Al-Ali et al.
9,131,883	B2	9/2015	Al-Ali
9,131,917	B2	9/2015	Telfort et al.
9,138,180	B1	9/2015	Coverston et al.
9,138,182	B2	9/2015	Al-Ali et al.
9,138,192	B2	9/2015	Weber et al.
9,142,117	B2	9/2015	Muhsin et al.
9,153,112	B1	10/2015	Kiani et al.
9,153,121	B2	10/2015	Kiani et al.
9,161,696	B2	10/2015	Al-Ali et al.
9,161,713	B2	10/2015	Al-Ali et al.
9,167,995	B2	10/2015	Lamego et al.
9,176,141	B2	11/2015	Al-Ali et al.
9,186,102	B2	11/2015	Bruinsma et al.
9,192,312	B2	11/2015	Al-Ali
9,192,329	B2	11/2015	Al-Ali
9,192,351	B1	11/2015	Telfort et al.
9,195,385	B2	11/2015	Al-Ali et al.
9,211,072	B2	12/2015	Kiani
9,211,095	B1	12/2015	Al-Ali
9,218,454	B2	12/2015	Kiani et al.
9,226,696	B2	1/2016	Kiani
9,241,662	B2	1/2016	Al-Ali et al.
9,245,668	B1	1/2016	Vo et al.
9,259,185	B2	2/2016	Abdul-Hafiz et al.
9,267,572	B2	2/2016	Barker et al.
9,277,880	B2	3/2016	Poeze et al.
9,289,167	B2	3/2016	Diab et al.
9,295,421	B2	3/2016	Kiani et al.
9,307,928	B1	4/2016	Al-Ali et al.
9,323,894	B2	4/2016	Kiani
D755,392	S	5/2016	Hwang et al.
9,326,712	B1	5/2016	Kiani
9,333,316	B2	5/2016	Kiani
9,339,220	B2	5/2016	Lamego et al.
9,341,565	B2	5/2016	Lamego et al.
9,351,673	B2	5/2016	Diab et al.
9,351,675	B2	5/2016	Al-Ali et al.
9,364,181	B2	6/2016	Kiani et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

