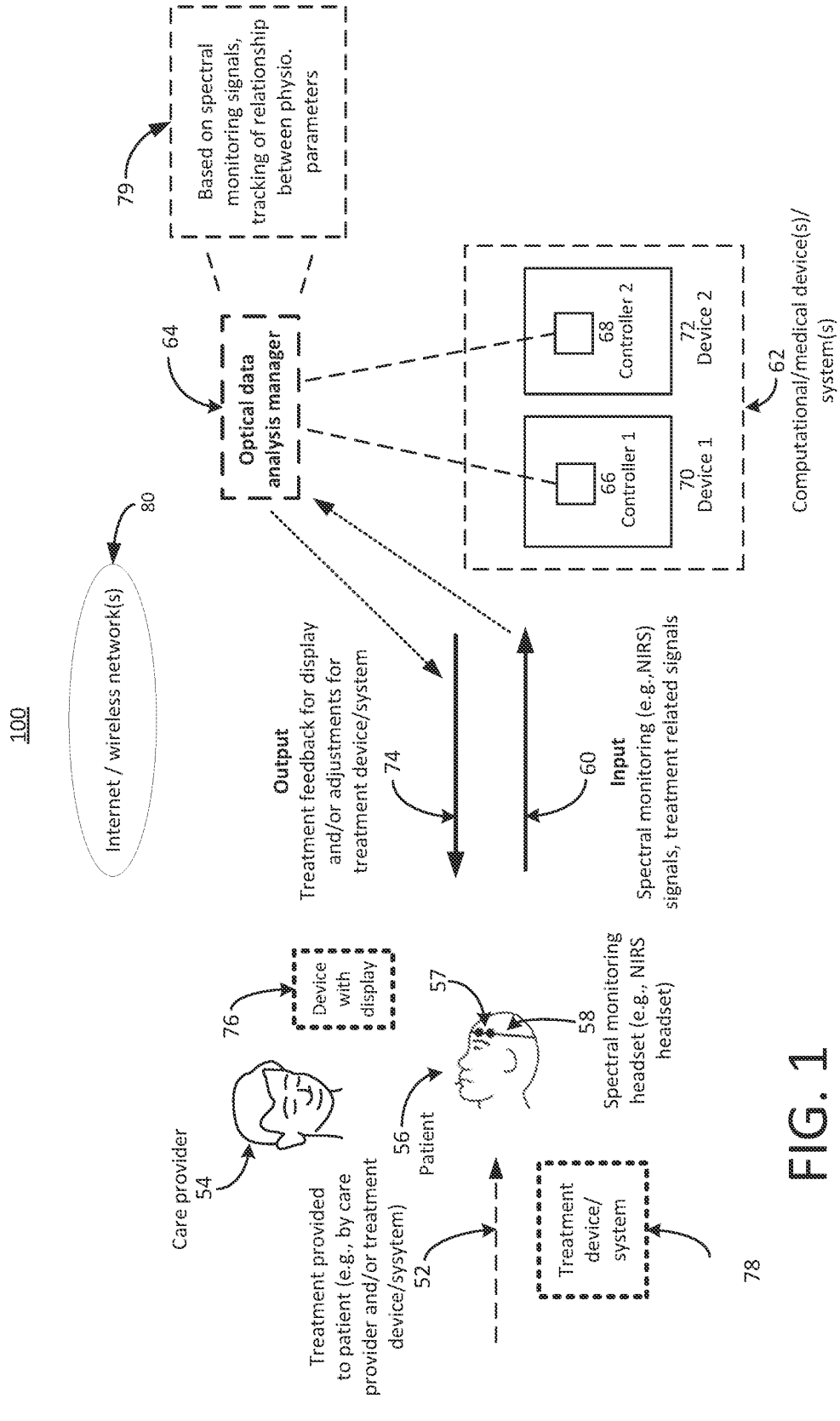

100
Internet / wireless network(s)
80
Output
Treatment feedback for display and/or adjustments for treatment device/system
74
Input
Spectral monitoring (e.g.,NIRS) signals, treatment related signals
60
64
Optical data analysis manager
79
Based on spectral monitoring signals, tracking of relationship between physio. parameters
66
Controller 1
70
Device 1
68
Controller 2
72
Device 2
62
Computational/medical device(s)/ system(s)
Care provider
54
Treatment provided to patient (e.g., by care provider and/or treatment device/sysytem)
52
Patient
56
57
58
Spectral monitoring headset (e.g., NIRS headset)
76
Device with display
Treatment device/ system
78

FIG. 1

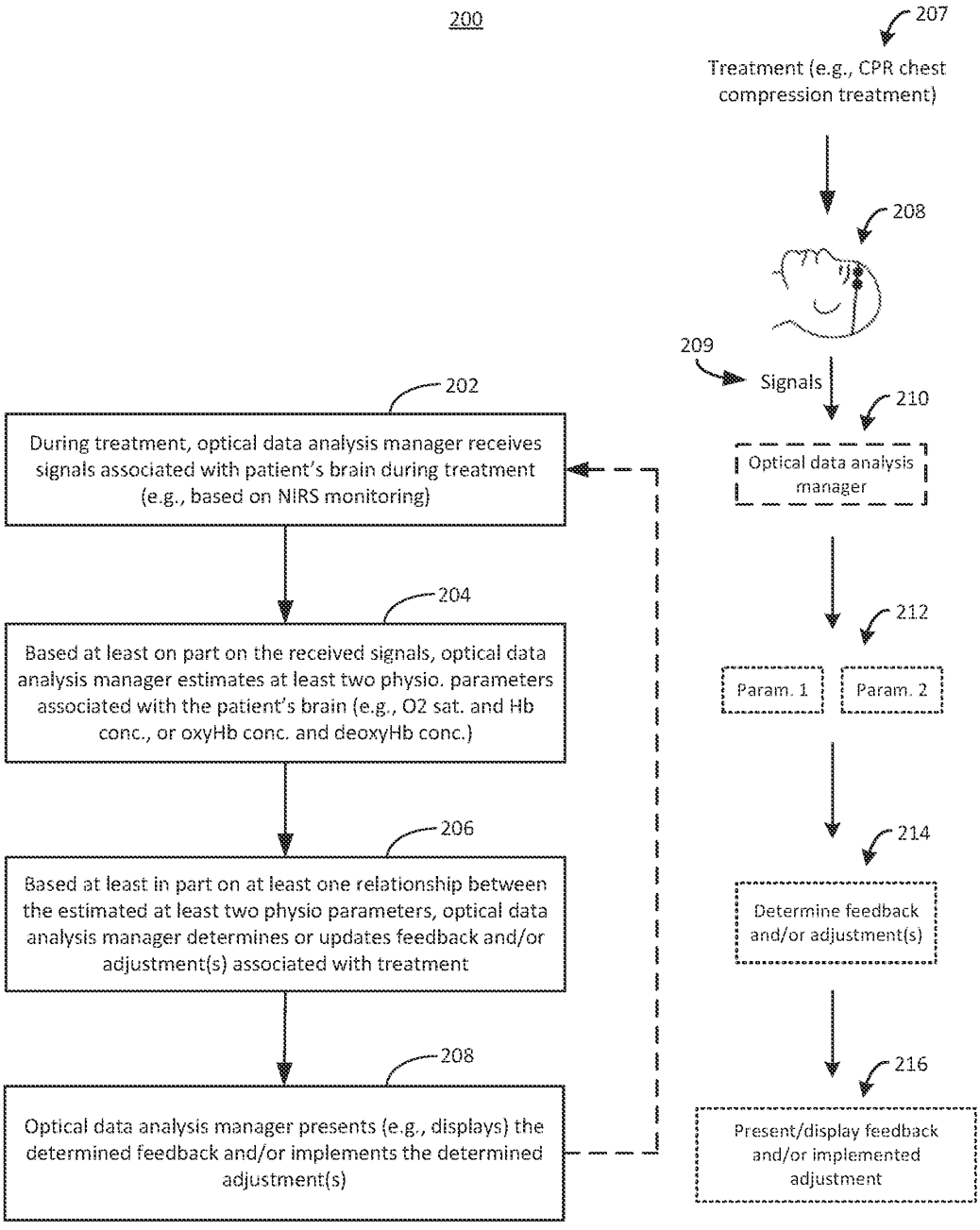

200
207
Treatment (e.g., CPR chest compression treatment)
208
209
Signals
210
Optical data analysis manager
212
Param. 1
Param. 2
214
Determine feedback and/or adjustment(s)
216
Present/display feedback and/or implemented adjustment
202
During treatment, optical data analysis manager receives signals associated with patient's brain during treatment (e.g., based on NIRS monitoring)
204
Based at least on part on the received signals, optical data analysis manager estimates at least two physio. parameters associated with the patient's brain (e.g., O2 sat. and Hb conc., or oxyHb conc. and deoxyHb conc.)
206
Based at least in part on at least one relationship between the estimated at least two physio parameters, optical data analysis manager determines or updates feedback and/or adjustment(s) associated with treatment
208
Optical data analysis manager presents (e.g., displays) the determined feedback and/or implements the determined adjustment(s)

