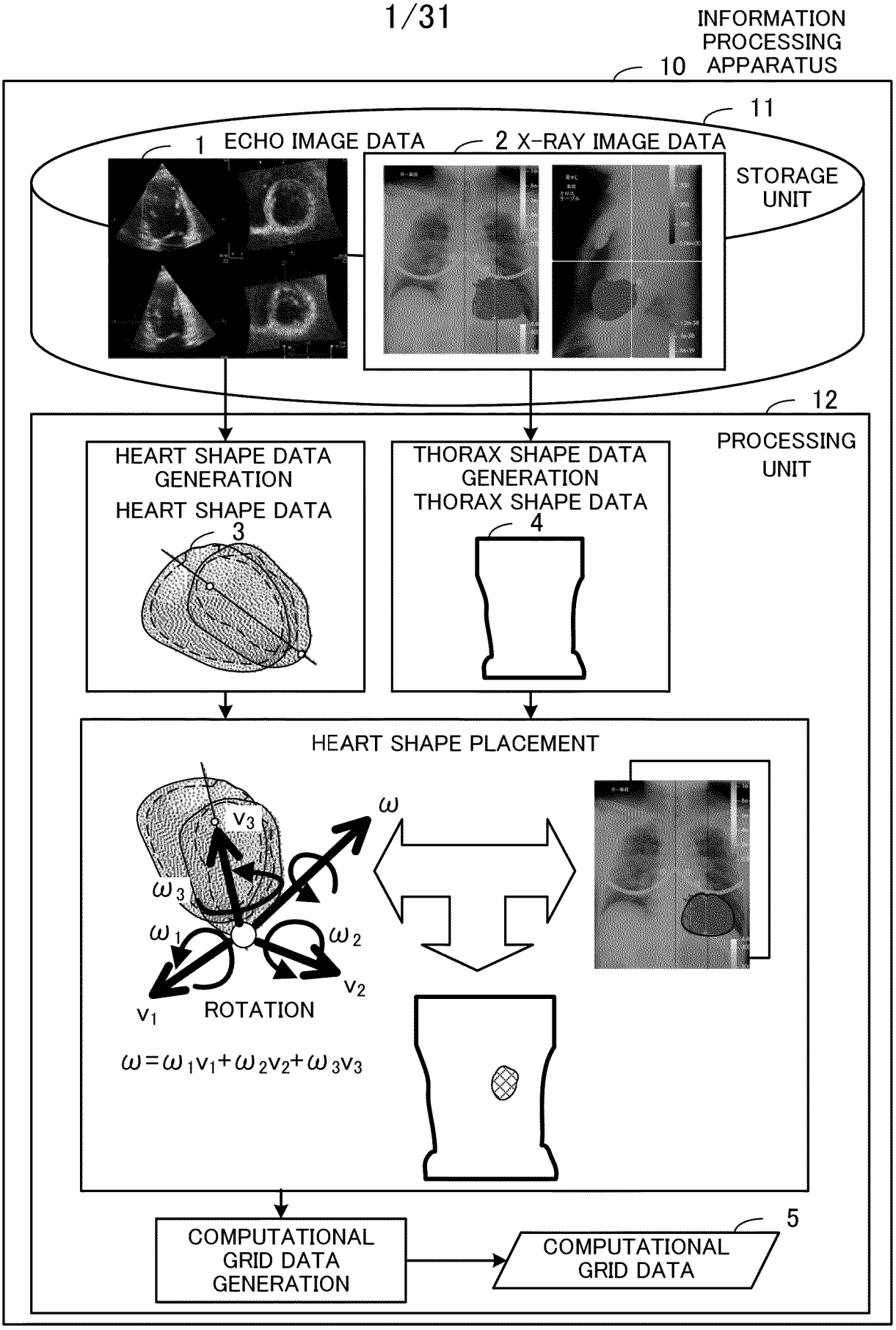

INFORMATION PROCESSING APPARATUS
10
11
1 ECHO IMAGE DATA
2 X-RAY IMAGE DATA
STORAGE UNIT
12
PROCESSING UNIT
HEART SHAPE DATA GENERATION
HEART SHAPE DATA
3
THORAX SHAPE DATA GENERATION
THORAX SHAPE DATA
4
HEART SHAPE PLACEMENT
ω
v3
ω3
ω1
ω2
v2
v1
ROTATION
ω=ω1v1+ω2v2+ω3v3
COMPUTATIONAL GRID DATA GENERATION
COMPUTATIONAL GRID DATA
5

FIG. 1

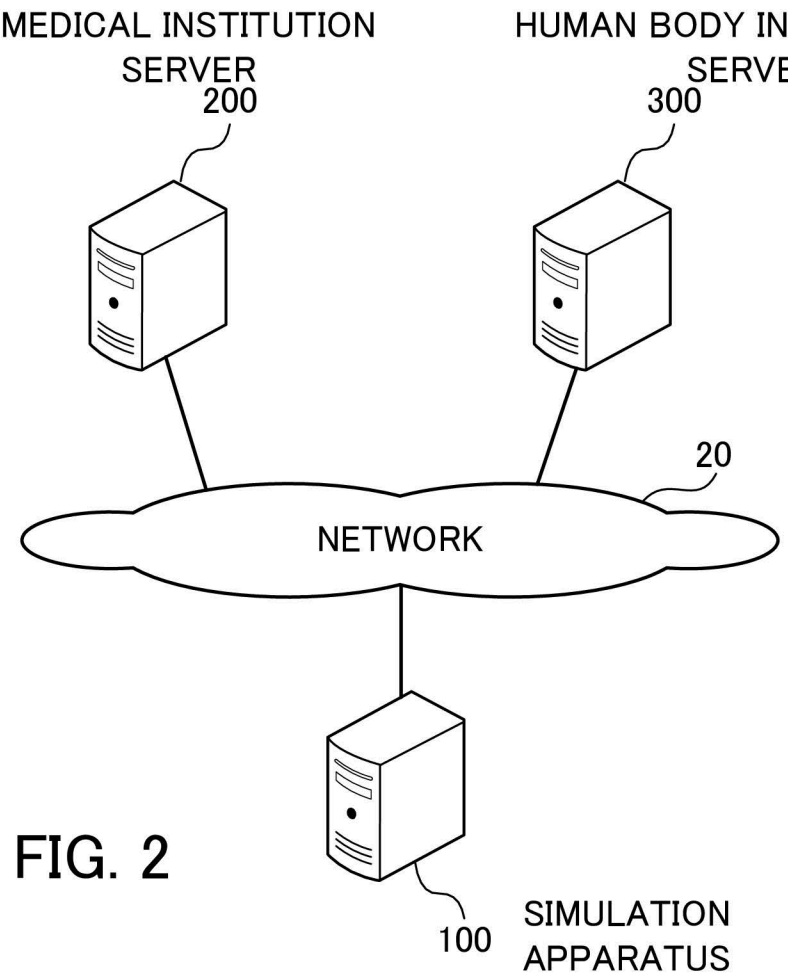

MEDICAL INSTITUTION SERVER
200
HUMAN BODY INFORMATION SERVER
300
20
NETWORK
100
SIMULATION APPARATUS

FIG. 2

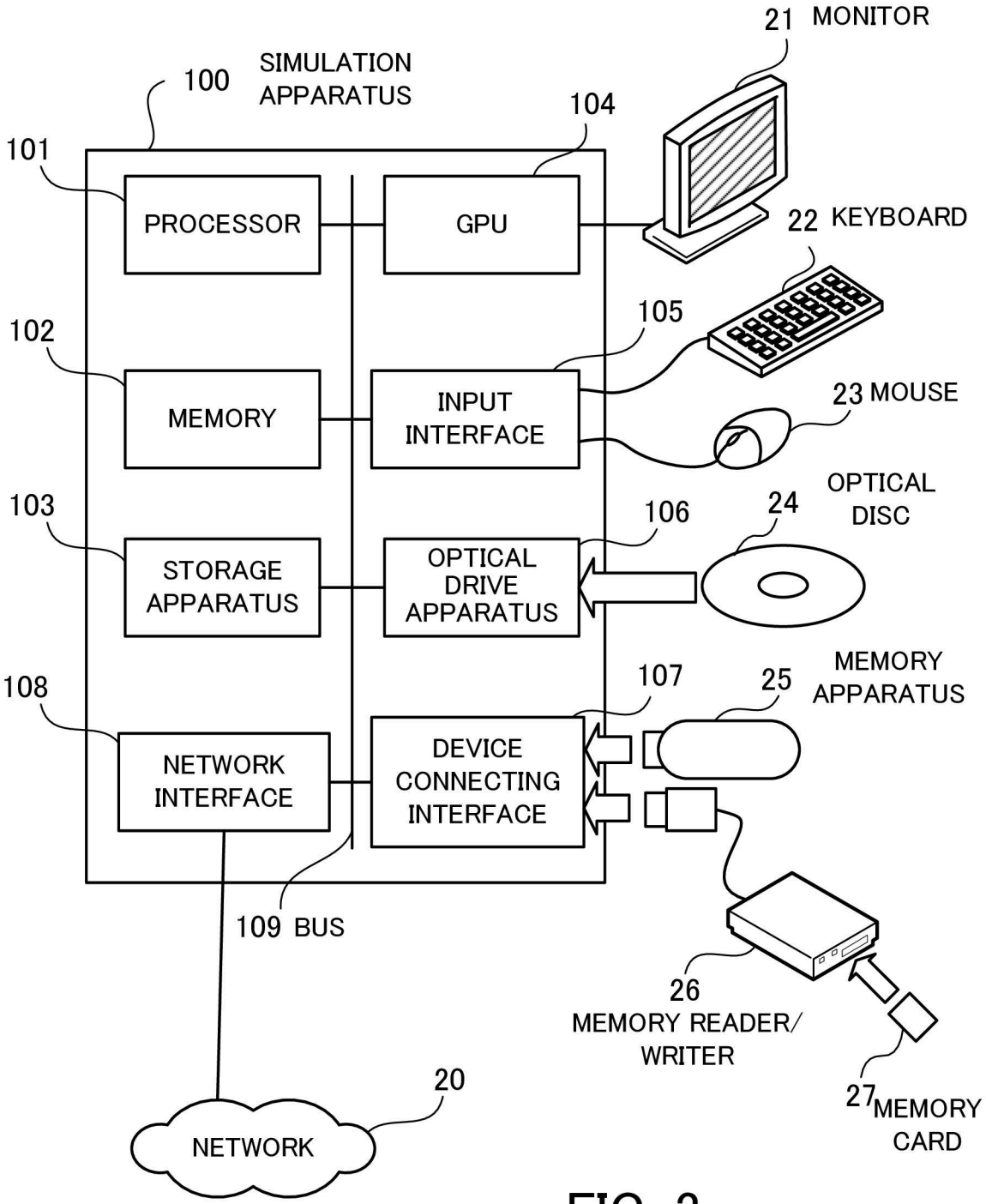

21 MONITOR
100 SIMULATION APPARATUS
104
101
PROCESSOR
GPU
22 KEYBOARD
105
102
MEMORY
INPUT INTERFACE
23 MOUSE
OPTICAL DISC
24
106
103
STORAGE APPARATUS
OPTICAL DRIVE APPARATUS
MEMORY APPARATUS
107
25
108
NETWORK INTERFACE
DEVICE CONNECTING INTERFACE
109 BUS
26 MEMORY READER/ WRITER
27 MEMORY CARD
20
NETWORK

FIG. 3

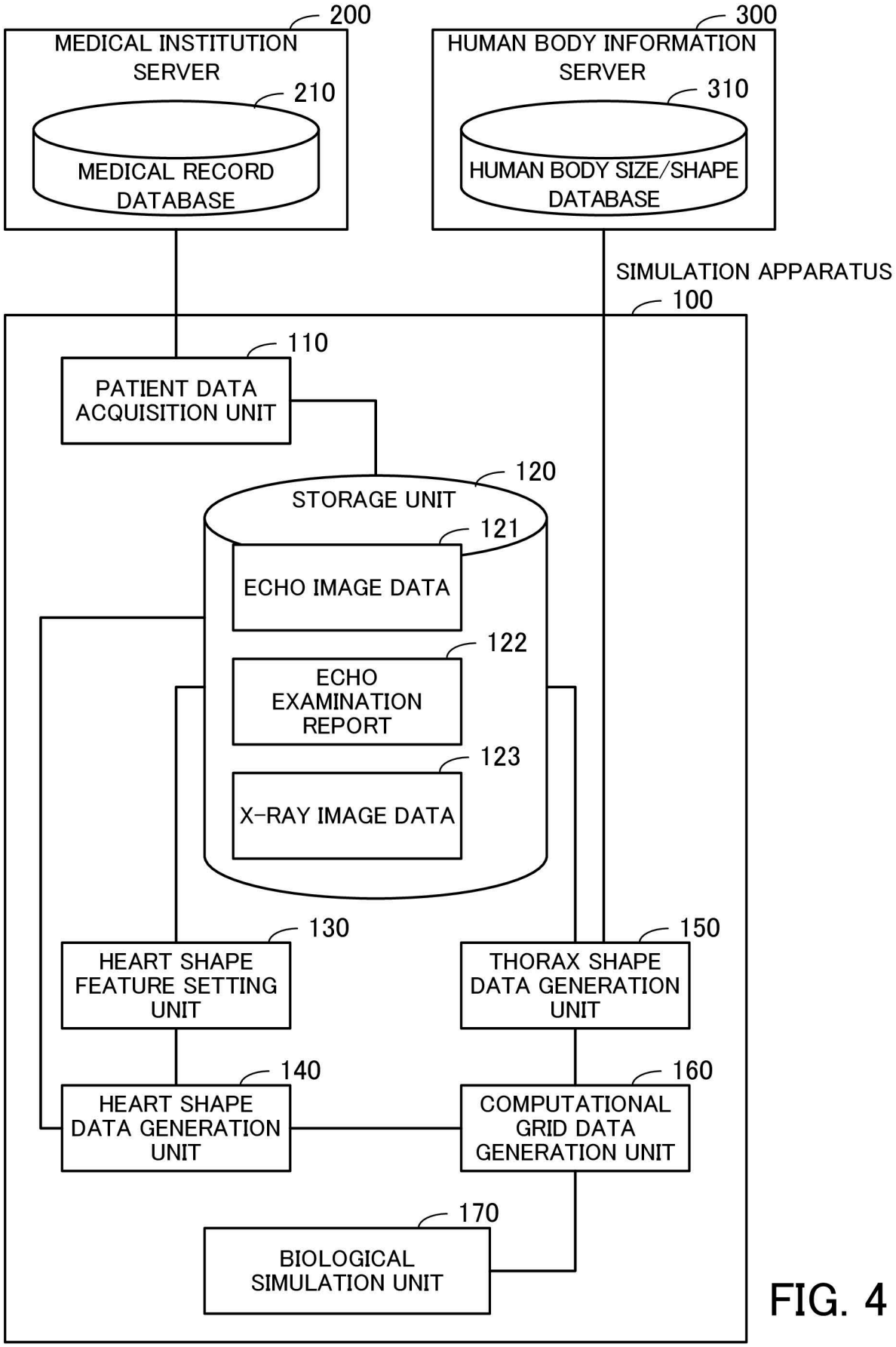

200
MEDICAL INSTITUTION SERVER
210
MEDICAL RECORD DATABASE
300
HUMAN BODY INFORMATION SERVER
310
HUMAN BODY SIZE/SHAPE DATABASE
SIMULATION APPARATUS
100
110
PATIENT DATA ACQUISITION UNIT
120
STORAGE UNIT
121
ECHO IMAGE DATA
122
ECHO EXAMINATION REPORT
123
X-RAY IMAGE DATA
130
HEART SHAPE FEATURE SETTING UNIT
150
THORAX SHAPE DATA GENERATION UNIT
140
HEART SHAPE DATA GENERATION UNIT
160
COMPUTATIONAL GRID DATA GENERATION UNIT
170
BIOLOGICAL SIMULATION UNIT

