(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 489 011 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
29.04.2020 Bulletin 2020/18

(21) Application number: **09741035.1**

(22) Date of filing: **14.10.2009**

(51) Int Cl.:
G06T 17/00 *(2006.01)* ***A61B 5/00*** *(2006.01)*

(86) International application number:
PCT/NL2009/050621

(87) International publication number:
WO 2011/046425 (21.04.2011 Gazette 2011/16)

(54) **A METHOD, A GRAPHIC USER INTERFACE, A SYSTEM AND A COMPUTER PROGRAM FOR OPTIMIZING WORKFLOW OF A MEDICAL INTERVENTION**

VERFAHREN, GRAFISCHE BENUTZEROBERFLÄCHE, ANORDNUNG UND COMPUTERPROGRAMM, ZUR OPTIMIERUNG DES ABLAUFS EINES MEDIZINISCHEN EINGRIFFS

PROCÉDÉ, INTERFACE GRAPHIQUE, SYSTÈME ET PROGRAMME D'ORDINATEUR POUR L'OPTIMISATION DU DÉROULEMENT D'UNE INTERVENTION MÉDICALE

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR

(43) Date of publication of application:
22.08.2012 Bulletin 2012/34

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EP 2 489 011 B1

Printed by Jouve, 75001 PARIS (FR)

Description

FIELD

[0001] The invention relates to the field of medical interventions, in particular to the field of heart valve replacements or stent placements. More in particular the invention relates to a method of optimizing workflow for a medical intervention. The invention further relates to a computer program for optimizing workflow for an intervention. The invention still further relates to a graphic user interface for enabling optimization of the workflow for an intervention. The invention still further relates to a system for optimizing workflow for an intervention.

BACKGROUND OF THE INVENTION

[0002] Medical interventions, in particular, cardiac and vascular interventions are gaining profound importance in contemporary medical practice. For example, annually a great number of interventions is carried out with respect to heart valve replacements.
It will be appreciated that the heart of a mammal, such as a human being or an animal, includes four valves (i.e. mitral valve, aortic valve, pulmonary valve and tricuspid valve). The mitral valve controls the blood flow between the left atrium and the left ventricle. The tricuspid valve controls the blood flow between the right atrium and the right ventricle. The aortic valve controls the blood flow from the left ventricle to the vascular system of the body. The pulmonary valve controls the blood flow from the right ventricle to the lungs. Defective operation of any of these four valves may cause a specific medical condition. For example, a defective mitral valve may cause regurgitation (i.e. leakage between the left ventricle and the left atrium), thereby reducing the pumping efficiency of the heart, and depriving major organs of the body from oxygen and the necessary substances.

[0003] During a medical intervention regarding a heart valve replacement a suitable heart valve is replaced by an artificial valve, which may be either a mechanical valve or a tissue valve. Those skilled in the art will readily appreciate which valves are commonly used for facilitating the heart valve replacement.

[0004] Regarding the course of intervention, a closed-chest setting is preferred wherein access to the heart valve is gained either by performing a number of access holes in the chest or by entering the heart chambers through the vascular system, for example through the right subclavian vein, or inferior vena cava. Such closed-chest approach is commonly referred to as a minimally invasive surgery, which has gained its acknowledgement due to a considerable reduction of complications with respect to complications occurring after an open-chest surgery.

[0005] It is appreciated that for a successful intervention, be it a heart valve replacement or placing of a stent, accurate knowledge about target anatomy and position is required.

[0006] An embodiment of a method of assessing the size, shape and topography of vessel lumens for facilitating implantation of a prosthetic heart valve is known from US2008/0009746 A1. In the known method a catheter based device is used for determining at least one physical parameter of the cardiac valve and surrounding tissue in a body of a patient. For this purpose an assessment member provided near the distal end of a catheter is introduced to a treatment location within the patient, like the native cardiac valve, wherein the assessment member is activated for performing assessment for providing information to a clinician. The assessment member may relate to an intra cardiac echo, 3D ultrasound, electrode-based mapping and imaging device, electronic topographical mapping device. In the known method in addition an external imaging, like MRI or CT may be used.

[0007] Paper by Gessat M et al. "A planning system for transapical aortic valve implantation", Proceedings of the SPIE - The International Society for Optical Engineering, USA, vol. 7261, 2009 discloses a planning software for the perioperative use that allows for selection of the best fitting implant and calculation of the safe target area for that implant.

[0008] Paper by Kanitsar A. et al. "CPR - curved planar reformation", Proceedings of the annual IEEE conference on Visualization, November 2002, pages 37-44 discloses three Curved Planar Reformation (CPR) methods to display tubular structures.

SUMMARY OF THE INVENTION

[0009] It is a disadvantage of the known method that assessment of quantitative information pertaining to the target area is obtained invasively and substantially directly during the intervention. As a result, the patient may have to be conditioned for a longer period of time deteriorating workflow of the intervention. In addition, due to the fact that the clinician obtains quantitative information during the intervention there may be no time for optimization or other suitable brain storming.

[0010] It is an object of the invention to provide a method for optimization workflow of a medical intervention in the field of heart valve transplantations.

[0011] To this end a method according to the invention, comprises the steps of claim 1.

[0012] The technical feature of the invention is based on the insight that an a-priori acquired imaging dataset, like CT data, MRI data, 3D ultrasound data, X-ray angio data or the like may be used for determination an optimal viewing direction or directions for enabling quantitative analysis of the target area of a heart valve. It will be appreciated that the imaging dataset may relate to a three-dimensional dataset or a four-dimensional dataset. In the latter case dynamic studies of the target area are enabled. An intervention feature may, for, example relate to a measurement within a volume of interest, or to a selection of an implant based on said measurement.

[0013] It will be appreciated that the optimal viewing direction is defined as a direction wherein a diameter of the heart valve may be measured, i.e. a viewing direction substantially perpendicular on a plane of the heart valve. It will be appreciated that due to the fact that for different individuals the heart is oriented differently in the three-dimensional space the optimal viewing direction may only be defined with respect to the heart anatomy.

[0014] In the method according to the invention, wherein the intervention relates to a heart valve replacement, the target area comprises a heart valve and a portion of a lumen arranged in fluid communication with the heart valve. Alternatively or additionally, the target area may comprise a heart valve and one or more chambers of the heart. Still additionally or alternatively, the target area may comprise the heart valve and the apex of the heart.

[0015] In the method according to the invention, wherein the intervention relates to a heart valve replacement, the method further comprises the steps of:

- accessing image data representative of the heart valve and the surrounding anatomy;
- based on the image data calculating a pre-determined reference line for reconstructing an optimal image projection comprising the heart valve,
  wherein for the pre-determined reference line, a centre line of said lumen is selected.

[0016] It will be appreciated that the heart valve replacement may relate to replacement of any of the following heart valves: mitral valve, aortic valve, pulmonary valve and tricuspid valve. It is found that quantitative analysis does not necessarily have to be based on planar geometries. In some instances, for example, when dimensions and properties of a vessel or lumen are to be determined visualization along a curved line may be advantageous, especially when such visualization provided a clear view on the vessel cross-section and on a junction between the vessel and the heart. Preferably, for the predetermined reference line a centre lumen line is selected.

[0017] In a further embodiment of the method of the invention the image projection is obliquely oriented with respect to the centre lumen line.

[0018] It is found that heart valves are optimally viewed in an oblique projection, wherein one or more two-dimensional images representing the target area may be reconstructed using a per se known technique of a multiplanar reconstruction along the reference line. It is further found that heart valves are surprisingly clearly visible on such oblique projections.

[0019] In a further embodiment of the method according to the invention, the method further comprises the step of defining a centre line annulus point position using the image projection.

[0020] It will be appreciated that this step may be carried out interactively, wherein a clinician provided with the automatically calculated center line of the lumen may reposition the centre line annulus point position and annulus plane orientation, preferably in a combined viewing screen comprising three multi-planar reconstruction images calculated about the center line. It will be appreciated that the annulus point position may be determined automatically. The method used to determine the annulus point is to analyze the planes perpendicular along the center line. In the area where the annulus valve is located, the planes contain calcifications and tissue which can be detected by assessing the diversity in voxel values. The annulus point is then positioned in the middle of the area on the center line.