FIG. 2

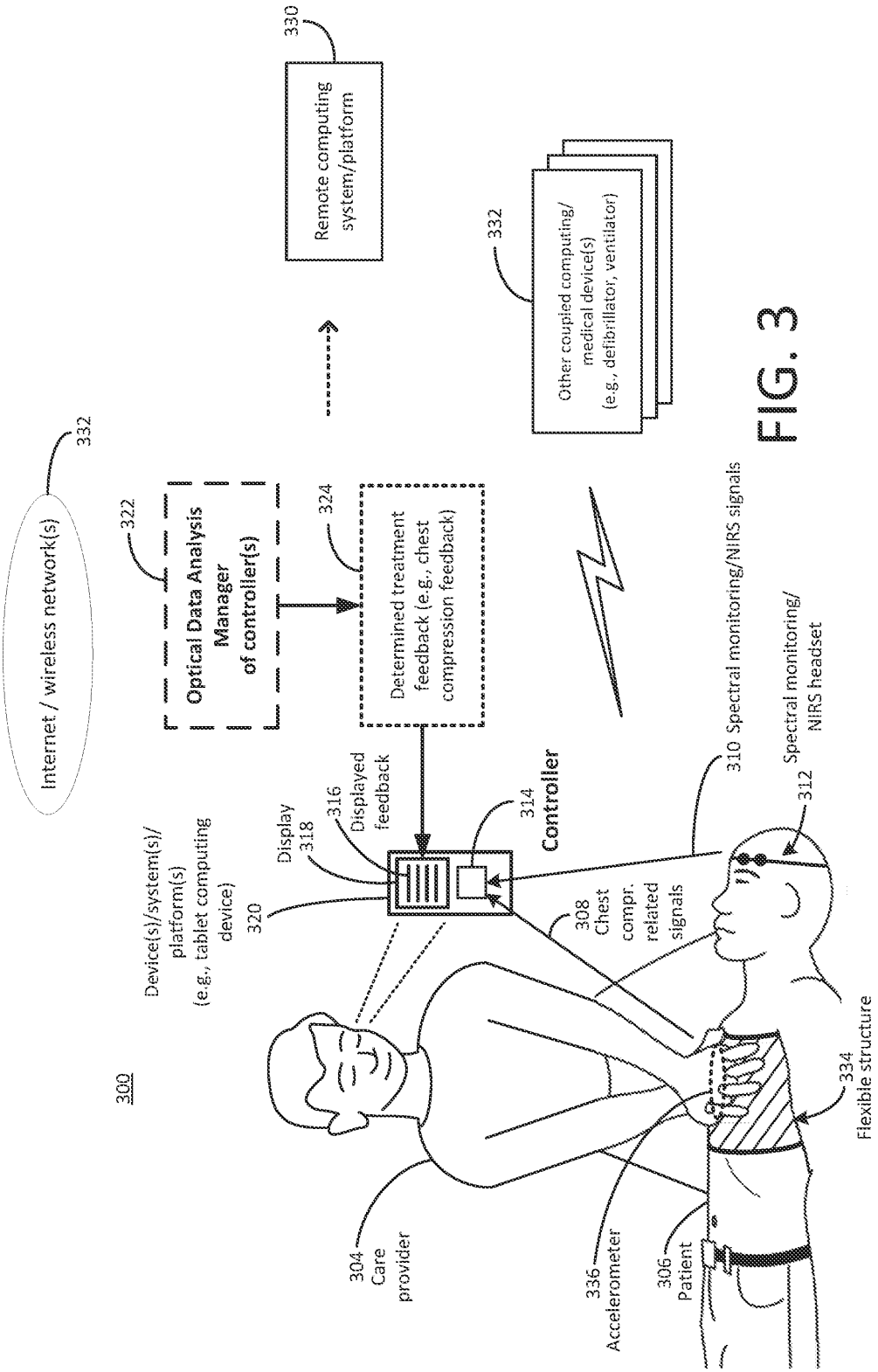

300
Internet / wireless network(s)
332
Device(s)/system(s)/ platform(s) (e.g., tablet computing device)
320
Optical Data Analysis Manager of controller(s)
322
Determined treatment feedback (e.g., chest compression feedback)
324
Remote computing system/platform
330
Other coupled computing/ medical device(s) (e.g., defibrillator, ventilator)
332
Display 318
Displayed feedback 316
Controller 314
310 Spectral monitoring/NIRS signals
Spectral monitoring/ NIRS headset 312
308 Chest compr. related signals
304 Care provider
336 Accelerometer
306 Patient
334 Flexible structure

FIG. 3

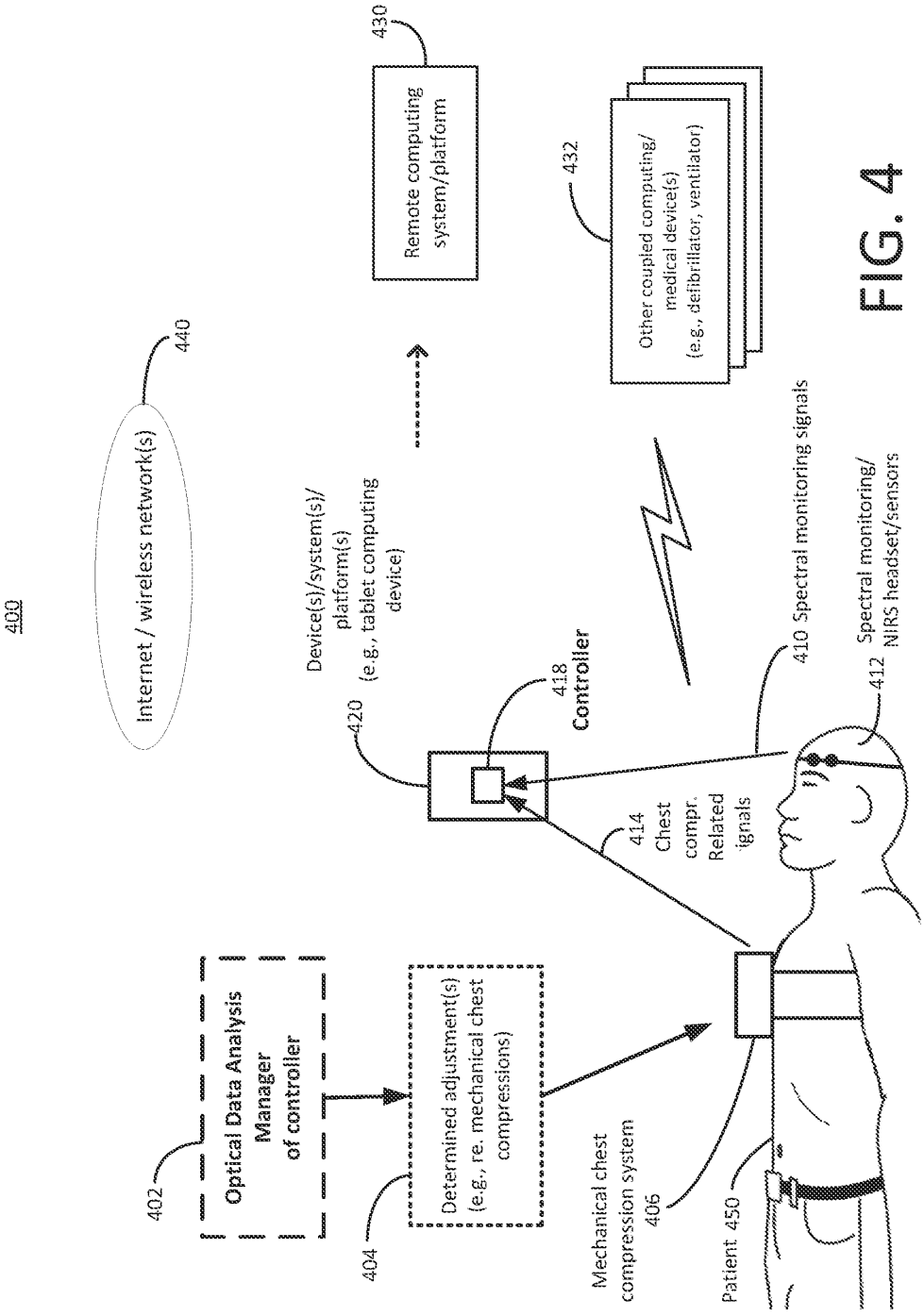

400
Internet / wireless network(s)
440
Remote computing system/platform
430
Other coupled computing/ medical device(s) (e.g., defibrillator, ventilator)
432
Device(s)/system(s)/ platform(s) (e.g., tablet computing device)
420
418 Controller
410 Spectral monitoring signals
412 Spectral monitoring/ NIRS headset/sensors
414 Chest compr. Related signals
Optical Data Analysis Manager of controller
402
Determined adjustment(s) (e.g., re. mechanical chest compressions)
404
Mechanical chest compression system 406
Patient 450

