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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
12 November 2015 (12.11.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/170959 A1

(51) International Patent Classification:
A61B 6/00 (2006.01) *A61B 6/03* (2006.01)

(21) International Application Number:
PCT/MY2015/000027

(22) International Filing Date:
30 April 2015 (30.04.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
PI 2014701179 7 May 2014 (07.05.2014) MY

(71) Applicant: **MIMOS BERHAD** [MY/MY]; Technology Park Malaysia, 57000 Kuala Lumpur (MY).

(72) Inventors: **CHONG, Chin Jou**; c/o Mimos Berhad, Technology Park Malaysia, 57000 Kuala Lumpur (MY). **PRETUM SINGH, Harjinthar Singh**; c/o Mimos Berhad, Technology Park Malaysia, 57000 Kuala Lumpur (MY). **NOOR BATCHA, Mohamed Fraid**; c/o Mimos Berhad, Technology Park Malaysia, 57000 Kuala Lumpur (MY).

(74) Agent: **TAY, Wee Chao**; c/o Author IP, No. 2-3, Taman Arosa, Jalan Haji Jaib, 84000 Muar, Johor (MY).

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

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

Declarations under Rule 4.17:
— *as to the identity of the inventor (Rule 4.17(i))*
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
— *of inventorship (Rule 4.17(iv))*

Published:
— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) Title: A SYSTEM AND METHOD FOR DETECTING AND MEASURING A CONSTRICTED REGION OF A BLOOD VESSEL FROM A MEDICAL IMAGE

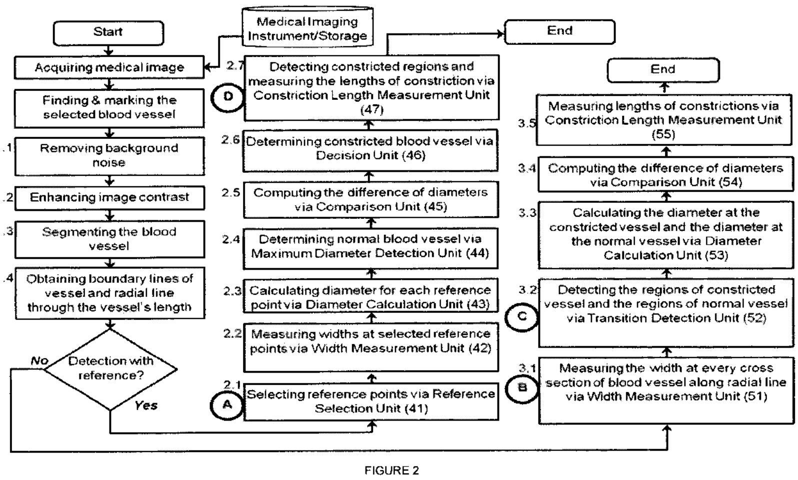


FIGURE 2

(57) Abstract: The present invention relates to a system for detecting and measuring a constricted region of a blood vessel from a medical image, characterized by a width measurement unit (42, 51) for measuring the width values of the blood vessel, a diameter calculation unit (43, 53) for determining the diameter of the blood vessel based on the measured width values, a comparison unit (45, 54) for computing the diameter difference in percentage as compared to a maximum diameter, and a constriction length measurement unit (47, 55) for determining the length of the constricted region. The present invention further relates to a method measuring the width of the blood vessel at a plurality of points by a width measuring unit (42, 51), obtaining diameter of a single or a group of the plurality of points by a diameter calculation unit (43, 53) based on the widths obtained by the width measuring unit (42, 51), and computing the differences in percentage of the diameter from a maximum diameter by a comparison unit (54).

WO 2015/170959 A1

A SYSTEM AND METHOD FOR DETECTING AND MEASURING A CONSTRICTED REGION OF A BLOOD VESSEL FROM A MEDICAL IMAGE

TECHNICAL FIELD OF THE INVENTION

The present invention relates to a system and method for diagnostic detection of a constricted region of a blood vessel, and more particularly, the present invention relates to a system and method for measuring the length of the constricted region in a blood vessel based on computer vision in medical image analysis.

BACKGROUND OF THE INVENTION

A region of blood vessel becomes constricted or narrower when the lumen of a blood vessel is partially obstructed or locally reduced by compression which then leads to reduction in blood flow. The obstructed or narrowed blood vessel may develop as the cholesterol-laden plaque deposits on the wall of the blood vessels. The constricted region of blood vessel may result in various crucial diseases, such as heart diseases. Early diagnosis and detection of the blood vessel constriction therefore plays an important role as a precaution and preventive measures on the blood flow related diseases.

The current technologies used in the beginning states of constricted blood vessel detection include visual detection using medical imaging such as conventional ultrasound, duplex ultrasound, positron emission tomography (PET) and angiogram. Detection of the constricted region of the blood vessel is also conventionally performed via manual measurement using tools such as ruler, caliper and eyepiece micrometer. The problem encountered by the manual detection is the vast amount of time required to detect the blockages blood stream, due to the fact that in an image there could be hundreds of blood vessels and it requires laborious efforts to detect constricted region in a blood vessel. Furthermore, the measurements may not be accurate and might be prone to human errors.

International Publication No. WO 2010/101660 A2 discloses a method for determining at least one feature including the diameter for indicating the thickening of the blood vessel within each of the plurality of regions, and defining the boundary of the portion of the vasculature based on the diameter each of the plurality of regions, wherein the boundary forms a volume defining a separation between inside and outside of the portion of the vasculature.

United States Patent No. US 8,437,520 B2 discloses a medical image processing method comprising the steps of extracting a longitudinal line from three-dimensional volume data for a medical image, generating multiple longitudinal cross-sectional images extending along the longitudinal line, generating multiple short-axis cross-sectional images intersecting the longitudinal line, detecting a specific structural element of the tubular structure from each of the plurality of short-axis cross-sectional images, wherein the structural element includes the calcification of the lumen; and a correction unit configured to correct the specific structural element detected from each of the multiple short-axis cross-sectional images on a basis of the multiple longitudinal cross-sectional images.

United States Patent No. US 8,538,105 B2 discloses a medical image processing apparatus. An index value calculation unit of the apparatus calculates an index value representing a characteristic of a tubular structure according to a three-dimensional medical image in each direction of radial visual lines orthogonal to a core line of the tubular structure. A map image generation unit generates a characteristic map image by mapping the index value calculated in each direction of the radial visual lines at each point on the core line to a coordinate plane defined by a first coordinate component representing a position in a direction of the core line and a second coordinate component representing a direction of each visual line.