[0021] It is also possible to seed two points defining a plane, for example an annulus plane. The method according to the invention may comprise a step of automatically defining the 90 degrees line perpendicular to this plane that enables an angle measurement to be made with respect to this 90 degrees line. This feature may be advantageous as it allows the user to measure angles orthogonally to the annulus plane for preparing the intervention.

[0022] In a still further embodiment of the method according to the invention, it further comprises the step of using the rendered image view for assessing features in the heart valve and/or the vessel associated with the lumen. For example, for the features of the vessel a length of the vessel, and/or a diameter of the lumen may be selected. It is found to be advantageous to select for the rendered image, a MinIP, a MIP, a stretched curved MPR, a volume rendered, or an average IP.

[0023] For example, in a suitable graphic user interface a number of optimal or preferential viewing directions may be provided in separate sub-windows, wherein each viewing direction may serve its own purpose. For example, a compass viewing sub-window may be provided for facilitation orientation in 3D. In addition, a minimum intensity projection (MinIP) sub-window may be provided for assessing anatomy of leaflets, like their number and configuration. A maximum intensity projection (MIP) or a volume rendered sub-window may be provided for assessing calcifications on the inner surface of the lumen or on the heart valves. Still additionally, stretched curved MPR views may be provided for enabling length measurements. The stretched curved MPR are reconstructed along the lumen center line, and can be rotated along the lumen center line. Such sub-windows may be toggled with double oblique views for enabling diameter measurements. It will be appreciated that a selection of suitable angulation for the oblique or double oblique imaging lies within an ordinary skill of the person skilled in the art. It will be appreciated that the sub-windows may be provided for facilitating control whereas quantitative analysis may be carried out in a fully automated way, for example based on the MRI or CT pixel values.

[0024] For example, a suitable rendered image, as discussed above, may be used for assessing abnormalities in the heart valve and/or the vessel. It will be appreciated that abnormalities may relate to calcifications, aneurism's, stenosis, abrupt change of lumen spatial angulation and so forth.

[0025] In a still further embodiment of method according to a further aspect of the invention, the method further comprises the step of using the MIP view for calculating an optimal setting of an imaging device for acquiring an image of the heart valve mimicking the MIP image. It is found that additional advantages with respect to the ease of comprehension of the complex anatomy and improving the workflow are obtained when the images are rendered in circular or in "hockey puck"-like shaped volume of interest. It will be further appreciated that the hockey-puck volume of interest represents a cylindrically shaped geometry. Accordingly, those skilled in the art having knowledge of image rendering in the orthogonal geometry may readily apply the rendering methods for the circular volume of interest or the cylindrical volume of interest (the hockey puck).

[0026] It will be appreciated that the method according to the invention is preferably carried-out beforehand, i.e. substantially in advance to the intervention. Accordingly, the clinician may determine an optimal viewing angle for viewing the heart valve interactively or in a fully automated way. It may be preferable to record this angle for installing an imaging device, for example a C-arm of the operation room for reproducing the simulated image in reality. Such control of the imaging device is advantageous not only because it saves considerable time (about 0.5 hour) for on-line optimization of the imaging angle, but contributes to increasing safety of the procedure, as lower amounts of contrast medium have to be introduced into the system of the patient for procedures which are shortened in time.

[0027] In a still further embodiment of a method according to a further aspect of the invention the step of calculating a stretched curved MPR view for enabling a length measurement along the center line lumen is envisaged.

[0028] It will be appreciated that this step may be carried out for calculating a length of a lumen for either the transluminal heart interventions or angiographic studies. In both cases based on determination of the lumen length a suitable catheter may be selected.

[0029] In a still further embodiment of a method according to an aspect of the invention, it further comprises the step of analyzing a diameter of the lumen in the MPR view.

[0030] It is found that the diameter of the lumen may be accurately determined using the MPR view along the centerline of the lumen, wherein for diameter determination any suitable known calculation technique may be used. For example, a virtual coin approach may be used, or other suitable technique, for example based on pixel values.

[0031] In a still further embodiment of the method according a further aspect of the invention, the method further comprises the step of providing indications of tortuosity of vessel based on said analysis.

[0032] Preferably, tortuosity is calculated along the vessel and is presented as a graph or a color code along the vessel or superposed on it. This feature has an advantage of providing quantitative data to the clinician in a highly perceptive way. In particular, dangerous regions or areas requiring specific attention maybe highlighted by a color or any other suitable indication.

[0033] In a further embodiment of the method according to a still further aspect of the invention, the target area comprises a heart valve and an apex of the heart, the method further comprising the step of defining a transapical line of approach.

[0034] It is found that by suitably rendering the imaging dataset and by providing an optimal viewing projection, for example corresponding to a minimum distance between the heart valve and the apex the transapical line of approach may be securely defined. Due to this feature safety of the procedure is improved next to improving the workflow as the clinician can make a plan of the future intervention beforehand.

[0035] For example, the method of the invention may be adapted to automatically calculate a position of an apical seeding point for establishing the optimal line of approach. In this way the clinician is provided with a first educated guess regarding the point of entry into the heart. Suitably, the graphic user interface allows the clinician to set the second point in the valve and to modify respective positions of these two points iteratively.

[0036] It is also possible that the user is enabled to analyze multiple approach routes to the target area and to quantitatively compare the results. The software may allow the user to first analyze the heart valve itself as to whether is it applicable to receive an aortic heart valve implantation and, if so, subsequently the user has the possibility to determine how to best perform the procedure on the patient depending on the patient specific anatomy which is analyzed during the different approach methods (for example, transapical, transfemoral, or transsubclavian approaches).

[0037] According to a still further embodiment of the method according to a still further aspect of the invention, the method further comprises the step of determining an entry angle for a catheter based on the selected line of approach.

[0038] This feature is advantageous as catheter bending may be simulated for checking whether the selected line of approach is feasible in practice. For example, additional points next to the apex entry point and the annulus point may be defined for calculating catheter bending in real space, as said entry angle may be variable along the line of approach. Preferably, the graphic user interface enables the user to rotate the rendered view with respect to the catheter for enabling a better comprehension of the underlying anatomy by the user.

[0039] A computer program according to an aspect of the invention comprises instructions for causing a processor to carry out the steps of the method according to any one of the preceding claims.

[0040] A graphic user interface according to an aspect of the invention comprises a plurality of graphic windows for visualizing steps of the method as is discussed with reference to the foregoing. Exemplary embodiments of the graphic user interface will be discussed in more details with reference to the Figures.

[0041] A system of optimizing workflow for an intervention according to an aspect of the invention, comprises a processor arranged for carrying out the method of the invention.

[0042] Preferably, the system further comprises a display unit for feedbacking results of image reconstruction and analysis. It will be appreciated that the display unit may be remotely arranged with respect to the processor. In addition, it will be appreciated that a plurality of display units may be provided, for example for purposes of remote patient discussions or teleconferencing. It will be appreciated that a system according to the invention may comprise a personal computer, a laptop, or it may be based on a graphic workstation.

[0043] In an embodiment of the system according to a still further aspect of the invention, the system comprises a device arranged to receive instructions from the processor based on results of the pre-operative quantitative analysis for carrying-out the intervention. For example, an imaging device or a suitable automatic manipulator conceived to carry out at least a portion of the intervention are contemplated.

[0044] It is found that by providing an integrated system comprising a data analysis component and a patient handling component a substantially unique closed system may be provided which still further may improve the workflow of medical interventions and may reduce errors due to the human factor.

[0045] Preferably, according to a further aspect of the invention, the system further comprises an imaging unit arranged to receive instructions from the processor for enabling imaging during the intervention.

[0046] It is found that when the imaging unit, like a C-arm is operationally coupled to the system according to the invention the workflow of medical interventions may be improved still further and errors due to the human factor may be still further reduced.