FIG. 4

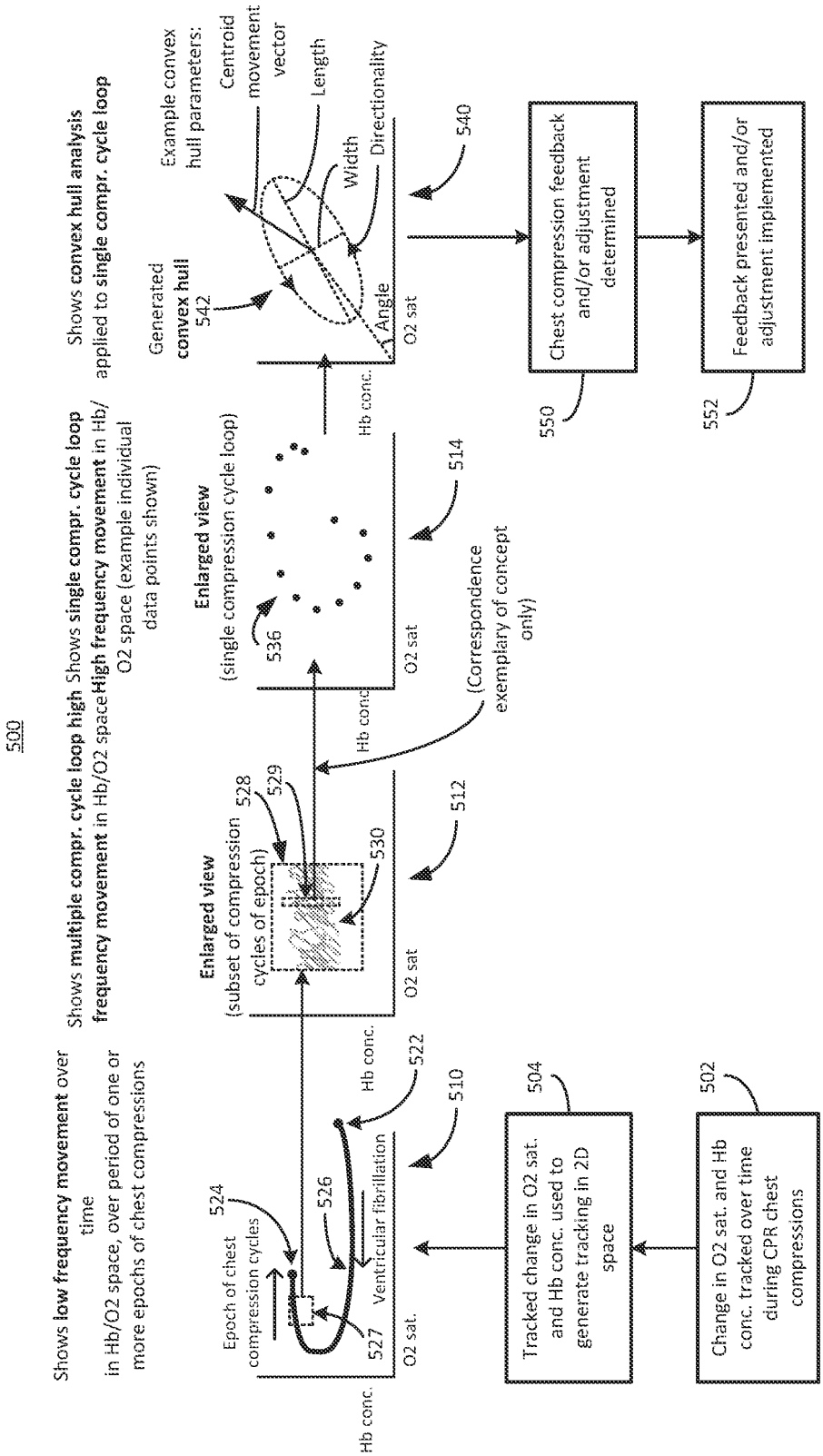

500
Shows low frequency movement over time in Hb/O2 space, over period of one or more epochs of chest compressions
Hb conc.
O2 sat.
Epoch of chest compression cycles
524
526
527
Ventricular fibrillation
522
510
Shows multiple compr. cycle loop high frequency movement in Hb/O2 space
Hb conc.
O2 sat
Enlarged view (subset of compression cycles of epoch)
528
529
530
512
Shows single compr. cycle loop High frequency movement in Hb/O2 space (example individual data points shown)
Hb conc.
O2 sat
Enlarged view (single compression cycle loop)
536
514
(Correspondence exemplary of concept only)
Shows convex hull analysis applied to single compr. cycle loop
Generated convex hull 542
Example convex hull parameters:
Centroid movement vector
Length
Width
Directionality
Angle
Hb conc.
O2 sat
540
Tracked change in O2 sat. and Hb conc. used to generate tracking in 2D space
504
Change in O2 sat. and Hb conc. tracked over time during CPR chest compressions
502
Chest compression feedback and/or adjustment determined
550
Feedback presented and/or adjustment implemented
552

FIG. 5

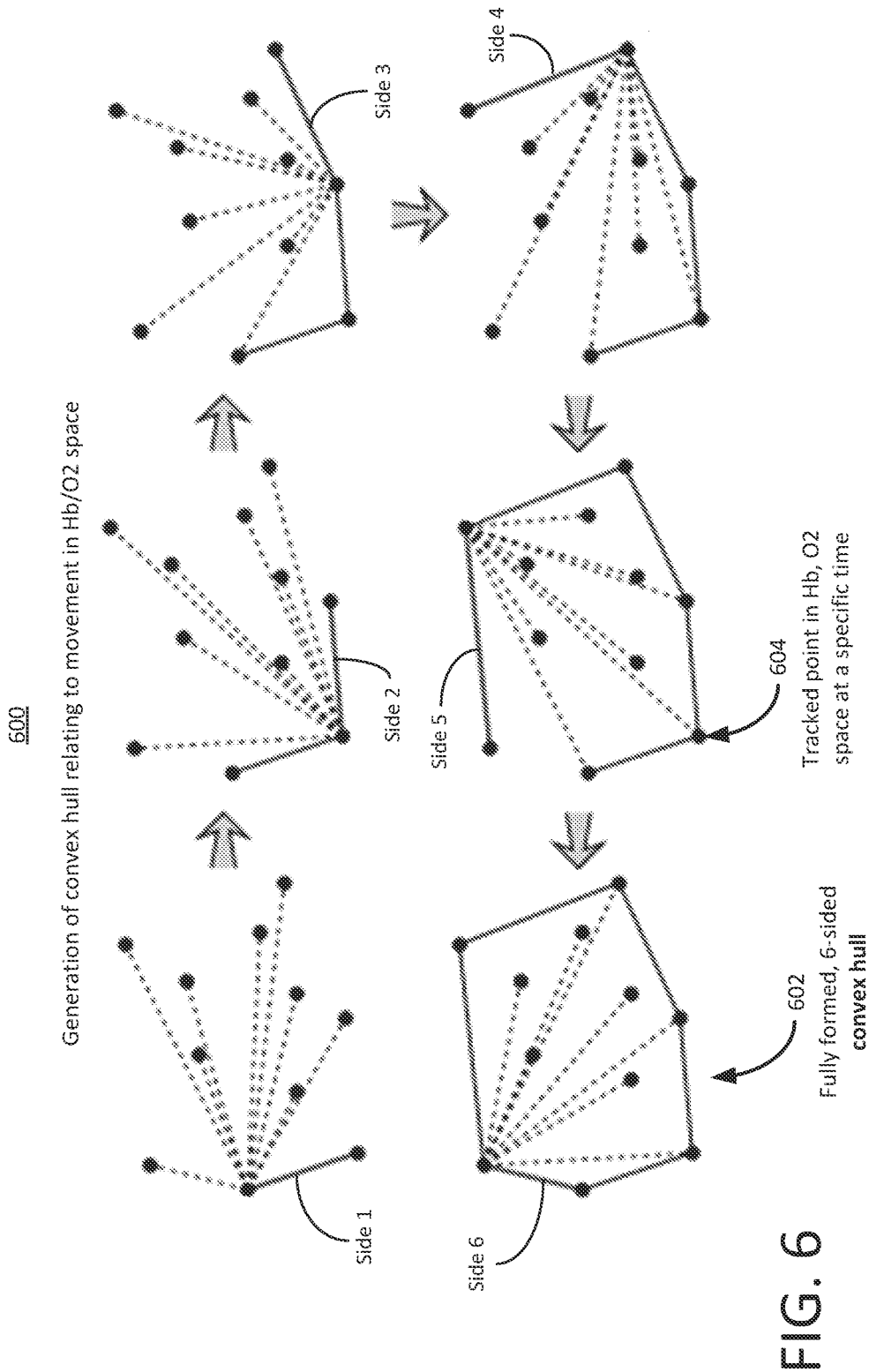
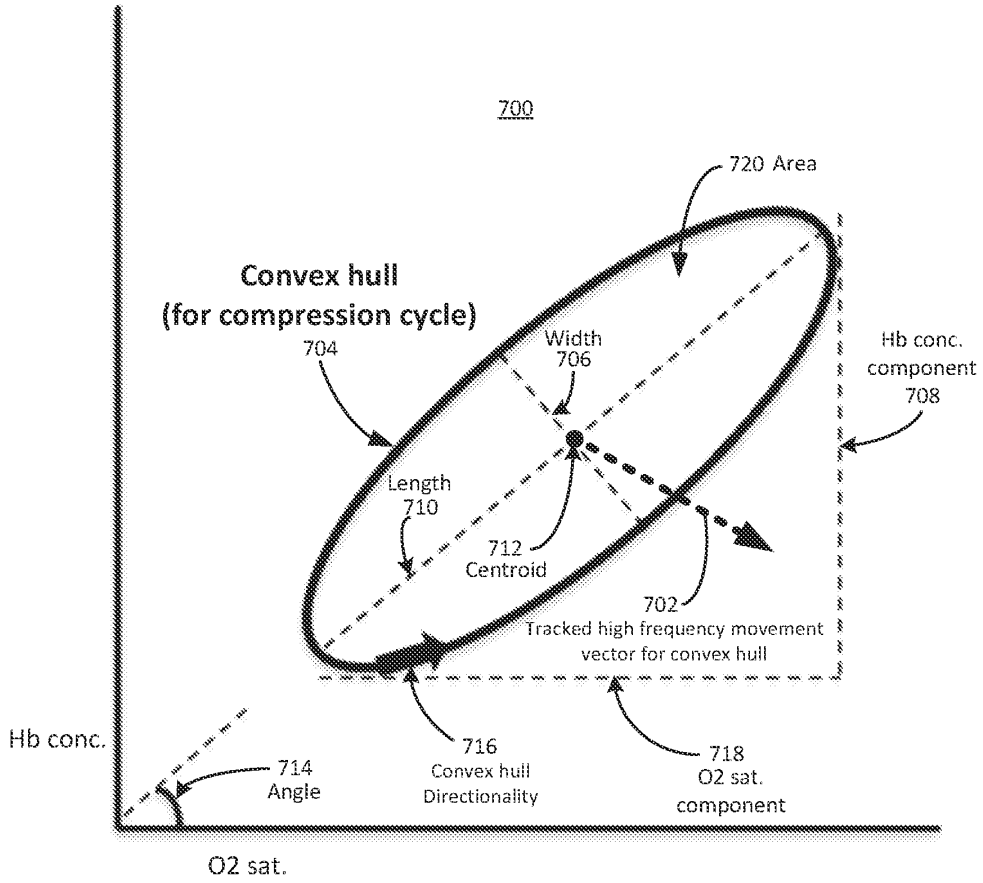

600
Generation of convex hull relating to movement in Hb/O2 space
Side 1
Side 2
Side 3
Side 4
Side 5
Side 6
602
Fully formed, 6-sided convex hull
604
Tracked point in Hb, O2 space at a specific time

FIG. 6



Convex hull directionality – In some examples, may be associated with dominant physiological or oxygenation related factors at different times during the cycle

Length – In some examples, may be associated with cardiac output from the chest compression

Width – In some examples, may be associated with degree of hemodynamic activity or change during the cycle

Angle – In some examples, may be associated with physiological cause(s) of movement in the parameter space during the cycle

Area – In some examples, may be indicative of amount of the hemodynamic variation during a cycle

Low frequency movement vector – In some examples, movement of centroid over time indicates change in O2 sat. and Hb conc., and represents low frequency movement over a period of chest compressions

FIG. 7

Convex hull (CH) related parameter: CH centroid movement along X axis (O2 sat.)