9,368,671	B2	6/2016	Wojtczuk et al.
9,370,325	B2	6/2016	Al-Ali et al.
9,370,326	B2	6/2016	McHale et al.
9,370,335	B2	6/2016	Al-Ali et al.
9,375,185	B2	6/2016	Al-Ali et al.
9,386,961	B2	7/2016	Al-Ali et al.
9,392,945	B2	7/2016	Al-Ali et al.
9,397,448	B2	7/2016	Al-Ali et al.
9,408,542	B1	8/2016	Kinast et al.
9,436,645	B2	9/2016	Al-Ali et al.
9,445,759	B1	9/2016	Lamego et al.
9,466,919	B2	10/2016	Kiani et al.
9,474,474	B2	10/2016	Lamego et al.
9,480,422	B2	11/2016	Al-Ali
9,480,435	B2	11/2016	Olsen
9,492,110	B2	11/2016	Al-Ali et al.
9,386,953	B2	12/2016	Al-Ali
9,510,779	B2	12/2016	Poeze et al.
9,517,024	B2	12/2016	Kiani et al.
9,532,722	B2	1/2017	Lamego et al.
9,538,949	B2	1/2017	Al-Ali et al.
9,538,980	B2	1/2017	Telfort et al.
9,549,696	B2	1/2017	Lamego et al.
9,554,737	B2	1/2017	Schurman et al.
9,560,996	B2	2/2017	Kiani
9,560,998	B2	2/2017	Al-Ali et al.
9,566,019	B2	2/2017	Al-Ali et al.
9,579,039	B2	2/2017	Jansen et al.
9,750,443	B2	9/2017	Smith et al.
9,839,381	B1	12/2017	Weber et al.
9,848,807	B2	12/2017	Lamego
2001/0044700	A1	11/2001	Kobayashi et al.
2001/0045532	A1	11/2001	Schulz et al.
2002/0021269	A1	2/2002	Rast
2002/0026107	A1	2/2002	Kiani et al.
2002/0035315	A1	3/2002	Ali et al.
2002/0035318	A1	3/2002	Mannheimer et al.
2002/0038078	A1	3/2002	Ito
2002/0038081	A1	3/2002	Fein et al.
2002/0051290	A1	5/2002	Hannington
2002/0059047	A1	5/2002	Haaland
2002/0068858	A1	6/2002	Braig et al.
2002/0082488	A1	6/2002	Al-Ali et al.
2002/0095076	A1	7/2002	Krausman et al.
2002/0095077	A1	7/2002	Swedlow et al.
2002/0095078	A1	7/2002	Mannheimer et al.
2002/0111748	A1	8/2002	Kobayashi et al.
2002/0115919	A1	8/2002	Al-Ali
2002/0154665	A1	10/2002	Funabashi et al.
2002/0156353	A1	10/2002	Larson
2002/0159002	A1	10/2002	Chang
2002/0161291	A1	10/2002	Kiani et al.
2002/0165440	A1	11/2002	Mason et al.
2002/0183819	A1	12/2002	Struble
2002/0198442	A1	12/2002	Rantala et al.
2003/0045784	A1	3/2003	Palatnik et al.
2003/0045785	A1	3/2003	Diab et al.
2003/0049232	A1	3/2003	Page et al.
2003/0109775	A1	6/2003	O'Neil et al.
2003/0116769	A1	6/2003	Song et al.
2003/0117296	A1	6/2003	Seely
2003/0120160	A1	6/2003	Yarita
2003/0120164	A1	6/2003	Nielsen et al.
2003/0135099	A1	7/2003	Al-Ali
2003/0139657	A1	7/2003	Solenberger
2003/0160257	A1	8/2003	Bader et al.
2003/0195402	A1	10/2003	Fein et al.
2004/0006261	A1	1/2004	Swedlow et al.
2004/0033618	A1	2/2004	Haass et al.
2004/0034898	A1	2/2004	Bruegl
2004/0059209	A1	3/2004	Al-Ali et al.
2004/0064259	A1	4/2004	Haaland et al.
2004/0081621	A1	4/2004	Arndt et al.
2004/0092805	A1	5/2004	Yarita
2004/0097797	A1	5/2004	Porges et al.
2004/0133087	A1	7/2004	Al-Ali et al.
2004/0138538	A1	7/2004	Stetson
2004/0138540	A1	7/2004	Baker, Jr. et al.
2004/0147822	A1	7/2004	Al-Ali et al.
2004/0147823	A1	7/2004	Kiani et al.
2004/0158132	A1	8/2004	Zaleski
2004/0158134	A1	8/2004	Diab et al.
2004/0158135	A1	8/2004	Baker, Jr. et al.
2004/0158162	A1	8/2004	Narimatsu
2004/0162472	A1	8/2004	Berson et al.
2004/0167382	A1	8/2004	Gardner et al.
2004/0171940	A1	9/2004	Narimatsu
2004/0176670	A1	9/2004	Takamura et al.
2004/0181134	A1	9/2004	Baker, Jr. et al.
2004/0199063	A1	10/2004	O'Neil et al.
2004/0204639	A1	10/2004	Casciani et al.
2004/0204868	A1	10/2004	Maynard et al.
2004/0229391	A1	11/2004	Ohya et al.
2004/0262046	A1	12/2004	Simon et al.
2004/0267103	A1	12/2004	Li et al.
2004/0267140	A1	12/2004	Ito et al.
2005/0011488	A1	1/2005	Doucet
2005/0033128	A1	2/2005	Al-Ali et al.
2005/0043902	A1	2/2005	Haaland et al.
2005/0049469	A1	3/2005	Aoyagi et al.
2005/0054908	A1	3/2005	Blank et al.
2005/0070773	A1	3/2005	Chin et al.
2005/0070775	A1	3/2005	Chin et al.
2005/0075546	A1	4/2005	Samsoondar et al.
2005/0085704	A1	4/2005	Schulz et al.
2005/0085735	A1	4/2005	Baker, Jr. et al.
2005/0115561	A1	6/2005	Stahmann et al.
2005/0124871	A1	6/2005	Baker, Jr. et al.
2005/0143634	A1	6/2005	Baker, Jr. et al.
2005/0143943	A1	6/2005	Brown
2005/0148834	A1	7/2005	Hull et al.
2005/0184895	A1	8/2005	Petersen et al.
2005/0187446	A1	8/2005	Nordstrom et al.
2005/0187447	A1	8/2005	Chew et al.
2005/0187448	A1	8/2005	Petersen et al.
2005/0187449	A1	8/2005	Chew et al.
2005/0187450	A1	8/2005	Chew et al.
2005/0187452	A1	8/2005	Petersen et al.
2005/0187453	A1	8/2005	Petersen et al.
2005/0197549	A1	9/2005	Baker, Jr.
2005/0197579	A1	9/2005	Baker, Jr.
2005/0197793	A1	9/2005	Baker, Jr.
2005/0203357	A1	9/2005	Debreczeny et al.
2005/0207943	A1	9/2005	Puzey
2005/0209515	A1	9/2005	Hockersmith et al.
2005/0228253	A1	10/2005	Debreczeny
2005/0250997	A1	11/2005	Takedo et al.
2006/0030764	A1	2/2006	Porges et al.
2006/0210120	A1	9/2006	Rowe et al.
2006/0211922	A1	9/2006	Al-Ali et al.
2006/0211923	A1	9/2006	Al-Ali et al.
2006/0211924	A1	9/2006	Smith et al.
2006/0211925	A1	9/2006	Lamego et al.
2006/0211932	A1	9/2006	Al-Ali et al.
2006/0226992	A1	10/2006	Al-Ali et al.
2006/0229509	A1	10/2006	Al-Ali et al.
2006/0238358	A1	10/2006	Al-Ali et al.
2006/0241358	A1	10/2006	Al-Ali et al.
2006/0241363	A1	10/2006	Al-Ali et al.
2006/0264718	A1	11/2006	Ruchti et al.
2007/0078311	A1	4/2007	Al-Ali et al.
2007/0093701	A1	4/2007	Myers
2007/0149864	A1	6/2007	Laakkonen
2007/0129616	A1	7/2007	Rantala
2007/0185397	A1	8/2007	Govari et al.
2007/0282478	A1	12/2007	Al-Ali et al.
2008/0281174	A1	11/2008	Dietiker
2009/0163775	A1	6/2009	Barrett et al.
2009/0247849	A1	10/2009	McCutcheon et al.
2009/0247924	A1	10/2009	Lamego et al.
2009/0247984	A1	10/2009	Lamego et al.
2009/0275844	A1	11/2009	Al-Ali
2010/0004518	A1	1/2010	Vo et al.
2010/0030040	A1	2/2010	Poeze et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2011/0009719 A1 1/2011 Al-Ali et al.
2011/0082711 A1 4/2011 Poeze et al.
2011/0105854 A1 5/2011 Kiani et al.
2011/0125060 A1 5/2011 Telfort et al.
2011/0208015 A1 8/2011 Welch et al.
2011/0213212 A1 9/2011 Al-Ali
2011/0230733 A1 9/2011 Al-Ali
2011/0237914 A1 9/2011 Lamego
2011/0237969 A1 9/2011 Eckerbom et al.
2011/0288383 A1 11/2011 Diab
2012/0041316 A1 2/2012 Al-Ali et al.
2012/0046530 A1 2/2012 Al-Ali
2012/0046557 A1 2/2012 Kiani
2012/0059267 A1 3/2012 Lamego et al.
2012/0088984 A1 4/2012 Al-Ali et al.
2012/0161970 A1 6/2012 Al-Ali
2012/0165629 A1 6/2012 Merritt et al.
2012/0179006 A1 7/2012 Jansen et al.
2012/0209082 A1 8/2012 Al-Ali
2012/0209084 A1 8/2012 Olsen et al.
2012/0232359 A1 9/2012 Al-Ali et al.
2012/0232363 A1 9/2012 Al-Ali et al.
2012/0283524 A1 11/2012 Kiani et al.
2012/0296178 A1 11/2012 Lamego et al.
2012/0319816 A1 12/2012 Al-Ali
2013/0023775 A1 1/2013 Lamego et al.
2013/0041591 A1 2/2013 Lamego
2013/0046204 A1 2/2013 Lamego et al.
2013/0060147 A1 3/2013 Welch et al.
2013/0096405 A1 4/2013 Garfio
2013/0096936 A1 4/2013 Sampath et al.
2013/0172701 A1 7/2013 Smith
2013/0178749 A1 7/2013 Lamego
2013/0243021 A1 9/2013 Siskavich
2013/0253334 A1 9/2013 Al-Ali et al.
2013/0267804 A1 10/2013 Al-Ali
2013/0274572 A1 10/2013 Al-Ali et al.
2013/0296672 A1 11/2013 O'Neil et al.
2013/0296713 A1 11/2013 Al-Ali et al.
2013/0317327 A1 11/2013 Al-Ali
2013/0317370 A1 11/2013 Dalvi et al.
2013/0324808 A1 12/2013 Al-Ali et al.
2013/0331660 A1 12/2013 Al-Ali et al.
2013/0331670 A1 12/2013 Kiani
2014/0012100 A1 1/2014 Al-Ali et al.
2014/0031650 A1 1/2014 Weber et al.
2014/0034353 A1 2/2014 Al-Ali et al.
2014/0051953 A1 2/2014 Lamego et al.
2014/0066783 A1 3/2014 Kiani et al.
2014/0077956 A1 3/2014 Sampath et al.
2014/0081100 A1 3/2014 Muhsin et al.
2014/0081175 A1 3/2014 Telfort
2014/0100434 A1 4/2014 Diab et al.
2014/0114199 A1 4/2014 Lamego et al.
2014/0120564 A1 5/2014 Workman et al.
2014/0121482 A1 5/2014 Merritt et al.
2014/0127137 A1 5/2014 Bellott et al.
2014/0129702 A1 5/2014 Lamego et al.
2014/0135588 A1 5/2014 Al-Ali et al.
2014/0142401 A1 5/2014 Al-Ali et al.
2014/0142402 A1 5/2014 Al-Ali et al.
2014/0163344 A1 6/2014 Al-Ali
2014/0163402 A1 6/2014 Lamego et al.
2014/0166076 A1 6/2014 Kiani et al.
2014/0171763 A1 6/2014 Diab
2014/0180038 A1 6/2014 Kiani
2014/0180154 A1 6/2014 Sierra et al.
2014/0180160 A1 6/2014 Brown et al.
2014/0187973 A1 7/2014 Brown et al.
2014/0194709 A1 7/2014 Al-Ali et al.
2014/0266790 A1 9/2014 Al-Ali et al.
2014/0275808 A1 9/2014 Poeze et al.
2014/0275835 A1 9/2014 Lamego et al.
2014/0275871 A1 9/2014 Lamego et al.
2014/0275872 A1 9/2014 Merritt et al.
2014/0276115 A1 9/2014 Dalvi et al.
2014/0288400 A1 9/2014 Diab et al.
2014/0309506 A1 10/2014 Lamego
2014/0309559 A1 10/2014 Telfort et al.
2014/0316217 A1 10/2014 Purdon et al.
2014/0316218 A1 10/2014 Purdon et al.
2014/0316228 A1 10/2014 Blank et al.
2014/0323825 A1 10/2014 Al-Ali et al.
2014/0323897 A1 10/2014 Brown et al.
2014/0323898 A1 10/2014 Purdon et al.
2014/0330092 A1 11/2014 Al-Ali et al.
2014/0330098 A1 11/2014 Merritt et al.
2014/0330099 A1 11/2014 Al-Ali et al.
2014/0336481 A1 11/2014 Shakespeare et al.
2014/0357966 A1 12/2014 Al-Ali et al.
2015/0005600 A1 1/2015 Blank et al.
2015/0011907 A1 1/2015 Purdon et al.
2015/0012231 A1 1/2015 Poeze et al.
2015/0025406 A1 1/2015 Al-Ali
2015/0032029 A1 1/2015 Al-Ali et al.
2015/0038859 A1 2/2015 Dalvi et al.
2015/0045637 A1 2/2015 Dalvi
2015/0051462 A1 2/2015 Olsen
2015/0080754 A1 3/2015 Purdon et al.
2015/0087936 A1 3/2015 Al-Ali et al.
2015/0094546 A1 4/2015 Al-Ali
2015/0097701 A1 4/2015 Al-Ali et al.
2015/0099950 A1 4/2015 Al-Ali et al.
2015/0099951 A1 4/2015 Al-Ali et al.
2015/0099955 A1 4/2015 Al-Ali et al.
2015/0101844 A1 4/2015 Al-Ali et al.
2015/0106121 A1 4/2015 Muhsin et al.
2015/0112151 A1 4/2015 Muhsin et al.
2015/0116076 A1 4/2015 Al-Ali et al.
2015/0126830 A1 5/2015 Schurman et al.
2015/0133755 A1 5/2015 Smith et al.
2015/0141781 A1 5/2015 Weber et al.
2015/0165312 A1 6/2015 Kiani
2015/0196237 A1 7/2015 Lamego
2015/0201874 A1 7/2015 Diab
2015/0208966 A1 7/2015 Al-Ali
2015/0216459 A1 8/2015 Al-Ali et al.
2015/0230755 A1 8/2015 Al-Ali et al.
2015/0238722 A1 8/2015 Al-Ali
2015/0245773 A1 9/2015 Lamego et al.
2015/0245794 A1 9/2015 Al-Ali
2015/0257689 A1 9/2015 Al-Ali et al.
2015/0272514 A1 10/2015 Kiani et al.
2015/0351697 A1 12/2015 Weber et al.
2015/0351704 A1 12/2015 Kiani et al.
2015/0359429 A1 12/2015 Al-Ali et al.
2015/0366472 A1 12/2015 Kiani
2015/0366507 A1 12/2015 Blank
2015/0374298 A1 12/2015 Al-Ali et al.
2015/0380875 A1 12/2015 Coverston et al.
2016/0000362 A1 1/2016 Diab et al.
2016/0007930 A1 1/2016 Weber et al.
2016/0029932 A1 2/2016 Al-Ali
2016/0029933 A1 2/2016 Al-Ali et al.
2016/0045118 A1 2/2016 Kiani
2016/0051205 A1 2/2016 Al-Ali et al.
2016/0058338 A1 3/2016 Schurman et al.
2016/0058347 A1 3/2016 Reichgott et al.
2016/0066823 A1 3/2016 Al-Ali et al.
2016/0066824 A1 3/2016 Al-Ali et al.
2016/0066879 A1 3/2016 Telfort et al.
2016/0072429 A1 3/2016 Kiani et al.
2016/0081552 A1 3/2016 Wojtczuk et al.
2016/0095543 A1 4/2016 Telfort et al.
2016/0095548 A1 4/2016 Al-Ali et al.
2016/0103598 A1 4/2016 Al-Ali et al.
2016/0113527 A1 4/2016 Al-Ali et al.
2016/0143548 A1 5/2016 Al-Ali
2016/0166182 A1 6/2016 Al-Ali
2016/0166183 A1 6/2016 Poeze et al.
2016/0166188 A1 6/2016 Bruinsma et al.
2016/0166210 A1 6/2016 Al-Ali
2016/0192869 A1 7/2016 Kiani et al.
2016/0196388 A1 7/2016 Lamego