It is therefore apparent that all of the above prior arts require cross sectional images to be taken along the longitudinal line of the blood vessel in order to detect the constricted region of the blood vessel. The capturing of the cross sectional requires technologies which may not be readily available for detecting the blood vessel constriction. Further, the method as disclosed in the prior art is labor intensive if no preliminary information is available on the targeted region of blood vessel.

Accordingly, there is a need to provide a system and method of detecting and measuring a constricted region of a blood vessel from a medical image from a single longitudinal image on the blood vessel. Further, it is desirable that the system and method for detection of the blood vessel constriction is implemented with a computing environment to eliminate the need for manual inspection on the medical image by human.

SUMMARY OF THE INVENTION

It is an objective of the present invention to provide a system and method for detecting constricted region of blood vessel from a medical image.

It is also an objective of the present invention to provide a system and method for accurately determining the severity of blood vessel constriction by measuring the length of the constricted region of blood vessel from a medical image.

It yet another objective of the present invention to provide a system and method for detecting the average diameter at different region of the blood vessel.

It is a further objective of the present invention to apply computer vision analysis in detecting constricted region and measuring the size of the constriction based on a medical image analysis.

Accordingly, the present invention is provided for overcoming the disadvantages and drawbacks of the prior arts as well as to achieve the above objectives. The present invention relates to a system for detecting and measuring a constricted region of a blood vessel from a medical image, comprising an acquisition module for acquiring a medical image from a medical imaging instrument or medical imaging database, an area selection module for selecting a region from the medical image which contains at least one blood vessel, and a detection module for determining a constricted region of the blood vessel. The detection module further comprises a width measurement unit for measuring the width values of the blood vessel, a diameter calculation unit for determining the diameter of the blood vessel based on the measured width values, a comparison unit for computing the diameter difference in percentage as compared to a maximum diameter, a constriction length measurement unit for determining the length of the constricted region.

In one aspect of the invention, the detection module is a reference dependent detection module which comprises a reference selection unit for selecting reference points of the blood vessel for the measurement of width by the width measurement unit, and a decision unit for determining the constricted region of the blood vessel according the difference in percentage as obtained by the comparison unit.

In another aspect of the invention, the detection module is a reference independent detection module which comprises a transition detection unit for determining the constricted region and non-constricted region of the blood vessel based on the deviation between two neighboring widths as obtained from the width measuring unit, wherein the width measurement unit measures the width values of every cross sections along the blood vessel.

The present invention also relates to a method for detecting and measuring a constricted region in a blood vessel from a medical image, comprising the steps of obtaining a top boundary line, a bottom boundary line, and a radial line along the blood vessel from the medical image of the blood vessel, measuring the width of the blood vessel at a plurality of points by a width measuring unit, obtaining diameter of a single or a group of the plurality of points by a diameter calculation unit based on the widths obtained by the width measuring unit, computing the differences in percentage of the diameter from a maximum diameter by a comparison unit.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is further described hereinafter with reference to the embodiments shown in the accompanying drawings in which:

Figure 1 is a block diagram showing a system for detecting and measuring a constricted region of blood vessel according to the present invention.

Figure 2 is a flow chart showing a method for detecting and measuring a constricted region of blood vessel according to the present invention.

Figure 3 is a flow chart showing a method for detecting and measuring a constricted region of blood vessel via reference points according to an embodiment of the present invention.

Figure 4 is a flow chart showing a method for determining the number of constrictions and measuring respective lengths initiated from reference points of each constriction according to an embodiment of the present invention.

Figure 5 is a flow chart showing a method for detecting and measuring a constricted region of blood vessel continuously without reference points according to an embodiment of the present invention.

Figure 6 is a flow chart showing a method for detecting the regions of constricted blood vessel and regions of normal blood vessel without reference point according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention and the preferred embodiments will now be described in with reference to the accompanying drawings. These embodiments as described, however, should not be construed to limit the scope of the present invention.

The present invention relates to a system for detecting and measuring a constricted region of a blood vessel from a medical image. With reference to Figure 1, the system comprises an acquisition module (10) for acquiring and retrieving a medical image from a medical imaging instrument or medical imaging database. Each of the medical images contains at least one blood vessel for further processing. The acquired medical image from the acquisition module (10) is provided to an area selection module (20) for selecting a region from the medical image which contains at least one blood vessel. A detection module (40, 50) is provided in the system for determining a constricted region of the blood vessel.

In a preferred embodiment, the area selection module (20) is connected to a preprocessing module (30), wherein the medical image is processed for better detection in subsequent stages. The preprocessing module (30) comprises means for performing noise removal, image quality enhancement, blood vessel segmentation and feature extraction.

A detection module (40, 50) is provided for detecting normal blood vessels and constricted blood vessels from the acquired and processed medical image. The detection module (40, 50) generally comprises a width measurement unit (42, 51) for measuring the width values of the blood vessel, a diameter calculation unit (43, 53) for determining the diameter of the blood vessel based on the measured width values, a comparison unit (45, 54) for computing the diameter difference in percentage as compared to a maximum diameter, a constriction length measurement unit (47, 55) for determining the length of the constricted region.

With reference to Figure 1, according to a preferred embodiment of the present invention, the detection module is selected from one of reference dependent detection module (40) and reference independent detection module (50).

In the reference dependent detection module (40), a reference selection unit (41) is provided for selecting reference points of the blood vessel, wherein the selected reference points is subjected to measurement of width by the width measurement unit (42). The diameter calculation unit (43) connected to the width measurement unit (42) determines the diameter of blood vessel at each of the selected reference points. A maximum diameter detection unit (44) is provided for identifying the maximum diameter as obtained by the diameter calculation unit (43), and hence determines the normal blood vessel from all the diameter values. The comparison unit (45), which is connected to the maximum diameter detection unit (44), computes the difference in percentage of the referenced normal blood vessel diameter value against the rest of the diameter values. A decision unit (46) is provided for determining the constricted region of the blood vessel according to the diameter difference in percentage as obtained by the comparison unit (45). The constriction length measurement unit (47) is connected to the decision unit (46) for determining the regions of constriction along the blood vessel and the length of the constricted region.

In the reference independent detection module (50), the width measurement unit (51) is provided for measuring the width at every cross section along the blood vessel. A transition detection unit (52) is provided for determining the constricted region and non-constricted region of the blood vessel based on the deviation between two neighboring widths as obtained from the width measuring unit (51). The diameter calculation unit (53) connected to the width transition detection unit (52) computes the diameter of each region detected as non-constricted and each region detected as constricted. The comparison unit (54) provided in connection to the diameter calculation unit (53) computes the diameter difference in percentage of the non-constricted blood vessel diameter against the rest of the diameter values. The constriction length measurement unit (55) is provided for measuring the constriction length for each region detected as constricted.