Associated physiology & treatment conditions, in some examples:

800

• In some examples, increases in O2 sat./rightward movement may be lead to greater oxygen delivery
• In some examples, increase in O2 sat. may be due to arterial dilation leading to increased proportion of arterial blood volume
• In some examples, **in hemorrhage,** O2 sat. may decrease with increased loss of arterial blood volume
• in some examples, **in long duration CPR,** O2 sat. may depend on CPR depth and, with ventilation, PEEP levels

FIG. 8A

Convex hull (CH) related parameter: CH centroid movement along Y axis (Hb conc.)

Associated physiology & treatment conditions, in some examples:

820

• In some examples, increases in Hb conc./upward movement may be lead to greater oxygen delivery
• In some examples, decreases in Hb conc. may correspond with decreases in blood delivery
• In some examples, Hb conc. may increase due to arterial dilation leading to increase in proportion of arterial blood volume
• In some examples, **in hemorrhage,** Hb conc. may decrease with increased loss of arterial blood volume, and may increase with return of blood
• In some examples, **in long duration CPR,** O2 sat. may depend on CPR depth and, with ventilation, PEEP levels

FIG. 8B

Convex hull (CH) related parameter: CH Length

Associated physiology & treatment conditions, in some examples:

840

• In some examples, larger lengths may lead to greater oxygen delivery, and length may be proportional to arterial and/or venous blood volume shifts
• In some examples, changes in length may reflect: changes in patient status during normal sinus rhythm, changes in patient responsiveness to chest compressions
• In some examples, larger lengths may – may lead to greater oxygen delivery, and may indicate larger pulse pressures, better cardiac output
• In some examples, CO2 induced vasodilation may lead volume to transient declines in pulsatile shifts, and constriction following the removal of CO2 may lead to increased pulsatility, causing an increase in length
• In some examples, **in hemorrhage,** length may increase with increased pulse pressure, but later decrease with blood volume and blood pressure decreases
• In some examples, **in long duration CPR,** length may vary with chest compression depth, may decrease for later epochs, and, with ventilation, length may be greatest with mid-level ventilation PEEP levels

FIG. 8C

Convex hull (CH) related parameter: CH angle

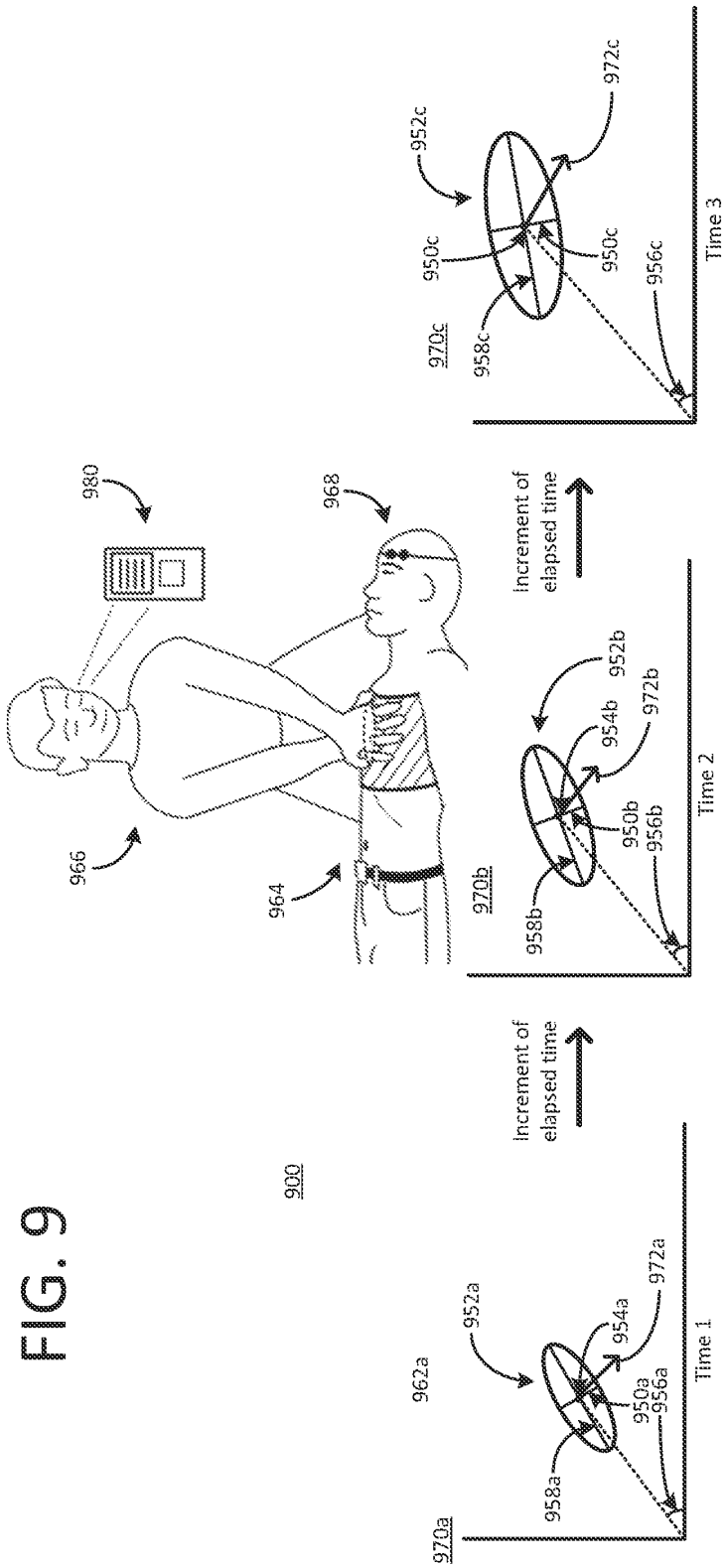
Associated physiology & treatment conditions, in some examples:

860

• In some examples, smaller angles may lead to greater oxygen delivery, and angle may depend on the relative blood volume shifts of arterial and venous blood
• In some examples, in the O2 sat./Hb conc. space, smaller angles may correspond with larger changes in O2 saturation relative to blood volume shift, which may indicate that blood volume shift is driven more by arterial blood
• In some examples, in the deoxyHb conc./oxyHb conc. space, smaller angles may correspond with larger shifts in oxyHb concentration relative to deoxyHb concentration.
• In some examples, in the O2 sat./Hb conc. space, generally, angle may increase when arterial blood volume shift declines more relative to the venous blood volume shift
• In some examples, **in hemorrhage**, when blood volume loss causes convex hull length to become small enough, angle may become more variable
• In some examples, **in long duration CPR,** compression depths (and, with ventilation, ventilation strategies) that optimize coronary perfusion pressure (CPP) may decrease angle, but the angle may increase over time

FIG. 8D

FIG. 9


900
980
968
966
964
962a
970a
952a
954a
972a
950a
956a
958a
Time 1
Increment of elapsed time
970b
952b
954b
972b
950b
956b
958b
Time 2
Increment of elapsed time
970c
952c
950c
972c
950c
956c
958c
Time 3

