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

(19) World Intellectual Property Organization
International Bureau

PCT

(43) International Publication Date
2 May 2008 (02.05.2008)

(10) International Publication Number
WO 2008/051841 A2

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

(21) International Application Number:
PCT/US2007/081942

(22) International Filing Date: 19 October 2007 (19.10.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/862,418 20 October 2006 (20.10.2006) US

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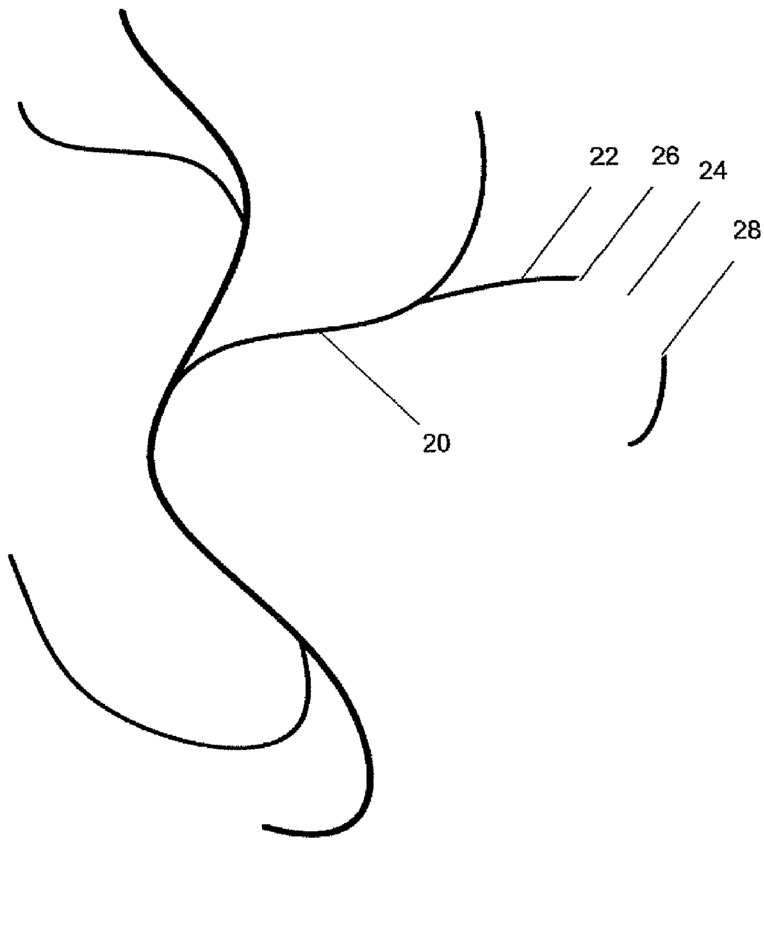
(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, 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,

[Continued on next page]

(54) Title: LOCATION AND DISPLAY OF OCCLUDED PORTIONS OF VESSELS ON 3-D ANGIOGRAPHIC IMAGES



(57) Abstract: A method of finding the location of an occluded portion of a blood vessel relative to a three-dimensional angiographic image of a subject's vasculature includes identifying the location of the occluded portion of the blood vessel on each of a series of displayed two dimensional images derived from the three dimensional image data in planes substantially transverse to direction of the occluded portion of the vessel. The identified locations in the occluded portion of the vessel can then be used to determine the path of the occluded portion of the vessel.

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GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report*

Location and Display of Occluded Portions of Vessels On 3-D Angiographic Images

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to prior U.S. Provisional Patent Application Serial No. 60/862,418, filed October 20, 2006, the entire disclosure of which is incorporated herein by reference.

BACKGROUND

[0002] This invention relates to the treatment of occluded blood vessels, and in particular to the location and display of occluded portions of vessels on 3-D angiographic images.

[0003] Three dimensional angiographic is a valuable imaging technique in which contrast agent is introduced into the subject's vasculature and a three dimensional image of the vasculature is made with an appropriate imaging system such as an x-ray or MR imaging system. Three dimensional angiography provides an accurate image of the vasculature that among other things reveals occluded portions of the vasculature, which, because of the occlusion, contain little or no contrast agent, and thus are not as visible in the resulting angiogram.

[0004] With the advent of remote navigation techniques for navigating medical devices through a subject's vasculature, angiograms are used for planning and conducting vascular navigation. However the gaps in angiograms caused by occlusions impair the use of angiograms for planning and conducting navigations. This is particularly true in the treatment of vascular occlusions because to navigate successfully through an occluded vessel, for example to remove the occlusion, it is important to know the location of the vessel.