(56) **References Cited**

U.S. PATENT DOCUMENTS

2016/0197436	A1	7/2016	Barker et al.
2016/0213281	A1	7/2016	Eckerbom et al.
2016/0228043	A1	8/2016	O'Neil et al.
2016/0233632	A1	8/2016	Scruggs et al.
2016/0234944	A1	8/2016	Schmidt et al.
2016/0270735	A1	9/2016	Diab et al.
2016/0283665	A1	9/2016	Sampath et al.
2016/0287090	A1	10/2016	Al-Ali et al.
2016/0287786	A1	10/2016	Kiani
2016/0296169	A1	10/2016	McHale et al.
2016/0310052	A1	10/2016	Al-Ali
2016/0314260	A1	10/2016	Kiani
2016/0324486	A1	11/2016	Al-Ali et al.
2016/0324488	A1	11/2016	Olsen
2016/0327984	A1	11/2016	Al-Ali et al.
2016/0328528	A1	11/2016	Al-Ali et al.
2016/0331332	A1	11/2016	Al-Ali
2016/0367173	A1	12/2016	Dalvi et al.
2017/0007134	A1	1/2017	Al-Ali et al.
2017/0007190	A1	1/2017	Al-Ali et al.
2017/0007198	A1	1/2017	Al-Ali et al.
2017/0014084	A1	1/2017	Al-Ali et al.
2017/0021099	A1	1/2017	Al-Ali et al.
2017/0027456	A1	2/2017	Kinast et al.
2017/0042488	A1	2/2017	Muhsin
2018/0007086	A1	1/2018	Smith

FOREIGN PATENT DOCUMENTS

EP	41 92 23		3/1991
EP	0 569 670		2/1993
EP	0 675 540		10/1995
EP	0 675 541		10/1995
EP	0469395	B1	2/1996
EP	0417447	B1	10/1997
EP	0606356	B1	6/1998
EP	0734221	B1	7/1998
EP	0 529 412		11/1998
EP	1 080 683		3/2001
EP	1 207 536		5/2002
EP	1 860 989		12/2007
EP	1 860 990		12/2007
EP	1 860 994		12/2007
EP	1 860 995		12/2007
EP	1 860 996		12/2007
EP	1 860 997		12/2007
EP	1 863 380		12/2007
EP	1 895 892		5/2010
EP	2 286 721		2/2011
EP	2 305 104		4/2011
EP	2 476 369		7/2012
EP	2 139 383		2/2013
EP	2 476 369		10/2014
JP	61-28172		2/1986
JP	62-000324		1/1987
JP	63-275327		11/1988
JP	64-500495		2/1989
JP	2-126829		5/1990
JP	2-145457		12/1990
JP	03-252604		11/1991
JP	05-200017		8/1993
JP	05-207993		8/1993
JP	H06-178776		6/1994
JP	6-505903		7/1994
JP	6-237013		8/1994
JP	H07-391		1/1995
JP	H07-171089		7/1995
JP	H07-171090		7/1995
JP	7-281618		10/1995
JP	07-325546		12/1995
JP	09-108203		4/1997
JP	9-192120		7/1997
JP	09-308623		12/1997
JP	10-500026		1/1998
JP	H10-500026		1/1998
JP	10-216112		8/1998
JP	10-509352		9/1998
JP	10-269344	A	10/1998
JP	10-295676		11/1998
JP	10-305026		11/1998
JP	11-037932		2/1999
JP	11-163412		6/1999
JP	11-164826		6/1999
JP	11-506834		6/1999
JP	11-183377		7/1999
JP	2011-508691		7/1999
JP	2000-116625		4/2000
JP	2000-199880		7/2000
JP	2001-504256		3/2001
JP	2002-150821		5/2002
JP	2002-516689		6/2002
JP	2002-228579		8/2002
JP	2002-525151		8/2002
JP	2002-315739		10/2002
JP	2002-352609		12/2002
JP	2003-507718		2/2003
JP	2003-084108		3/2003
JP	2003-521985		7/2003
JP	2004-070179		3/2004
JP	2004-510467		4/2004
JP	2004-173866		6/2004
JP	2004-226277		8/2004
JP	2004-296736		10/2004
JP	2004-532526		10/2004
JP	2004-327760		11/2004
JP	2005-501589		1/2005
JP	2005-253478		9/2005
JP	2008-505706		2/2008
JP	4865737		11/2011
JP	4879913		12/2011
JP	2012-110746		6/2012
JP	2012-130756		7/2012
JP	5096174		9/2012
JP	5166619		3/2013
JP	5456976		1/2014
WO	WO 88/01150		2/1988
WO	WO 88/002020		2/1988
WO	WO 92/16142		10/1992
WO	WO 93/06776		4/1993
WO	WO 95/05621		2/1995
WO	WO 95/16387		6/1995
WO	WO 96/013208		5/1996
WO	WO 96/41138		12/1996
WO	WO 97/01985		1/1997
WO	WO 97/29678		8/1997
WO	WO 97/029710		8/1997
WO	WO 98/43071		10/1998
WO	WO 00/18290		4/2000
WO	WO 00/42911		7/2000
WO	WO 00/59374		10/2000
WO	WO 01/13790		3/2001
WO	WO 01/30414		5/2001
WO	WO 01/058347		8/2001
WO	WO 02/017780		3/2002
WO	WO 02/026123		4/2002
WO	WO 02/089664		11/2002
WO	WO 03/020129		3/2003
WO	WO 03/068060		8/2003
WO	WO 03/077761		9/2003
WO	WO 04/034898		4/2004
WO	WO 04/038801		5/2004
WO	WO 05/004712		1/2005
WO	WO 05/011488		2/2005
WO	WO 06/017117		2/2006
WO	WO 06/094107		9/2006
WO	WO 06/094108		9/2006
WO	WO 06/094155		9/2006
WO	WO 06/094168		9/2006
WO	WO 06/094169		9/2006
WO	WO 06/094170		9/2006
WO	WO 06/094171		9/2006
WO	WO 06/094279		9/2006
WO	WO 06/115580		11/2006