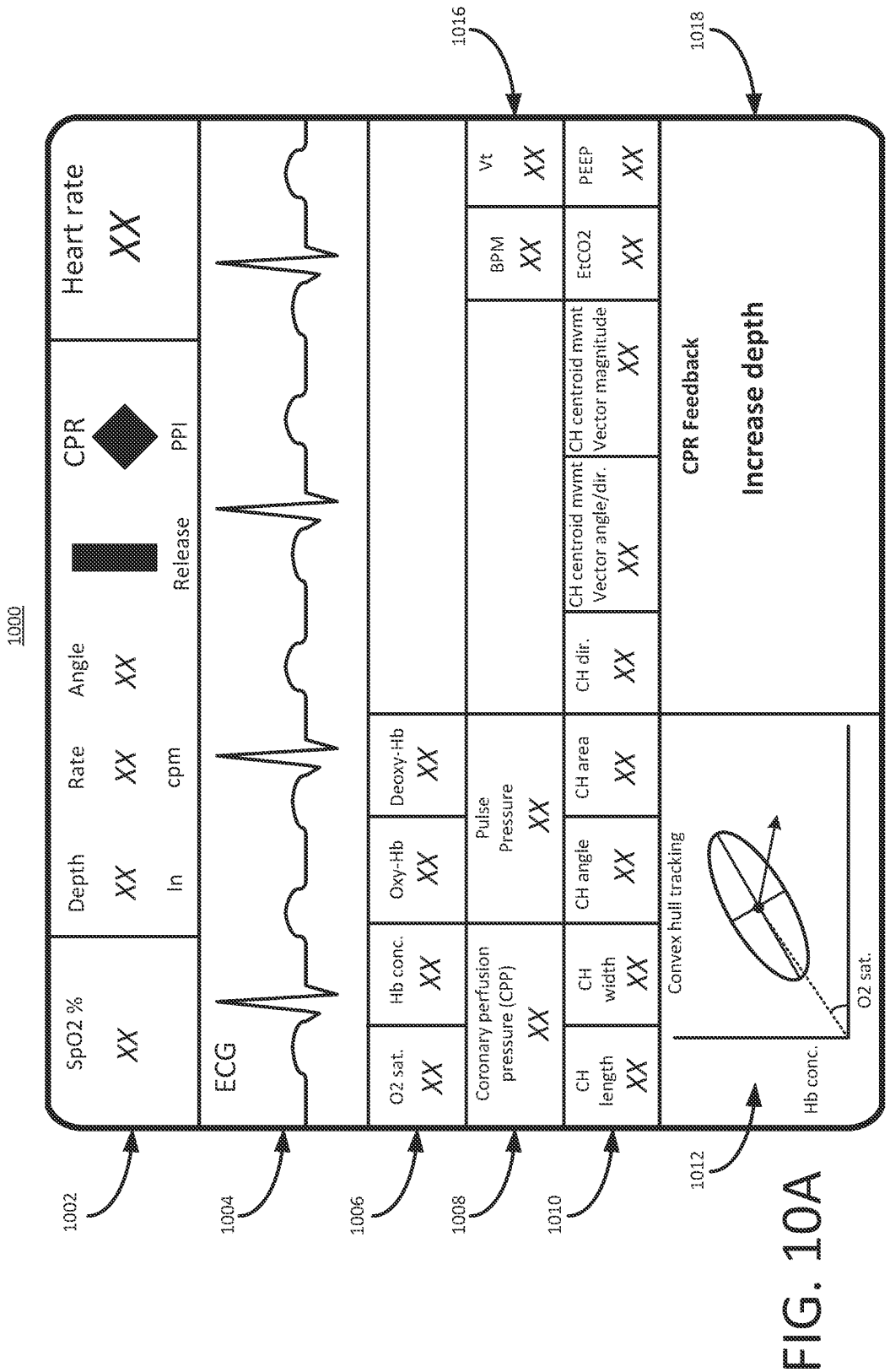

1000
SpO2 %
XX
Depth
XX
In
Rate
XX
cpm
Angle
XX
CPR
Release
PPI
Heart rate
XX
ECG
O2 sat.
XX
Hb conc.
XX
Oxy-Hb
XX
Deoxy-Hb
XX
Coronary perfusion pressure (CPP)
XX
Pulse Pressure
XX
CH length
XX
CH width
XX
CH angle
XX
CH area
XX
CH dir.
XX
CH centroid mvmt Vector angle/dir.
XX
CH centroid mvmt Vector magnitude
XX
BPM
XX
EtCO2
XX
Vt
XX
PEEP
XX
CPR Feedback
Increase depth
Convex hull tracking
Hb conc.
O2 sat.
1002
1004
1006
1008
1010
1012
1016
1018

FIG. 10A

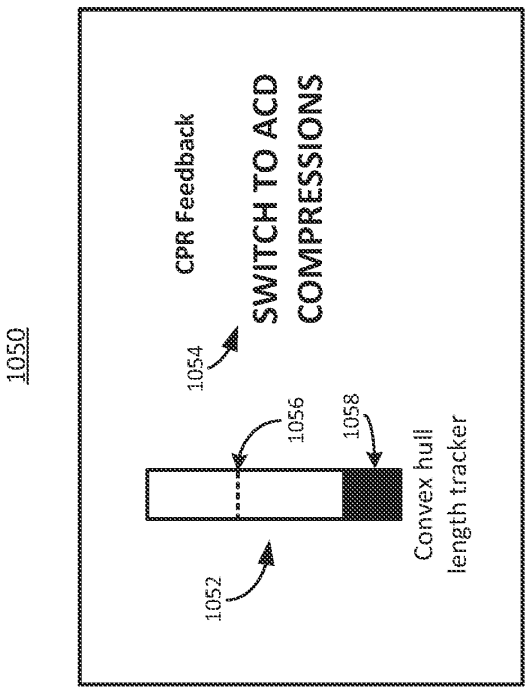

1050
CPR Feedback
SWITCH TO ACD COMPRESSIONS
1054
1056
1058
Convex hull length tracker
1052

FIG. 10B

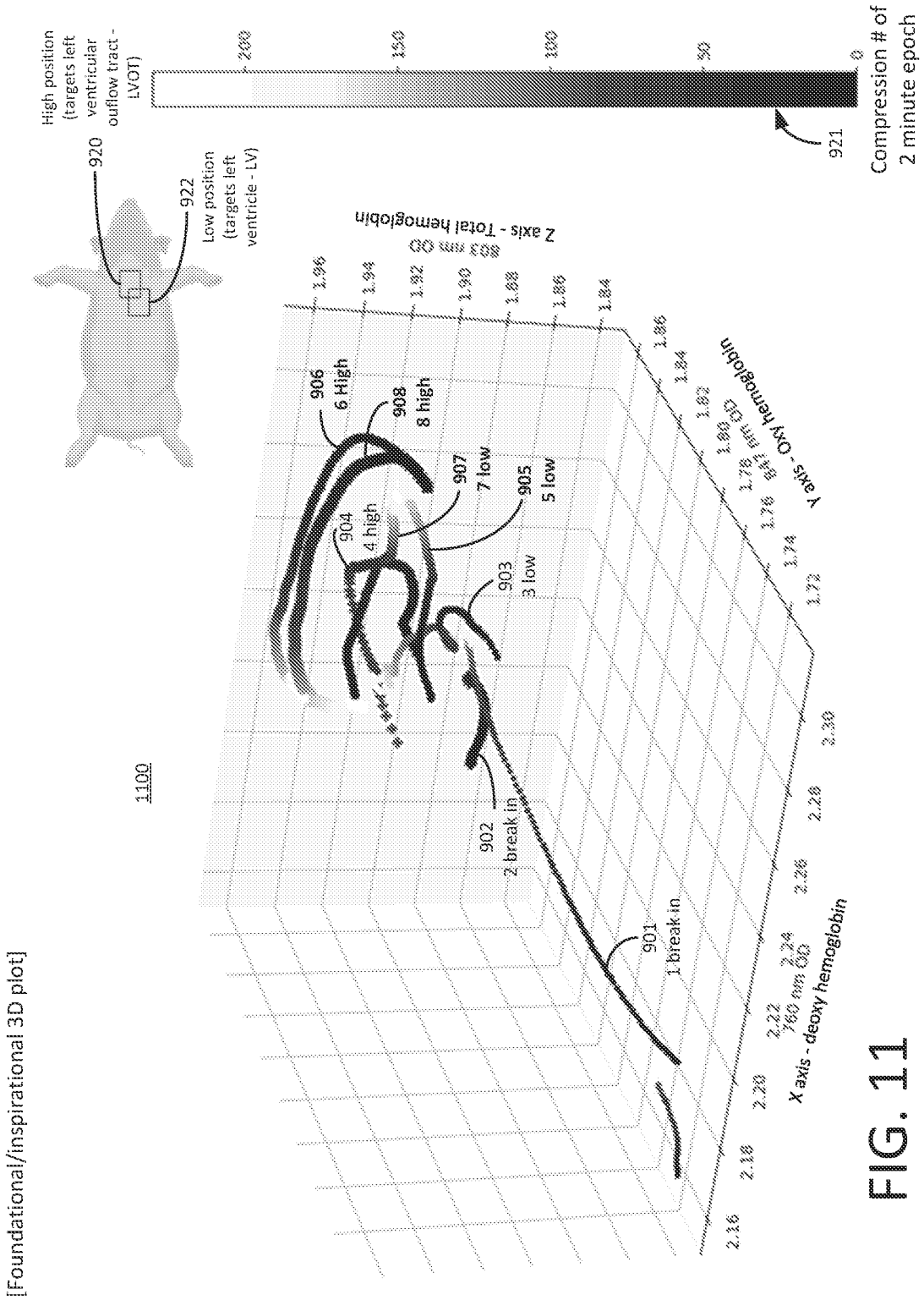

[Foundational/inspirational 3D plot]
1100
High position (targets left ventricular outflow tract - LVOT)
Low position (targets left ventricle - LV)
920
922
200
150
100
50
0
921
Compression # of 2 minute epoch
Z axis - Total hemoglobin
803 nm OD
1.96
1.94
1.92
1.90
1.88
1.86
1.84
906 6 High
908 8 high
907 7 low
905 5 low
904 4 high
903 3 low
902 2 break in
901 1 break in
Y axis - Oxy hemoglobin
880 nm OD
1.86
1.84
1.82
1.80
1.78
1.76
1.74
1.72
2.30
2.28
2.26
2.24
2.22
2.20
2.18
2.16
X axis - deoxy hemoglobin
760 nm OD