The present invention also relates to a method for detecting and measuring a constricted region in a blood vessel from a medical image, comprising the steps of obtaining a top boundary line, a bottom boundary line, and a radial line along the blood vessel from the medical image of the blood vessel, measuring the width of the blood vessel at a plurality of points by a width measuring unit (42, 51), obtaining diameter of a single or a group of the plurality of points by a diameter calculation unit (43, 53) based on the widths obtained by the width measuring unit (42, 51), computing the differences in percentage of the diameter from a maximum diameter by a comparison unit (54).

With reference to Figure 2, the method for detecting constriction is initiated with acquiring medical image by an acquisition module (10) from a medical imaging instrument or medical imaging database. The method then proceeds to selecting a region from the medical image in which the selected blood vessel is identified and marked. The preprocessing of the medical image then follows which include removing the background noise, enhancing the image contrast, segmenting the vessel, and obtaining top boundary lines and bottom boundary lines of the vessel and radial line through the vessels' length. The method then proceeds to detection of the constricted region wherein the detection can be performed with or without reference.

In the embodiment in which the detection is performed with reference, a plurality of points is selected as reference points via the reference selection unit (41). The width measurement unit (42) then measures the widths at the selected reference points follow by calculation of diameter based on the measured widths via the diameter calculation unit (43). The maximum diameter detection unit (44) identifies the maximum diameter which will be used as reference normal blood vessel. The difference in percentage of the calculated diameter is computed against the maximum diameter via the comparison unit (45). The reference points which belong to the non-constricted region and constricted region are then determined by the decision unit (46), based on the difference in percentage of the diameter from the maximum diameter. After identification of the constricted region of the blood vessel, the lengths of the constricted regions are measured by the constriction length measurement unit (47).

With reference to Figure 3 which shows a detailed process in the detection method with reference, a reference selection unit (41) selects a plurality of points as reference points, wherein the plurality of points includes points at both the normal and constricted region of the blood vessel. The total number of the reference points selected is indicated as P. Reference lines are extrapolated across the blood vessel perpendicularly from each of the plurality of reference points to intersect the top boundary line and the bottom boundary line. The coordinates of the intersecting points between the radial line and P reference lines are obtained. The method then proceeds with a first reference point for measurement of the widths for a total of N adjacent points.to the first reference point. The diameter is then determined by averaging the widths for a total of N adjacent points. The widths and diameter determination step is reiterated with the second reference point and so forth until all the P number of reference points has been measured in terms of widths and diameter. This is then followed by determining the maximum diameter which will be taken as the diameter of a reference normal blood vessel and will be used as comparison to compare with all other diameter obtained. The computation of the percentage of difference in diameter is then carried out by comparing the maximum diameter with the diameters of all other plurality of points. The decision unit (46) then determines each of the plurality of points of the blood vessel based on the percentage difference in diameter, the reference point of which the percentage difference in diameter exceeding a predetermined threshold value will be considered as constricted point and reference point of which the percentage difference in diameter is less than the threshold value will be considered as non-constricted point. The number of the constricted points is then determined and the constricted regions of the blood vessel are then identified by extending diameter measurement from all the identified constricted points, and the lengths of all the constricted regions are measured.

Figure 4 shows a detailed process for identifying the constricted region from the constricted point as detected. The total number of constricted points detected is indicated as Q. Starting from a first constricted point, the width measurement is carried out first in the backward along the radial line. The variance of the measured width is calculated against the diameter of the constricted point to determine whether the variance exceeds a predetermined threshold value. The measurement of the width stops when the variance exceeds the threshold value or the end of radial line is encountered. Otherwise, if the variance is less than the threshold value, measurement of width and determination of variance continue with the subsequent point until a stop to the constricted region is encountered. The position where the measurement is stopped is marked and taken as the starting point of the constricted region of the first constricted point. The measurement of the width and determination of variance is then reset to the first constricted point and proceeds now in forward direction. If the variance detected less than the threshold value, the measurement will proceed with subsequent point in the forward direction. Otherwise, the measurement of width and determination of variance is stopped and the variance is larger than the threshold value or when an end of the radial line is met. The position where the measurement is stopped is marked and taken as the ending point of the constricted region of the first constricted point. The method then proceeds with a second constricted point for determination of the starting point and the ending point of the constricted region of the second constricted point. With the consecutive order of measurement for all the Q number of constricted points, all the constricted regions can then be determined. If a constricted point is found within a previously identified constricted region, the method will proceeds to a subsequent constricted point.

With reference to Figure 5, in the detection of constricted region of blood vessel without reference, the plurality of points comprises each point along the blood vessel radial line. The width measurement is performed for one point and continues to the subsequent point until the end of radial line or when a fork is met. The total number of points measured is recorded and indicated as R. Constricted regions and non-constricted regions are detected via a transition detection unit (52). The diameter at the constricted region and the diameter at the non-constricted region are calculated, wherein the width measurements along the region are averaged to obtain the diameter. The maximum diameter value is obtained from the diameter as detected from all the regions of the blood vessel. The percentage difference in diameter between the maximum diameter and the other diameters is computed via a comparison unit (54). Eventually, the lengths of constricted regions are measured by computing the distance between the starting point and ending point.

With reference to Figure 6, the steps of determining constricted regions and non-constricted regions as detected by transition detection unit (52) will now be described. With the total number of R points along the radial lines identified, the process proceeds with the calculation of deviation of width measurement between the current point with the previous point. If the deviation exceeding a predetermined threshold value is encountered, the current position will be taken as the transition point, and the process proceeds with the subsequent point for the calculation of deviation of width measurements. Otherwise, the current position will be taken for determination of whether the point is an end of the transition. If the current position is not an end of the transition, it will be assigned into the same region. Otherwise, the current position is assigned into a subsequent region. The point which has been assigned into a subsequent region will further be categorized into a non-constricted region if the slope of the current position is negative or a constricted region when the slope of the current position is positive. The process is carried out for all the R number of points.

It will be apparent to those skilled in the art that various changes and modification may be made therein without departing from the principle of the invention or from the scope of the appended claims.

CLAIMS

1) A system for detecting and measuring a constricted region of a blood vessel from a medical image, comprising:

a) an acquisition module (10) for acquiring a medical image from a medical imaging instrument or medical imaging database;

b) an area selection module (20) for selecting a region from the medical image which contains at least one blood vessel;

c) a detection module for determining a constricted region of the blood vessel;

characterized in that the detection module further comprising:

d) a width measurement unit (42, 51) for measuring the width values of the blood vessel;

e) a diameter calculation unit (43, 53) for determining the diameter of the blood vessel based on the measured width values;

f) a comparison unit (45, 54) for computing the diameter difference in percentage as compared to a maximum diameter;

g) a constriction length measurement unit (47, 55) for determining the length of the constricted region.