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

WO	WO 2006/118654	11/2006
WO	WO 09/013835	1/2009
WO	WO 09/137524	11/2009

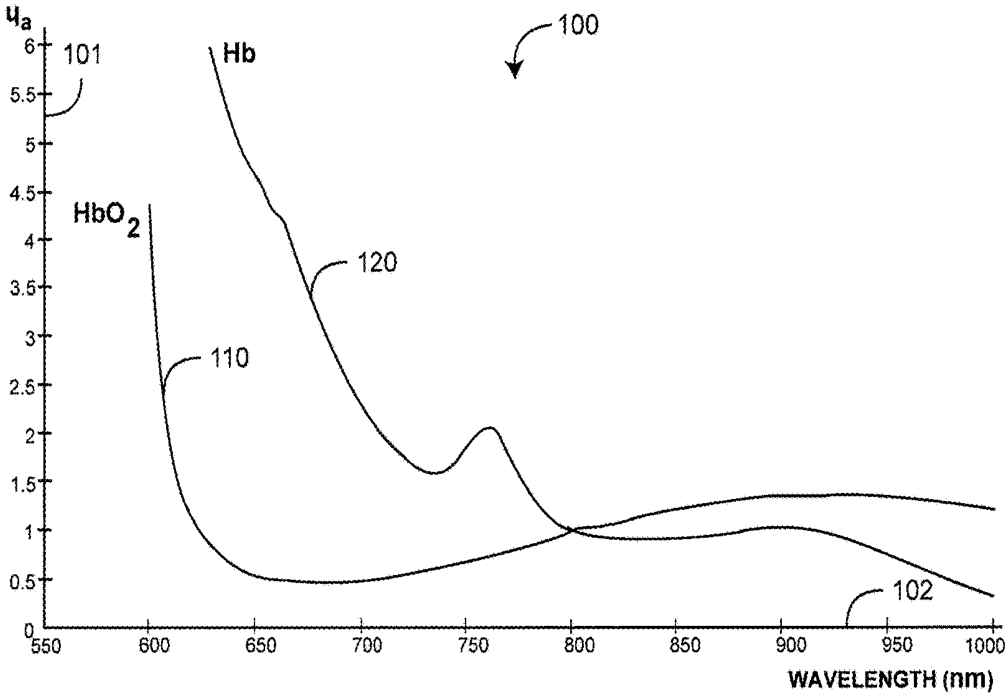
OTHER PUBLICATIONS

"Medical." 50 Ways to Touch Memory. 3rd ed. Dallas: Dallas Semiconductor Corporation, Aug. 1994: pp. 24-25. Print.
"Application Note 84 Use of Add-Only Memory for Secure Storage of Monetary Equivalent Data," Dallas Semiconductor, Jun. 22, 1999, in 5 pages.
Burritt, Mary F.; Current Analytical Approaches to Measuring Blood Analytes; vol. 36; No. 8(B); 1990.
Dallas Semiconductor Corp: DS2430A Announcement, retrieved Jun. 10, 1998, in 2 pages. <https://web.archive.org/web/19980610045525/http://dalsemi.com/News_Center/New_Products/1996/2430a.html>.
European Examination Report, re EP Application No. 06736799.5, dated Nov. 30, 2012.
European Examination Report, re EP Application No. 06736799.5, dated Oct. 28, 2014.
European Extended Search Report, re EP Application No. 10191029.7, dated Jun. 5, 2012.
European Extended Search Report re EPO App. No. 10162402.1, SR dated Aug. 9, 2010.
European Examination Report dated Apr. 1, 2010, re EP App. No. 08 744 412.1-2319.
European Examination Report dated Mar. 18, 2011, re EP App. No. 08 744 412.1-2319.
European Examination Report dated Sep. 2, 2010, re EP App. No. 08 744 412.1-2319.
European Examination Report, re EP Application No. 12163719.3, dated Feb. 6, 2013.
European Extended Search Report, re EP Application No. 12163719.3, dated Jun. 18, 2012.
European Extended Search Report, re EP Application No. 10 18 1436, completion date Nov. 26, 2010.
Favennec, J.M. "Smart sensors in industry." J. Phys. E: Sci. Instrum. 20(9): Sep. 1987, pp. 1087-1090.
Hall, et al., Jeffrey W.; Near-Infrared Spectrophotometry: A New Dimension in Clinical Chemistry; vol. 38; No. 9; 1992.
International Preliminary Report on Patentability for PCT/US2010/058981 dated Jun. 5, 2012, dated Jun. 14, 2012.
International Search Report for PCT/US2006/007516, dated Jan. 11, 2007, in 4 pages.
Japanese Final Office Action re Amendments re JP Application No. 2007-558249, dated Apr. 17, 2012.
Japanese First Office Action (Notice of Reasons for Rejection), re JP App. No. 2007-558207, dated Jun. 28, 2011.
Japanese First Office Action (Notice of Reasons for Rejection), re JP App. No. 2007-558247, dated Jun. 28, 2011.
Japanese Office Action (Decision of Rejection), re JP Application No. JP 2007-558328, dated Jun. 25, 2013.
Japanese Office Action (Notice of Allowance), re JP App. No. 2007-558247, dated Oct. 24, 2011.
Japanese Office Action (Notice of Reasons for Rejection) re JP App. No. 2007-558246, dated Jun. 28, 2011.
Japanese Office Action (Notice of Reasons for Rejection), re JP App. No. 2007-558238, dated Jun. 28, 2011.
Japanese Office Action (Official Inquiry) re JP App. No. 2007-558246, dated Dec. 11, 2012.
Japanese Office Action (Official Inquiry), re JP App. No. 2007-558238/Appeal No. 2012-004053, dated Dec. 11, 2012.
Japanese Office Action (Reasons for Rejection) re JP App. No. 2007-558246, dated Nov. 1, 2011.
Japanese Office Action re JP Application No. 2007-558249, dated Aug. 28, 2012.
Japanese Office Action re JP Application No. 2007-558249, dated Jul. 13, 2011.
Japanese Office Action re JP Application No. 2007-558249, dated Nov. 8, 2011.
Japanese Office Action re JP Application No. JP 2007-558208, dated Aug. 23, 2011.
Japanese Office Action re JP Application No. JP 2007-558248, dated Nov. 27, 2012.
Japanese Office Action re JP Application No. JP 2007-558248, dated Nov. 8, 2011.
Japanese Office Action re JP Application No. 2007-558209, dated Oct. 25, 2011.
Japanese Office Action re JP Application No. 2007-558209, dated Oct. 30, 2012.
Japanese Office Action re JP Application No. 2007-558245, dated Oct. 25, 2011.
Japanese Office Action re JP Application No. 2007-558245, dated Jan. 15, 2013.
Japanese Office Action re JP Application No. 2007-558245, dated Oct. 29, 2013.
Japanese Office Action, re JP Application No. 2007-558237, dated Aug. 1, 2011.
Japanese Office Action, re JP Application No. 2012-045419, dated Jun. 26, 2012.
Japanese Office Action, re JP Application No. JP 2007-558237, dated Oct. 16, 2012.
Japanese Office Action/Notice of Reasons for Rejection, re Application No. 2000-606119, dated Nov. 4, 2009.
Jones, K. L. et al. "A Protocol for Automatic Sensor Detection and Identification in a Wireless Biodevice Network," IEEE, Jun. 1998, 6 pages.
Kuenstner, et al., J. Todd; Measurement of Hemoglobin in Unlysed Blood by Near-Infrared Spectroscopy; vol. 48; No. 4, 1994.
Manzke, et al., B., Multi Wavelength Pulse OXimetry in the Measurement of Hemoglobin Fractions; vol. 2676, date unknown.
Naumenko, E. K.; Choice of Wavelengths for Stable Determination of Concentrations of Hemoglobin Derivatives from Absorption Spectra of Erythrocytes; vol. 63; No. 1; pp. 60-66 Jan.-Feb. 1996; Original article submitted Nov. 3, 1994.
Patent Cooperation Treaty (PCT) International Search Report; PCT/US 2006/007389; dated Jul. 17, 2006; pp. 1-9.
PCT International Search Report; PCT/US2006/007387; dated Jul. 17, 2006; pp. 1-9.
PCT International Search Report; PCT/US2006/007388; dated Jul. 17, 2006; pp. 1-9.
PCT International Search Report; PCT/US2006/007506; dated Jul. 17, 2006; pp. 1-10.
PCT International Search Report; PCT/US2006/007536; dated Jul. 17, 2006; pp. 1-9.
PCT International Search Report; PCT/US2006/007537; dated Jul. 17, 2006; pp. 1-10.
PCT International Search Report; PCT/US2006/007538; dated Jul. 17, 2006; pp. 1-9.
PCT International Search Report; PCT/US2006/007539; dated Jul. 17, 2006; pp. 1-9.
PCT International Search Report; PCT/US2006/007540; dated Jul. 17, 2006; pp. 1-9.
PCT International Search Report; PCT/US2006/007958; dated Jul. 17, 2006; pp. 1-8.
PCT Report on Patentability of International Application No. PCT/US2008/058327, dated Jun. 30, 2009, in 12 pages.
PCT Search Report of International Application No. PCT/US2008/058327, dated Aug. 12, 2008, in 12 pages.
Schmitt, Joseph M.; Simple Photon Diffusion Anaylsis of the Effects of Multiple Scattering on Pulse Oximetry; Mar. 14, 1991; revised Aug. 30, 1991.
Schmitt, Joseph M.; Zhou, Guan-Xiong; Miller, Justin, Measurement of Blood Hematocrit by Dual-wavelength Near-IR Photoplethysmography, published May 1992, Proc. SPIE vol. 1641, p. 150-161, Physiological Monitoring and Early Detection Diagnostic Methods, Thomas S. Mang; Ed. (SPIE homepage), in 12 pages.