FIG. 11

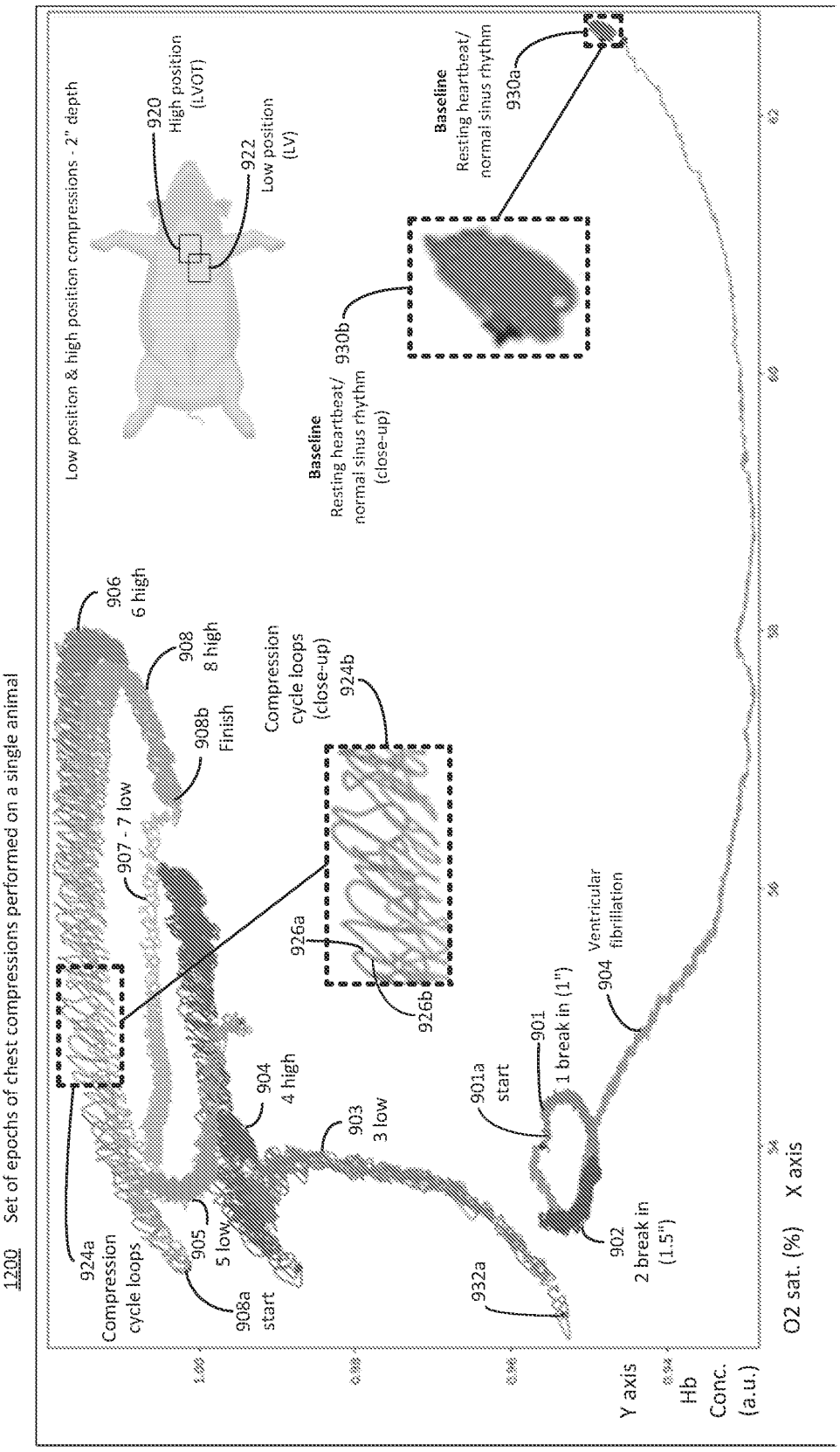

1200 Set of epochs of chest compressions performed on a single animal
Low position & high position compressions - 2" depth
920 High position (LVOT)
922 Low position (LV)
Baseline Resting heartbeat/ normal sinus rhythm (close-up)
930b
Baseline Resting heartbeat/ normal sinus rhythm
930a
924a Compression cycle loops
906 6 high
908 8 high
908b Finish
907 - 7 low
905 5 low
908a start
904 4 high
903 3 low
932a
902 2 break in (1.5")
901a start
901 1 break in (1")
904 Ventricular fibrillation
926a
926b
Compression cycle loops (close-up)
924b
Y axis Hb Conc. (a.u.)
O2 sat. (%) X axis

FIG. 12

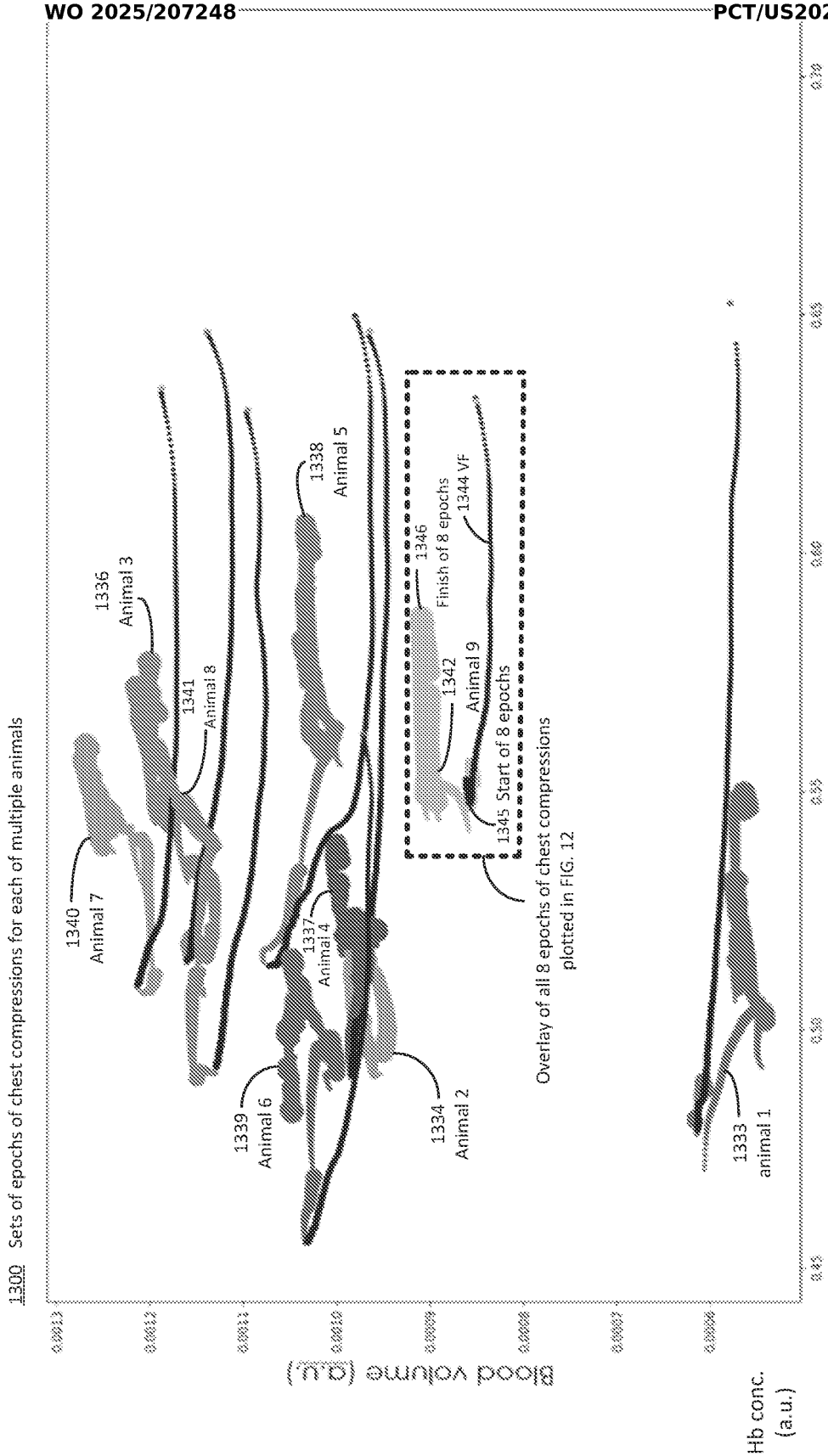

1300 Sets of epochs of chest compressions for each of multiple animals
blood volume (a.u.)
Hb conc. (a.u.)
O2 sat. (%)
1340 Animal 7
1336 Animal 3
1341 Animal 8
1339 Animal 6
1337 Animal 4
1338 Animal 5
1334 Animal 2
1342 Animal 9
1346 Finish of 8 epochs
1344 VF
1345 Start of 8 epochs
Overlay of all 8 epochs of chest compressions plotted in FIG. 12
1333 animal 1