2) A system for detecting and measuring a constricted region of a blood vessel from a medical image according to claim 1, wherein the detection module is a reference dependent detection module (40) and further comprising :

a) a reference selection unit (41) for selecting reference points of the blood vessel for the measurement of width by the width measurement unit (42);

b) a decision unit (46) for determining the constricted region of the blood vessel according to the diameter difference in percentage as obtained by the comparison unit (45).

3) A system for detecting and measuring a constricted region of a blood vessel from a medical image according to claim 1, wherein the detection

module is a reference independent detection module (50) and further comprising a transition detection unit (52) for determining the constricted region and non-constricted region of the blood vessel based on the deviation between two neighboring widths as obtained from the width measuring unit (51), wherein the width measurement unit (51) measures the width values of every cross sections along the blood vessel.

4) A method for detecting and measuring a constricted region in a blood vessel from a medical image, characterized by the steps of:
   a) obtaining a top boundary line, a bottom boundary line, and a radial line along the blood vessel from the medical image of the blood vessel;
   b) measuring the width of the blood vessel at a plurality of points by a width measuring unit (42, 51);
   c) obtaining diameter by a diameter calculation unit (43, 53) based on the widths obtained by the width measuring unit (42, 51) on each or a group of the plurality of points;
   d) computing the differences in percentage of the diameter from a maximum diameter by a comparison unit (54).

5) A method for detecting and measuring a constricted region in a blood vessel from a medical image according to claim 4, wherein the plurality of points are selected by a reference selection unit (41) for the measurement of width by the width measuring unit (42), and further comprises the steps of:
   a) identifying whether each of the plurality of point is a constricted point based on the differences in percentage of the diameter from a maximum diameter;
   b) extending the width measurement in a forward and backward direction from each of the identified constricted point until a predetermined width deviation is encountered for identifying an end of the constricted region;
   c) measuring the length of the constricted region by a length measuring unit (47).

6) A method for detecting and measuring a constricted region in a blood vessel from a medical image according to claim 5, wherein the width of each of the plurality of points is measured by interpolating a perpendicular reference line from each of plurality of points to intersect the top boundary line and the bottom boundary line and taking the distance between the top boundary line and the bottom boundary line.

7) A method for detecting and measuring a constricted region in a blood vessel from a medical image according to claim 5, wherein the diameter of each of the plurality of points is obtained by averaging the width measured on at least one cross section immediately adjacent each of the plurality of points.

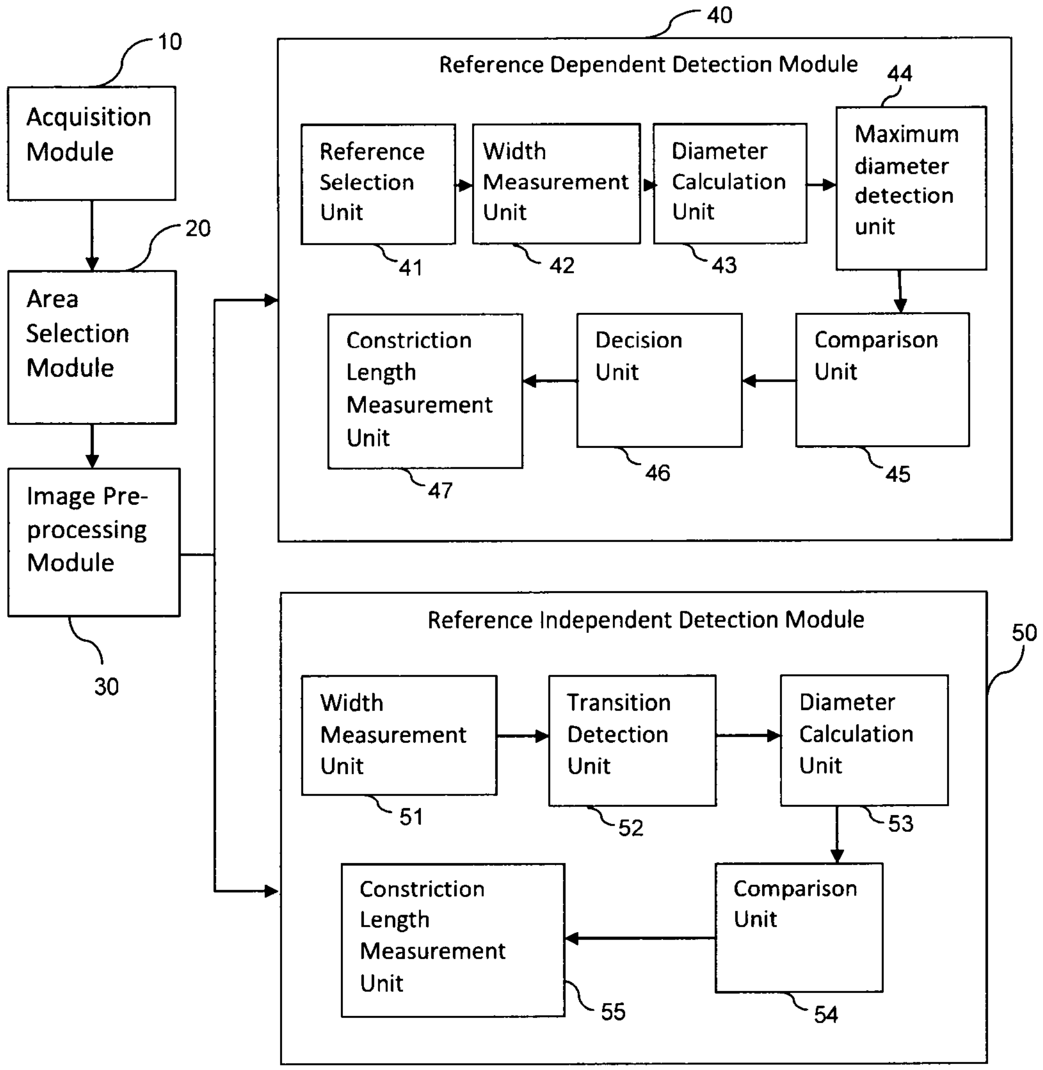
8) A method for detecting and measuring a constricted region in a blood vessel from a medical image according to claim 4, wherein the plurality of points comprises points which are continuous along the blood vessel, and further comprises the steps of:

a) detecting a region of blood vessel by identifying a transition point on the blood vessel, wherein the transition point is a point having a width deviation exceeding a threshold value from a previous point;
b) assigning a region into a constricted region or a non-constricted region; and
c) measuring the length of the constricted region by a length measurement unit (55).

9) A method for detecting and measuring a constricted region in a blood vessel from a medical image according to claim 8, wherein the non-constricted region is assigned when the slope of the transition is negative, and the constricted region is assigned when the slope of the transition is positive.