[0047] These and other aspects of the invention will be discussed in more detail with reference to the Figures, wherein like reference signs represent like features. It will be appreciated that the Figures are provided for illustration purposes only and may not be used for limiting the scope of appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0048]

Figure 1 presents an embodiment of a graphical user interface according to a first aspect of the invention.
Figure 2 presents an embodiment of a graphical user interface according to a second aspect of the invention.
Figure 3 presents an embodiment of a graphical user interface according to a third aspect of the invention.
Figure 4 presents an embodiment of a graphical user interface according to a fourth aspect of the invention.
Figure 5 presents an embodiment of a graphical user interface according to a fifth aspect of the invention.
Figure 6 presents a graphical user interface for stent placement.

DETAILED DESCRIPTION OF THE DRAWINGS

[0049] Figure 1 presents an embodiment of a graphical user interface according to a first aspect of the invention. In the present embodiment of a graphic user interface 10 four sub-windows 10a, 10b, 10c and 10d are provided. It will be appreciated that a number of suitable rendered optimal projections may be customized tailoring demands of a particular situation.

[0050] Sub-window 10a presents a reconstructed image of a plane of aortic valve of a human heart, wherein a centerline of the lumen (aorta) is given by reference number 4. Along the curved center line 4 a number of reference points may be provided in an automatic, semi-automatic or manual way.

[0051] For example, points 1 and 3 may correspond to begin and end of a relevant trajectory along the vessel 6 (aorta). The point 2 corresponds to the annulus point position, which may be determined automatically during image reconstruction and analysis, or, it may be determined semi-automatically or manually. It will be appreciated that it may be possible to readjust a position of the annulus point position after it is seeded in an automatic way. Besides the annulus position, the annulus plane orientation may be also determined automatically or manually.

[0052] Due to the fact that for optimal imaging of heart valves reconstruction of oblique images may be required, the sub-window 10a may comprise an orientation indicator animated in a suitable way.

[0053] Sub-windows 10b, 10c present a second oblique image and a further oblique image, respectively, which may be rendered together with the image in sub-window in 10a using an MPR reconstruction.

[0054] Window 10d may be used for presenting 3D reconstruction of anatomy in the imaging dataset, wherein the current plane shown in projection 10a, 10b, 10c may be indicated by a frame 7.

[0055] Accordingly, due to the fact that the heart valve 6 shown in the sub-window 10c is depicted in the optimal projection, accurate analysis of the heart valve parameters and features, such as leaflets is enabled. In addition, due to the fact that the graphic user interface 10 may be used as a tool for planning a medical intervention (in this case - replacement of a heart valve) the workflow may be improved as the clinician has a clear and easy understanding of the otherwise complicated geometry.

[0056] It will be appreciated that the graphic user interface 10 may comprise a number of supplementary regions, which may be used for input/output operations with respect to data or commands as well as for feedbacking patient ID data. Preferably, the graphic user interface is used for accessing hospital information system (HIS) or any other suitable database for selecting patient data. It will be appreciated that in the context of the present application the image data may refer to raw image data, or to processed image data. For example, initial analysis of the image data may be carried out automatically as a batch job beforehand.

[0057] The graphic user interface 10 may comprise a number of modules, like Valve Analysis, Apex Analysis, Femoral Analysis, Subclavian Analysis or the like, which may be used in an alternative fashion if the context of the casus allows it. It may be advantageous to subject the same patient imaging dataset for analysis for different intervention approaches, like a transapical approach or transfemoral approach for deducing an optimal strategy for the medical intervention. Due to this feature the workflow is further improved and the accuracy of the intervention (heart valve replacement or stent placement) may be improved.

[0058] The graphic user interface 10 may further comprise suitable tools for enabling distance measurements, angle measurement or measurements of other type, which may be carried out automatically or in a manual mode.

[0059] Figure 2 presents an embodiment of a graphical user interface according to a second aspect of the invention. In the present embodiment a Valve Analysis screen is presented, which may be used for obtaining quantitative information about the vessel and its spatial position.

[0060] For example, the Valve Analysis screen 20 may comprise a suitable plurality of sub-windows, for example sub-windows 20a, 20b, 20c, 20d, 20e. The sub-window 20a may be used as a compass viewer for assisting the user in orientation of two sub-windows 20d, 20e. The sub-window 20b may relate to a MinIP view for assessing valve anatomy, for example relating to number and condition of the leaflets. The sub-window 20c may be used for visualizing results of the MIP or volume rendered image about the lumen center line. This view is particularly useful for assessing calcifications as well as for establishing an optimal imaging angle of a C-arm. The sub-windows 20d, 20e relate to stretched curved MPR views enabling quantitative determination of the lumen length along the lumen center line. Preferably, the sub-windows 20d, 20e may be toggled between the MPR view and the double oblique view, the latter enabling diameter measurement of the lumen.

[0061] It will be appreciated that the view 20a may relate to the optimal viewing direction according to the invention.

[0062] The image presented in view 20c may be referred to as a hockey puck view. The hockey puck view is a cylindrical area with a configurable diameter and a configurable height. The view is used to focus the user on the heart valve itself by removing any surrounding voxels that are outside the hockey puck confines that may obstruct a clear view of the heart valve.

[0063] It will be appreciated that there may be two optimal viewing directions for the hockey puck view, namely when perpendicular to the disk for viewing the anatomy of the heart valve and one from the side to determine the optimal angle of the C-arm. The optimal angle for the C-arm is when the heart valve is viewed in a perpendicular manner.

[0064] Different render methods (MIP/MinIP/Volume Rendering) may be used to show calcifications of the heart valve, the dynamics of the heart valve itself using 4D data, as well as the anatomy of the heart valve.

[0065] It will be appreciated that data rendering may be carried out either starting from a 3D imaging data set or a 4D imaging dataset, the latter allowing for a dynamic study as a function of time. For example, dynamics in leaflets behavior as a function of heartbeat and the phase therein may be studied.

[0066] Figure 3 presents an embodiment of a graphical user interface according to a third aspect of the invention. In this exemplary embodiment an Apex Analysis screen 30 is presented. In this case, for example, the sub-windows may relate to sub-windows 30a, 30b, 30c depicting regular orthogonal reconstruction slices and a relatively larger sub-window 30d presenting an oblique slice through the heart, which runs through the annulus point 2. This projection is particularly useful, as an optimum line of approach for transapical interventions may be determined. It will be appreciated that the method according to the invention enables the user to study a suitable plurality of line of approaches and to compare them quantitatively for making an educated selection of a preferred intervention route. Suitable reporting may be envisaged as well, like a length on the route, or other clinically relevant parameters, like angles, vicinity to critical organs or regions and the like.

[0067] The optimal line of approach 32 may run between the annular point 2 and the apex point 3. Preferably, the graphic user interface supports a real-time changing of point positions for analysis and optimization. It is also possible that some regions are organs are virtually dimmed out or otherwise highlighted or de-highlighted for enabling an easy comprehension of the anatomy and the planned intervention by the clinician.

[0068] It may be also possible to suitably rotate around line of MPR view for path analysis, for example a virtual catheter size viewing may be envisaged, wherein thickness of the catheter may be adapted.

[0069] In addition the sub-window 30d may be used for analyzing the entry angle for the catheter. The entry angle may be of a crucial importance, for example for checking whether induced catheter bending do not supersede allowable tolerances. In order to work around corners or the like, it may be possible to define additional points between the point 2, 3.

[0070] In addition, the sub-window 30d may be used for enabling measurement of lengths of myocardium and septal wall thickness for planning the intervention.

[0071] Accordingly, due to one or more above features workflow of the heart valve replacement intervention may be substantially optimized, wherein probability of a human error may be reduced.

[0072] Figure 4 presents an embodiment of a graphical user interface according to a fourth aspect of the invention. In this exemplary embodiment a Femoral Analysis screen 40 is discussed. The screen 40 may also comprise a suitable plurality of windows, some of which may be used for reference, like windows 40a, 40b, 40c. A central portion of the screen 40 may be used for the sub-windows 40e, 40f for depicting suitable vessels, in casu, left and right stretched curved MPR views.