FIG. 4

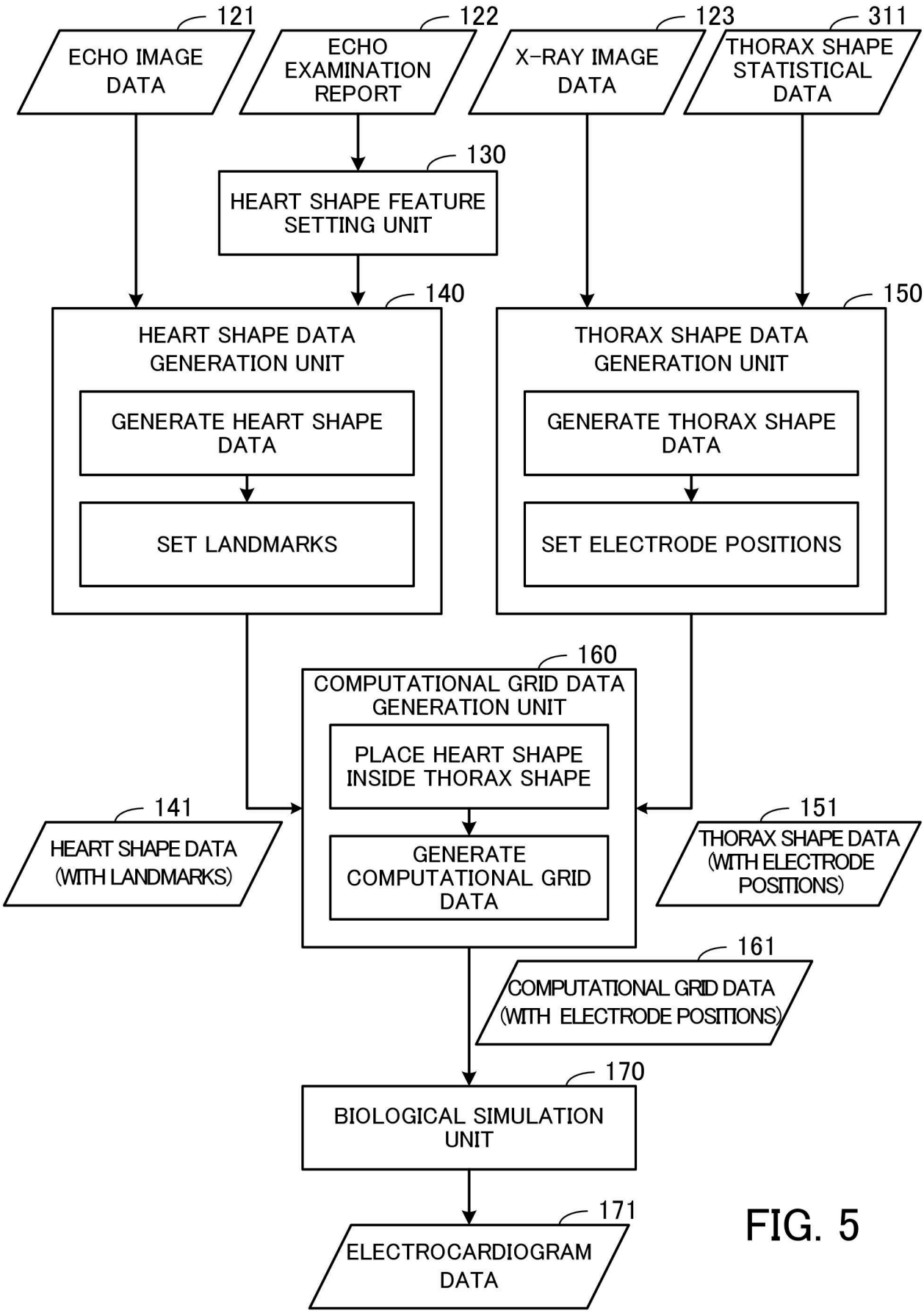

121
ECHO IMAGE DATA
122
ECHO EXAMINATION REPORT
123
X-RAY IMAGE DATA
311
THORAX SHAPE STATISTICAL DATA
130
HEART SHAPE FEATURE SETTING UNIT
140
HEART SHAPE DATA GENERATION UNIT
GENERATE HEART SHAPE DATA
SET LANDMARKS
150
THORAX SHAPE DATA GENERATION UNIT
GENERATE THORAX SHAPE DATA
SET ELECTRODE POSITIONS
160
COMPUTATIONAL GRID DATA GENERATION UNIT
PLACE HEART SHAPE INSIDE THORAX SHAPE
GENERATE COMPUTATIONAL GRID DATA
141
HEART SHAPE DATA (WITH LANDMARKS)
151
THORAX SHAPE DATA (WITH ELECTRODE POSITIONS)
161
COMPUTATIONAL GRID DATA (WITH ELECTRODE POSITIONS)
170
BIOLOGICAL SIMULATION UNIT
171
ELECTROCARDIOGRAM DATA

FIG. 5

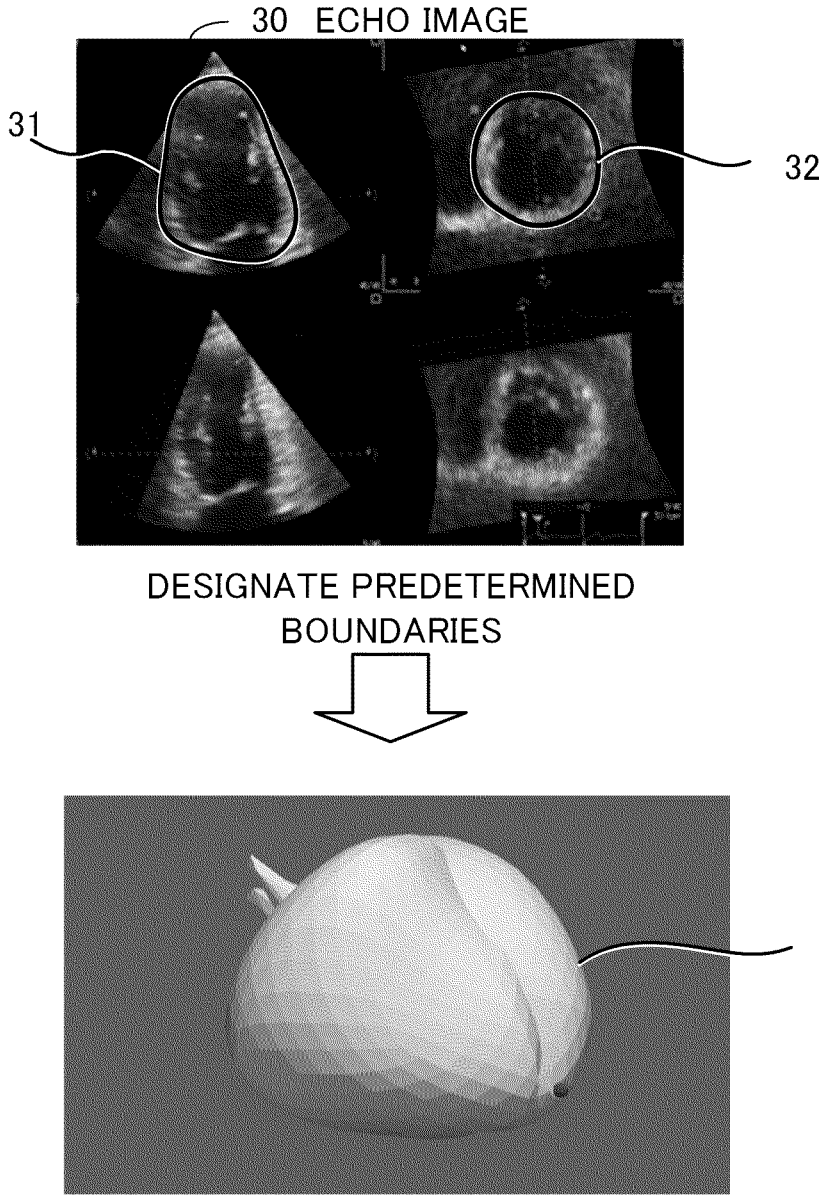

30 ECHO IMAGE
31
32
DESIGNATE PREDETERMINED BOUNDARIES
33 HEART MODEL
SEGMENTATION
141
HEART SHAPE DATA (POLYGON DATA)

FIG. 6

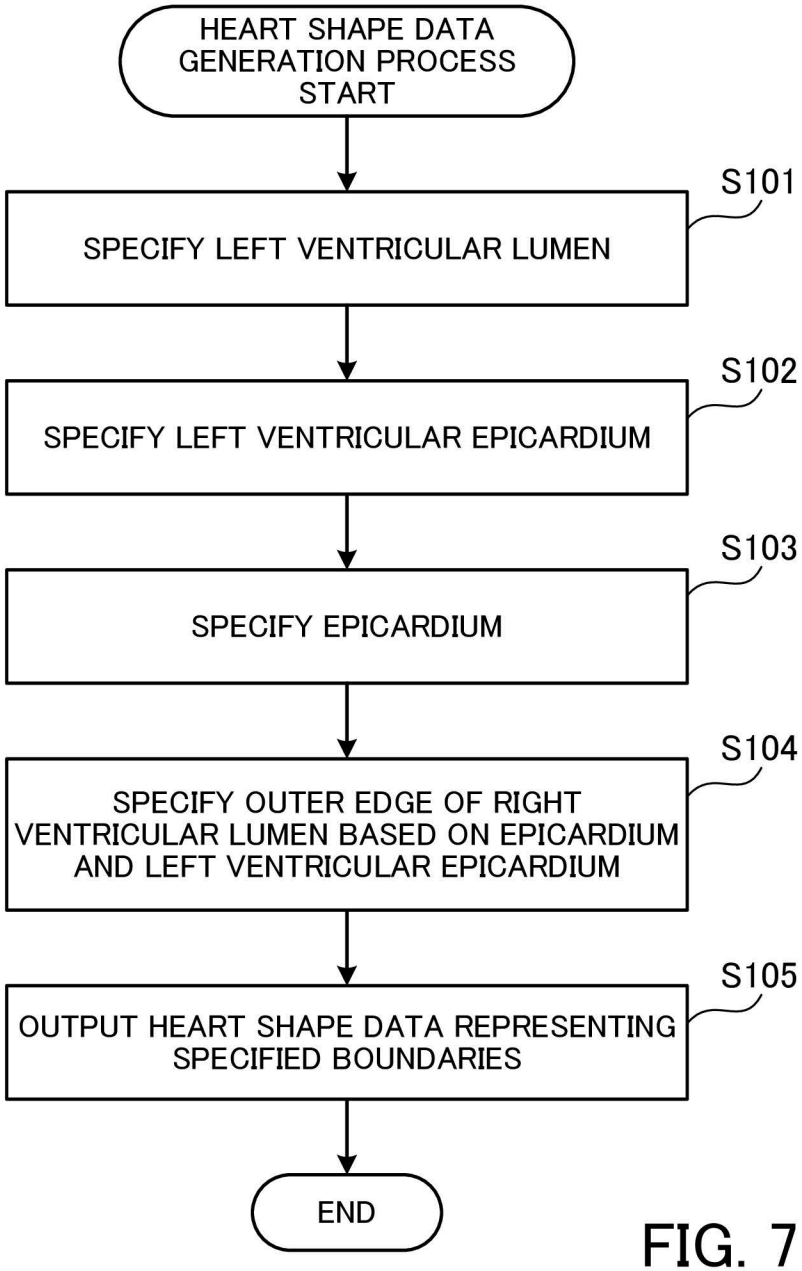

HEART SHAPE DATA GENERATION PROCESS START
S101
SPECIFY LEFT VENTRICULAR LUMEN
S102
SPECIFY LEFT VENTRICULAR EPICARDIUM
S103
SPECIFY EPICARDIUM
S104
SPECIFY OUTER EDGE OF RIGHT VENTRICULAR LUMEN BASED ON EPICARDIUM AND LEFT VENTRICULAR EPICARDIUM
S105
OUTPUT HEART SHAPE DATA REPRESENTING SPECIFIED BOUNDARIES
END

FIG. 7

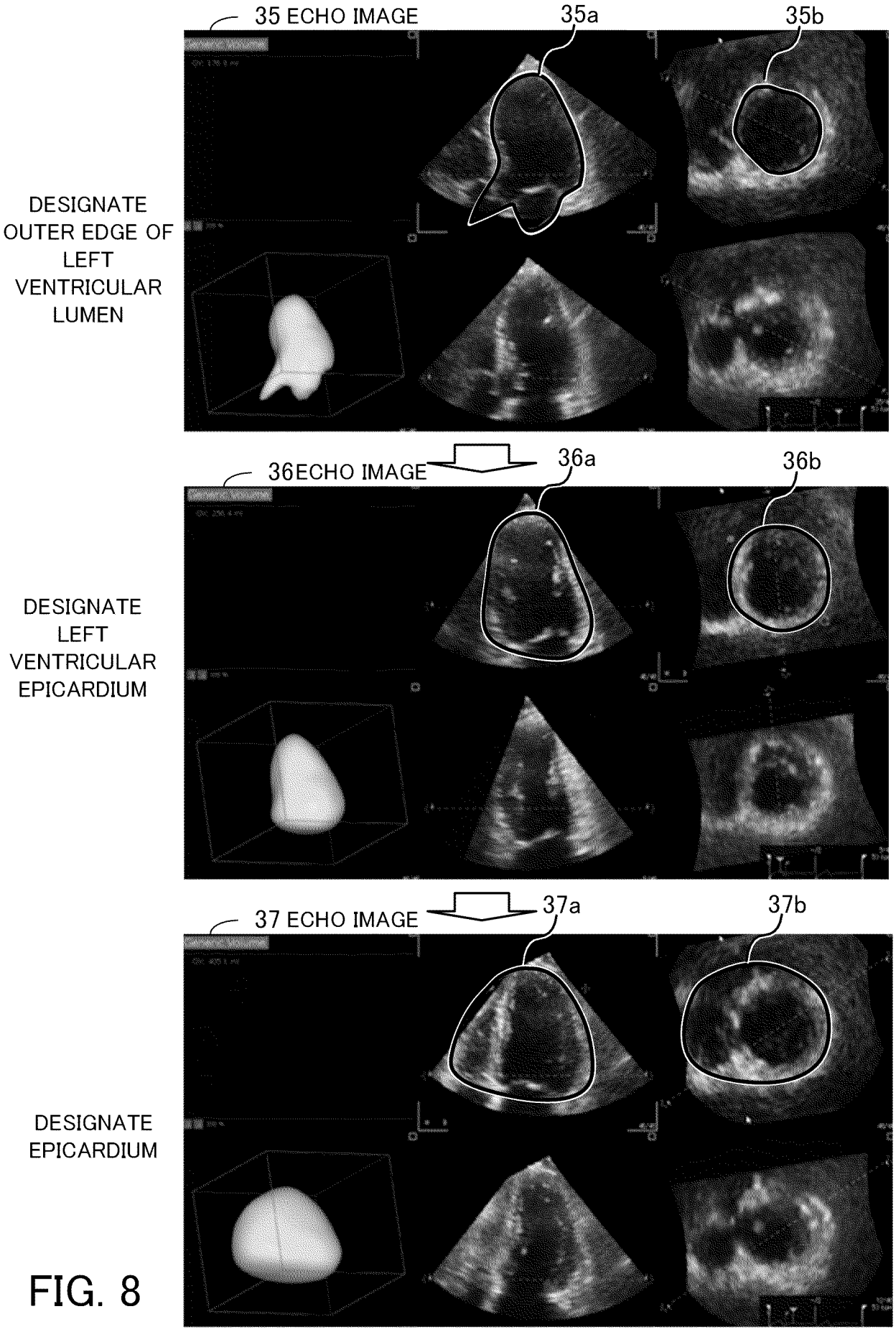

35 ECHO IMAGE
35a
35b
DESIGNATE OUTER EDGE OF LEFT VENTRICULAR LUMEN
36ECHO IMAGE
36a
36b
DESIGNATE LEFT VENTRICULAR EPICARDIUM
37 ECHO IMAGE
37a
37b
DESIGNATE EPICARDIUM