(56) **References Cited**

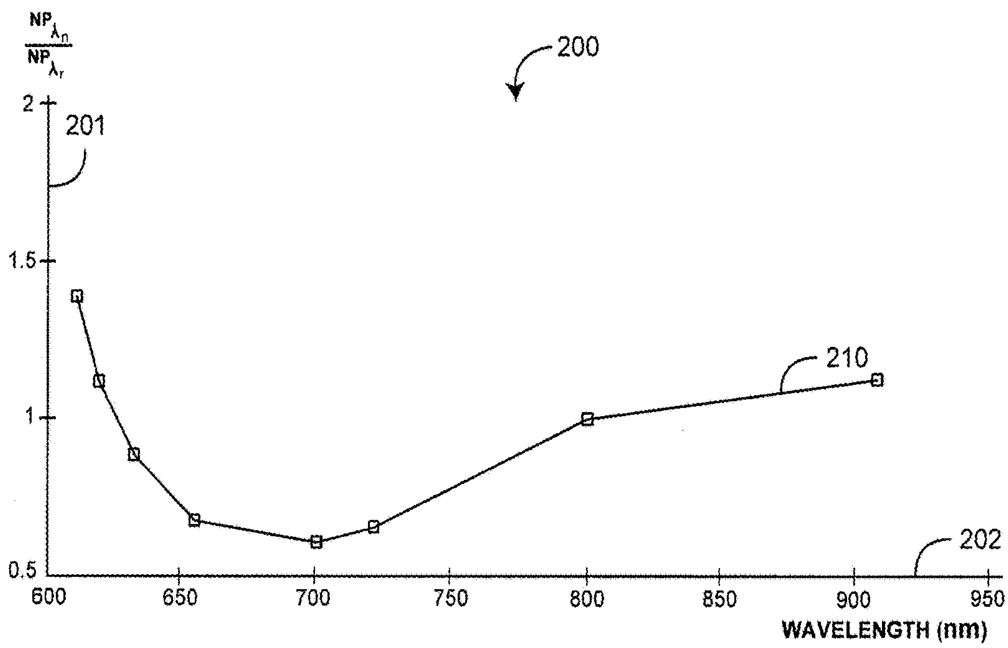
OTHER PUBLICATIONS

Schnapp, et al., L.M.; Pulse Oximetry. Uses and Abuses.; Chest 1990; 98; 1244-125000110.1378/Chest.98.5.1244.
Subramanian, S., et al. "Design for Constraint Violation Detection in Safety-Critical Systems," IEEE, Nov. 1998: pp. 1-8.
U.S. Pat. No. 7,764,982, Multiple Wavelength Sensor Emitters, Jul. 27, 2010.
U.S. Pat. No. 8,385,996, Multiple Wavelength Sensor Emitters, Feb. 26, 2013.
U.S. Pat. No. 8,849,365, Multiple Wavelength Sensor Emitters, Sep. 30, 2014.
U.S. Pat. No. 9,750,443, Multiple Wavelength Sensor Emitters, Sep. 5, 2017.
U.S. Pat. No. 7,729,733, Configurable Physiological Measurement System, Jun. 1, 2010.
U.S. Pat. No. 8,634,889, Configurable Physiological Measurement System, Jan. 21, 2014.
U.S. Pat. No. 9,241,662, Configurable Physiological Measurement System, Jan. 26, 2016.
U.S. Pat. No. 8,190,223, Noninvasive Multi-Parameter Patient Monitor, May 29, 2012.
U.S. Pat. No. 8,626,225, Noninvasive Multi-Parameter Patient Monitor, Jan. 7, 2014.
U.S. Pat. No. 8,130,105, Noninvasive Multi-Parameter Patient Monitor, Mar. 6, 2012.
U.S. Pat. No. 8,581,732, Noninvasive Multi-Parameter Patient Monitor, Nov. 12, 2013.
U.S. Pat. No. 8,912,909, Noninvasive Multi-Parameter Patient Monitor, Dec. 16, 2014.
U.S. Pat. No. 9,351,675, Noninvasive Multi-Parameter Patient Monitor, May 31, 2016.
U.S. Pat. No. 8,781,544, Multiple Wavelength Optical Sensor, Jul. 15, 2014.
U.S. Pat. No. 8,265,723, Oximeter Probe Off Indicator Defining Probe Off Space, Sep. 11, 2012.
U.S. Pat. No. 9,370,326, Oximeter Probe Off Indicator Defining Probe Off Space, Jun. 21, 2016.
U.S. Pat. No. 8,374,665, Tissue Profile Wellness Monitor, Feb. 12, 2013.
U.S. Pat. No. 8,965,471, Tissue Profile Wellness Monitor, Feb. 24, 2015.
U.S. Pat. No. 9,848,807, Tissue Profile Wellness Monitor, Dec. 26, 2017.
U.S. Appl. No. 15/694,541, Multiple Wavelength Sensor Emitters, filed Sep. 1, 2017.
U.S. Appl. No. 14/967,998, Configurable Physiological Measurement System, filed Dec. 14, 2015.
U.S. Appl. No. 14/148,462, Noninvasive Multi-Parameter Patient Monitor, filed Jan. 6, 2014.
U.S. Appl. No. 15/138,008, Noninvasive Multi-Parameter Patient Monitor, filed Apr. 25, 2016.
U.S. Appl. No. 12/082,810, Optical Sensor Assembly, filed Apr. 14, 2008.
U.S. Appl. No. 15/187,719, Oximeter Probe Off Indicator Defining Probe Off Space, filed Jun. 20, 2016.



u_a
100
101
Hb
HbO_2
120
110
102
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
550
600
650
700
750
800
850
900
950
1000
WAVELENGTH (nm)

FIG. 1



$\frac{NP_{\lambda_n}}{NP_{\lambda_r}}$
200
201
210
202
0.5
1
1.5
2
600
650
700
750
800
850
900
950
WAVELENGTH (nm)

FIG. 2

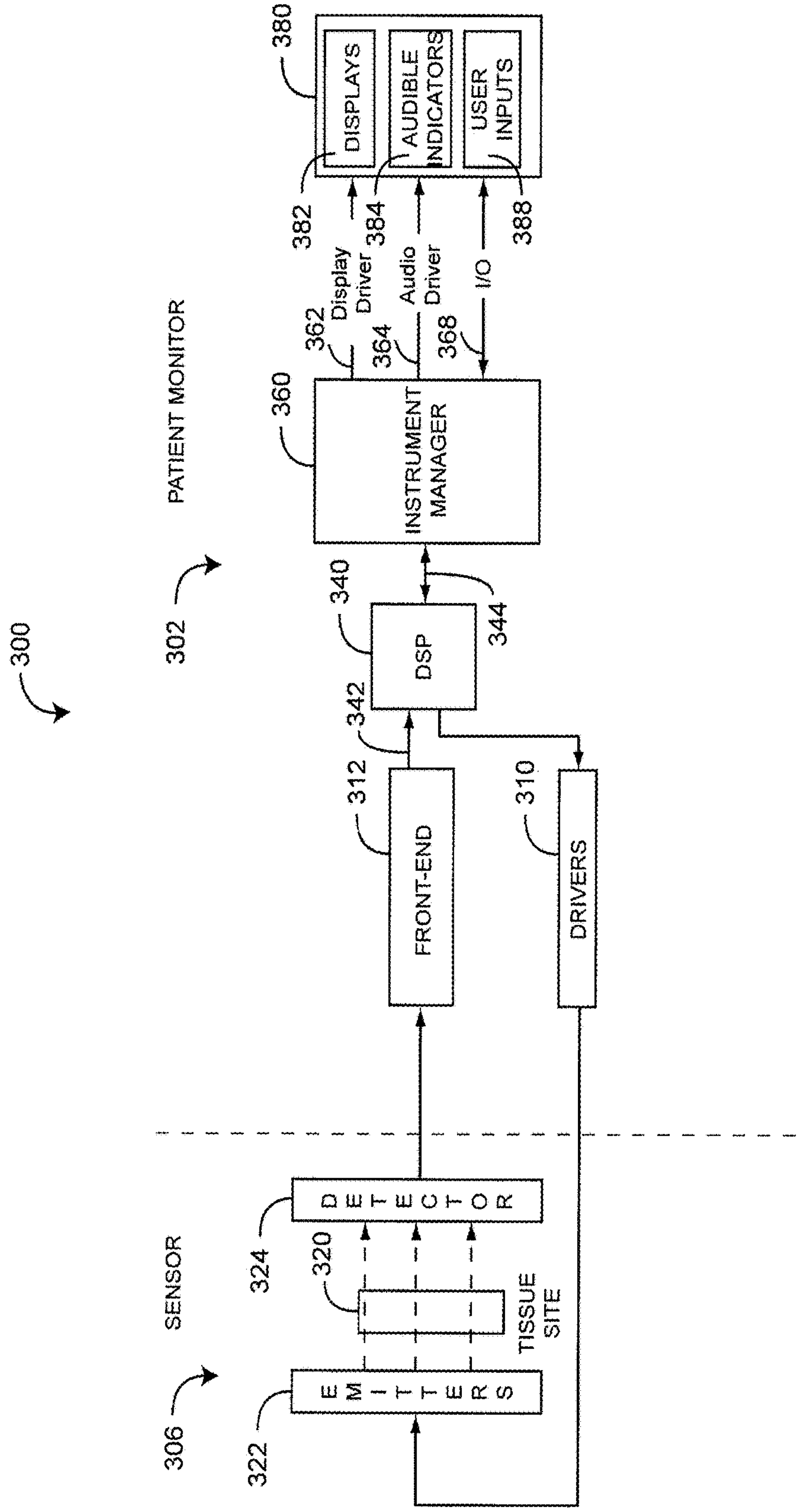

300
302
PATIENT MONITOR
306
SENSOR
322
EMITTERS
320
TISSUE SITE
324
DETECTOR
312
FRONT-END
310
DRIVERS
342
340
DSP
344
360
INSTRUMENT MANAGER
362
364
368
Display Driver
Audio Driver
I/O
380
DISPLAYS
AUDIBLE INDICATORS
USER INPUTS
382
384
388

FIG. 3

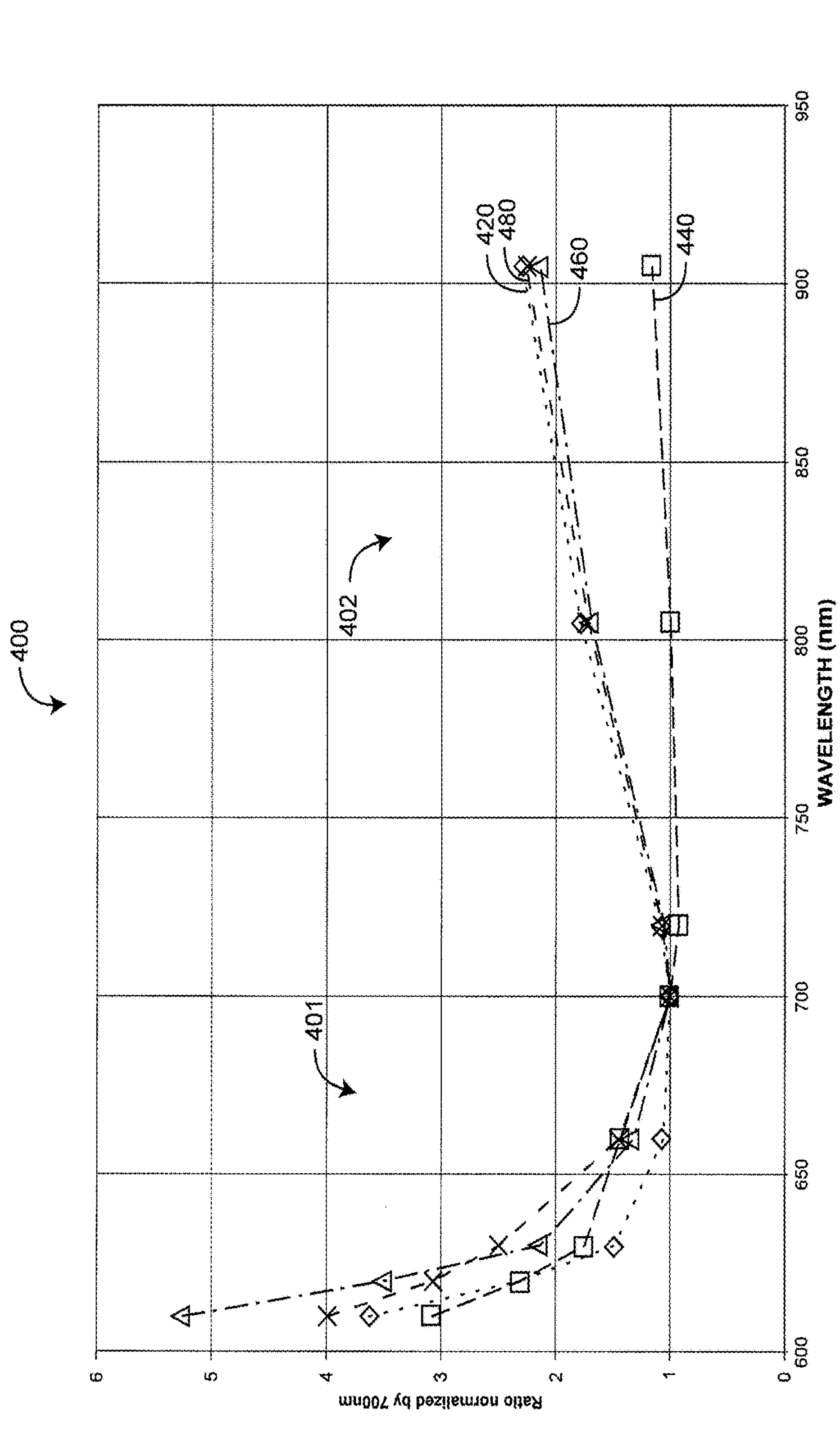

400
401
402
420
480
460
440
Ratio normalized by 700nm
0
1
2
3
4
5
6
WAVELENGTH (nm)
600
650
700
750
800
850
900
950