FIG. 13A

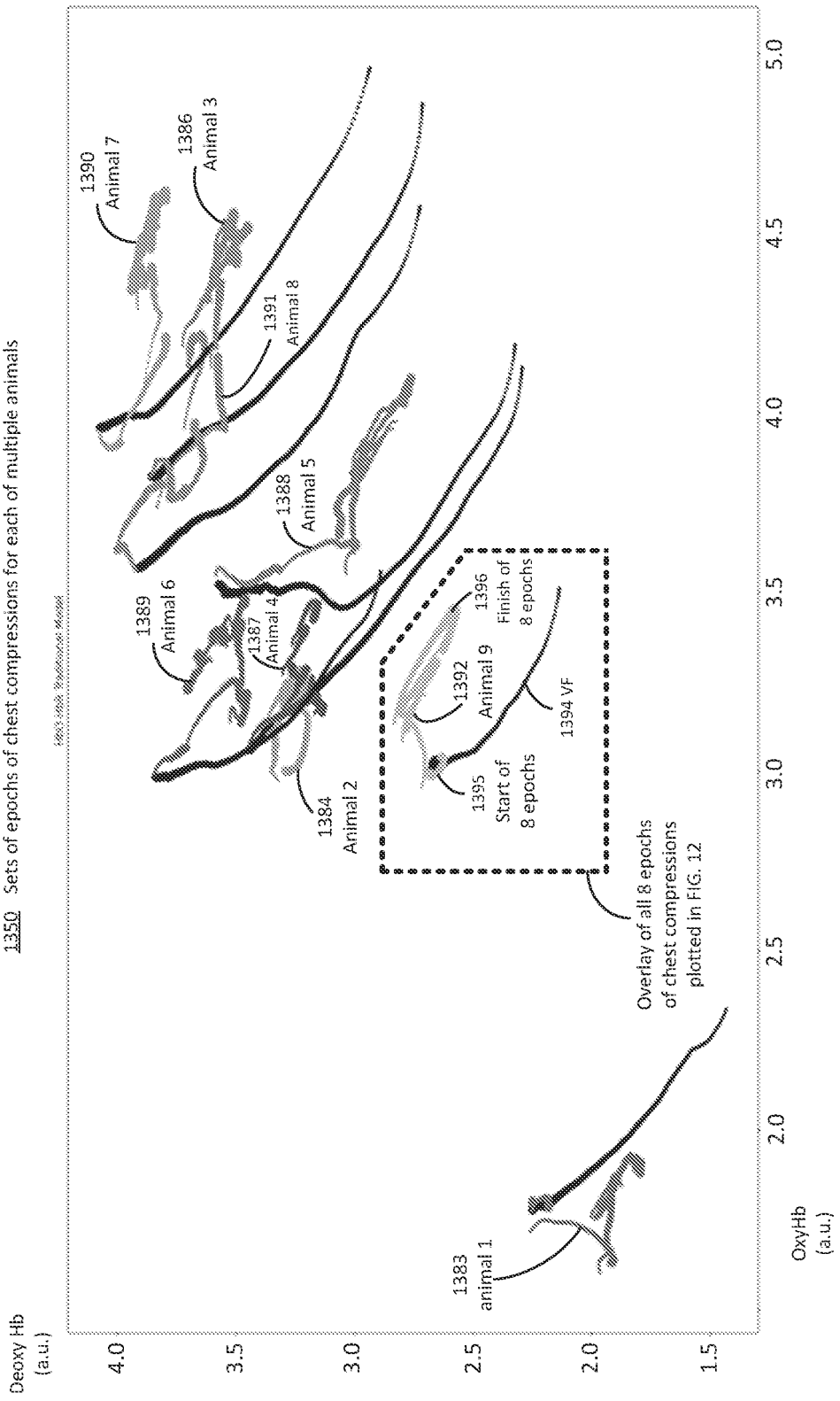

1350 Sets of epochs of chest compressions for each of multiple animals
Deoxy Hb (a.u.)
OxyHb (a.u.)
O2 sa %)
4.0
3.5
3.0
2.5
2.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
1383 animal 1
1384 Animal 2
1386 Animal 3
1387 Animal 4
1388 Animal 5
1389 Animal 6
1390 Animal 7
1391 Animal 8
1392 Animal 9
1394 VF
1395 Start of 8 epochs
1396 Finish of 8 epochs
Overlay of all 8 epochs of chest compressions plotted in FIG. 12

FIG. 13B

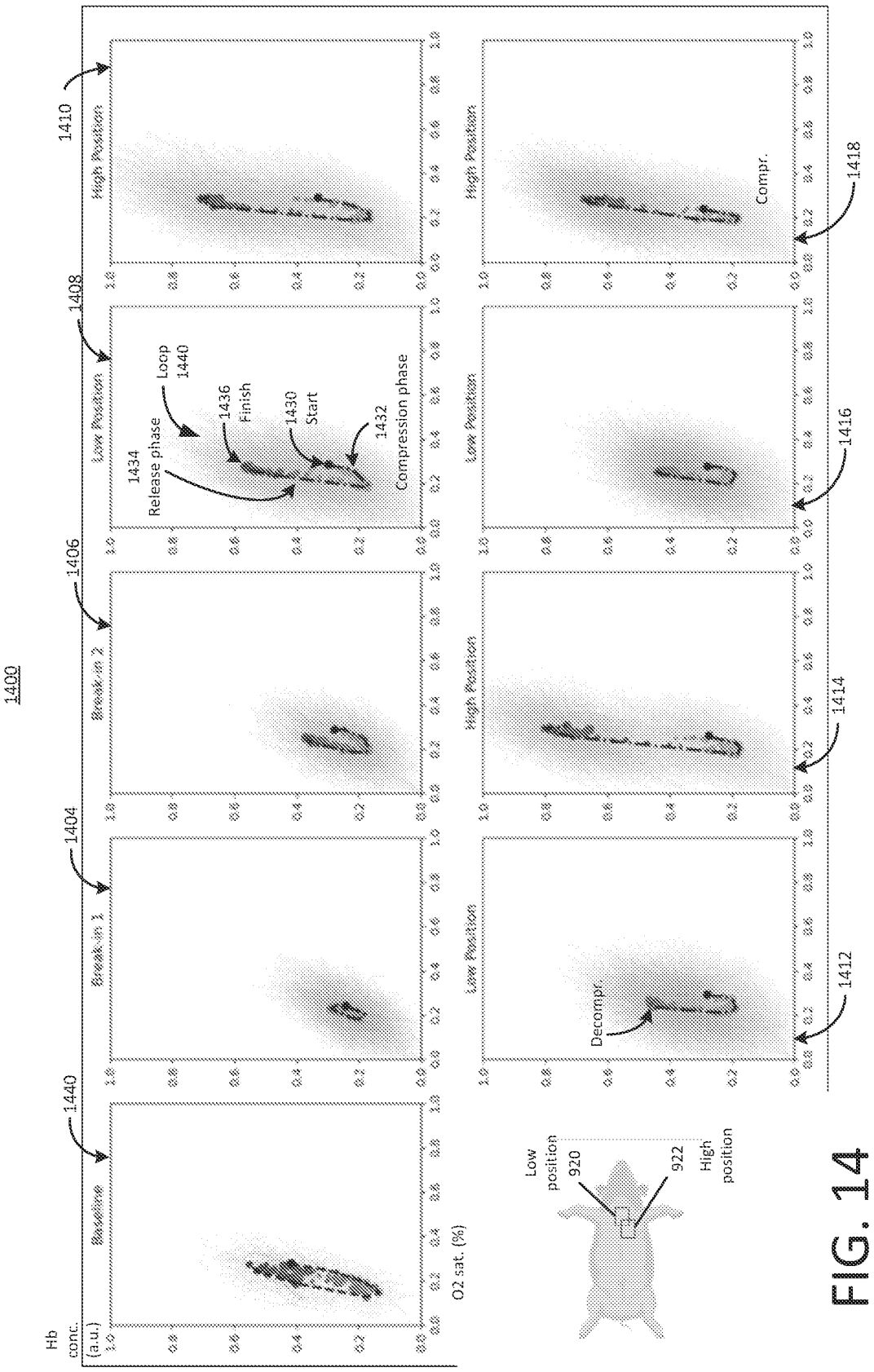

1400
Hb conc. (a.u.)
O2 sat. (%)
Baseline
Breath-in 1
Breath-in 2
Low Position
High Position
Decompr.
Compr.
Loop 1440
1434 Release phase
1436 Finish
1430 Start
1432 Compression phase
1440
1404
1406
1408
1410
1412
1414
1416
1418
Low position 920
High position 922

FIG. 14

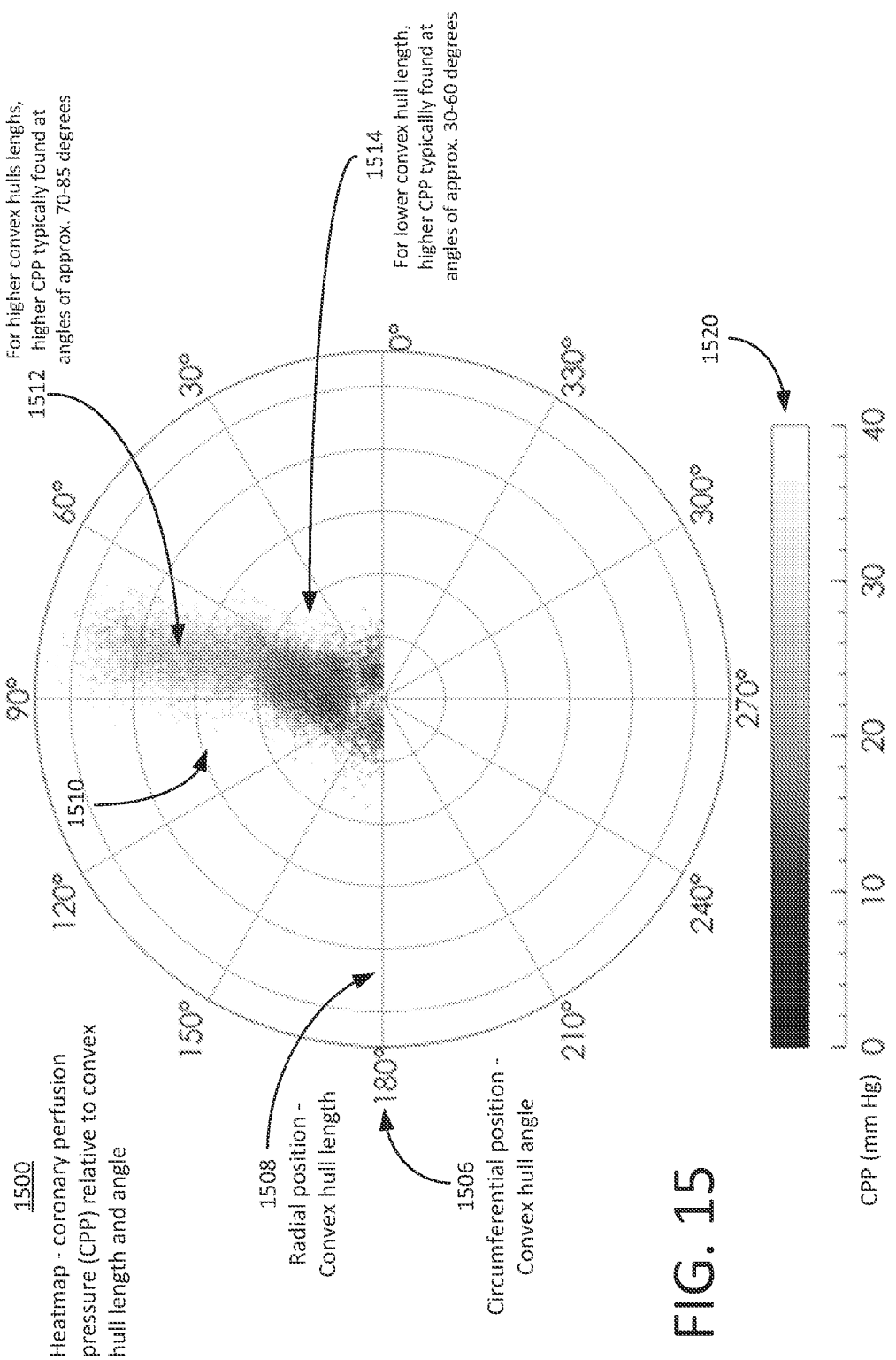

1500
Heatmap - coronary perfusion pressure (CPP) relative to convex hull length and angle
1508
Radial position - Convex hull length
1506
Circumferential position - Convex hull angle
1512
For higher convex hulls lenghs, higher CPP typically found at angles of approx. 70-85 degrees
1514
For lower convex hull length, higher CPP typicallly found at angles of approx. 30-60 degrees
1510
1520
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
0
10
20
30
40
CPP (mm Hg)