FIG. 8

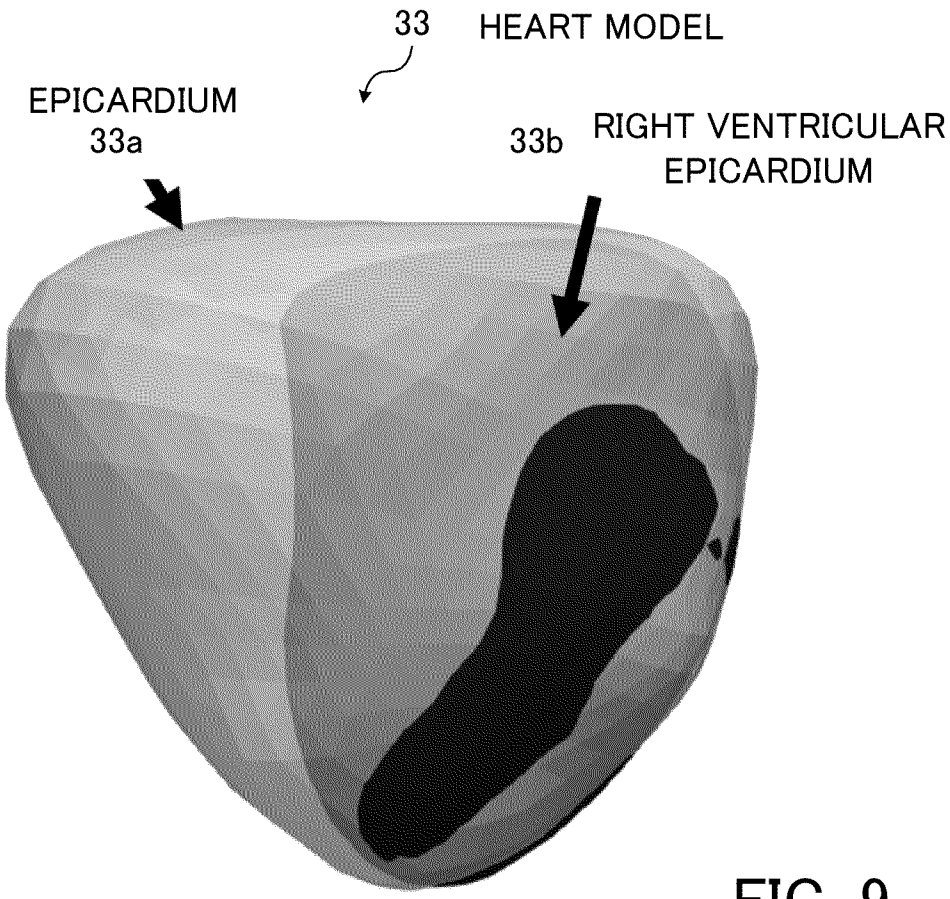

33
HEART MODEL
EPICARDIUM
33a
33b
RIGHT VENTRICULAR
EPICARDIUM

FIG. 9

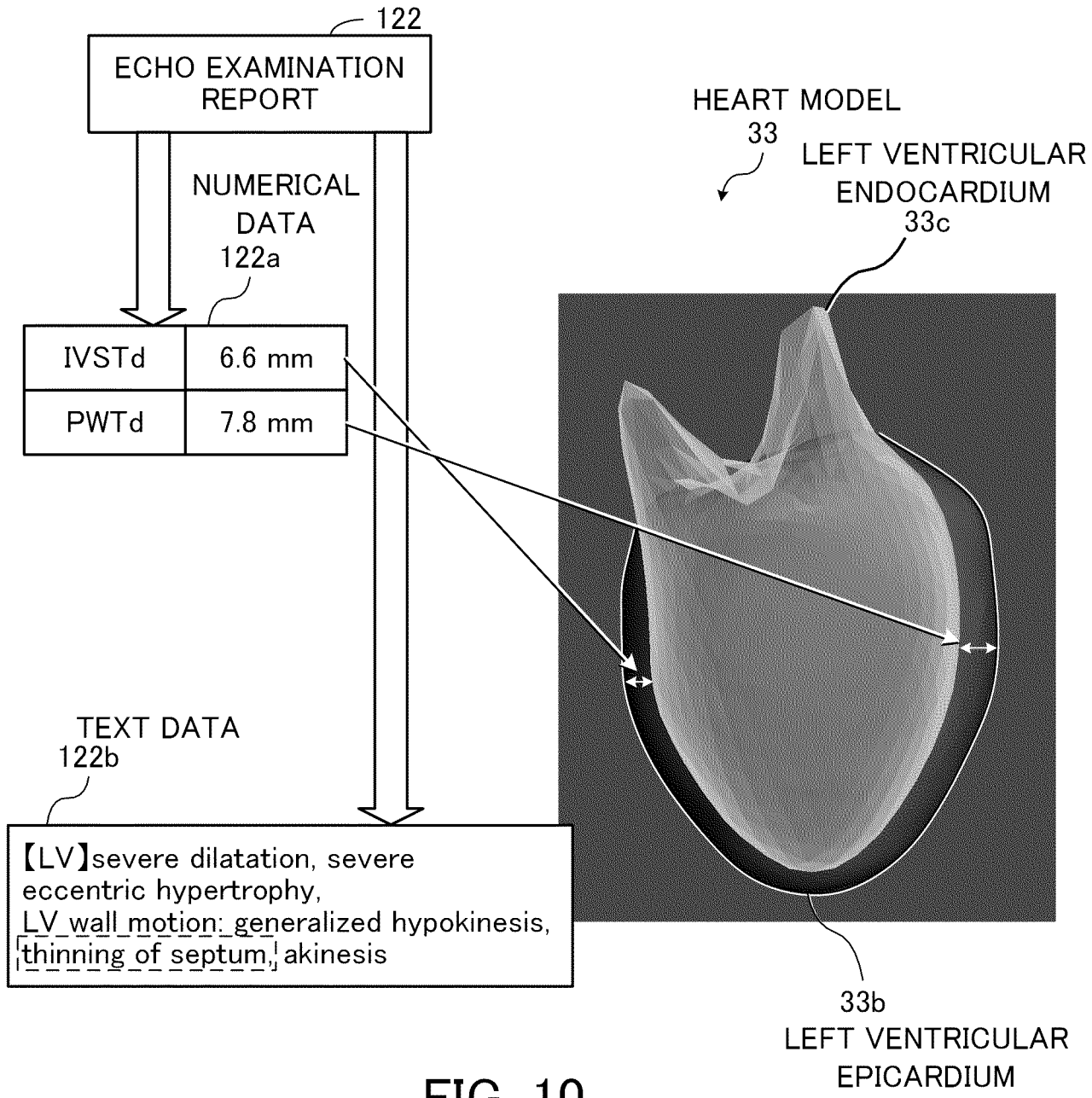

122
ECHO EXAMINATION REPORT
NUMERICAL DATA
122a
IVSTd
6.6 mm
PWTd
7.8 mm
TEXT DATA
122b
【LV】severe dilatation, severe eccentric hypertrophy, LV wall motion: generalized hypokinesis, thinning of septum, akinesis
HEART MODEL
33
LEFT VENTRICULAR ENDOCARDIUM
33c
33b
LEFT VENTRICULAR EPICARDIUM

FIG. 10

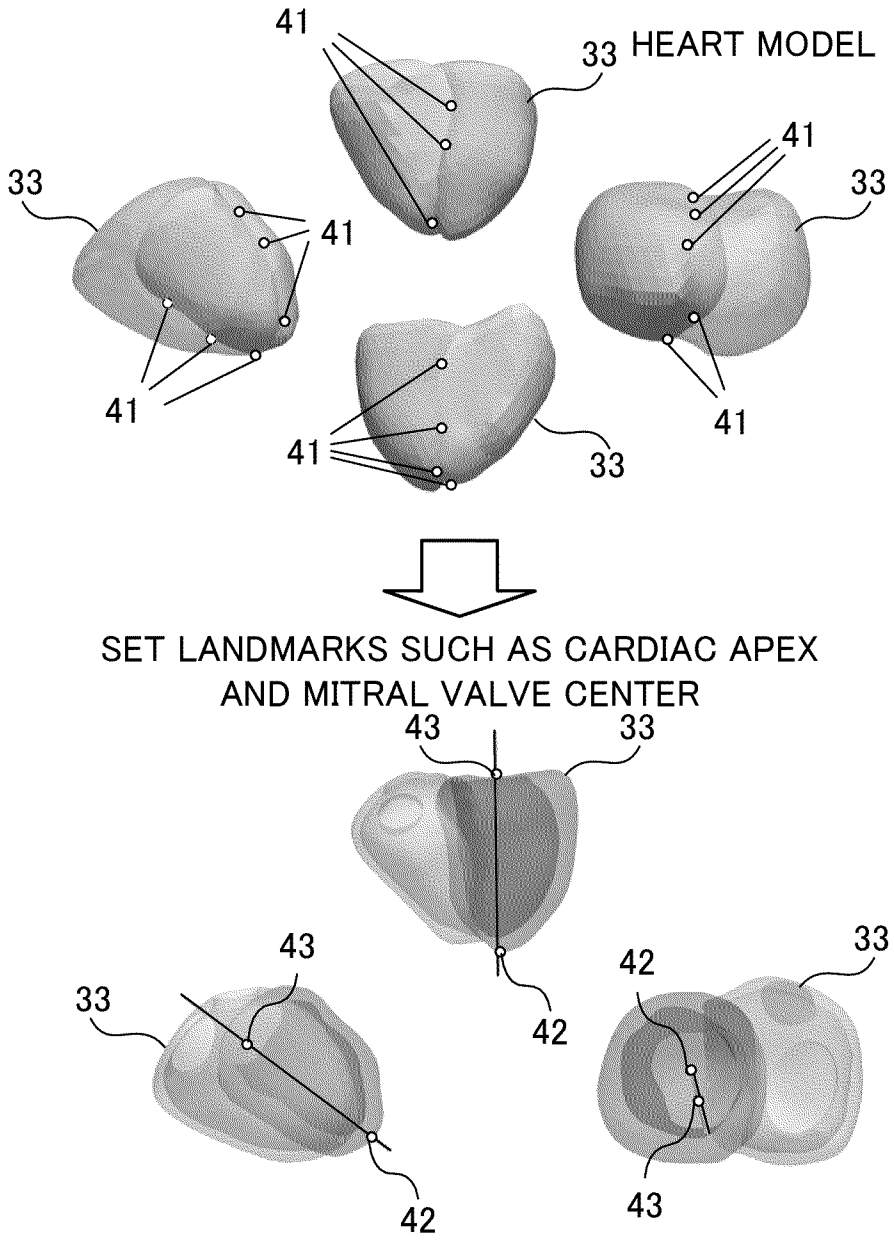

SET LANDMARKS ON ANTERIOR INTERVENTRICULAR SULCUS AND POSTERIOR INTERVENTRICULAR SULCUS
41
33
HEART MODEL
41
33
41
33
41
41
41
33
SET LANDMARKS SUCH AS CARDIAC APEX AND MITRAL VALVE CENTER
43
33
43
33
42
42
33
43
42

FIG. 11

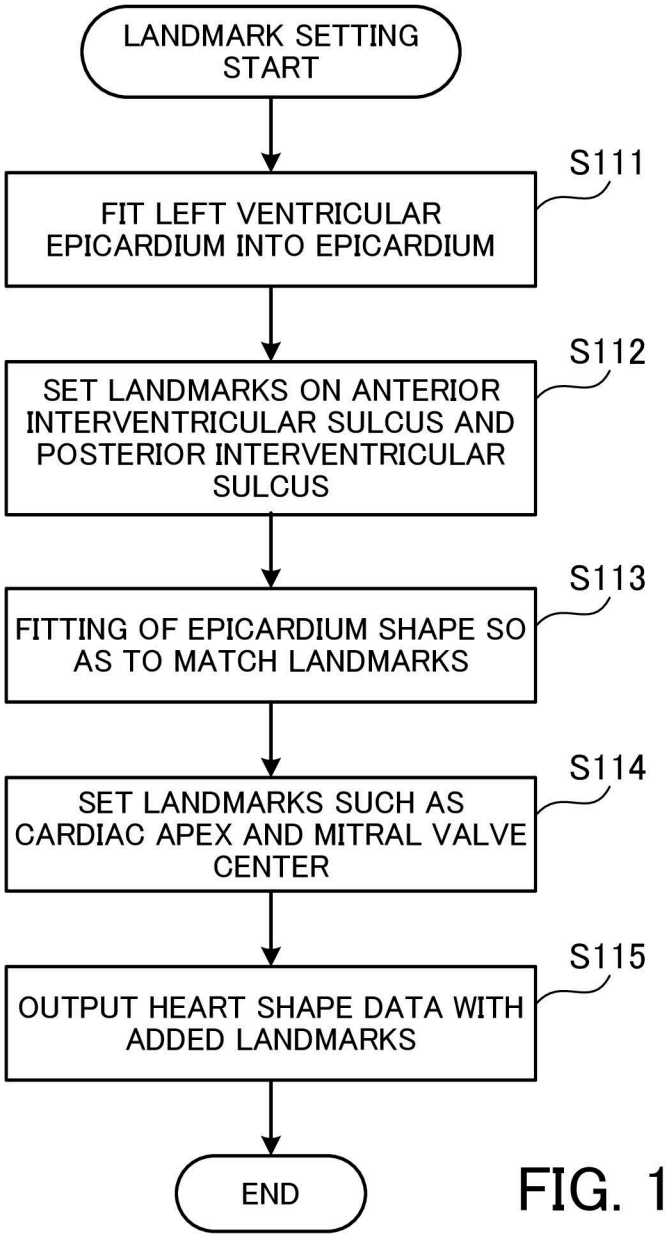

LANDMARK SETTING START
S111
FIT LEFT VENTRICULAR EPICARDIUM INTO EPICARDIUM
S112
SET LANDMARKS ON ANTERIOR INTERVENTRICULAR SULCUS AND POSTERIOR INTERVENTRICULAR SULCUS
S113
FITTING OF EPICARDIUM SHAPE SO AS TO MATCH LANDMARKS
S114
SET LANDMARKS SUCH AS CARDIAC APEX AND MITRAL VALVE CENTER
S115
OUTPUT HEART SHAPE DATA WITH ADDED LANDMARKS
END