FIG. 4

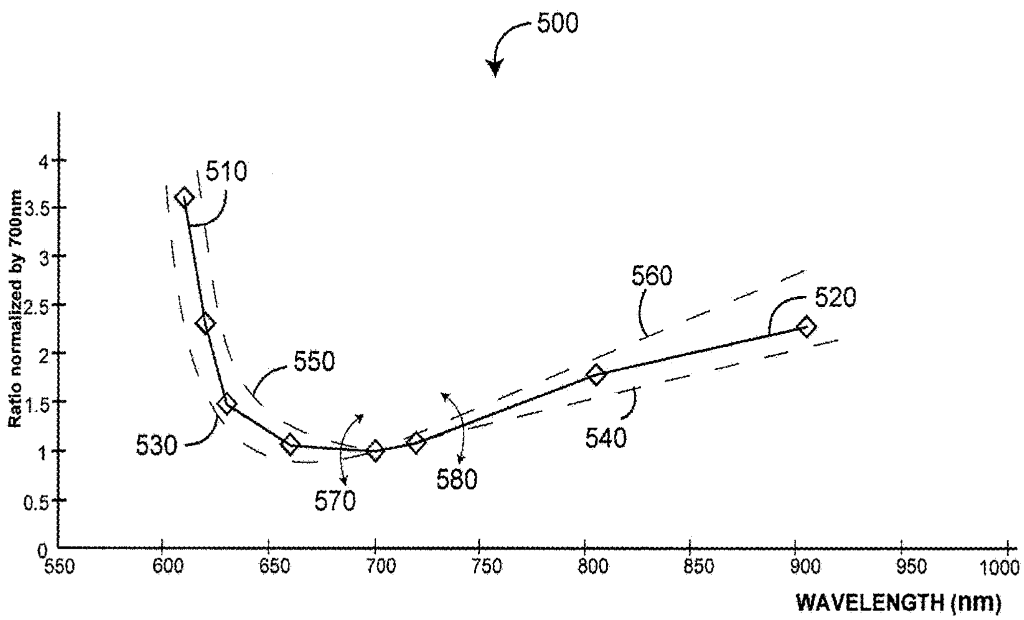

500
510
520
530
540
550
560
570
580
Ratio normalized by 700nm
4
3.5
3
2.5
2
1.5
1
0.5
0
550
600
650
700
750
800
850
900
950
1000
WAVELENGTH (nm)

FIG. 5

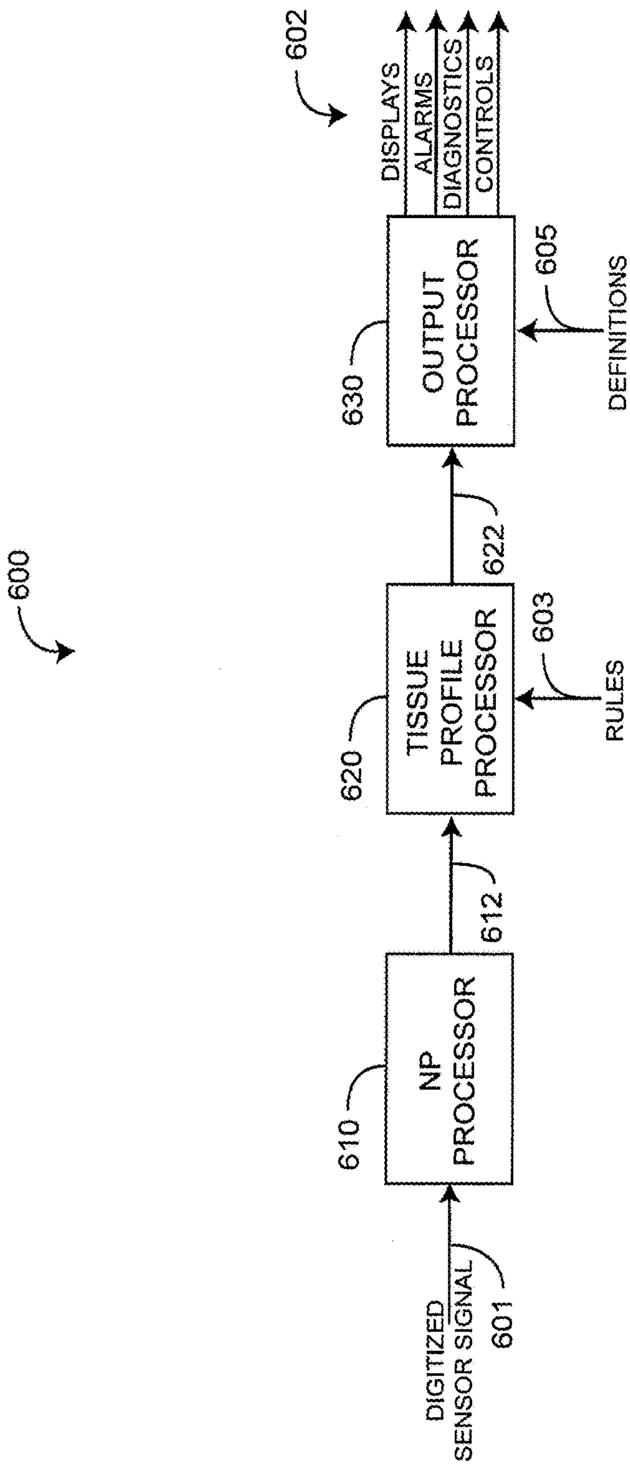

600
DIGITIZED SENSOR SIGNAL
601
610
NP PROCESSOR
612
620
TISSUE PROFILE PROCESSOR
603
RULES
622
630
OUTPUT PROCESSOR
605
DEFINITIONS
DISPLAYS
ALARMS
DIAGNOSTICS
CONTROLS
602

FIG. 6

TISSUE PROFILE WELLNESS MONITOR

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation of U.S. patent application Ser. No. 14/599,342, filed Jan. 16, 2015, entitled "TISSUE PROFILE WELLNESS MONITOR," which is a continuation of U.S. patent application Ser. No. 13/764,007, filed Feb. 11, 2013, entitled "TISSUE PROFILE WELLNESS MONITOR," which is a continuation of U.S. patent application Ser. No. 12/106,969, filed Apr. 21, 2008, entitled "TISSUE PROFILE WELLNESS MONITOR," which claims priority benefit under 35 U.S.C. § 119(e) to U.S. Provisional Application Ser. No. 60/925,811, filed Apr. 21, 2007, entitled "TISSUE PROFILE WELLNESS MONITOR." All of the above referenced applications are hereby incorporated by reference in their entirety herein.

BACKGROUND OF THE INVENTION

Spectroscopy is a common technique for measuring the concentration of organic and some inorganic constituents of a solution. The theoretical basis of this technique is the Beer-Lambert law, which states that the concentration c_i of an absorbent in solution can be determined by the intensity of light transmitted through the solution, knowing the path length d_λ, the intensity of the incident light $I_{0,\lambda}$, and the extinction coefficient $\varepsilon_{i,\lambda}$ at a particular wavelength λ. In generalized form, the Beer-Lambert law is expressed as:

$$I_\lambda = I_{0,\lambda} e^{-d_\lambda \cdot \mu_{a,\lambda}} \tag{1}$$

$$\mu_{a,\lambda} = \sum_{i=1}^{n} \varepsilon_{i,\lambda} \cdot c_i \tag{2}$$

Where $\mu_{a,\lambda}$ is the bulk absorption coefficient and represents the probability of absorption per unit length. The minimum number of discrete wavelengths that are required to solve EQS. 1-2 are the number of significant absorbers that are present in the solution.

A practical application of this technique is pulse oximetry, which utilizes a noninvasive sensor to measure oxygen saturation (SpO_2) and pulse rate. The sensor has light emitting diodes (LEDs) that transmit optical radiation of red and infrared wavelengths into a tissue site and a detector that responds to the intensity of the optical radiation after attenuation by pulsatile arterial blood flowing within the tissue site. Based on this response, a processor determines measurements for $SpO_2$and pulse rate, and outputs representative plethysmographic waveforms. Thus, "pulse oximetry" as used herein encompasses its broad ordinary meaning known to one of skill in the art, which includes at least those noninvasive procedures for measuring parameters of circulating blood through spectroscopy. Moreover, "plethysmograph" as used herein encompasses its broad ordinary meaning known to one of skill in the art, which includes at least data representative of a change in the absorption of particular wavelengths of light as a function of the changes in body tissue resulting from pulsing blood.