[0073] Advantageously quantitative supplementary information is provided in sub-windows 40e, 40f. For example, graphs representing a running value of a lumen diameter, wherein, advantageously regions of particular attention, like narrowings may be highlighted. For example, a critical value of 23 F (about 8 mm) may be indicated throughout the graph for immediate perception whether a particular catheter fits into the lumen. The sub-window 40a, depicting a running lumen diameter may be synchronized with the area along the window 40d, 40e so that when a cursor falls within the image of 40e a cross-sectional image of the lumen 402 together with a fitted coin 401 corresponding to the same 'longitudinal' level may be shown. In this way the user may easily check whether the automated algorithm did not fail while calculating a running value of the lumen diameter.

[0074] In addition, regions having particular properties, like tortuosity data, may be suitably indicated along the graph. It will be appreciated that such indication may be carried out using color-code or by implementing other illustrative means.

[0075] It will be appreciated that the view 40a may relate to the optimal viewing direction according to the insights of the invention.

[0076] Figure 5 presents an embodiment of a graphical user interface according to a fifth aspect of the invention. In the present exemplary embodiment an Angiographic View screen 50 is presented, which may be a separate data analysis package, or, it may be a part of the data analysis package discussed with reference to Figure 1. Image 50 shows reconstructed data enabling interactive viewing and analysis of position angles for the C-arm for optimal viewing of patient anatomy during intervention.

[0077] Also in this case it is preferable that panning, zooming and windowing of this view is rendered along the center line of the lumen. The segmented vessels may be highlighted using per se known thresholding methods. When the optimal projection is established automatically or interactively, the corresponding position of the C-arm for generating such image may be recorded.

[0078] As a result, workflow in the operation room is improved. In case when the C-arm is controllable (directly or indirectly) by the processor operating the graphic user interface, the position of the C-arm may be automatically installed upon uploading saved data.

[0079] It will be appreciated that the functionality discussed with reference to angiography may also be applied for analyzing valve leaflets, as it may be important to understand the structure and the spatial position of the leaflets prior to replacing the heart valve.

[0080] In addition, it is possible that vessel anatomy is studied in more detail using a graphics tool. For example, a clock position overlay may be used to determine the angle in which a vessel branches off another vessel. In particular such tool may be used to determine the angles under which the renal arteries branch off the aorta. The angle is measured either in degrees or the position on the clock where 12 o'clock is defined as pointing towards the posterior side of the patient and looked at from above. For fenestrated stents theses angles provide valuable information for guiding the intervention.

[0081] Figure 6 presents a graphical user interface for stent placement which is not part of the claimed invention. In this example a Stent Form Templates screen 60 is presented. The screen 60 may comprise a number of sub-windows, like a transversal view, a first longitudinal view 60b (right iliac) and a second longitudinal view 60c (left iliac).

In accordance with aspects of the invention discussed earlier, the windows 60b, 60c may relate to a stretched curved MPR views. Preferably, the views 60b, 60c are linked with an automatic measuring tool, for determining a running value of the lumen diameter of the vessels under consideration. Preferably, results of the automatic measurement of the lumen diameter are automatically recorded in a Stent Form Template, comprising a number of assigned characteristic areas 610, 612, 614, 620, 616 for enabling an educated selection of a suitable stent for treating the aneurism 601. It will be appreciated that due to the automatic data log the workflow may further be improved and human errors may be avoided.

[0082] It will be further appreciated that a similar template may be used to enabling the user to analyze multiple implant devices and to quantitatively compare the results. For example, for the heart valve replacement module the software may be adapted to add form templates that can be tied to the different measurements carried out on the rendered image.

[0083] It will be appreciated that while specific embodiments of the invention have been described above, that the invention may be practiced otherwise than as described. In addition, isolated features discussed with reference to different figures may be combined.

Claims

1. A method of optimizing workflow for an intervention, comprising the steps of:

- reconstruction of an image of a target area (6) representative of an envisaged intervention

based on imaging dataset;
- automatically selecting an optimal viewing direction (10c) for enabling a pre-operative quantitative analysis of intervention features,

wherein the intervention relates to a heart valve replacement and the target area (6) comprises a heart valve and a portion of a lumen arranged in fluid communication with the heart valve, the method further being **characterised by** comprising the steps of:

- accessing the image representative of the heart valve and the surrounding anatomy;
- based on the image, calculating a pre-determined reference line for reconstructing an optimal image projection (10c) comprising the heart valve,

wherein for the pre-determined reference line a centre line of said lumen (4) is selected.

2. A method according to claim 1, wherein the image projection is obliquely oriented with respect to the centre lumen line.

3. A method according to claim 2, further comprising the step of defining a centre line annulus point position using the image projection.

4. A method according to claim 3, further comprising the step of reconstructing a rendered image along the center lumen line.

5. A method according to claim 4, further comprising the step of using the rendered image view for assessing features in the heart valve and/or the vessel corresponding to the lumen.

6. A method according to claim 5, wherein for the features of the vessel a length of the vessel, and/or a diameter of the lumen are selected.

7. A method according to claim 5 or 6, further comprising the step of using the rendered image for calculating an optimal setting of an imaging device for acquiring an image of the heart valve mimicking the rendered image.

8. A method according to any one of the preceding claims 4 to 7, wherein for the rendered image, a Min-IP, a MIP, a stretched curved MPR, a volume rendered, or an average IP is selected .

9. A method according to claim 8, further comprising the step of providing indications of tortuosity of vessel.

10. A method according to claim 8, further comprising the step providing indications on calcification along the lumen.

11. A method according to claim 1, wherein the target area comprises a heart valve and an apex of the heart, the method further comprising the step of defining a transapical line of approach.

12. A method according to claim 11, wherein the initial seed for the apical point is placed automatically.

13. A method according to claim 12, further comprising the step of determining an entry angle for a catheter based on the selected line of approach.

14. A method according to claim 13, wherein said entry angle is variable along the line of approach.

15. A method according to claim 1, wherein the imaging dataset corresponds to a three-dimensional or a four-dimensional dataset.

16. A computer program comprising instructions for causing a processor to carry out the steps of the method according to any one of the preceding claims.

17. A system of optimizing workflow for an intervention, comprising a processor arranged for carrying out the steps of the method according to any of claims 1 to 15, and a graphic user interface (10, 20, 30, 40, 50) for visualizing a number of optimal views on a plurality of graphic windows according to one or more steps of the method of claims 1 to 15.

18. A system according to claim 17, further comprising a device, such as an imaging unit or an automated manipulator, arranged to receive instructions from the processor based on results of the pre-operative quantitative analysis for carrying-out at least a part of the intervention.

Patentansprüche

1. Eine Methode zur Optimierung des Arbeitsablaufs eines Eingriffs, bestehend aus folgenden Schritten:

- Rekonstruktion des Bildes eines Zielbereichs (6), der auf der Grundlage eines bildgebenden Datensatzes für den beabsichtigten Eingriff repräsentativ ist;
- Automatische Auswahl einer optimalen Blickrichtung (10c), um eine präoperative quantitative Analyse der Eingriffsmerkmale zu ermöglichen,

wobei sich der Eingriff auf einen Herzklappenersatzes bezieht und der Zielbereich (6) sich auf eine Herzklappe und einen Teil eines Lumens bezieht, der in ständiger Kommunikation mit der Herzklappe angeordnet ist, wobei die Methode durch folgende Schritte gekennzeichnet ist:

- Zugriff auf das repräsentative Bild der Herzklappe und der umgebenden Anatomie;
- Berechnung einer optimalen Bildprojektion (10c) mit Herzklappe auf der Grundlage einer vorgegebenen Referenzlinie für die Rekonstruktion,

wobei als Referenzlinie eine Mittellinie des genannten Lumens (4) ausgewählt wird.