FIG. 12

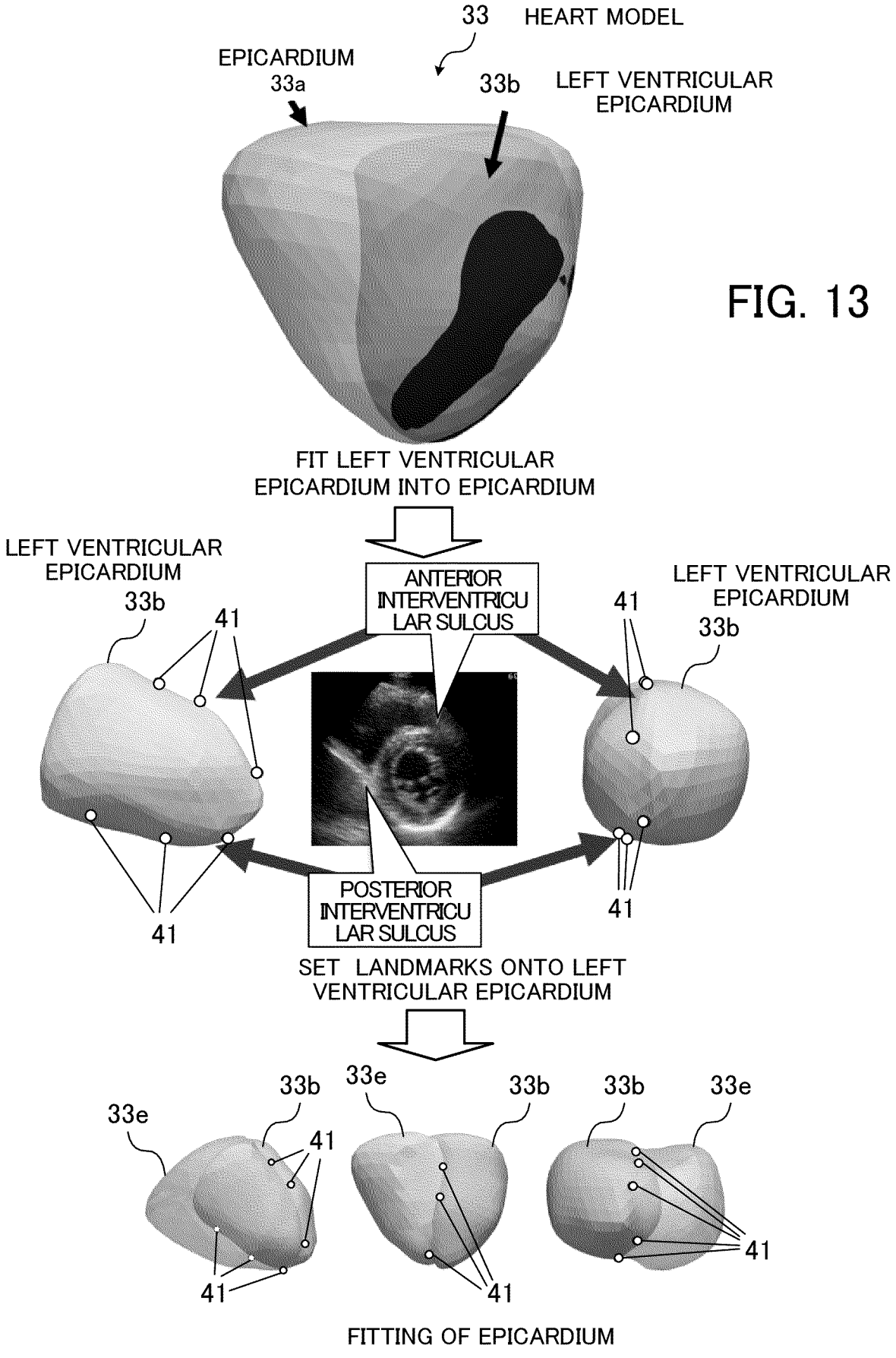

33
HEART MODEL
EPICARDIUM
33a
33b
LEFT VENTRICULAR
EPICARDIUM
FIT LEFT VENTRICULAR
EPICARDIUM INTO EPICARDIUM
LEFT VENTRICULAR
EPICARDIUM
33b
41
ANTERIOR
INTERVENTRICU
LAR SULCUS
41
LEFT VENTRICULAR
EPICARDIUM
33b
POSTERIOR
INTERVENTRICU
LAR SULCUS
41
41
SET LANDMARKS ONTO LEFT
VENTRICULAR EPICARDIUM
33b
33e
33e
33b
33b
33e
41
41
41
41
FITTING OF EPICARDIUM

FIG. 13

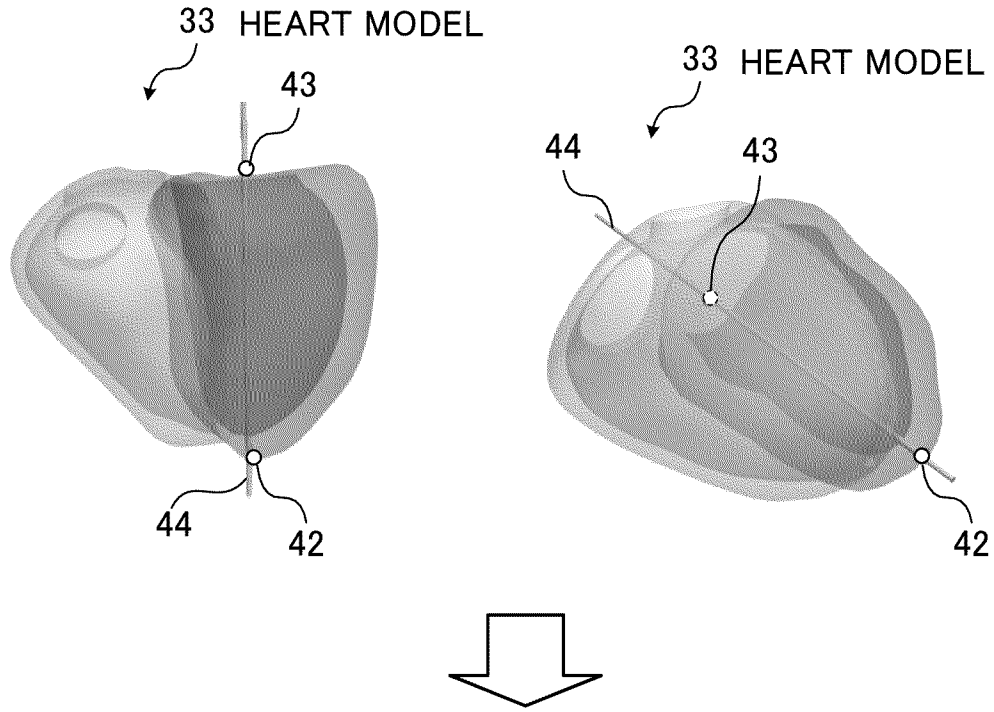
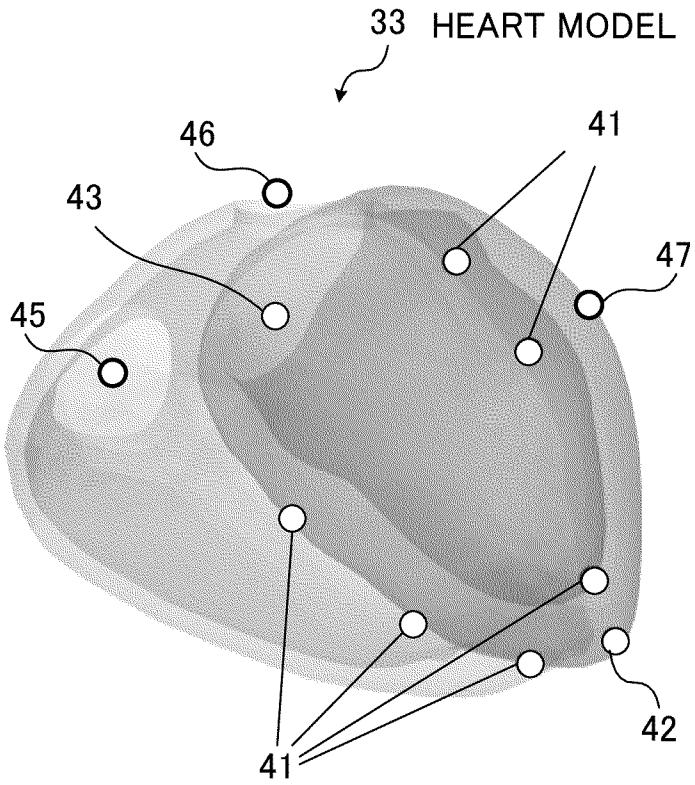
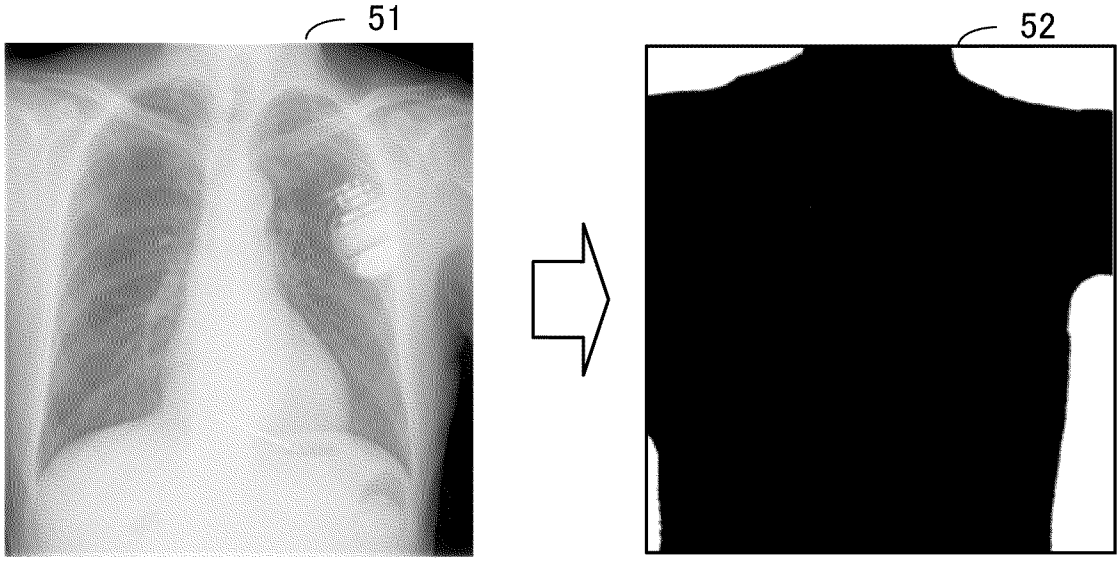
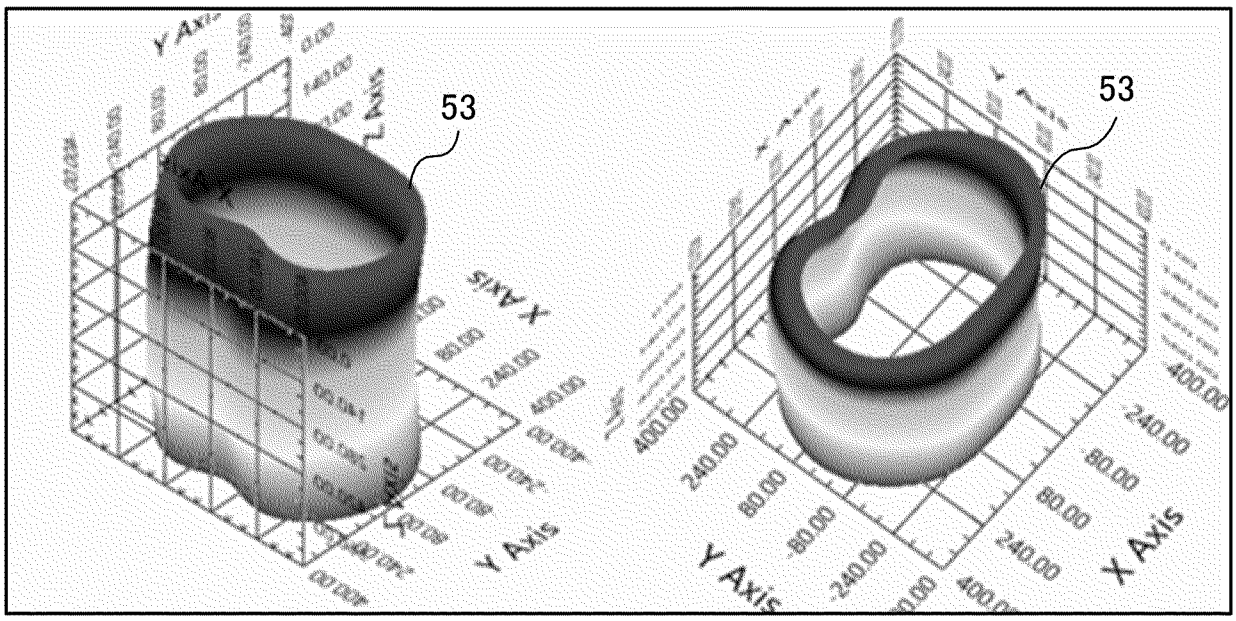

33 HEART MODEL
43
44
42
33 HEART MODEL
44
43
42

FIG. 14


33 HEART MODEL
46
41
43
47
45
41
42



SEGMENTATION (IN TWO DIRECTIONS)



CALCULATE BOUNDARY POINT GROUP

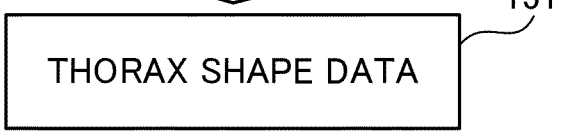


FIG. 15

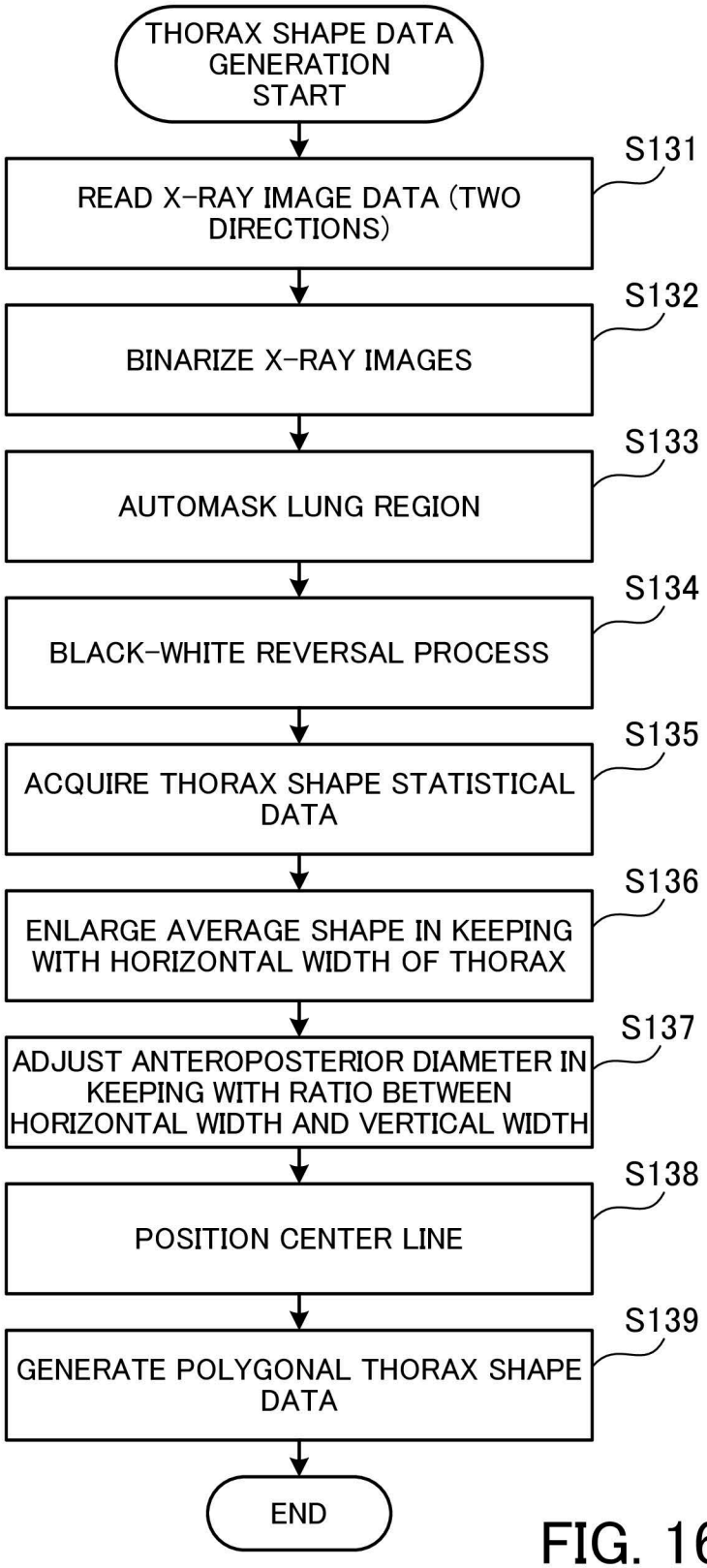
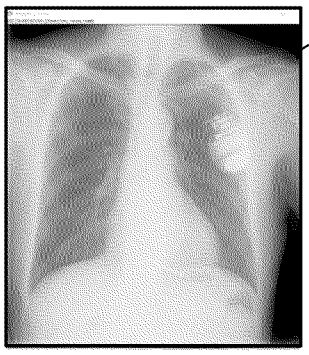
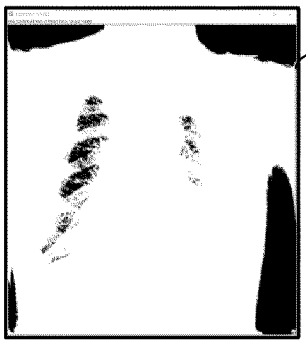