FIG. 15

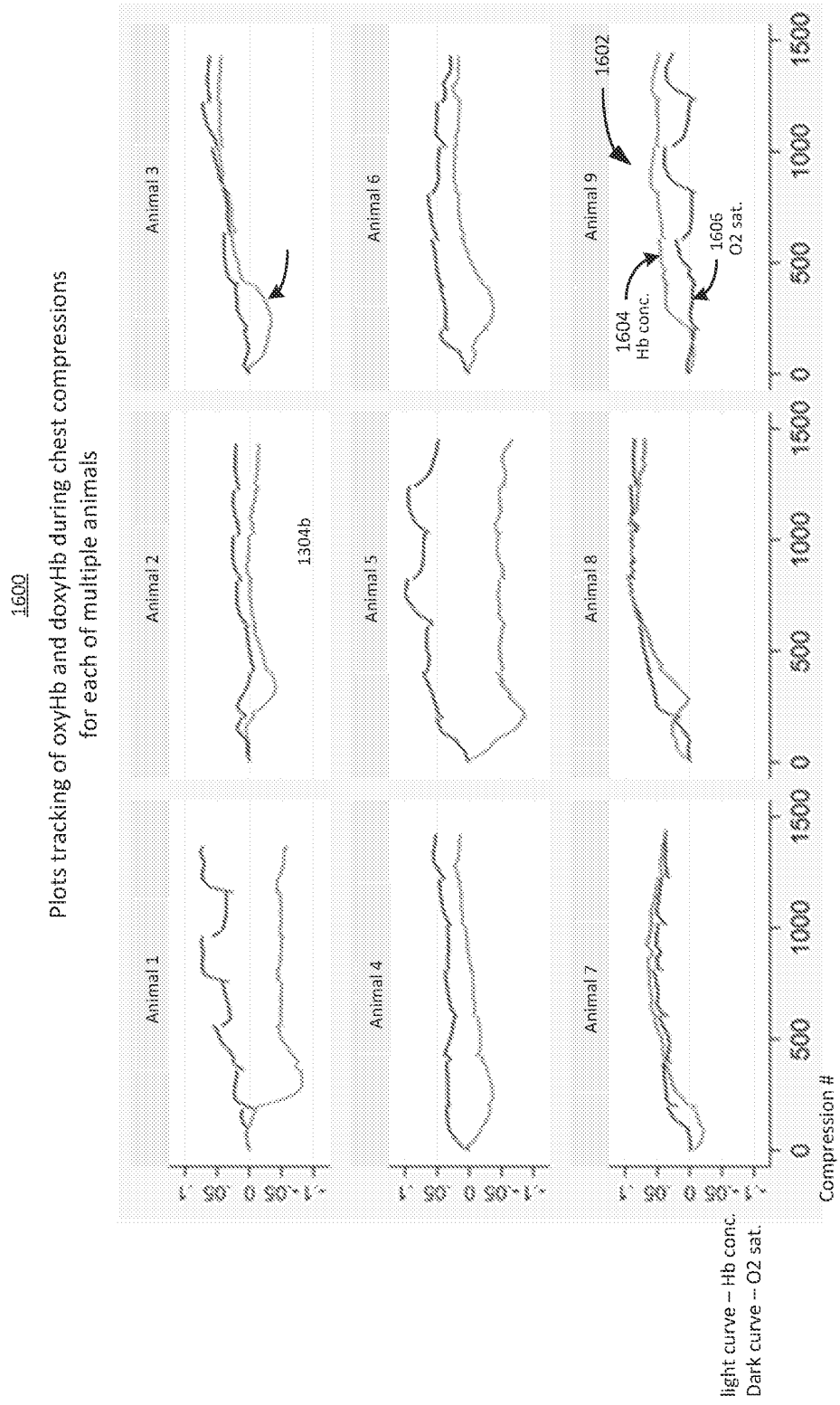

1600
Plots tracking of oxyHb and doxyHb during chest compressions for each of multiple animals
Animal 1
Animal 2
Animal 3
Animal 4
Animal 5
Animal 6
Animal 7
Animal 8
Animal 9
1304b
1602
1604
Hb conc.
1606
O2 sat.
0
500
1000
1500
Compression #
light curve – Hb conc.
Dark curve -- O2 sat.

FIG. 16

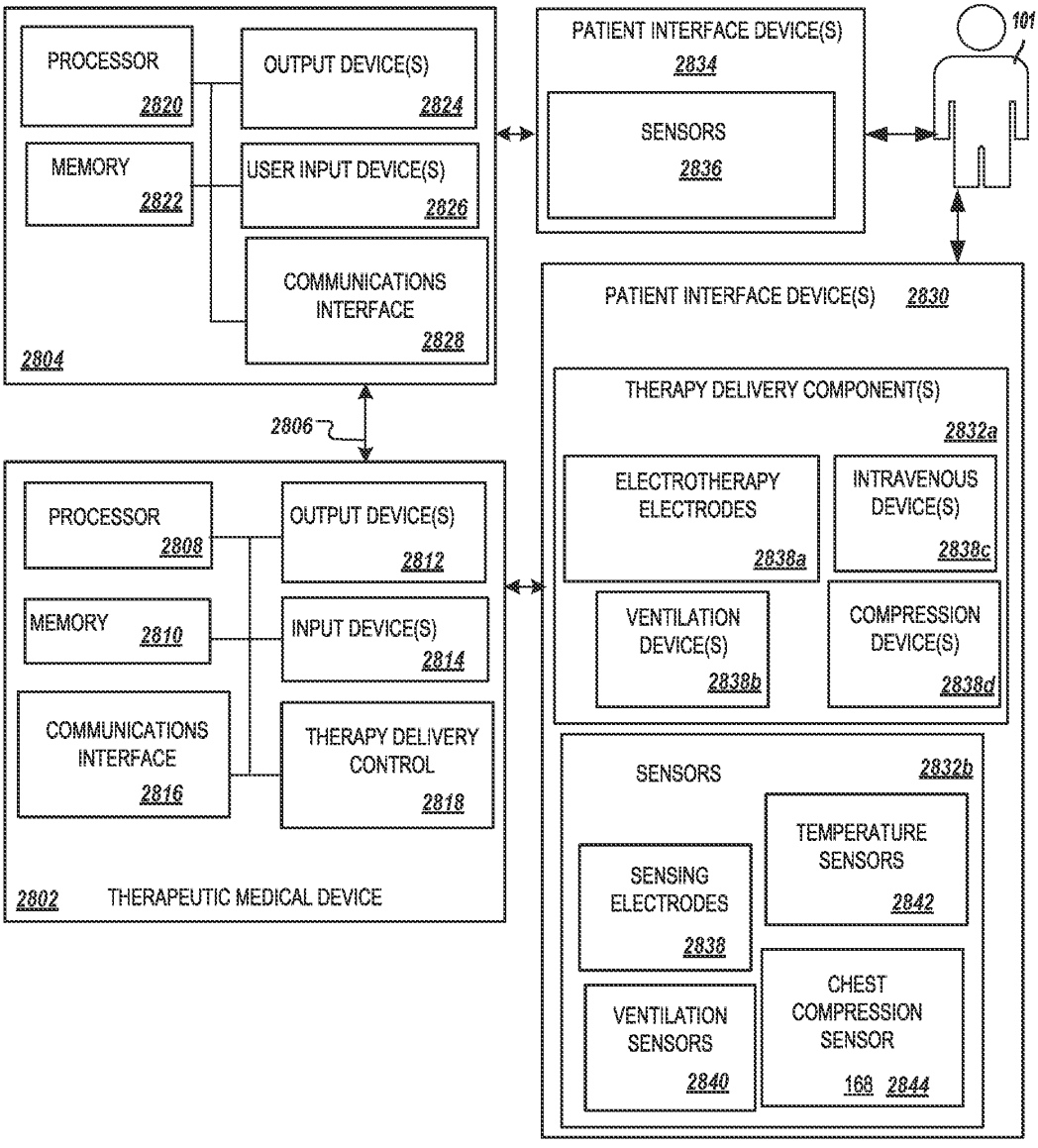

PROCESSOR
2820
OUTPUT DEVICE(S)
2824
MEMORY
2822
USER INPUT DEVICE(S)
2826
COMMUNICATIONS INTERFACE
2828
2804
2806
PROCESSOR
2808
OUTPUT DEVICE(S)
2812
MEMORY
2810
INPUT DEVICE(S)
2814
COMMUNICATIONS INTERFACE
2816
THERAPY DELIVERY CONTROL
2818
2802
THERAPEUTIC MEDICAL DEVICE
PATIENT INTERFACE DEVICE(S)
2834
SENSORS
2836
101
PATIENT INTERFACE DEVICE(S)
2830
THERAPY DELIVERY COMPONENT(S)
2832a
ELECTROTHERAPY ELECTRODES
2838a
INTRAVENOUS DEVICE(S)
2838c
VENTILATION DEVICE(S)
2838b
COMPRESSION DEVICE(S)
2838d
SENSORS
2832b
TEMPERATURE SENSORS
2842
SENSING ELECTRODES
2838
VENTILATION SENSORS
2840
CHEST COMPRESSION SENSOR
168
2844

FIG. 17