Pulse oximeters capable of reading through motion induced noise are available from Masimo Corporation ("Masimo") of Irvine, Calif. Moreover, portable and other oximeters capable of reading through motion induced noise are disclosed in at least U.S. Pat. Nos. 6,770,028, 6,658,276, 6,584,336, 6,263,222, 6,157,850, 5,769,785, and 5,632,272, which are owned by Masimo, and are incorporated by reference herein. Such reading through motion oximeters have gained rapid acceptance in a wide variety of medical applications, including surgical wards, intensive care and neonatal units, general wards, home care, physical training, and virtually all type of monitoring scenarios.

FIG. **1** illustrates an absorption graph **100** having a dimensionless vertical axis **101** of relative light absorption and a horizontal axis **102** of transmitted wavelength in nm. Shown is a plot of HbO_2absorption **110** and Hb absorption **120** versus wavelength, both normalized to the absorption at 800 nm. At red and near IR wavelengths below 970 nm, where water has a significant peak, Hb and $HbO_2$are the only significant absorbers normally present in the blood. Thus, typically only two wavelengths are needed to resolve the concentrations of Hb and HbO_2, e.g. a red (RD) wavelength at 660 nm and an infrared (IR) wavelength at 940 nm. In particular, $SpO_2$is computed based upon a red ratio Red_{AC}/Red_{DC} and an IR ratio IR_{AC}/IR_{DC}, which are the AC detector response magnitude at a particular wavelength normalized by the DC detector response at that wavelength. The normalization by the DC detector response reduces measurement sensitivity to variations in tissue thickness, emitter intensity and detector sensitivity, for example. The AC detector response is a plethysmograph, as described above. Thus, the red and IR ratios can be denoted as NP_{RD} and NP_{IR} respectively, where NP stands for "normalized plethysmograph." In pulse oximetry, oxygen saturation is calculated from the ratio NP_{RD}/NP_{IR}.

SUMMARY OF THE INVENTION

Oxygen saturation is a very useful physiological parameter for indicating the cardiovascular status of a patient, but allows healthcare providers only a few minutes warning that a patient is potentially having a medical crisis. A wellness indicator advantageously monitors changes in a patient's "tissue profile" so as to provide an advance warning of a deteriorating medical condition. This tissue profile is provided by a multiple wavelength sensor and a noninvasive multi-parameter patient monitor, which make blood absorption measurements at more than a red wavelength and an IR wavelength of conventional pulse oximetry. In one embodiment, described below, blood absorption measurements are made at eight wavelengths. Advantageously, this rich wavelength data characterizes a tissue site over a wavelength spectrum.

FIG. **2** illustrates an example of a tissue profile. In this example, the sensor emits eight wavelengths (610, 620, 630, 655, 700, 720, 800 and 905 nm). A tissue profile graph **200** has a NP ratio axis **201** and a wavelength axis **202**, where the NP ratios are of the form $NP_{\lambda 1}/NP_{\lambda 2}$. This is a generalization to multiple wavelengths of the ratio NP_{RD}/NP_{IR} described above for two (red and IR) wavelengths. In order to provide a common scale for these NP ratios, the ratios are calculated with respect to a reference wavelength, λr, which may be any of the available wavelengths. Thus, the plotted NP ratios **210** are denoted $NP_{\lambda n}/NP_{\lambda r}$. Note that the NP ratio at the reference wavelength is $NP_{\lambda r}/NP_{\lambda r}=1$, which is 700 nm in this example. In this example, a tissue profile **210** is plotted for SpO2=97%.

Not surprisingly, the tissue profile **210** has the same general shape as the absorption curves **110**, **120** of FIG. **1**. In particular, the AC component of the detector signal relative to the DC component (NP) for a specific wavelength is proportional to the light absorption at that wavelength.

Thus, the NP ratio magnitudes and hence the points along a tissue profile curve are proportional to absorption. Assuming negligible abnormal Hb species, if SpO_2 is close to 100%, most of the absorption is due to HbO_2 and, accordingly, the tissue profile is shaped closely to the HbO_2 absorption curve. As SpO_2 decreases from 100%, the tissue profile shape is increasing influenced by the shape of the Hb absorption curve.

In one embodiment, the tissue profile **210** consists solely of the measured NP ratios at the sensor wavelengths, i.e. a finite set of discrete values. In another embodiment, the tissue profile **210** consists of the measured NP ratios and defined NP ratio values between the sensor wavelengths, which are based upon tissue absorption characteristics. That is, the tissue profile **210** is a curve defined over a continuous range of wavelengths, including the sensor wavelengths. Although described above with respect to NP ratios derived from the AC component of the detector signal, a DC tissue profile may also be defined and applied to patient monitoring, as described below.

A tissue profile or tissue characterization is described in U.S. patent application Ser. No. 11/367,034, filed Mar. 1, 2006 entitled Physiological Parameter Confidence Measure; a multiple wavelength sensor is disclosed in U.S. patent application Ser. No. 11/367,013, filed Mar. 1, 2006 entitled Multiple Wavelength Sensor Emitters; and a multi-parameter patient monitor is disclosed in U.S. patent application Ser. No. 11/367,033, filed Mar. 1, 2006 entitled Noninvasive Multi-Parameter Patient Monitor, all of the aforementioned applications are assigned to Masimo Laboratories, Inc., Irvine, Calif. and all are incorporated by reference herein.

One aspect of a tissue profile wellness monitor comprises generating a tissue profile, predetermining rules and applying the rules to the tissue profile. The tissue profile is responsive to absorption of emitted wavelengths of optical radiation by pulsatile blood flowing within a tissue site. The rules are used to evaluate at least a portion of the tissue profile. A patient condition is indicated according to the applied rules.

Another aspect of a tissue profile wellness monitor comprises measuring a normalized plethysmograph (NP) to generate a tissue profile, testing the tissue profile and outputting the test results. The NP is measured at each of multiple wavelengths of optical radiation, and the NP is responsive to attenuation of the optical radiation by constituents of pulsatile blood flowing within a tissue site illuminated by the optical radiation. The tissue profile is tested against predetermined rules. The test results are output as at least one of a display, alarm, diagnostic and control.

A further aspect of a tissue profile wellness monitor comprises measuring a physiological parameter, generating a tissue profile, defining limits and indicating when the tissue profile exceeds the defined limits. The physiological parameter is responsive to multiple wavelengths of optical radiation after attenuation by constituents of pulsatile blood flowing within a tissue site. The tissue profile is responsive to the physiological parameter. The limits are defined for at least a portion of the tissue profile.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a graph of oxyhemoglobin and reduced hemoglobin light absorption versus wavelength across portions of the red and IR spectrum;

FIG. **2** is a graph of normalized plethysmograph (NP) ratios versus wavelength illustrating a tissue profile for 97% oxygen saturation;

FIG. **3** is a general block diagram of a patient monitoring system embodiment that implements a tissue profile wellness monitor;

FIG. **4** is a graph of tissue profiles for high saturation, low saturation, high carboxyhemoglobin (HbCO) and high methemoglobin (MetHb);

FIG. **5** is a graph illustrating tissue profile changes indicative of patient wellness; and

FIG. **6** is a block diagram of a tissue profile wellness monitor embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **3** illustrates a patient monitoring system **300**, which generates NP ratios and blood parameter measurements, such SpO_2, HbCO and HbMet, accordingly. The patient monitoring system is advantageously adapted as a tissue profile wellness monitor, as described below. The patient monitoring system **300** has a patient monitor **302** and a sensor **306**. The sensor **306** attaches to a tissue site **320** and includes a plurality of emitters **322** capable of irradiating the tissue site **320** with differing wavelengths of light, perhaps including the red and infrared wavelengths utilized in pulse oximeters. The sensor **306** also includes one or more detectors **324** capable of detecting the light after attenuation by the tissue site **320**. A multiple wavelength sensor is disclosed in U.S. application Ser. No. 11/367,013, filed on Mar. 1, 2006, titled Multiple Wavelength Sensor Emitters, cited above. Multiple wavelength sensors, such as Rainbow™-brand adhesive and reusable sensors are available from Masimo Corporation, Irvine, Calif.

As shown in FIG. **3**, the patient monitor **302** communicates with the sensor **306** to receive one or more intensity signals indicative of one or more physiological parameters. Drivers **310** convert digital control signals into analog drive signals capable of driving the sensor emitters **322**. A front-end **312** converts composite analog intensity signal(s) from light sensitive detector(s) **324** into digital data **342** input to the DSP **340**. The DSP **340** may comprise a wide variety of data and/or signal processors capable of executing programs for determining physiological parameters from input data. In an embodiment, the DSP **340** executes the processors **610**, **620**, **630** (FIG. **6**), described below.

The instrument manager **360** may comprise one or more microcontrollers providing system management, such as monitoring the activity of the DSP **340**. The instrument manager **360** also has an input/output (I/O) port **368** that provides a user and/or device interface for communicating with the monitor **302**. In an embodiment, the I/O port **368** provides threshold settings via a user keypad, network, computer or similar device, as described below.

Also shown in FIG. **3** are one or more user I/O devices **380** including displays **382**, audible indicators **384** and user inputs **388**. The displays **382** are capable of displaying indicia representative of calculated physiological parameters such as one or more of a pulse rate (PR), plethysmograph (pleth), perfusion index (PI), signal quality and values of blood constituents in body tissue, including for example, oxygen saturation (SpO_2), carboxyhemoglobin (HbCO) and methemoglobin (HbMet). The monitor **302** may also be capable of storing or displaying historical or trending data related to one or more of the measured parameters or combinations of the measured parameters. The monitor **302** may also provide a trigger for the audible indictors **384**, which operate beeps, tones and alarms, for example. Displays **382** include for example readouts, colored lights or graphics generated by LEDs, LCDs or CRTs to name a few. Audible indicators **384** include speakers or other audio transducers. User input devices **388** may include, for example, keypads, touch screens, pointing devices, voice recognition devices, or the like.