THORAX SHAPE DATA GENERATION START
S131
READ X-RAY IMAGE DATA (TWO DIRECTIONS)
S132
BINARIZE X-RAY IMAGES
S133
AUTOMASK LUNG REGION
S134
BLACK-WHITE REVERSAL PROCESS
S135
ACQUIRE THORAX SHAPE STATISTICAL DATA
S136
ENLARGE AVERAGE SHAPE IN KEEPING WITH HORIZONTAL WIDTH OF THORAX
S137
ADJUST ANTEROPOSTERIOR DIAMETER IN KEEPING WITH RATIO BETWEEN HORIZONTAL WIDTH AND VERTICAL WIDTH
S138
POSITION CENTER LINE
S139
GENERATE POLYGONAL THORAX SHAPE DATA
END

FIG. 16



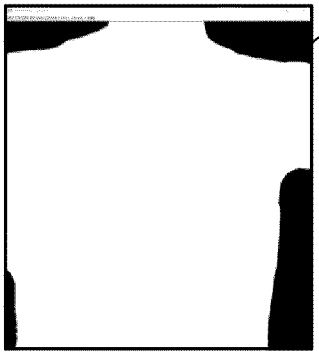
51 X-RAY IMAGE

BINARIZATION



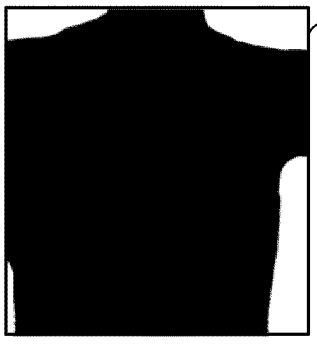
52a BINARIZED IMAGE

AUTOMASKING PROCESS OF LUNG REGION



52b BINARIZED IMAGE

BLACK-WHITE REVERSAL



52 BINARIZED IMAGE

FIG. 17

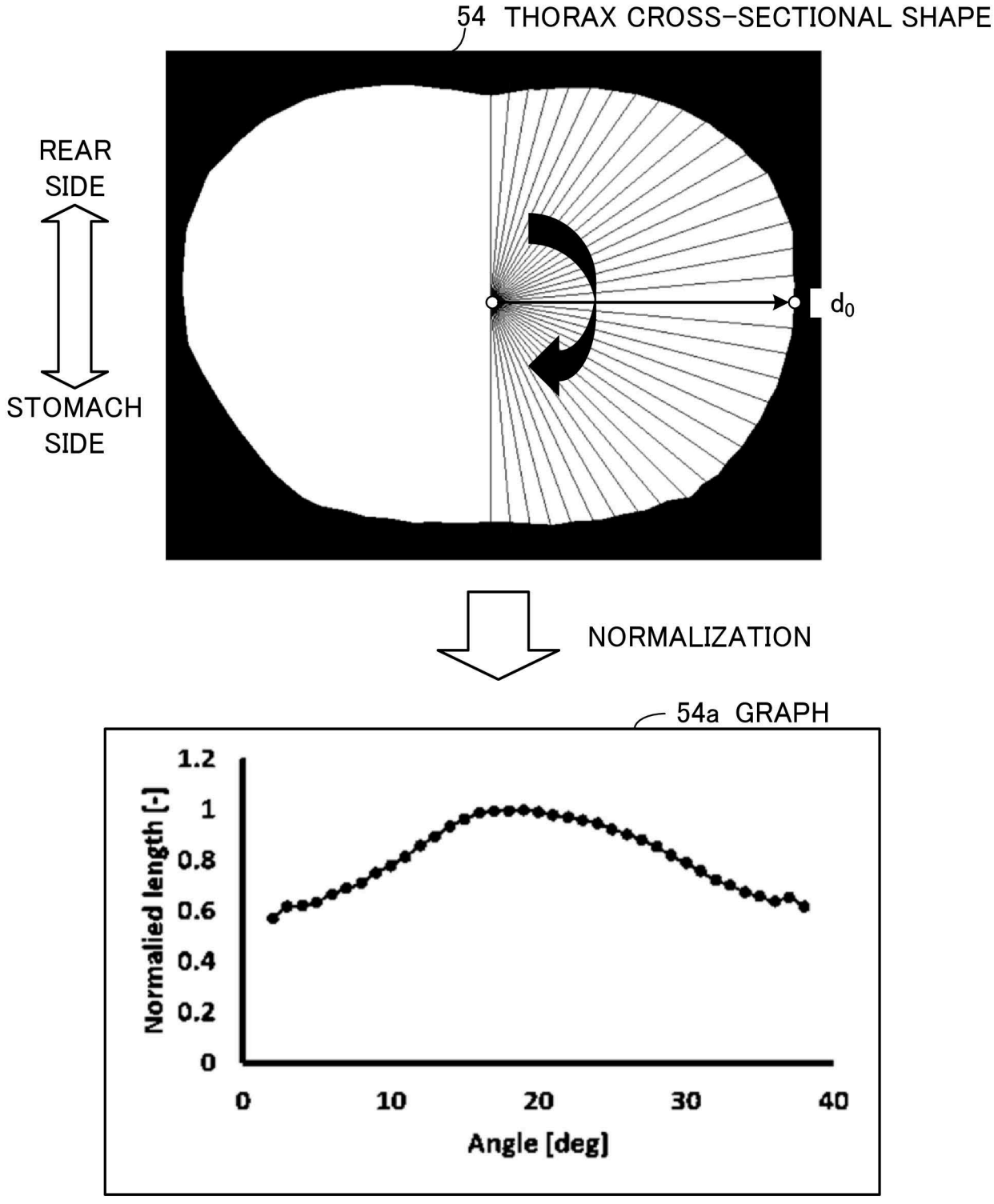

54 THORAX CROSS-SECTIONAL SHAPE
REAR SIDE
STOMACH SIDE
d_0
NORMALIZATION
54a GRAPH
Normalied length [-]
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
Angle [deg]

FIG. 18

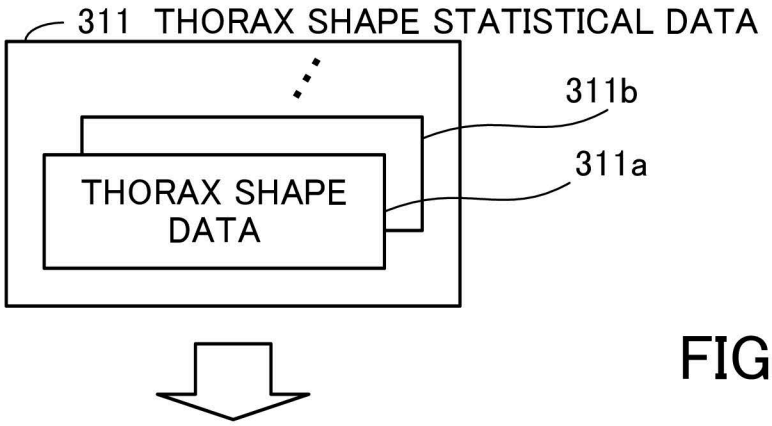
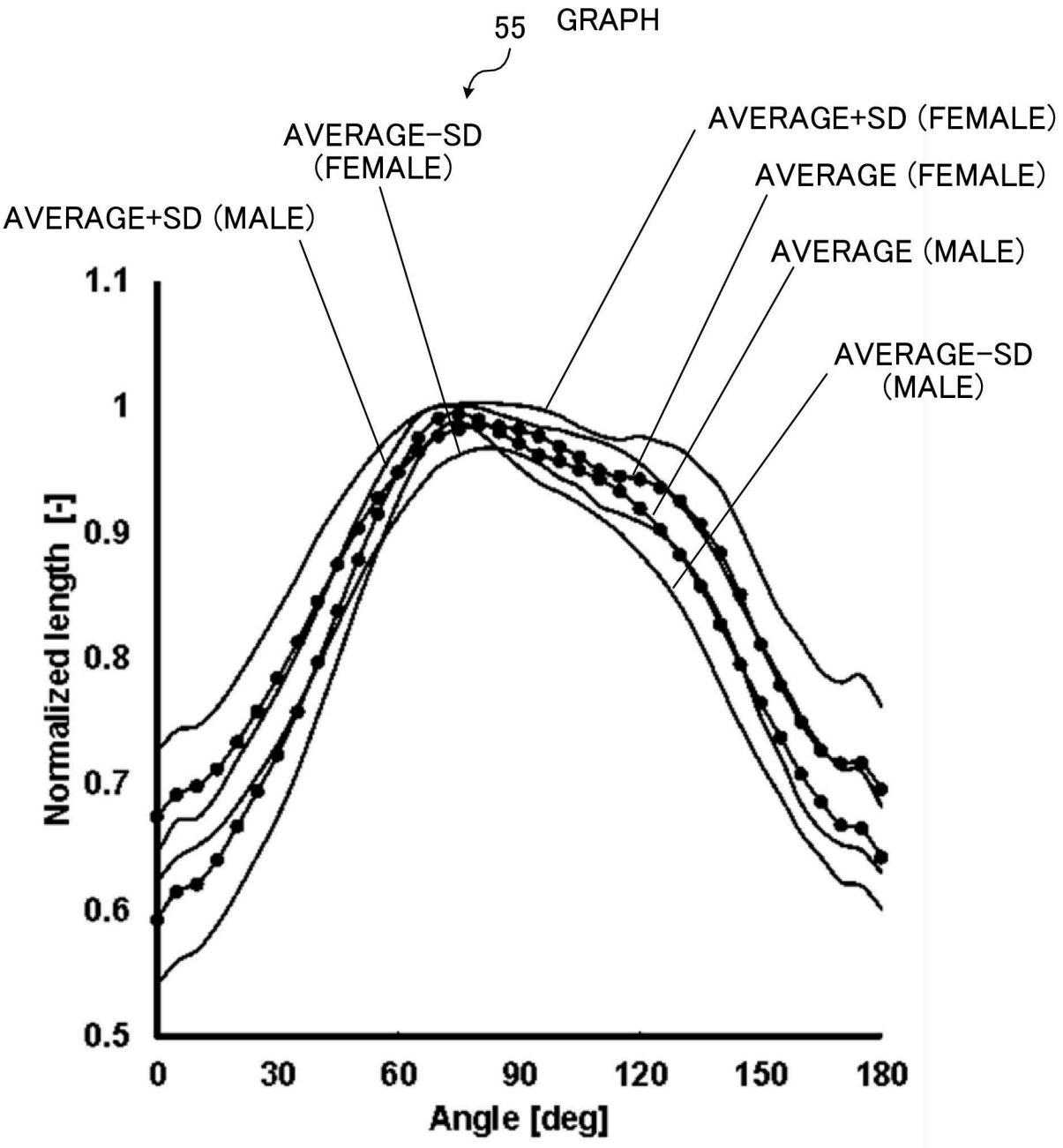

311 THORAX SHAPE STATISTICAL DATA
311b
311a
THORAX SHAPE DATA

FIG. 19


55 GRAPH
AVERAGE-SD (FEMALE)
AVERAGE+SD (FEMALE)
AVERAGE (FEMALE)
AVERAGE+SD (MALE)
AVERAGE (MALE)
AVERAGE-SD (MALE)
Normalized length [-]
1.1
1
0.9
0.8
0.7
0.6
0.5
0
30
60
90
120
150
180
Angle [deg]