SUMMARY

[0005] Embodiments of this invention provide methods of locating and displaying the location of occluded blood vessels which are generally difficult or impossible to see in 3D angiograms. One preferred embodiment provides a method of finding the location of an occluded portion of a blood vessel relative to a three-dimensional angiographic image of a subject's vasculature. This method generally comprises identifying the location of the occluded portion of the blood vessel on each of a series of displayed two dimensional images that are derived from the three dimensional image data in planes that are substantially transverse to the direction of the occluded portion of the vessel. These identified locations are connected together to define the path of the occluded vessel, which can be displayed on the three-dimensional angiographic image.

[0006] Embodiments of this invention make it possible to locate and display occluded portions of a subject's vasculature that are difficult or impossible to locate in conventional angiograms. With some embodiments it is possible to obtain sufficiently accurate location information to permit remote navigation through the occluded portion, and if desired, to open occluded blood vessels. These and other features and advantages will be in part apparent and in part pointed out herein after.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Fig. 1 is a schematic view of a three dimensional angiogram, showing an occluded potion in the vasculature;

[0008] Fig. 2 is an enlarged schematic view of a vasculature branch with an occlusion, showing a series of planes from which two dimensional images from the three dimensional images can be displayed to locate the occluded portion of the vessel;

[0009] Fig. 3 is a schematic view of a two-dimensional image taken along one of the planes shown in Fig. 2, illustrating a first technique identifying the location of the occluded portion of a blood vessel;

[0010] Fig. 4 is a schematic view of a two-dimensional image taken along one of the planes shown in Fig. 2, illustrating a second technique of identifying the location of the occluded portion of a blood vessel;

[0011] Fig. 5 is a schematic view of a two-dimensional image taken along one of the planes shown in Fig. 2, illustrating a fourth technique of identifying the location of the occluded portion of a blood vessel;

[0012] Fig. 6 is a schematic view of a two-dimensional image taken along one of the planes shown in Fig. 2, illustrating a fifth technique of identifying the location of the occluded portion of a blood vessel;

[0013] Fig. 7 is a schematic view of a two-dimensional image taken along one of the planes shown in Fig. 2, illustrating third technique method of identifying the location of the occluded portion of a blood vessel;

[0014] Fig. 8 is an enlarged schematic view of a vasculature branch with an occlusion, showing one technique for predicting the path of the occluded portion of the vessel;

[0015] Fig. 9 is an enlarged schematic view of a vasculature branch with an occlusion, showing a second technique for predicting the path of the occluded portion of the vessel; and

[0016] Fig. 10 is a schematic view of a two-dimensional image taken along one of the planes shown in Fig. 2, illustrating a method of adjusting the plane in which the image is taken to facilitate identifying the location of the occluded portion of a blood vessel.

[0017] Correspondence reference numerals indicate corresponding parts throughout the several views of the drawings.

DETAILED DESCRIPTION

[0018] Generally embodiments of the present invention provide methods finding the location of an occluded portion of a blood vessel relative to a three-dimensional angiographic image of a subject's vasculature. Once the position of the occluded portion of the blood vessel has been determined, this information can be used to navigate through the occluded vessel, or at least to display the position of the occluded vessel.

[0019] The method of the preferred embodiment of this invention comprises identifying the location of the occluded portion of the blood vessel on each of a series of displayed two dimensional images derived from the three dimensional image data that are in planes that are substantially transverse to the direction of the occluded portion of the vessel.

[0020] A three-dimensional vascular tree from a three dimensional angiogram is indicated generally as 20 in Fig. 1. The vascular tree 20 can be generated from any three-dimensional imaging system, including but not limited to x-ray, CT or MR imaging. As shown in Fig. 1, the vascular tree 20 comprises a plurality of branches, and might represent, for example the coronary vasculature. One of the branches 22 has a gap 24, that is identifiable as having a start 26 and an end 28. This gap 24 is typically indicative of an occluded portion of the blood vessel which has reduced or no flow, so that the contrast agent cannot fill the portion and reveal the occluded portion in an image.

[0021] In order to navigate through the branch 22, it is desirable to know the location (i.e. the position and orientation) of the entire branch to minimize damage that the medical device might cause. Knowledge of the location of the branch is particularly desirable in the case of a procedure for removing or treating the occlusion, in order to ensure that the occlusion is being removed, but the vessel remains intact.

[0022] While occluded vessels are generally not visible or are only minimally visible, in three dimensional volume rendered angiograms, the profile of even an occluded vessel can often be resolved in a two-dimensional cross sectional view. Thus as shown schematically in Fig. 2, in accordance with the preferred embodiment of the methods of this invention, a plurality of two dimensional images in planes generally transverse to the expected path of the occluded portion 24 of the branch 22 are derived from the three dimensional imaging data. As shown schematically in Fig. 2, images are made in 5 planes 30A, 30B, 30C, 30D, and 30E, but the number of images used will depend upon the length of the occluded section, the geometry of the occluded section (i.e. whether it is substantially straight or tortuous), and the anticipated use of the location information (i.e. generally lesser resolution for simple navigations, and generally greater resolution for procedures attempting to remove the occlusion).