FIG. **4** illustrates tissue profile curves **400**, which are responsive to Hb constituents. In this example, the sensor emits eight wavelengths (610, 620, 630, 660, 700, 720, 805, 905 nm), which are normalized at 700 nm. Shown is a high saturation profile curve **420**, e.g. SpO2≈100% (◇); a low saturation profile curve **440**, e.g. SpO2=70% (□); a high HbCO profile curve **460**, e.g. HbCO=30% (Δ); and a high HbMet profile curve **480**, e.g. HbMet=6% (x). The profile curves **420-480** each has a head portion **401** at wavelengths less than 700 nm and a corresponding tail portion **402** at wavelengths of greater than 700 nm. As shown in FIG. **4**, a tissue profile head portion **401** has higher values when HbCO (Δ) or HbMet (x) has a higher percentage value. The head portion **401** has lower values when HbCO or HbMet has a lower percentage value. Also, both the head portion **401** and the tail portion **402** have higher values when SpO2 is a high percentage (◇) and lower values when SpO2 is a low percentage (□).

FIG. **5** illustrates an example tissue profile **500** utilized as a wellness indicator. As described with respect to FIG. **4** above, the position or shape of the tissue profile or changes in the position or shape of the tissue profile provide an indication of patient wellness. In particular, position, shape or relative movements of the curve "head" **510** or the curve "tail" **520** or both indicate potentially detrimental values or changes in values of hemoglobin constituents. For example, a drop in the tissue profile head **510** or tail **520** below a predefined boundary **530**, **540** may indicate reduced oxygen saturation. As another example, a rise in the tissue profile head **510** above a predefined boundary **550** may indicate increased concentrations of abnormal hemoglobin species, such as carboxyhemoglobin (HbCO) and methemoglobin (HbMet). Further, relative movements **570**, **580** of the tissue profile **500** faster than a predefined rate may indicate potentially serious trends in the concentrations of normal or abnormal hemoglobin species.

FIG. **6** illustrates a tissue profile wellness monitor **600** having a NP processor **610**, a tissue profile processor **620** and an output processor **630**. In an embodiment, these processors **610-630** execute in the DSP **340** (FIG. **3**) to monitor tissue profile changes. The NP processor **610** has digitized sensor signal input **601** from one or more sensor channels, such as described with respect to FIG. **3**, above, and generates normalized plethysmograph (NP) calculations **612** as described with respect to FIG. **1**, above.

As shown in FIG. **6**, the tissue profile processor **620** is configured to compare tissue profile changes **612** with respect to predetermined rules **603** and communicate the test results **622** to the output processor **630**. As an example, the tissue profile processor **620** may communicate to the output processor **630** when a tissue profile portion changes faster than a predetermined rate.

Also shown in FIG. **6**, the output processor **630** inputs the tissue profile processor results **622** and generates outputs **602** based upon predetermined output definitions **605**. For example, if a test profile result is "true", it might trigger an audible alarm. Rules and corresponding outputs are described in further detail with respect to TABLE 1, below.

In an embodiment, the tissue profile wellness monitor **600** provides outputs **602** according to TABLE 1, below. The terms listed in TABLE 1 are described with respect to FIG. **6**, above. Various other indicators, alarms, controls and diagnostics in response to various combinations of rules and output definitions can be substituted for, or added to, the rule-based outputs illustrated in TABLE 1.

In an embodiment, the tissue profile wellness monitor **600** grades a patient with respect to wellness utilizing green, yellow and red indicators. For example, a green panel light signals that the tissue profile is indicative of normal blood hemoglobin. A yellow panel light signals that changes in the tissue profile shape or position are indicative of potentially problematic changes in blood hemoglobin. A red panel light signals that the tissue profile is indicative of blood hemoglobin outside of normal ranges.

TABLE 1

Tissue Profile Rules and Outputs

TISSUE PROFILE RULES	OUTPUTS
If all portions of tissue profile are within boundaries and relatively unchanging over time	Then illuminate green indicator.
If tail drops faster than tail trend limit; or head rises faster than head trend limit	Then illuminate yellow indicator
If tail or head are outside of boundaries	Then illuminate red indicator

A tissue profile wellness monitor has been disclosed in detail in connection with various embodiments. These embodiments are disclosed by way of examples only and are not to limit the scope of the claims that follow. One of ordinary skill in art will appreciate many variations and modifications.

What is claimed is:

1. A physiological monitoring method comprising:

receiving, from a sensor comprising a light source that emits light into a tissue site of a patient and a detector that detects a plurality of wavelengths of the emitted light after attenuation by the tissue site, a signal indicative of the detected light at each of the plurality of wavelengths;

determining, at each of the plurality of wavelengths and based on the signal, normalized plethysmographs (NPs);

normalizing each of the determined NPs based on a reference wavelength;

determining a tissue profile curve based on the normalized NPs at the plurality of wavelengths;

analyzing a shape of the tissue profile curve relative to a predefined boundary curve to determine patient wellness; and

outputting an indication in response to determining the shape of the tissue profile curve exceeds the predefined boundary curve.

2. The method of claim **1**, wherein the indication comprises at least one of a display, an alarm, a diagnostic, or a control.

3. The method of claim **1**, wherein determining the tissue profile curve comprises:

measuring, from the signal, values indicative of an amount of light attenuation for at least some of the plurality wavelengths;

defining, based on characteristics of the tissue site, additional values corresponding to at least a portion of a wavelength spectrum between the respective wavelengths associated with the at least some of the plurality of wavelengths; and

combining the measured values at each of the at least some of the plurality wavelengths with the additional values.

4. The method of claim **1** further comprising:

outputting a first signal indicative of patient normalcy when the tissue profile curve is within the predefined boundary curve and a rate of change of the tissue profile curve is less than a maximum rate of change; and

outputting a second signal indicative of alert when at least a portion of the tissue profile curve is outside of the predefined boundary curve and the rate of change of the tissue profile curve is greater than the maximum rate of change.

5. The method of claim **1**, wherein the tissue profile curve is indicative of at least one of oxygen saturation of the patient, carboxyhemoglobin of the patient, or methemoglobin of the patient.

6. The method of claim **1**, wherein the tissue profile curve comprises a first portion and a second portion, and wherein the first portion is analyzed in comparison to a first portion predefined boundary curve, and the second portion is analyzed in comparison to a second portion predefined boundary curve.

7. The method of claim **6** further comprising:

providing a first indication in response to the first and second portions not exceeding the respective first and second portion predefined boundary curves;

providing a second indication in response to one of the first or second portions exceeding the respective first or second portion predefined boundary curves; and

providing a third indication in response to both of the first and second portions exceeding the respective first and second portion predefined boundary curves.

8. The method of claim **1**, wherein the reference wavelength is one of the plurality of wavelengths.

9. A physiological monitoring method comprising:

receiving, from a sensor comprising a light source that emits light into a tissue site of a patient and a detector that detects a plurality of wavelengths of the emitted light after attenuation by the tissue site, a signal indicative of the detected light at each of the plurality of wavelengths;

determining, at each of the plurality of wavelengths and based on the signal, normalized plethysmographs (NPs);

normalizing each of the determined NPs based on a reference wavelength;

determining a tissue profile curve indicative of a relationship among the normalized NPs at the plurality of wavelengths;

evaluating a trend in movement of the tissue profile curve relative to a predetermined trend limit to determine patient wellness; and

outputting an indication in response to determining the trend in movement of the tissue profile curve exceeds the predetermined trend limit.

10. The method of claim **9**, wherein the trend in movement of the tissue profile curve exceeding the predetermined trend limit indicates advance warning of deteriorating patient wellness.

11. The method of claim **9**, wherein the reference wavelength divides the tissue profile curve into a first portion and a second portion, and wherein the first portion is evaluated in relation to a first portion predetermined trend limit, and the second portion is evaluated in relation to a second portion predetermined trend limit.

12. The method of claim **11** further comprising:

providing a first indication in response to the first and second portions not exceeding the respective first and second portion predetermined trend limits;

providing a second indication in response to one of the first or second portions exceeding the respective first or second portion predetermined trend limits; and

providing a third indication in response to both of the first and second portions exceeding the respective first and second portion predetermined trend limits.

13. The method of claim **9**, wherein the reference wavelength is one of the plurality of wavelengths.

14. The method of claim **9**, wherein determining the tissue profile curve indicative of the relationship among the normalized NPs at the plurality of wavelengths comprises:

defining continuous normalized NP values corresponding to at least a portion of a wavelength spectrum between the two or more of the at least some of the plurality of wavelengths based at least in part on characteristics of the tissue site; and

combining the normalized NP values at each of the at least some of the plurality of wavelengths with the defined continuous normalized NP values.

15. The method of claim **9**, wherein the tissue profile curve is indicative of at least one of oxygen saturation of the patient, carboxyhemoglobin of the patient, or methemoglobin of the patient.

* * * * *

专利名称(译)	组织配置文件健康监视器		
公开(公告)号	US10251586	公开(公告)日	2019-04-09
申请号	US15/814229	申请日	2017-11-15
[标]申请(专利权)人(译)	梅西莫股份有限公司		
申请(专利权)人(译)	Masimo公司		
当前申请(专利权)人(译)	Masimo公司		
[标]发明人	LAMEGO MARCELO M		
发明人	LAMEGO, MARCELO M.		
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摘要(译)

组织轮廓健康监测器测量生理参数，生成组织轮廓，定义限制并指示组织轮廓何时超过限定的界限。在由组织部位内流动的脉动血液的成分衰减之后，生理参数响应于多个波长的光辐射。组织轮廓响应于生理参数。限制是针对组织轮廓的至少一部分定义的。