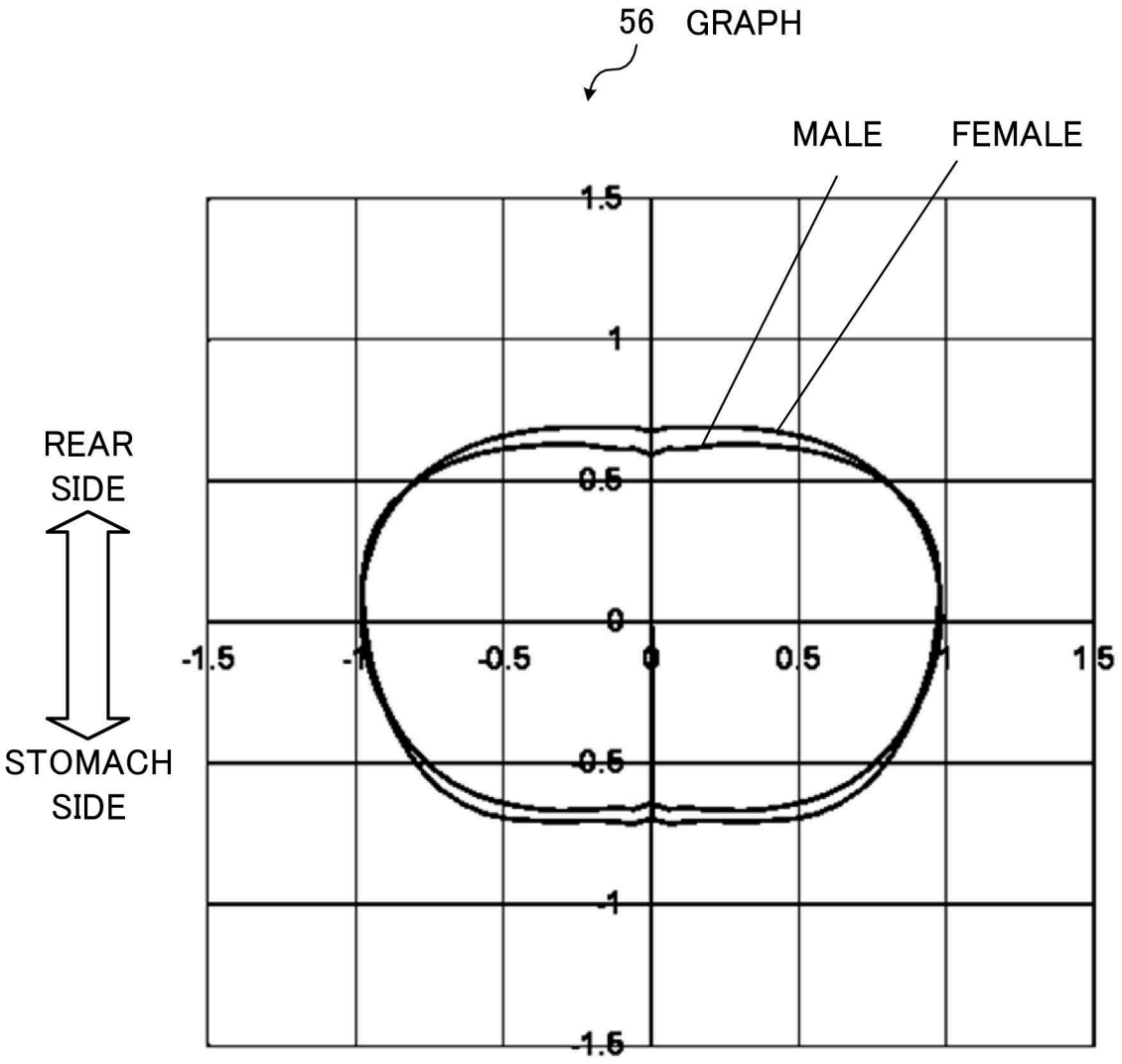
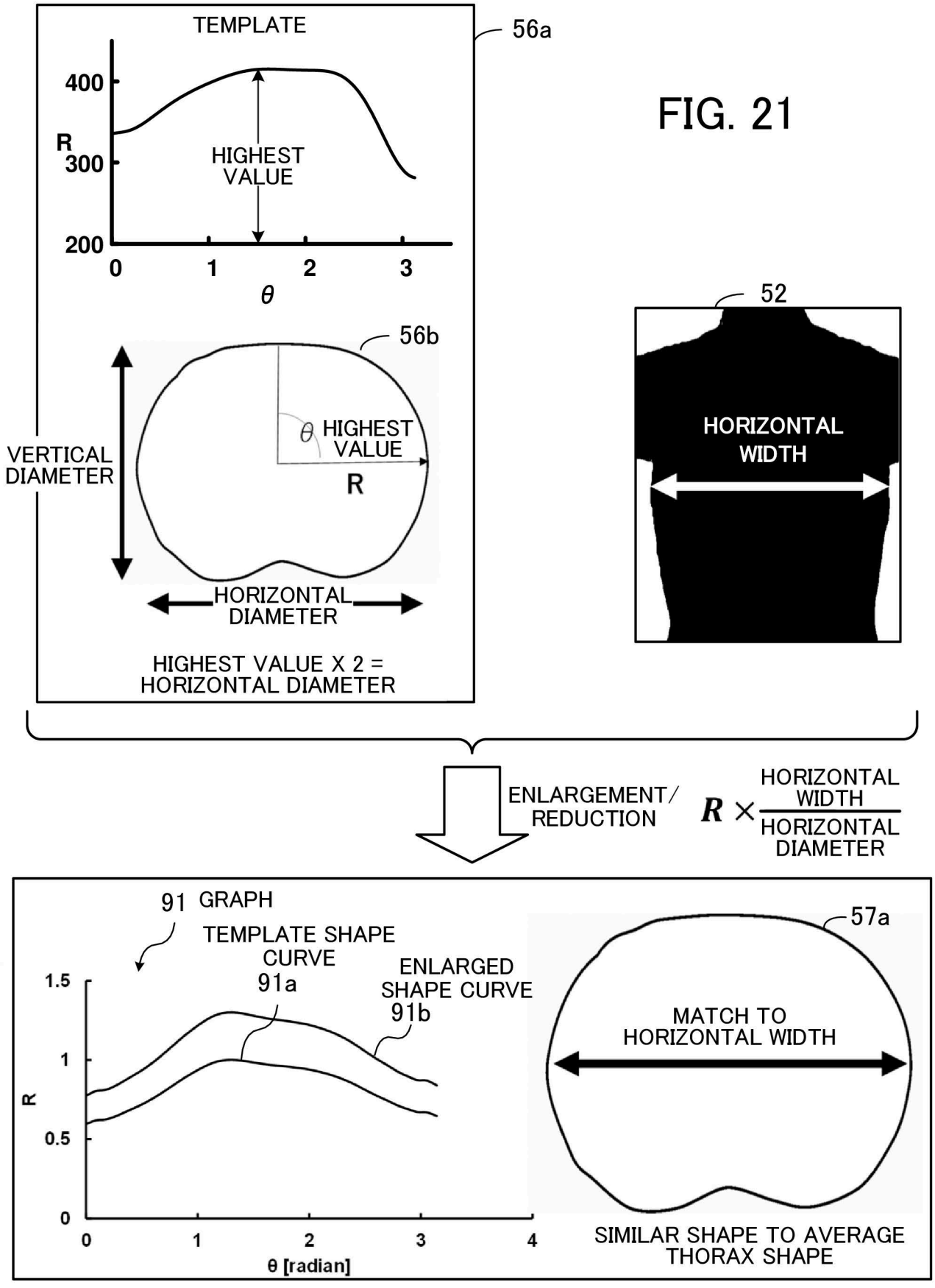

56 GRAPH
MALE
FEMALE
1.5
1
0.5
0
-0.5
-1
-1.5
-1.5
0.5
1
1.5
REAR SIDE
STOMACH SIDE

FIG. 20

FIG. 21


TEMPLATE
56a
400
R
300
200
0
1
2
3
θ
HIGHEST VALUE
56b
VERTICAL DIAMETER
θ HIGHEST VALUE
R
HORIZONTAL DIAMETER
HIGHEST VALUE X 2 = HORIZONTAL DIAMETER
52
HORIZONTAL WIDTH
ENLARGEMENT/ REDUCTION
R × HORIZONTAL WIDTH / HORIZONTAL DIAMETER
91 GRAPH
TEMPLATE SHAPE CURVE
91a
ENLARGED SHAPE CURVE
91b
1.5
1
0.5
0
R
0
1
2
3
4
θ [radian]
57a
MATCH TO HORIZONTAL WIDTH
SIMILAR SHAPE TO AVERAGE THORAX SHAPE

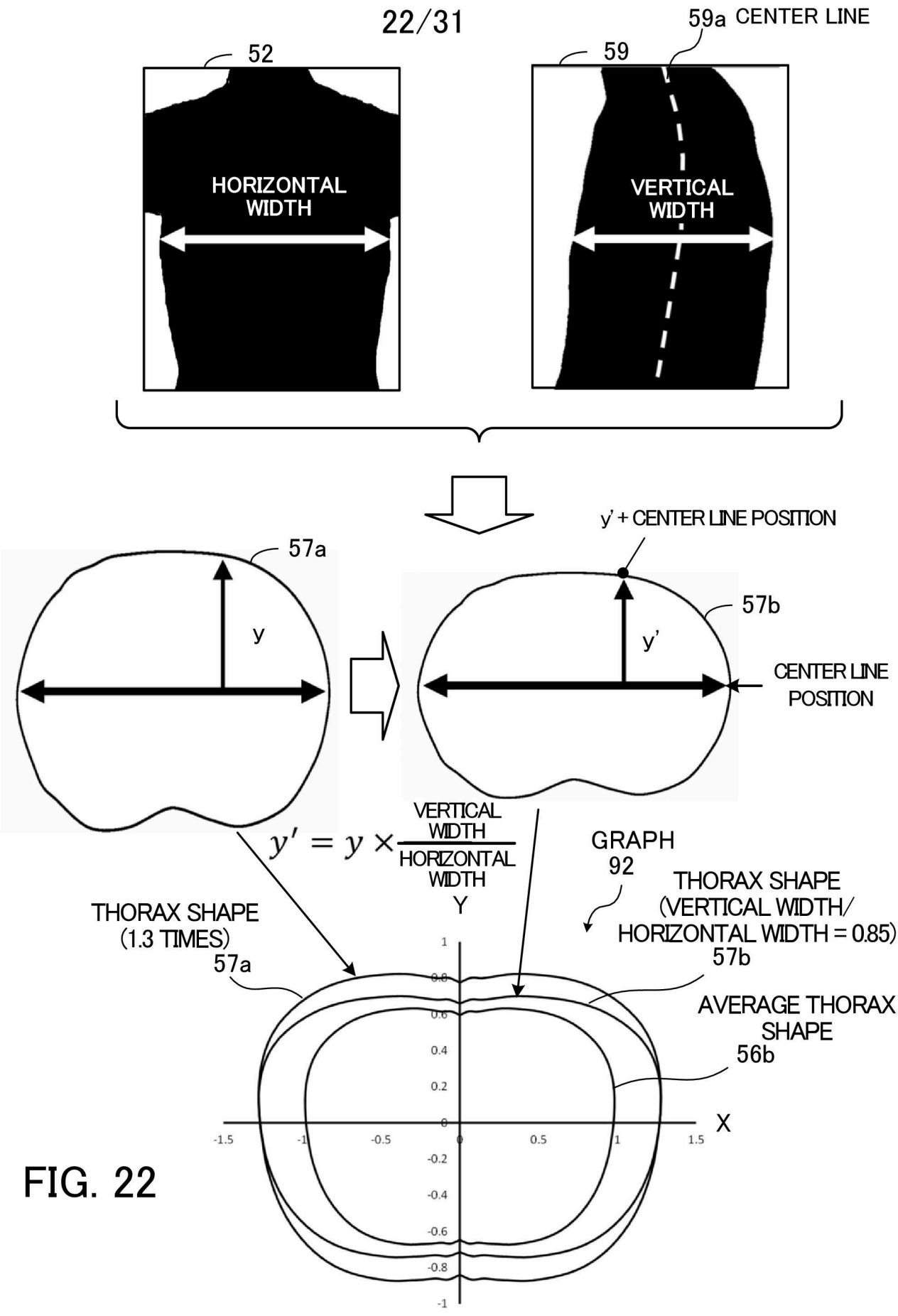
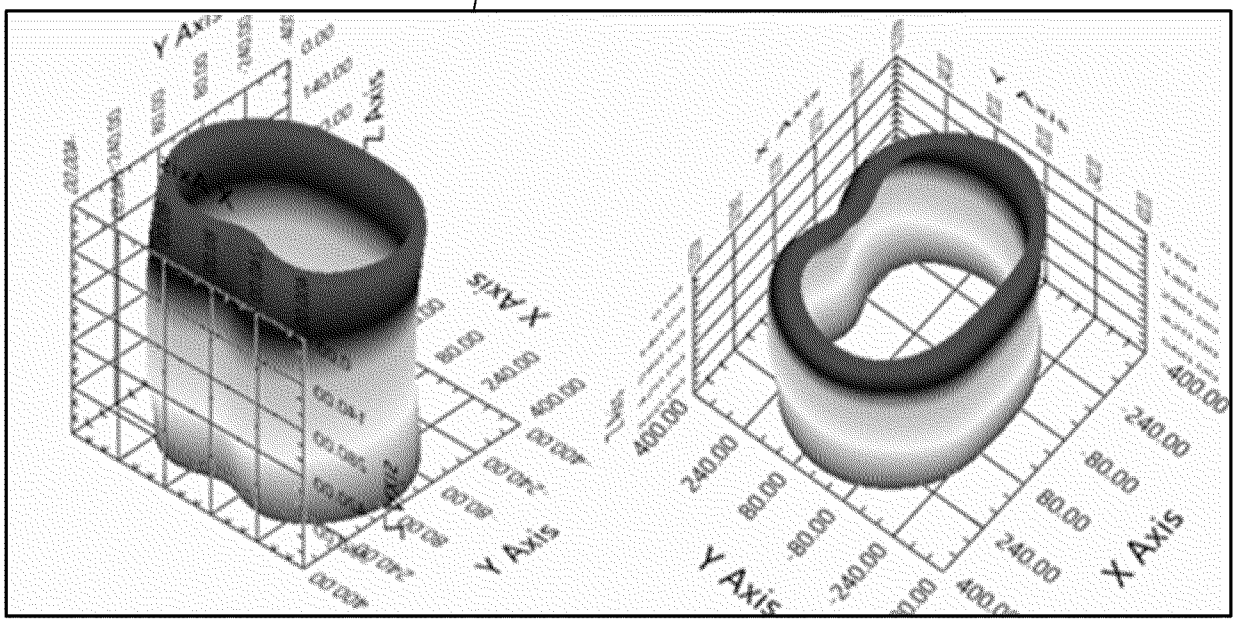

52
HORIZONTAL WIDTH
59
59a CENTER LINE
VERTICAL WIDTH
57a
y
y' + CENTER LINE POSITION
57b
y'
CENTER LINE POSITION
$y' = y \times \frac{\text{VERTICAL WIDTH}}{\text{HORIZONTAL WIDTH}}$
GRAPH
92
THORAX SHAPE (VERTICAL WIDTH/ HORIZONTAL WIDTH = 0.85)
57b
THORAX SHAPE (1.3 TIMES)
57a
AVERAGE THORAX SHAPE
56b
Y
X
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.5
-1
-0.5
0
0.5
1
1.5

FIG. 22

57 BOUNDARY POINT GROUP



151

THORAX SHAPE DATA
(POLYGON MODEL)

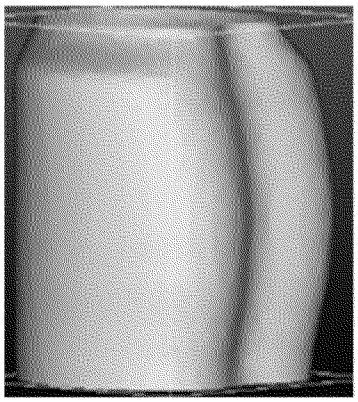


FIG. 23

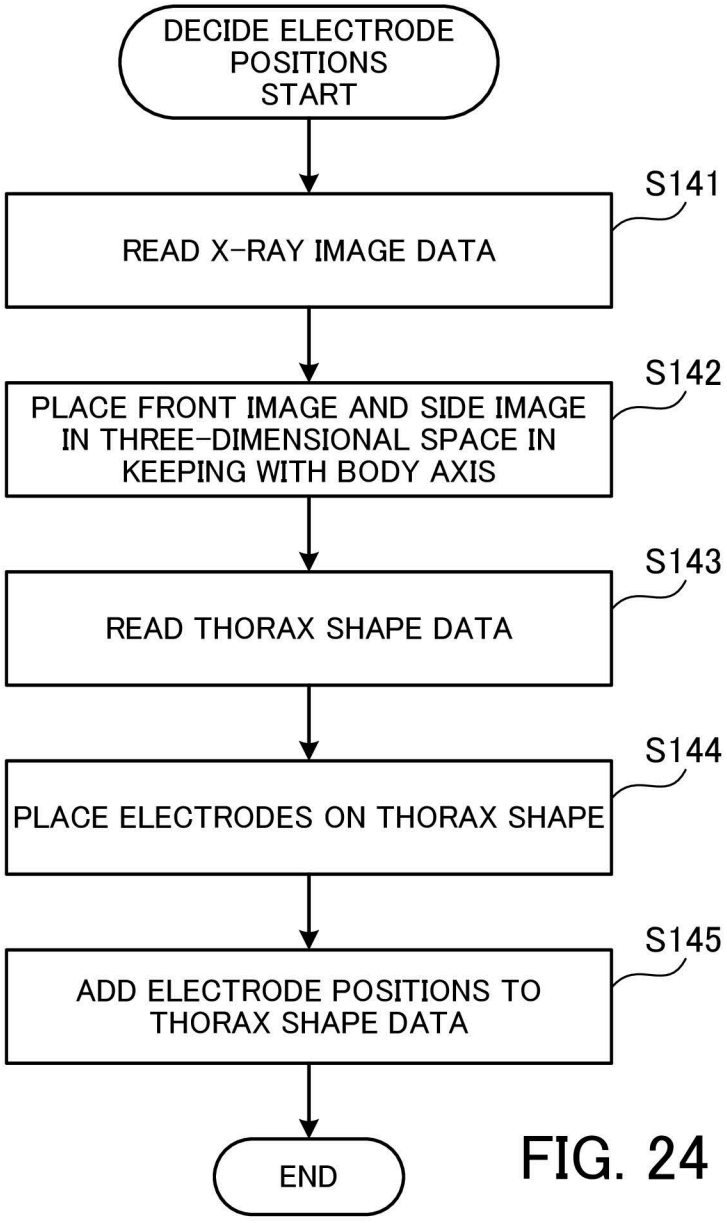

DECIDE ELECTRODE POSITIONS START
S141
READ X-RAY IMAGE DATA
S142
PLACE FRONT IMAGE AND SIDE IMAGE IN THREE-DIMENSIONAL SPACE IN KEEPING WITH BODY AXIS
S143
READ THORAX SHAPE DATA
S144
PLACE ELECTRODES ON THORAX SHAPE
S145
ADD ELECTRODE POSITIONS TO THORAX SHAPE DATA
END