10) A method for detecting and measuring a constricted region in a blood vessel from a medical image according to claim 8, wherein the diameter is

obtained by averaging the widths of a group of the plurality of points which belong to the same region.



10
Acquisition Module
20
Area Selection Module
Image Pre-processing Module
30
40
Reference Dependent Detection Module
Reference Selection Unit
41
Width Measurement Unit
42
Diameter Calculation Unit
43
44
Maximum diameter detection unit
Comparison Unit
45
Decision Unit
46
Constriction Length Measurement Unit
47
50
Reference Independent Detection Module
Width Measurement Unit
51
Transition Detection Unit
52
Diameter Calculation Unit
53
Comparison Unit
54
Constriction Length Measurement Unit
55

FIGURE 1

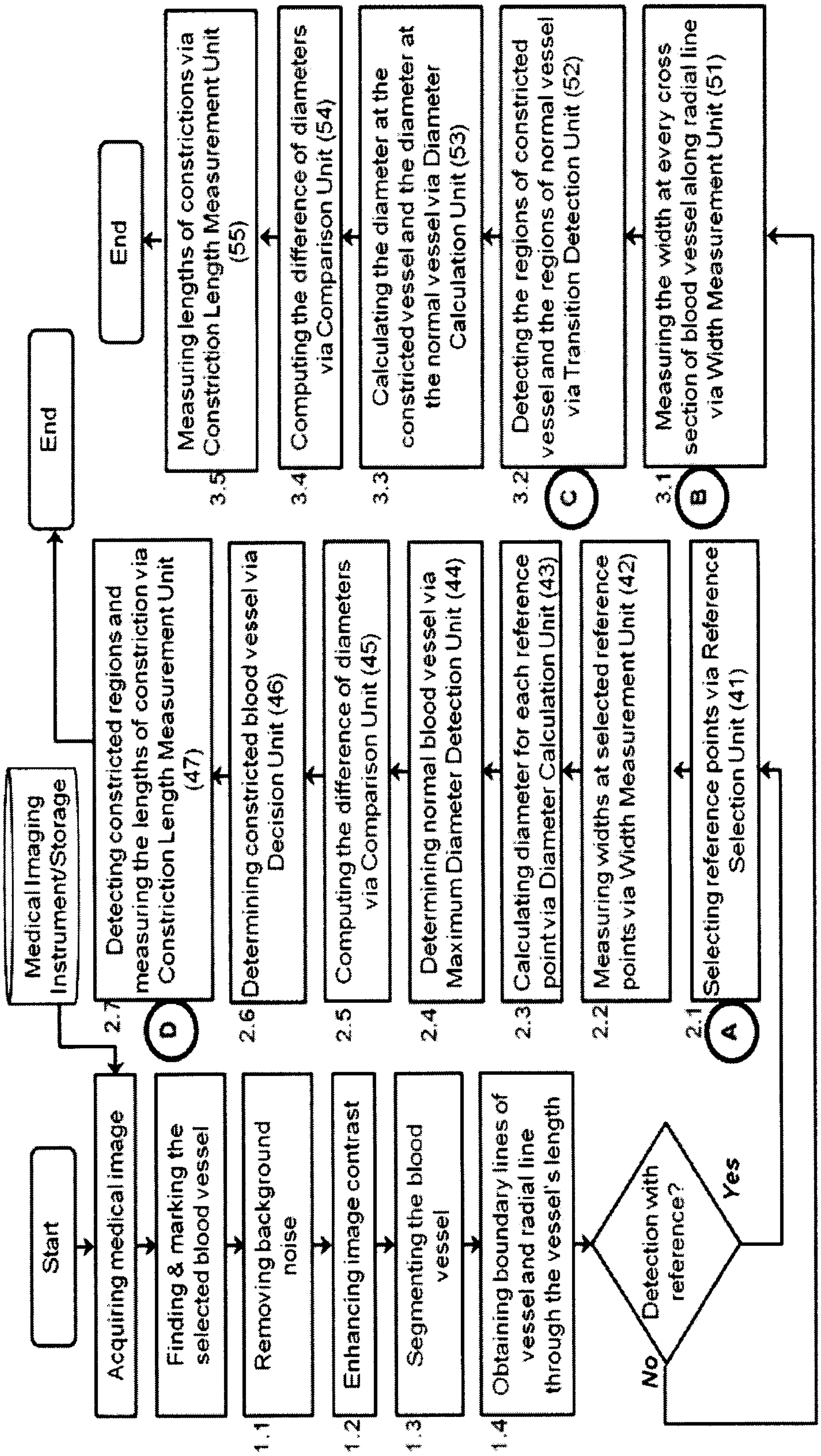

Start
Acquiring medical image
Medical Imaging Instrument/Storage
1.1
Finding & marking the selected blood vessel
1.2
Removing background noise
1.3
Enhancing image contrast
1.4
Segmenting the blood vessel
Obtaining boundary lines of vessel and radial line through the vessel's length
Detection with reference?
Yes
No
2.1
A
Selecting reference points via Reference Selection Unit (41)
2.2
Measuring widths at selected reference points via Width Measurement Unit (42)
2.3
Calculating diameter for each reference point via Diameter Calculation Unit (43)
2.4
Determining normal blood vessel via Maximum Diameter Detection Unit (44)
2.5
Computing the difference of diameters via Comparison Unit (45)
2.6
Determining constricted blood vessel via Decision Unit (46)
2.7
D
Detecting constricted regions and measuring the lengths of constriction via Constriction Length Measurement Unit (47)
End
3.1
B
Measuring the width at every cross section of blood vessel along radial line via Width Measurement Unit (51)
3.2
C
Detecting the regions of constricted vessel and the regions of normal vessel via Transition Detection Unit (52)
3.3
Calculating the diameter at the constricted vessel and the diameter at the normal vessel via Diameter Calculation Unit (53)
3.4
Computing the difference of diameters via Comparison Unit (54)
3.5
Measuring lengths of constrictions via Constriction Length Measurement Unit (55)
End