2. Eine Methode nach Anspruch 1, bei der eine Bildprojektion in Bezug auf die Lumen-Mittellinie schräg ausgerichtet ist.

3. Eine Methode nach Anspruch 2, die ferner einen Schritt der Definition der Position des Annulus-Punktes auf der Mittellinie mithilfe einer Bildprojektion vorsieht.

4. Eine Methode nach Anspruch 3, die ferner **gekennzeichnet ist durch** einen Schritt der Rekonstruktion eines gerenderten Bildes entlang einer Lumen-Mittellinie.

5. Eine Methode nach Anspruch 4, die durch einen Schritt gekennzeichnet ist, der ein gerendertes Bild für die Beurteilung der Merkmale der Herzklappe und/oder des Gefäßes umfasst, das dem Lumen entspricht.

6. Eine Methode nach Anspruch 5, die **dadurch gekennzeichnet ist, dass** für die Merkmale des Gefäßes eine Länge des Gefäßes und/oder ein Lumendurchmesser gewählt wurden.

7. Eine Methode nach Anspruch 5 und 6, die ferner durch einen Schritt gekennzeichnet ist, bei dem für die Berechnung der optimalen Einstellungen eines bildgebenden Geräts ein gerendertes Bild für die Erfassung eines Bildes der Herzklappe verwendet wird, welches das gerenderte Bild imitiert.

8. Eine Methode nach einem der vorstehenden Ansprüche 4 bis 7, wobei für das gerenderte Bild ein MinIP, ein MIP, ein gestreckter gekrümmter MPR, ein gerendertes Volumen und ein durchschnittlicher IP ausgewählt wird.

9. Eine Methode nach Anspruch 8, die ferner aus einem Schritt besteht, der die Gewundenheit des Gefäßes angibt.

10. Eine Methode nach Anspruch 8, die ferner durch einen Schritt gekennzeichnet ist, der die Kalzifikation entlang des Lumens anzeigt.

11. Eine Methode nach Anspruch 1, die den Zielbereich einer Herzklappe und einen Herz-Apex umfasst. Die Methode besteht darüber hinaus in der Definition einer transapikalen Annäherungslinie.

12. Eine Methode nach Anspruch 11, wobei der Startwert des apikalen Punktes automatisch platziert wird.

13. Eine Methode nach Anspruch 12, die einen Schritt beinhaltet, der den Einführungswinkel des Katheters auf der Grundlage einer ausgewählten Annäherungslinie bestimmt.

14. Eine Methode nach Anspruch 13, wobei der genannte Einführungswinkel entlang der Annäherungslinie variabel ist.

15. Eine Methode nach Anspruch 1, die **dadurch gekennzeichnet ist, dass** der Bilddatensatz einem dreidimensionalen oder vierdimensionalen Datensatz entspricht.

16. Ein Computerprogramm, bestehend aus Anweisungen, wie der Prozessor die Schritte der Methode gemäß einem der vorstehenden Ansprüche durchführt.

17. Ein System zur Optimierung des Arbeitsablaufs eines Eingriffs, bestehend aus einem Prozessor, der für die Durchführung der Schritte der Methode gemäß einem der Ansprüche 1 bis 15 angeordnet ist und einer grafischen Benutzeroberfläche für die Visualisierung einer Reihe optimaler Ansichten in einer Vielzahl von grafischen Fenstern gemäß einem oder mehr Schritten der Methode der Ansprüche 1 bis 15.

18. Ein System nach Anspruch 17, das darüber hinaus aus einem Gerät besteht, das eine Bildeinheit oder einen automatischen Manipulator umfasst, die auf der Grundlage der Ergebnisse der präoperativen quantitativen Analyse Anweisungen vom Prozessor für die Durchführung zumindest eines Teils des Eingriffs erhalten.

Revendications

1. Un procédé d'optimisation du flux de travail pour une intervention, constitué d'étapes de :

- reconstruction d'une image d'une zone cible (6) représentative d'une intervention envisagée sur la base d'un ensemble de données d'imagerie ;

- sélection automatique d'une direction d'observation optimale (10c) pour permettre une analyse quantitative préopératoire des caractéristiques d'intervention,

lorsque l'intervention concerne un remplacement de valvule cardiaque et la zone cible (6) comprend une valvule cardiaque et une partie d'un lumen disposé en communication fluide avec la valvule cardiaque, le procédé étant en outre **caractérisé par le fait qu'**il comprend les étapes :

- d'accès à l'image représentant la valvule cardiaque et de l'anatomie environnante ;
- sur la base de l'image, de calcul d'une ligne de référence prédéterminée pour reconstruire une projection d'image optimale (10c) comprenant la valvule cardiaque,

Lorsqu'une ligne centrale dudit lumen (4) est sélectionnée pour la ligne de référence prédéterminée.

2. Procédé selon la revendication 1, dans lequel la projection d'image est orientée obliquement par rapport à la ligne de lumen centrale.

3. Procédé selon la revendication 2, comprenant en outre l'étape de définition d'une position de point d'anneau de ligne centrale en utilisant la projection d'image.

4. Procédé selon la revendication 3, comprenant en outre l'étape de reconstruction d'une image rendue le long de la ligne de lumen centrale.

5. Procédé selon la revendication 4, comprenant en outre l'étape consistant à utiliser la vue d'image rendue pour évaluer des caractéristiques dans la valvule cardiaque et/ou le vaisseau correspondant au lumen.

6. Procédé selon la revendication 5, dans lequel une longueur du vaisseau et/ou un diamètre du lumen sont sélectionnés pour les caractéristiques du vaisseau.

7. Procédé selon la revendication 5 ou 6, comprenant en plus l'étape d'utilisation de l'image rendue pour calculer un réglage optimal d'un dispositif d'imagerie pour l'acquisition d'une image de la valvule cardiaque reproduisant l'image rendue.

8. Procédé selon l'une quelconque des revendications 4 à 7 précédentes, dans lequel pour l'image rendue, un MinIP, un MIP, un MPR incurvé étiré, un volume rendu ou une IP moyenne est sélectionné.

9. Procédé selon la revendication 8, comprenant en outre l'étape consistant à fournir des indications de tortuosité du vaisseau.

10. Procédé selon la revendication 8, comprenant en plus l'étape fournissant des indications sur la calcification le long du lumen.

11. Procédé selon la revendication 1, dans lequel la zone cible comprend une valvule cardiaque et un sommet du cœur, le procédé comprenant en outre l'étape de définition d'une ligne d'approche transapicale.

12. Procédé selon la revendication 11, dans lequel la graine initiale pour le point apical est placée automatiquement.

13. Procédé selon la revendication 12, comprenant en outre l'étape de détermination d'un angle d'entrée pour un cathéter sur la base de la ligne d'approche sélectionnée.

14. Procédé selon la revendication 13, dans lequel ledit angle d'entrée est variable le long de la ligne d'approche.

15. Procédé selon la revendication 1, dans lequel l'ensemble de données d'imagerie correspond à un ensemble de données en trois dimensions ou en quatre dimensions.

16. Programme informatique comprenant des instructions pour amener un processeur à exécuter les étapes du procédé selon l'une quelconque des revendications précédentes.

17. Système d'optimisation de flux de travail pour une intervention, comprenant un processeur agencé pour exécuter les étapes du procédé selon l'une quelconque des revendications 1 à 15, et une interface utilisateur graphique pour visualiser un certain nombre de vues optimales sur une pluralité de fenêtres graphiques selon une ou plusieurs étapes du procédé des revendications 1 à 15.

18. Système selon la revendication 17, comprenant en outre un dispositif, tel qu'une unité d'imagerie ou un manipulateur automatisé, agencé pour recevoir des instructions du processeur sur la base des résultats de l'analyse quantitative préopératoire pour effectuer au moins une partie de l'intervention.