FIG. 24

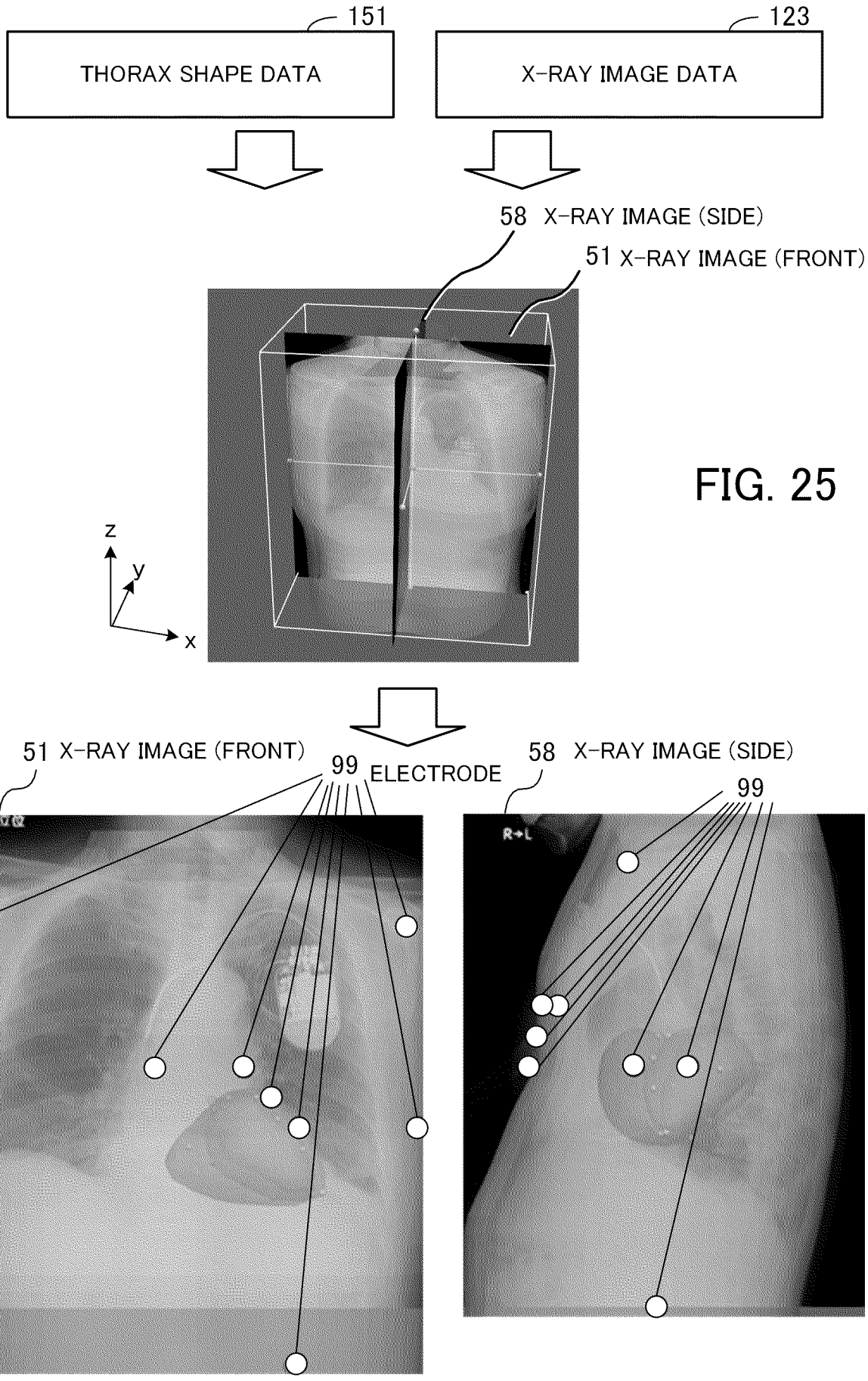

151
THORAX SHAPE DATA
123
X-RAY IMAGE DATA
58 X-RAY IMAGE (SIDE)
51 X-RAY IMAGE (FRONT)
z
y
x
51 X-RAY IMAGE (FRONT)
99 ELECTRODE
58 X-RAY IMAGE (SIDE)
99
R→L
R→L

FIG. 25

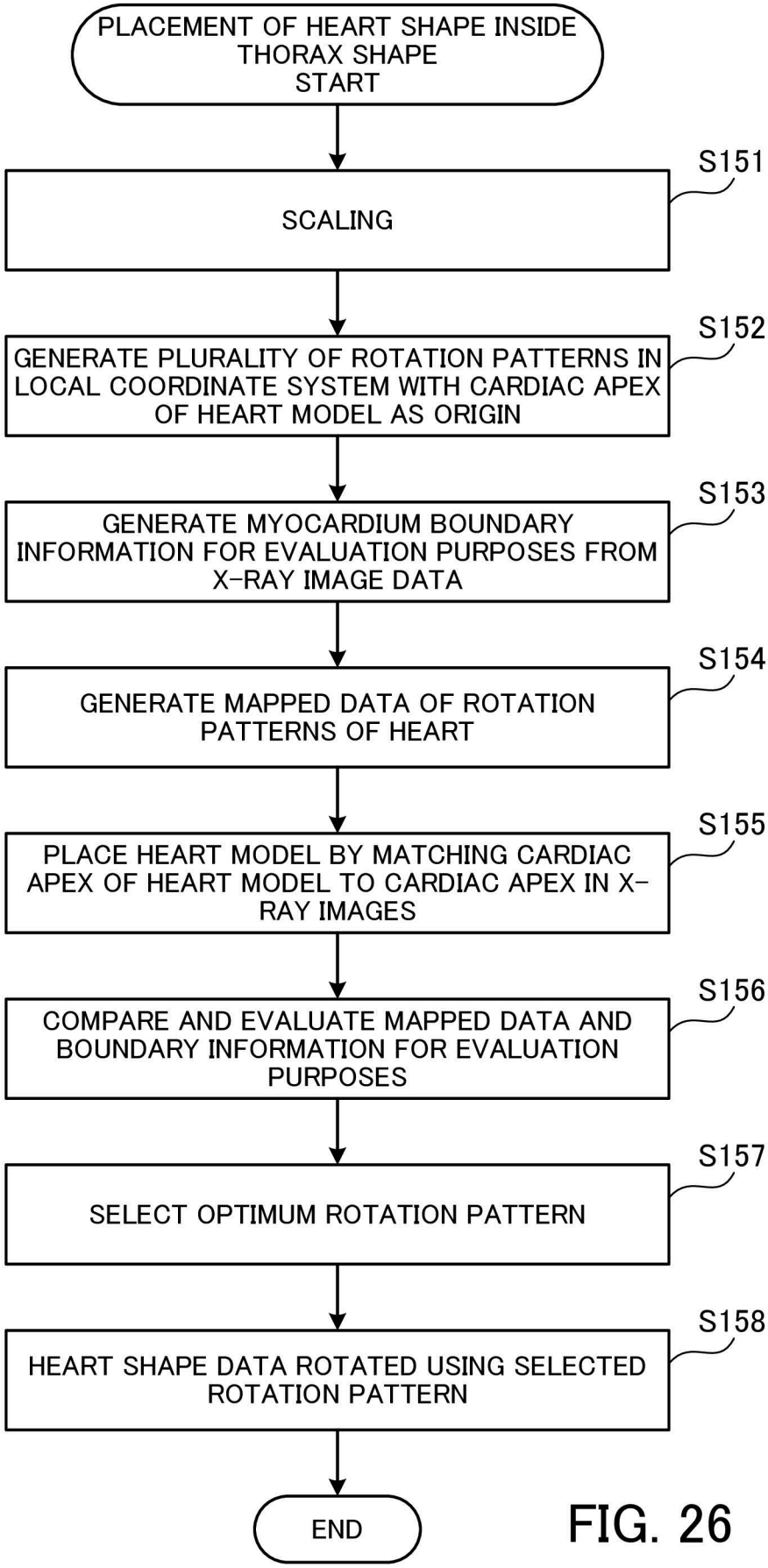

PLACEMENT OF HEART SHAPE INSIDE THORAX SHAPE START
S151
SCALING
S152
GENERATE PLURALITY OF ROTATION PATTERNS IN LOCAL COORDINATE SYSTEM WITH CARDIAC APEX OF HEART MODEL AS ORIGIN
S153
GENERATE MYOCARDIUM BOUNDARY INFORMATION FOR EVALUATION PURPOSES FROM X-RAY IMAGE DATA
S154
GENERATE MAPPED DATA OF ROTATION PATTERNS OF HEART
S155
PLACE HEART MODEL BY MATCHING CARDIAC APEX OF HEART MODEL TO CARDIAC APEX IN X-RAY IMAGES
S156
COMPARE AND EVALUATE MAPPED DATA AND BOUNDARY INFORMATION FOR EVALUATION PURPOSES
S157
SELECT OPTIMUM ROTATION PATTERN
S158
HEART SHAPE DATA ROTATED USING SELECTED ROTATION PATTERN
END

FIG. 26

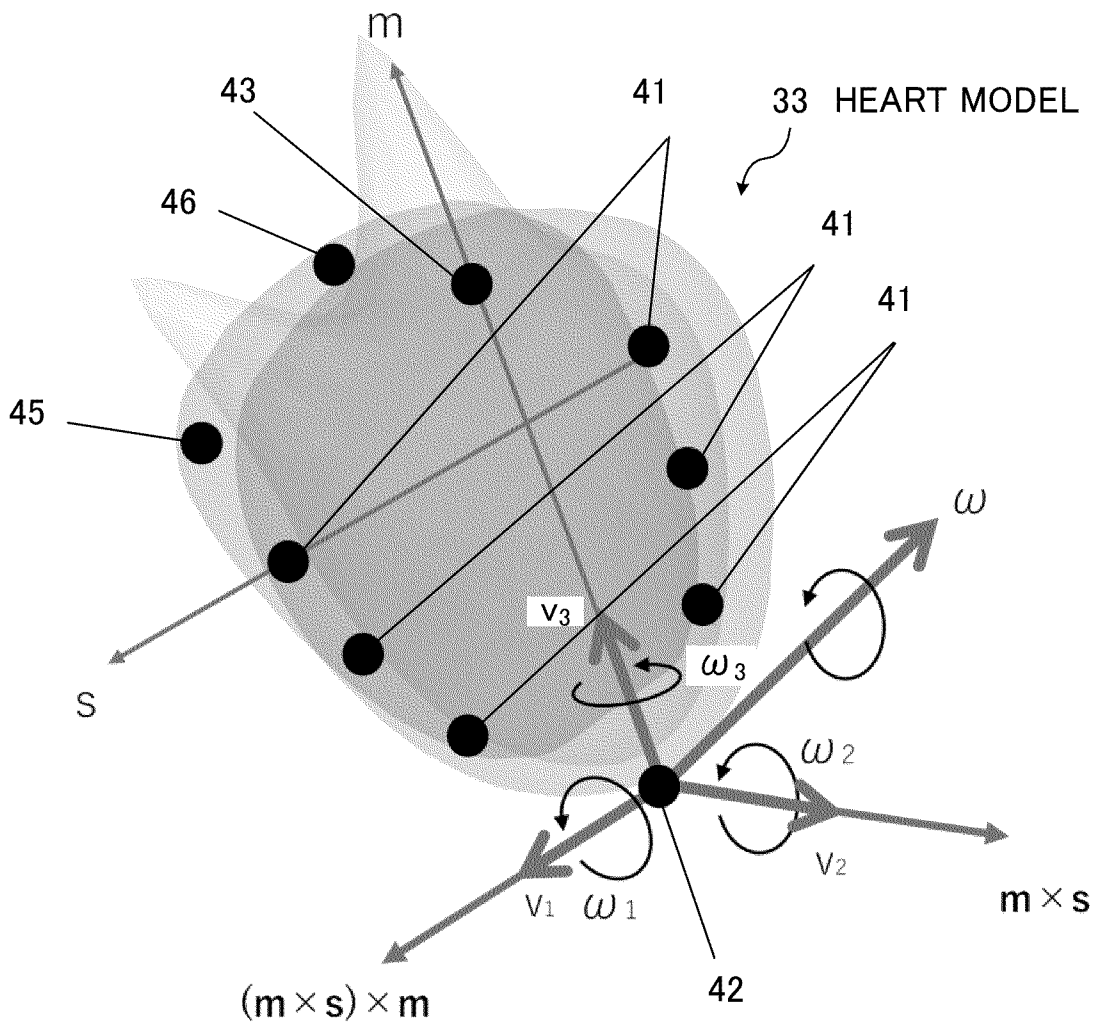


FIG. 27

61

ROTATION PATTERN
(ω_1 : ω_2 : ω_3,
ω ROTATION ANGLE)

62

ROTATION PATTERN
(ω_1 : ω_2 : ω_3,
ω ROTATION ANGLE)

...