FIGURE 2

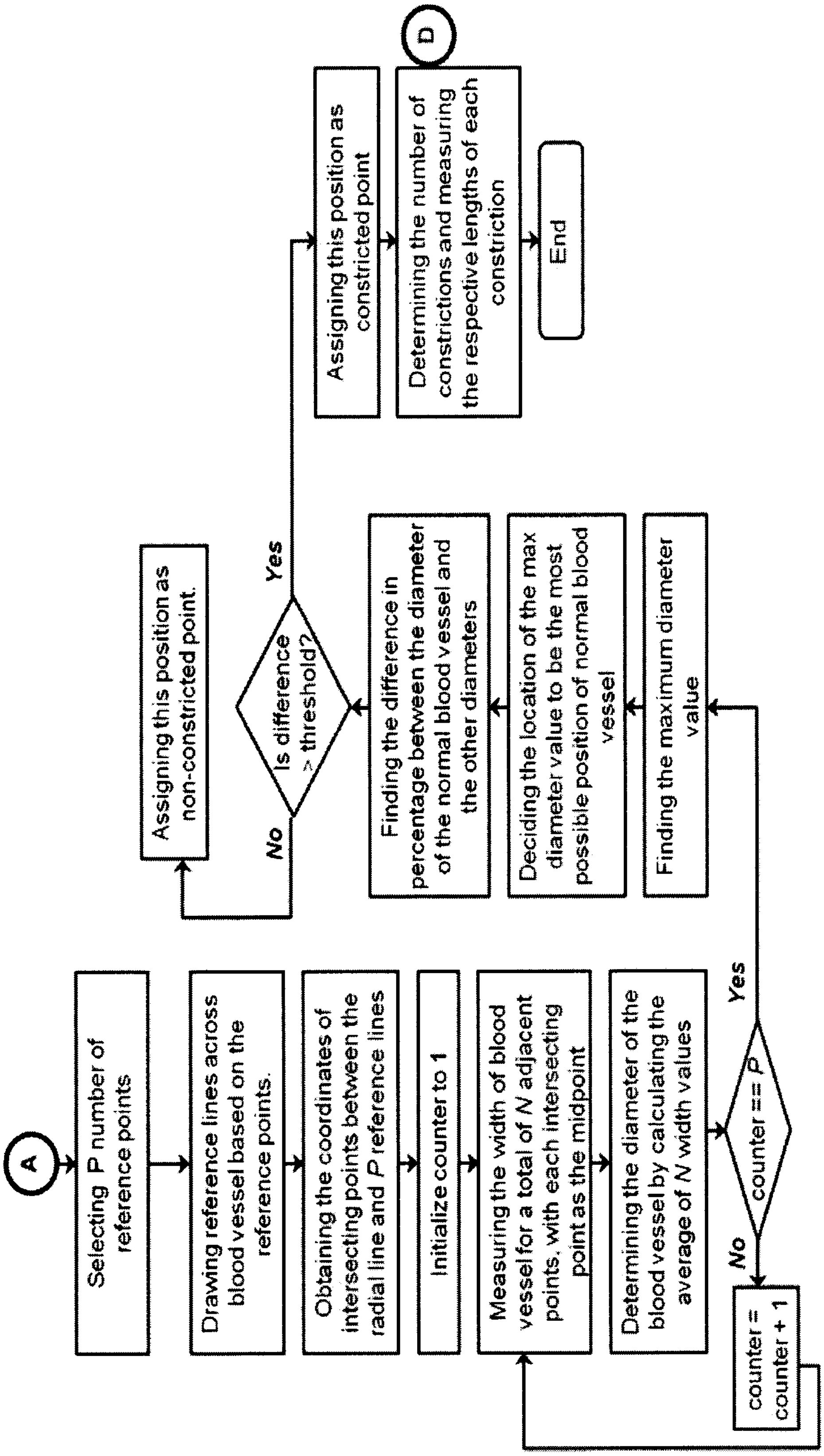

A
Selecting P number of reference points
Drawing reference lines across blood vessel based on the reference points.
Obtaining the coordinates of intersecting points between the radial line and P reference lines
Initialize counter to 1
Measuring the width of blood vessel for a total of N adjacent points, with each intersecting point as the midpoint
Determining the diameter of the blood vessel by calculating the average of N width values
counter == P
No
counter = counter + 1
Yes
Finding the maximum diameter value
Deciding the location of the max diameter value to be the most possible position of normal blood vessel
Finding the difference in percentage between the diameter of the normal blood vessel and the other diameters
Is difference > threshold?
No
Assigning this position as non-constricted point.
Yes
Assigning this position as constricted point
Determining the number of constrictions and measuring the respective lengths of each constriction
D
End