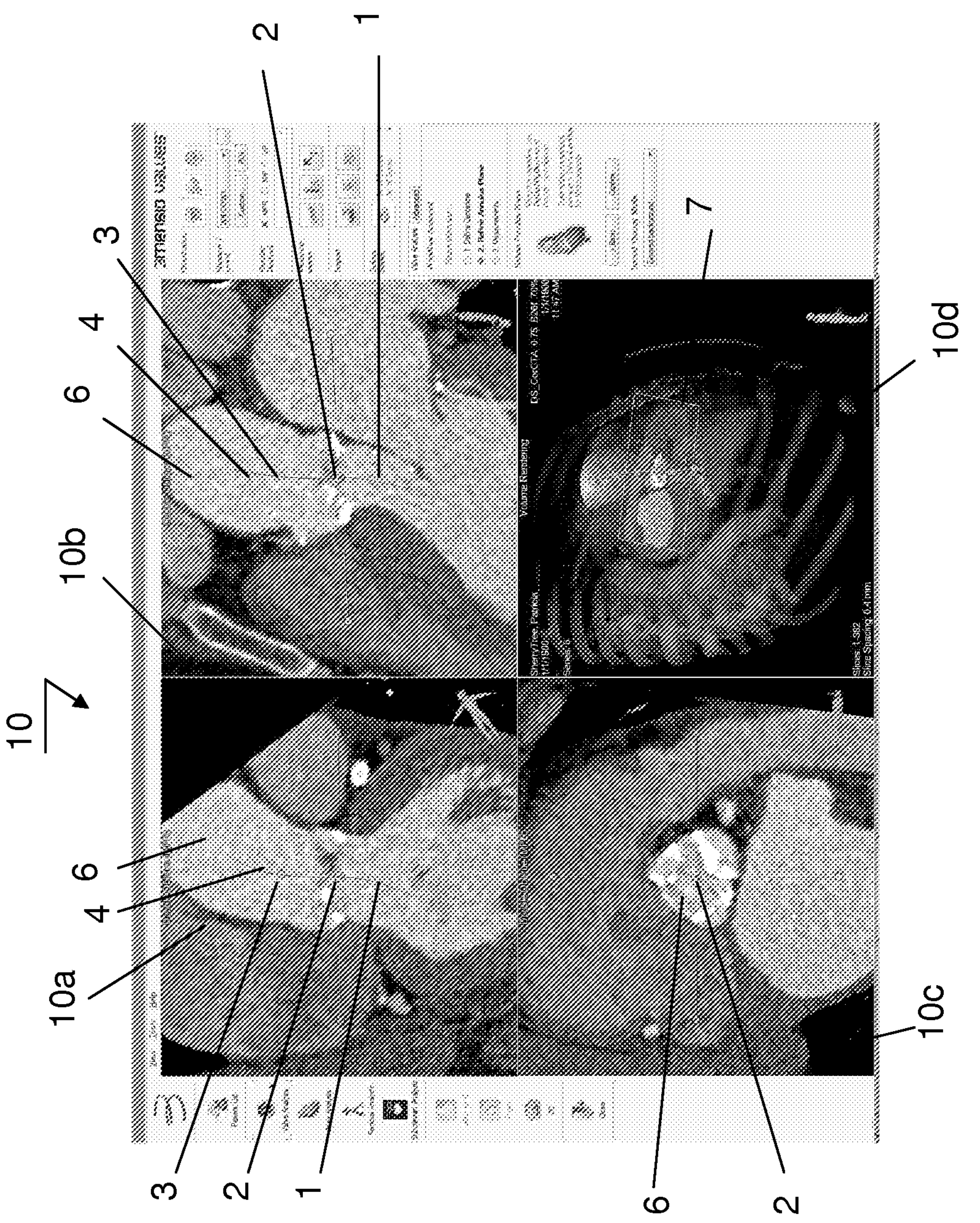

Fig. 1

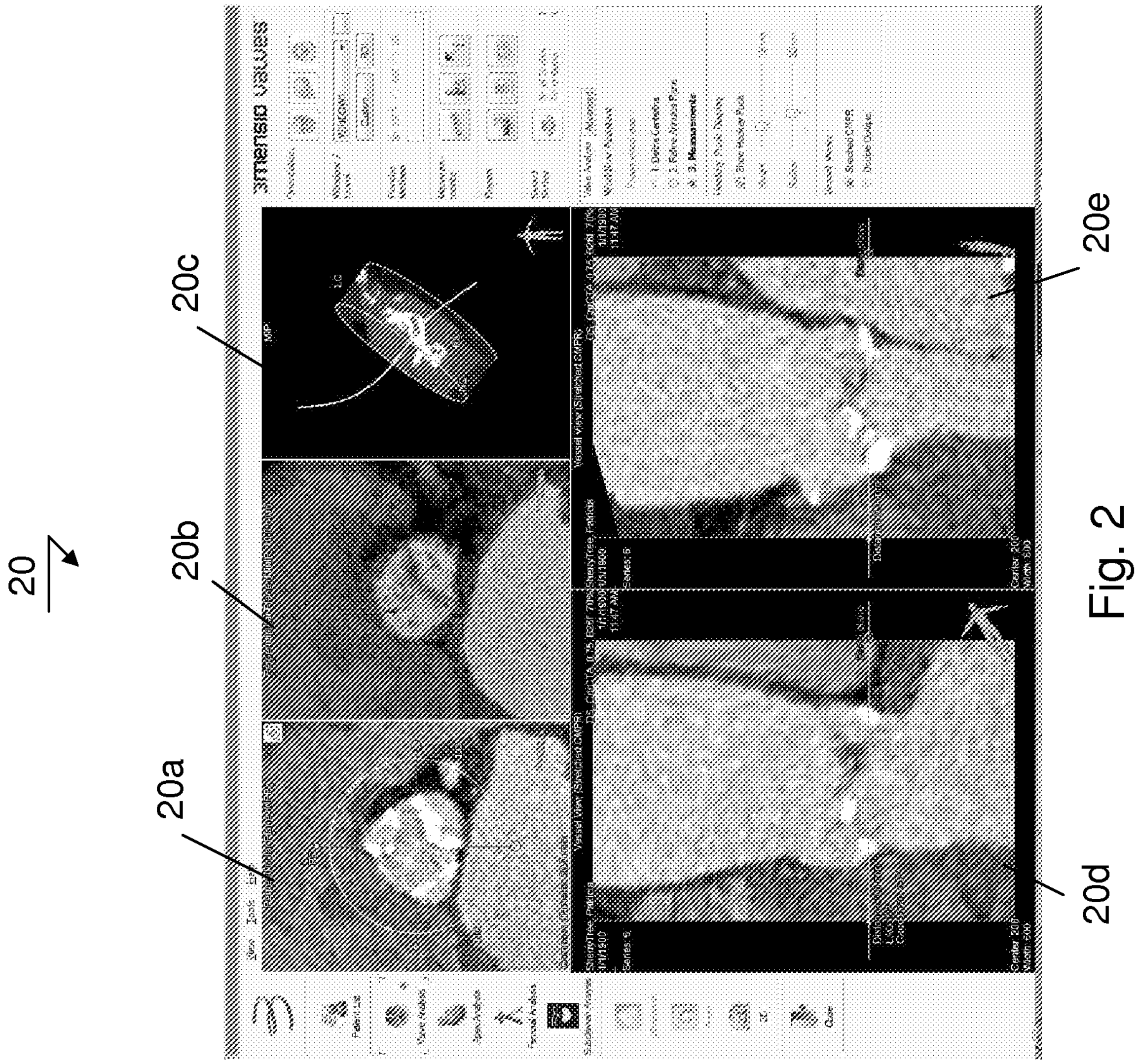

Fig. 2

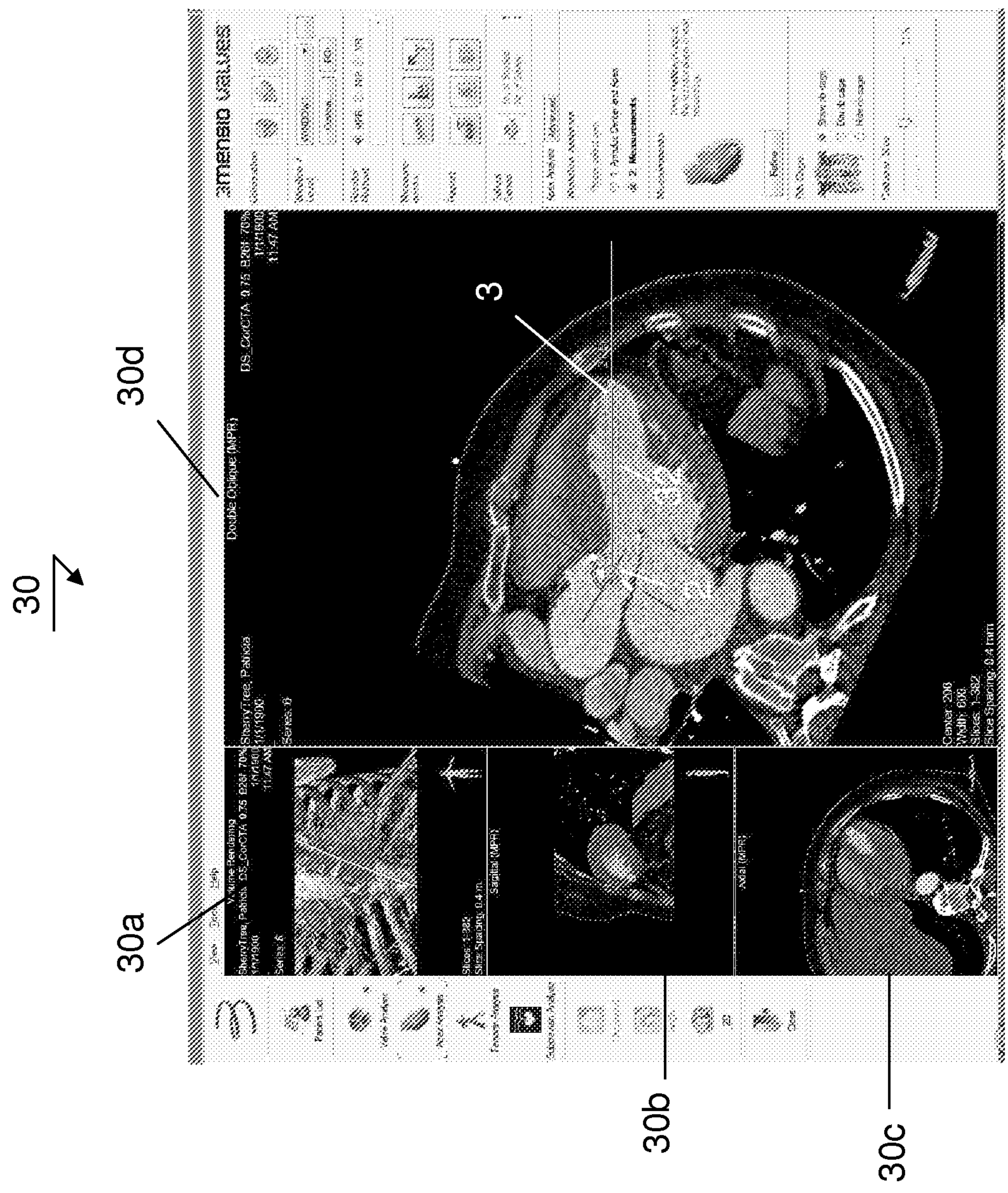

Fig. 3

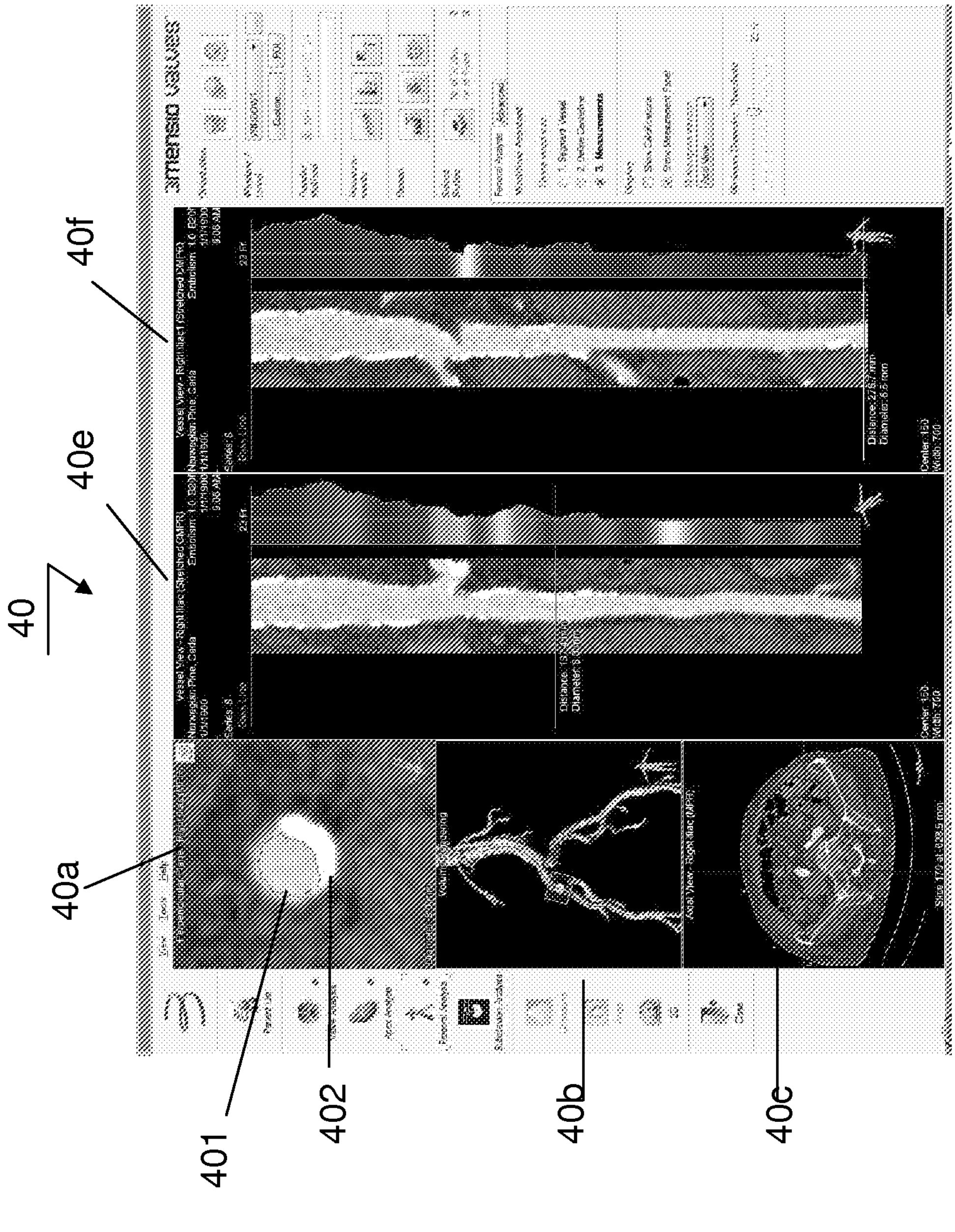

Fig. 4

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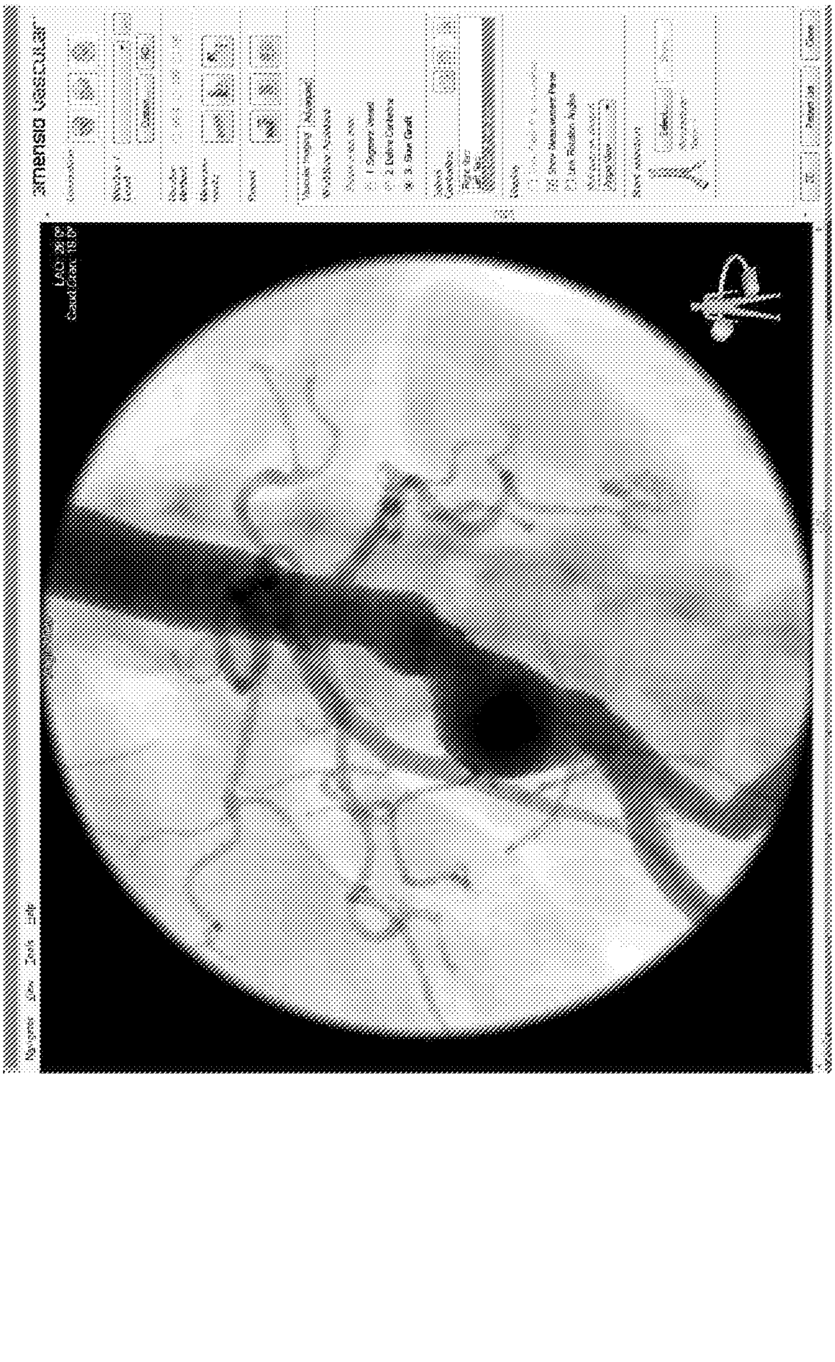

Fig. 5

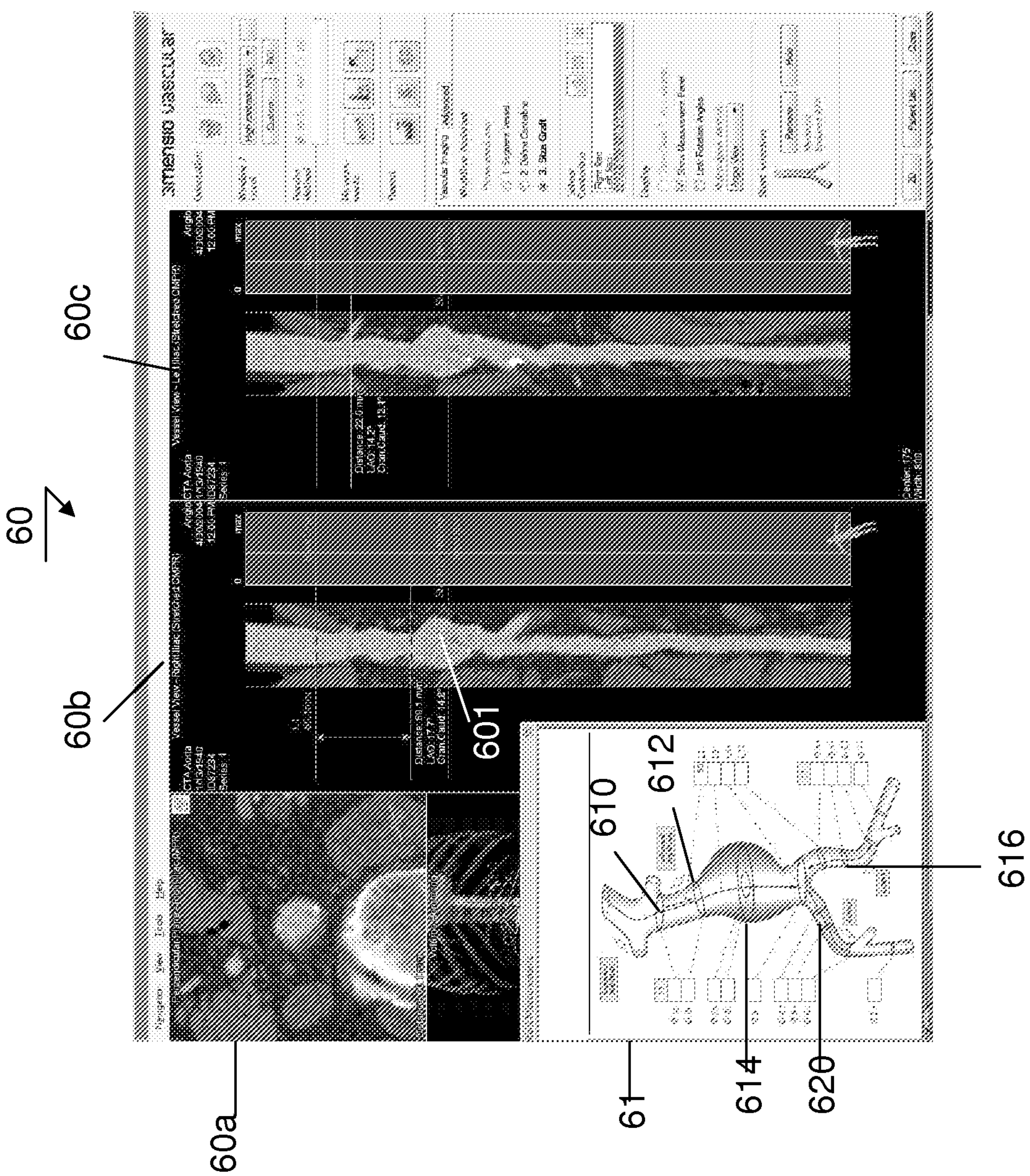

Fig. 6

REFERENCES CITED IN THE DESCRIPTION

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专利名称(译)	一种用于优化医疗干预的工作流程的方法，图形用户界面，系统和计算机程序

公开(公告)号	EP2489011A2	公开(公告)日	2012-08-22
申请号	EP2009741035	申请日	2009-10-14

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IPC分类号	G06T17/00 A61B5/00
CPC分类号	A61B34/25 G06F19/00 G06T7/0012 G06T19/00 G06T2200/24 G06T2207/10072 G06T2207/30048 G06T2207/30101 G16H30/20 G16H40/63 G16H50/50 Y10S128/922 Y10S128/923 G05B15/02 G06F3/04842 G06F19/321
代理机构(译)	BESSI，LORENZO
其他公开文献	EP2489011B1
外部链接	Espacenet

摘要(译)

本发明涉及一种优化干预的工作流程的方法，该方法包括以下步骤：基于成像数据集重建代表所设想的干预的目标区域的图像； 自动选择最佳观察方向，以进行术前干预特征的定量分析。 本发明还涉及用于优化干预的工作流程的计算机程序和系统。