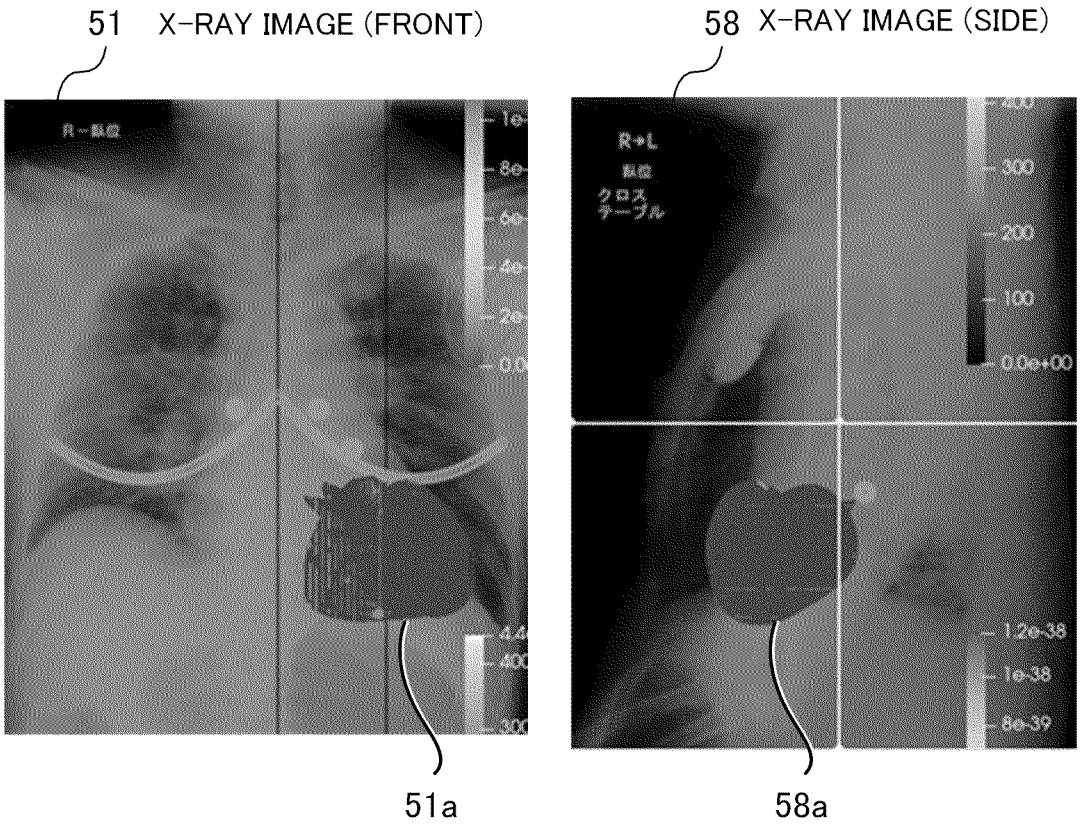
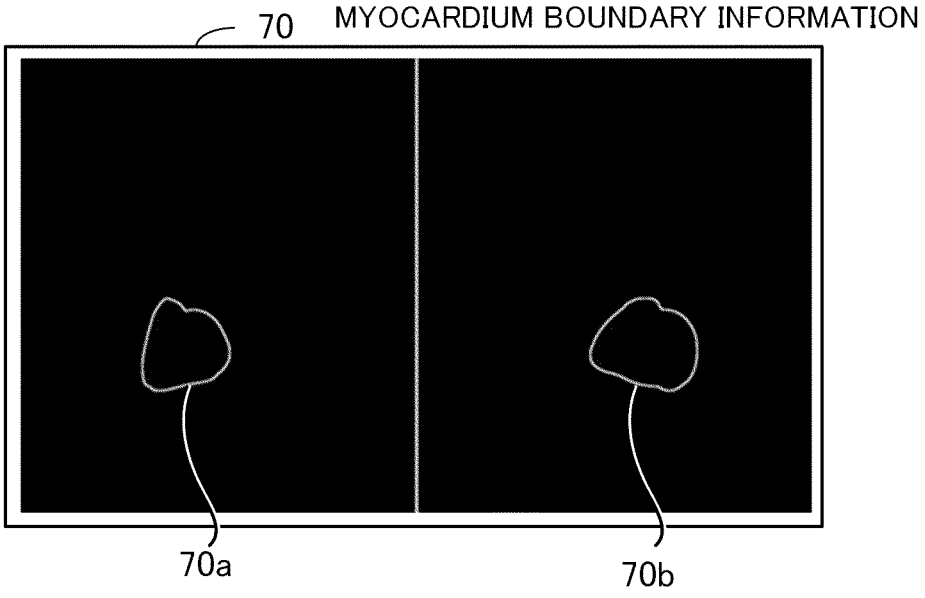

51
X-RAY IMAGE (FRONT)
58
X-RAY IMAGE (SIDE)
R+L
300
200
100
0.0e+00
1.2e-38
1e-38
8e-39
51a
58a

FIG. 28


70
MYOCARDIUM BOUNDARY INFORMATION
70a
70b

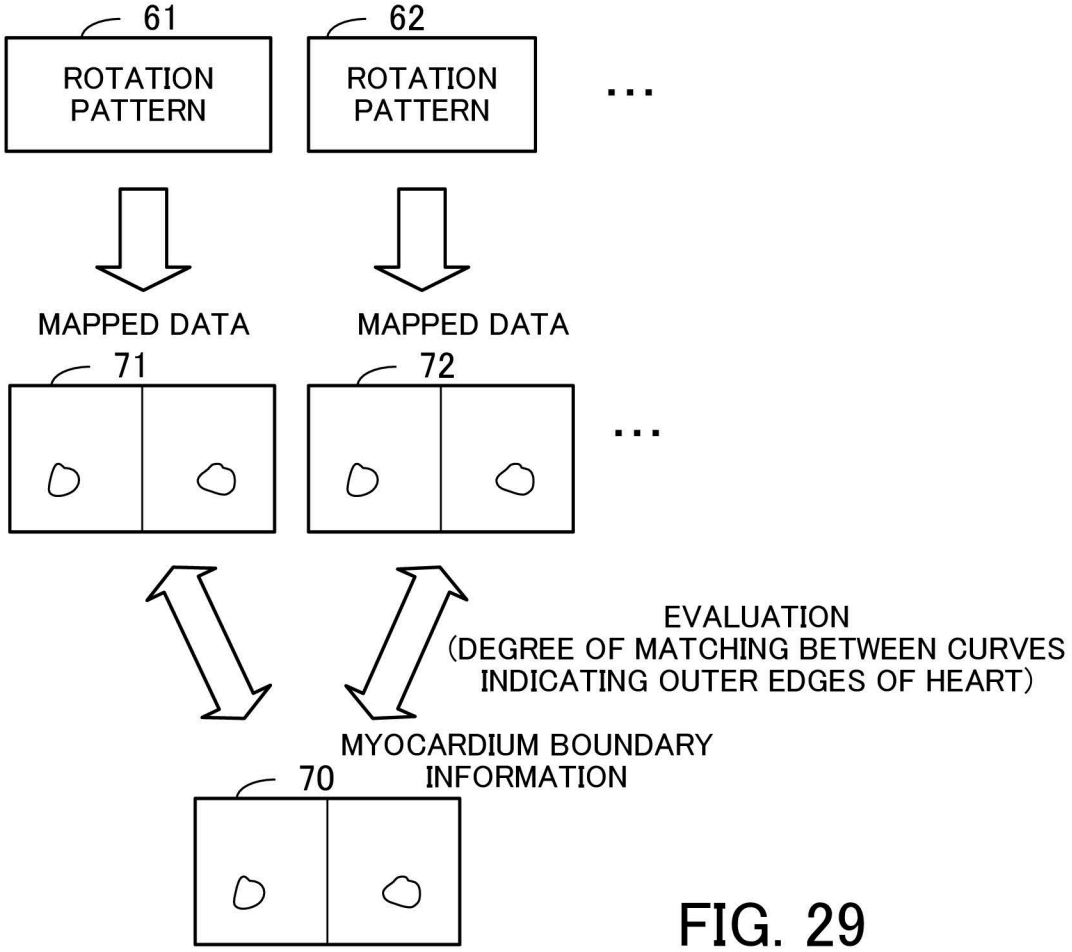

61
ROTATION PATTERN
62
ROTATION PATTERN
...
MAPPED DATA
MAPPED DATA
71
72
...
EVALUATION
(DEGREE OF MATCHING BETWEEN CURVES INDICATING OUTER EDGES OF HEART)
MYOCARDIUM BOUNDARY INFORMATION
70

FIG. 29

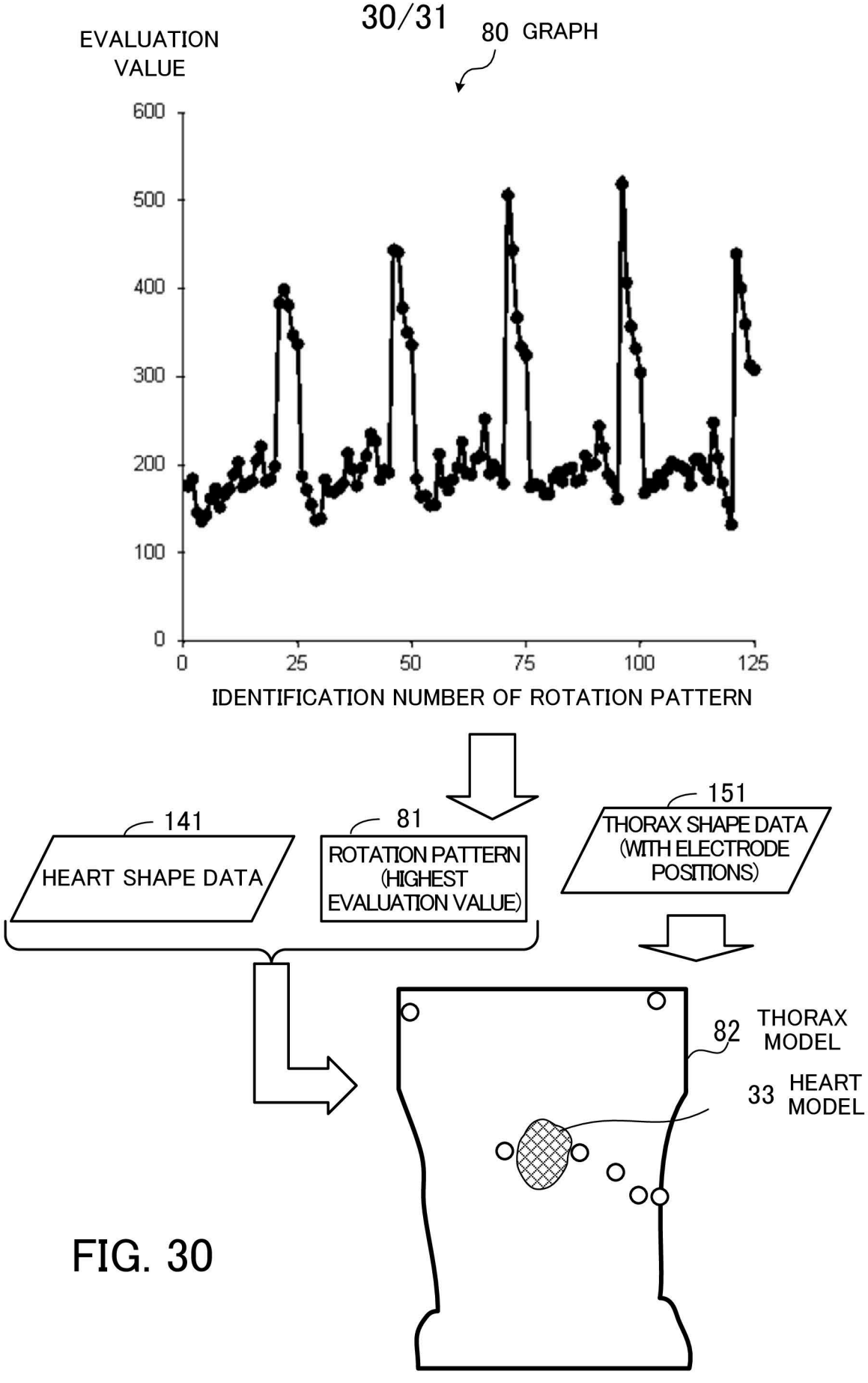

80 GRAPH
EVALUATION VALUE
600
500
400
300
200
100
0
0
25
50
75
100
125
IDENTIFICATION NUMBER OF ROTATION PATTERN
141
HEART SHAPE DATA
81
ROTATION PATTERN (HIGHEST EVALUATION VALUE)
151
THORAX SHAPE DATA (WITH ELECTRODE POSITIONS)
82 THORAX MODEL
33 HEART MODEL

FIG. 30

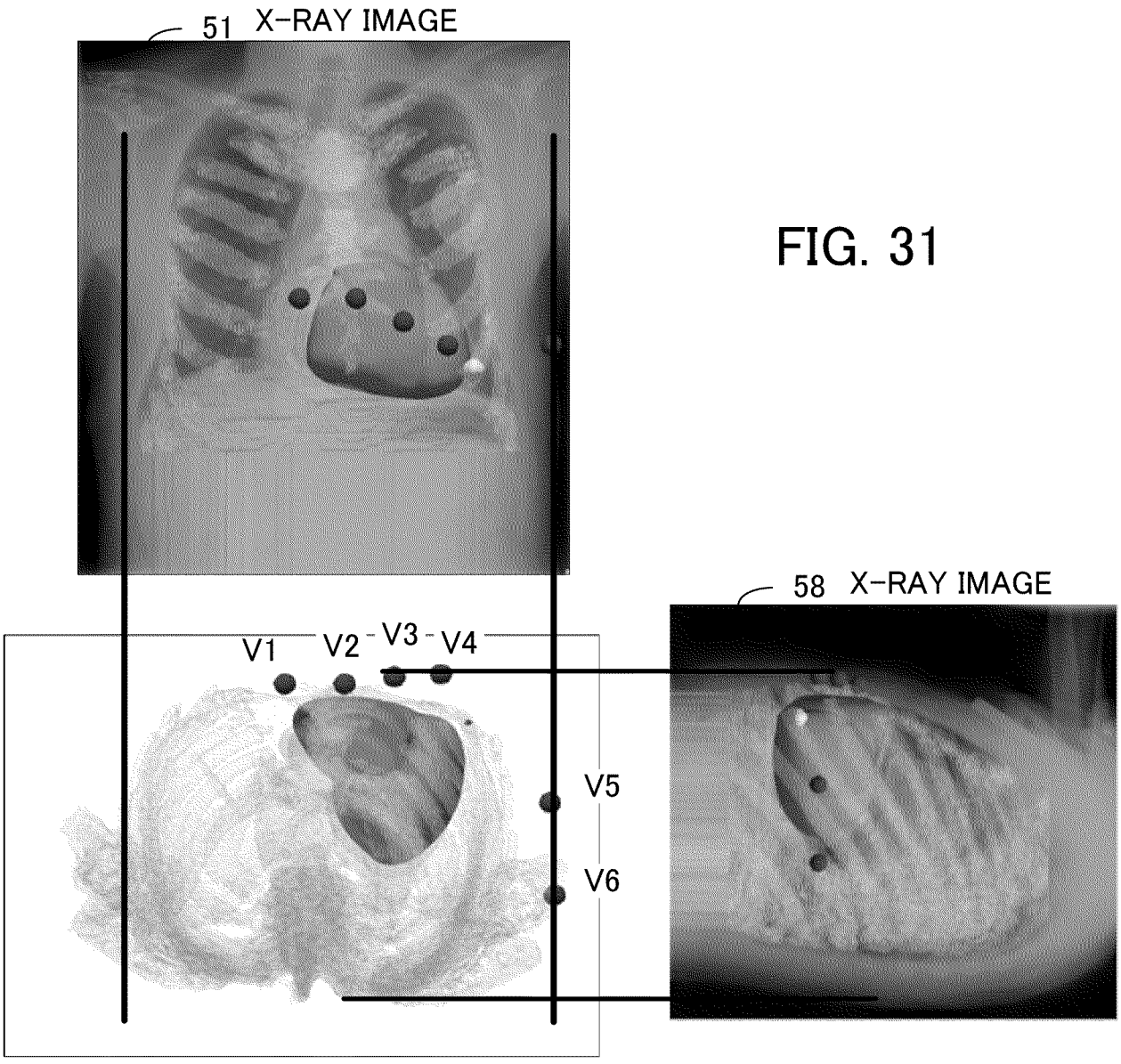


FIG. 31