FIGURE 3

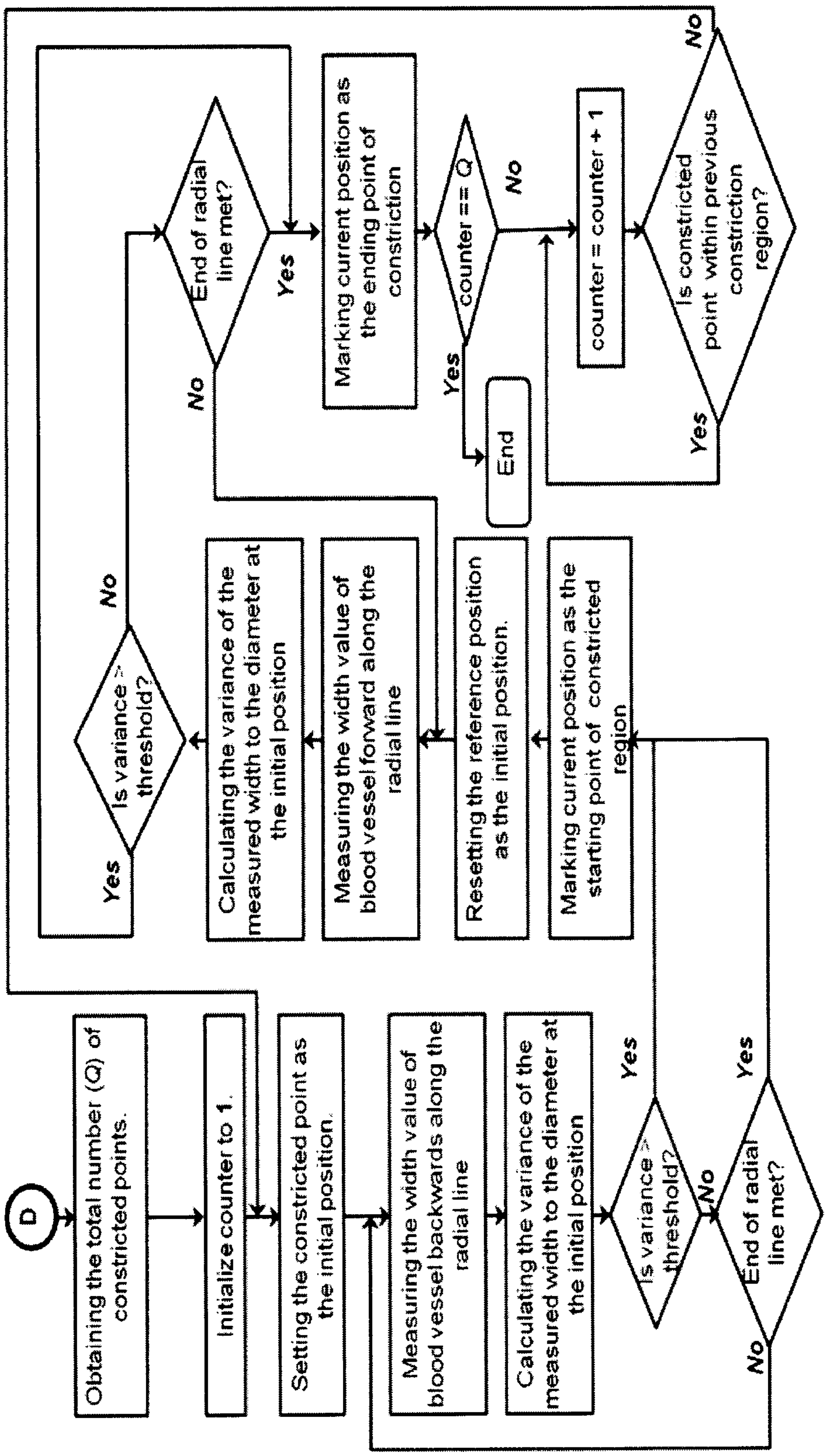

D
Obtaining the total number (Q) of constricted points.
Initialize counter to 1.
Setting the constricted point as the initial position.
Measuring the width value of blood vessel backwards along the radial line
Calculating the variance of the measured width to the diameter at the initial position
Is variance > threshold?
Yes
No
End of radial line met?
Yes
No
Marking current position as the starting point of constricted region
Resetting the reference position as the initial position.
Measuring the width value of blood vessel forward along the radial line
Calculating the variance of the measured width to the diameter at the initial position
Is variance > threshold?
Yes
No
End of radial line met?
Yes
No
Marking current position as the ending point of constriction
counter == Q
Yes
No
End
counter = counter + 1
Is constricted point within previous constriction region?
Yes
No

FIGURE 4

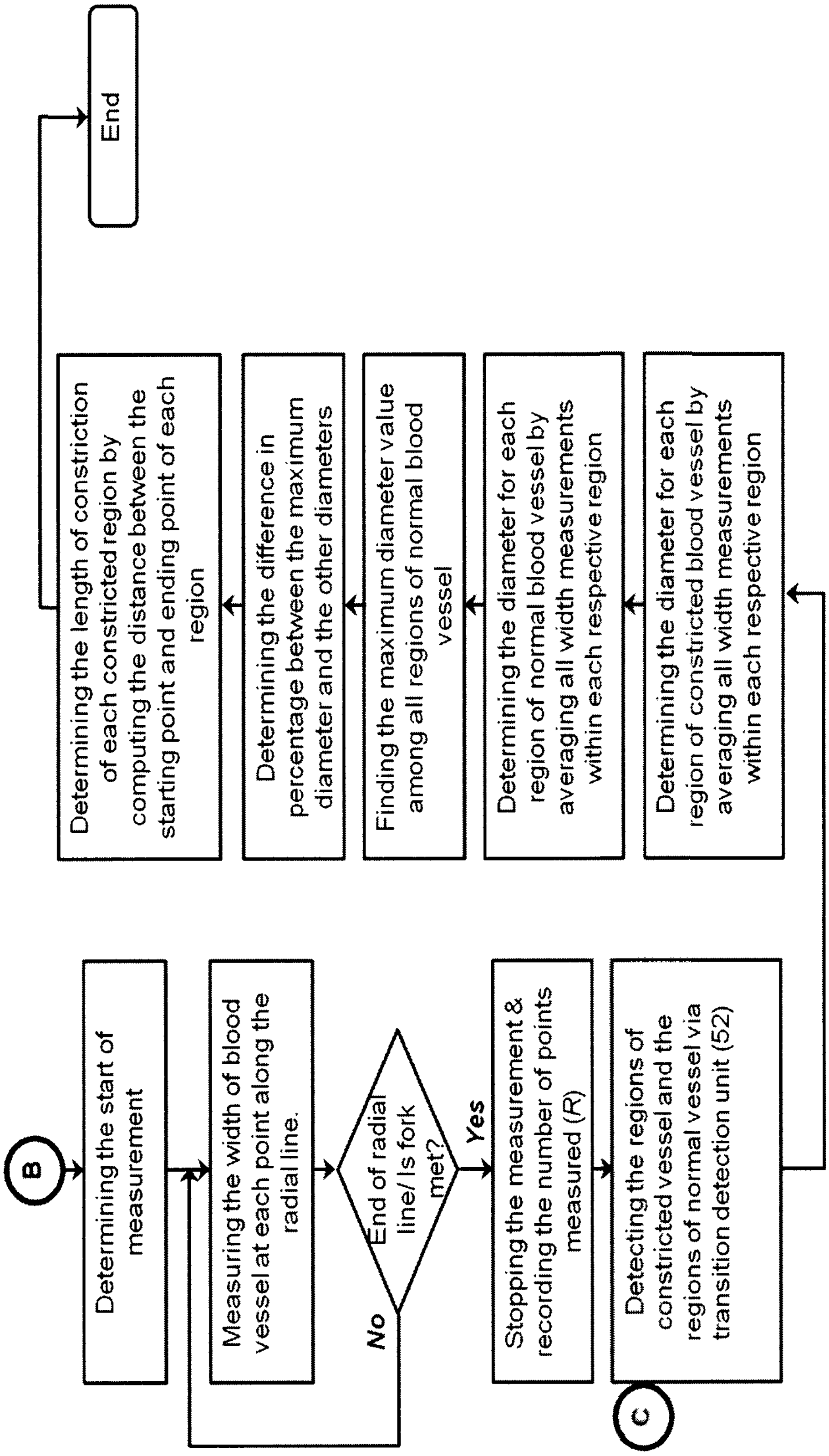

B
Determining the start of measurement
Measuring the width of blood vessel at each point along the radial line.
End of radial line/ Is fork met?
No
Yes
Stopping the measurement & recording the number of points measured (R)
Detecting the regions of constricted vessel and the regions of normal vessel via transition detection unit (52)
C
Determining the diameter for each region of constricted blood vessel by averaging all width measurements within each respective region
Determining the diameter for each region of normal blood vessel by averaging all width measurements within each respective region
Finding the maximum diameter value among all regions of normal blood vessel
Determining the difference in percentage between the maximum diameter and the other diameters
Determining the length of constriction of each constricted region by computing the distance between the starting point and ending point of each region
End

FIGURE 5

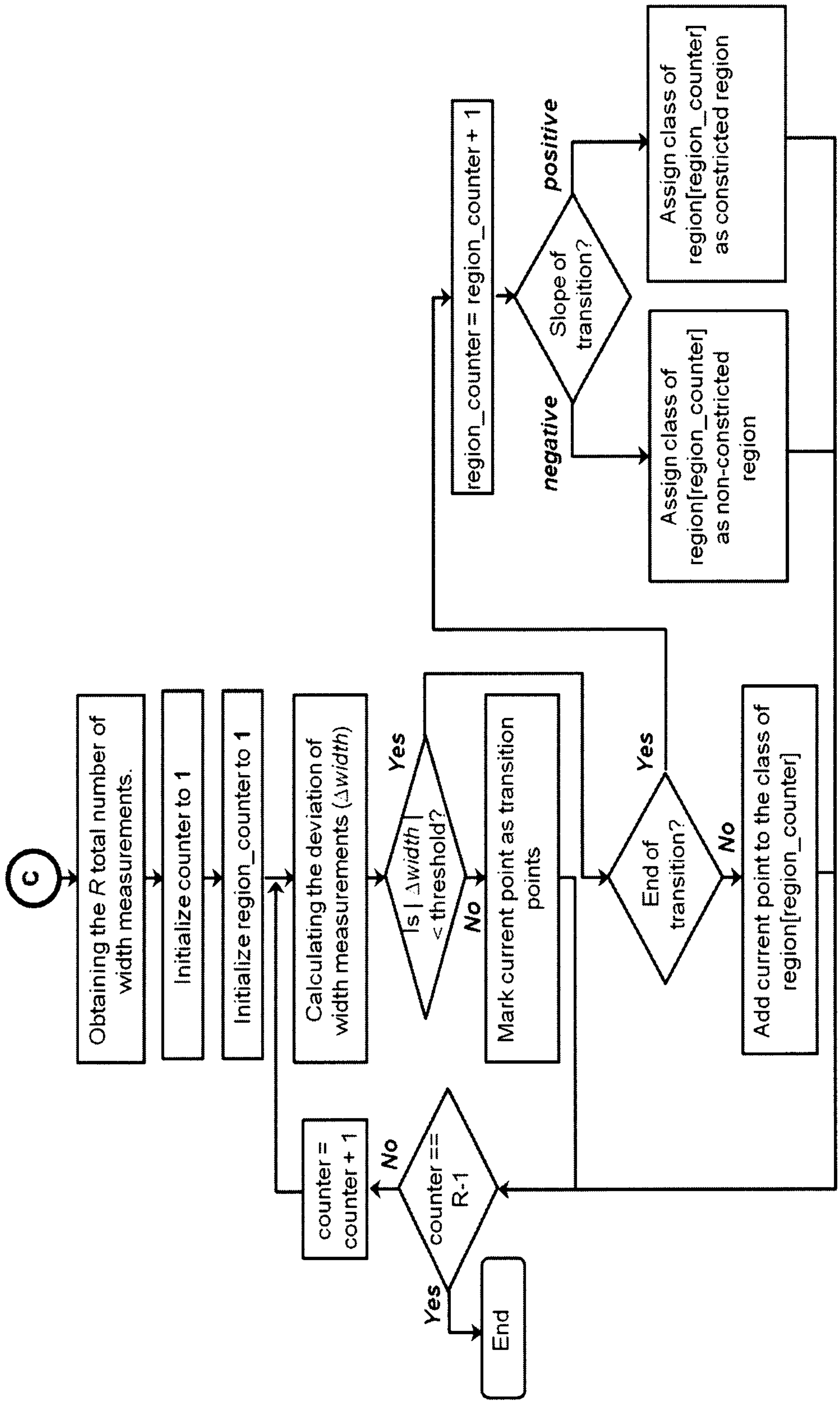

C
Obtaining the R total number of width measurements.
Initialize counter to 1
Initialize region_counter to 1
Calculating the deviation of width measurements (Δwidth)
Is | Δwidth | < threshold?
Yes
No
Mark current point as transition points
End of transition?
Yes
No
Add current point to the class of region[region_counter]
region_counter = region_counter + 1
Slope of transition?
positive
negative
Assign class of region[region_counter] as constricted region
Assign class of region[region_counter] as non-constricted region
counter == R-1
No
Yes
counter = counter + 1
End

FIGURE 6

INTERNATIONAL SEARCH REPORT	International application No. **PCT/MY2015/000027**

A. CLASSIFICATION OF SUBJECT MATTER

A61B 6/00(2006.01)i, A61B 6/03(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B 6/00; A61B 5/05; A61B 005/05; A61B 5/055; G06K 9/00; A61B 8/00; A61B 5/00; A61B 6/03

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: blood vessel, constrict, detect, area, width, diameter, percentage

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2007-0244393 A1 (MITSUHIRO OSHIKI et al.) 18 October 2007 See abstract, paragraphs [0090]-[0118], claim 20 and figure 2.	1-3
A		4-10
X	JP 2005-198708 A (TOSHIBA CORP. et al.) 28 July 2005 See abstract, paragraphs [0024],[0051]-[0069], claims 1,2 and figure 7.	4
Y		1-3
A	US 2003-0208116 A1 (ZHENGRONG LIANG et al.) 06 November 2003 See abstract, paragraphs [0030]-[0068] and figures 1-8.	1-10
A	US 2013-0116739 A1 (RAFAEL BRADA et al.) 09 May 2013 See abstract, paragraphs [0031]-[0057] and figures 2-5.	1-10
A	US 2007-0197898 A1 (NIKOLAUS BOLLE) 23 August 2007 See abstract, paragraphs [0034]-[0050] and figures 1-3.	1-10

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
09 September 2015 (09.09.2015)	**09 September 2015 (09.09.2015)**

Name and mailing address of the ISA/KR	Authorized officer
International Application Division Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 35208, Republic of Korea	KIM, Ja Young
Facsimile No. +82-42-472-7140	Telephone No. +82-42-481-8131

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/MY2015/000027

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007-0244393 A1	18/10/2007	JP 4942477 B2	30/05/2012
		US 8355775 B2	15/01/2013
		WO 2005-117712 A1	15/12/2005
JP 2005-198708 A	28/07/2005	None	
US 2003-0208116 A1	06/11/2003	AU 2001-268217 A8	17/12/2001
		AU 2001-68217 A1	17/12/2001
		US 7356367 B2	08/04/2008
		WO 01-093745 A2	13/12/2001
		WO 01-093745 A3	29/08/2002
US 2013-0116739 A1	09/05/2013	EP 2775922 A1	17/09/2014
		JP 2014-532509 A	08/12/2014
		US 8861830 B2	14/10/2014
		WO 2013-069011 A1	16/05/2013
US 2007-0197898 A1	23/08/2007	CN 101028198 A	05/09/2007
		DE 102006002259 A1	19/07/2007
		JP 2007-190386 A	02/08/2007