[0023] Each of the images from the planes is displayed, and the user can discern the location of the occluded vessel in the image and mark it in some manner. By marking the location of the vessel in each of a series of images, the path of the vessel can be determined even though it is not readily visible in the three dimensional angiogram. The path of the occluded portion can thus be displayed on the three dimensional angiogram, and the location information can be used to control navigations through the occluded portion and it can be used in a procedure removing the occlusion.

[0024] For example, as shown in Fig. 3, the two dimensional image from plane 30A is displayed and the user can discern the wall 34 from the background 32 of the image and even from the occlusive material 34 inside the vessel. The user can then mark what appears to be the centerline of the occluded portion of the vessel, for example by positioning a cursor 36 (which can be manipulated by a mouse or joystick or other device and clicking. Of course, as shown in Fig. 4, the user might select an off center location, if desired, for example to stay away from the inside or outside of a bend in the vessel, or in the case of a partially occluded vessel as shown in Fig. 7, to identify a path through the occluded portion of the vessel. Alternatively, instead of identifying a position in the vessel, the user might identify the vessel itself. Thus as shown in Fig, 5, the user might use a conventional oval drawing tool 40 to identify the vessel wall 34, which is typically circular to elliptical. Alternatively, as shown in Fig. 6, the user might use a conventional line drawing tool to draw two or more chords across the occluded vessel, the ends of which can be used to derive a circle or oval to approximate the vessel wall 24, which approximation is preferably displayed so that the user can adjust it if necessary. Alternatively, image processing programs can automatically detect either a point inside the occlusion or the vessel wall which can either be used directly, or simply displayed to facilitate the user selection, allowing the user to approve or to adjust and approve the automatically selected position.

[0025] The two-dimensional images are preferably generally transverse, and more preferably generally perpendicular to the direction of the occluded vessel so that the vessel cross section is easier to detect. To facilitate this, the user can identify the start 26 and end of 28 of the occluded portion, and as shown in Fig. 8, a straight line path 46 can be predicted between the start and the end of the occluded portion. The two dimensional displayed images can then be taken in planes transverse, more preferably in a plane perpendicular to the predicted path 46. As shown in Fig. 9 a more accurate prediction of the path of the occluded path can be made by using the direction of the non-occluded portion of the vessel adjacent to the start 26 of the occluded portion, and the direction of the non-occluded portion of the vessel adjacent to the end 28, and fitting a smoothly curved path 48 between the start and end points. The two dimensional displayed images can then be taken in planes transverse to the predicted path 48. Thus the path of the occluded portion of the blood vessel can be found using a series of images in parallel or non-parallel planes.

[0026] In a first alternative embodiment the displayed image is manually tiltable by the user to adjust the plane in which the image is taken. Tilt controls 50 can be provided on the image so that the user can tilt the image so that the plane of the image is as transverse as possible to the occluded vessel direction, to facilitate the identification of the location of the occluded vessel portion. As a general rule, the vessel will appear most clearly in a perpendicular cross section, although the vessel will also appear smallest in such a view. In a second alternative, rather than require the user to adjust the orientation of the plane, a plurality of images can be displayed each in a plane with a slightly different orientation, and the user can use what ever image in which the vessel appears clearest. The selection process can be automated, and through visual processing the image from the most advantageous plane can be automatically selected and displayed for the user.

[0027] The region in which the occluded portion is located is preferably identified by marking a volume on the three dimensional angiogram, or by at least marking the start and preferably the start and end points of the occlusion, to reduce the amount of data that must be processed, and to facilitate the generation of the two dimensional displays from the three dimensional data set. In an automated system, the identification and recognition of the non-occluded portions can result in the automatic identification of the gaps.

[0028] In a user interface that implements the methods of the preferred embodiments of this invention, software would preferably compute optimal x-ray viewing angles for the vessel. The "optimal" viewing angles about the x-ray vessel are typically those which rotate the c-arm about the vessel axis. These are optimal because one wants to monitor how well a guidewire or other device remains centered within the vessel lumen, and this needs to be done by rotating the c-arm and taking x-rays from more than one view. Ideally the views would be separated by 90 degrees, but constraints imposed by the navigation system, patient table, and other equipment don't always permit this. However, the software could take this into account to help the user position x-rays optimally for monitoring treatment device positioning within an occluded vessel. Once calculated, the x-ray view angles could be either transmitted directly to the x-ray system or displayed to the user so that they could move the x-ray system themselves.

[0029] In x-rays of an occluded vessel, one can normally see the vessel right up to the point of the occlusion, sometimes on either side of the occlusion. A medical device, such as a microcatheter could be pushed right up to the edge of the occlusion, and then be used as a "local reference point" so that the vessel path extracted from the three dimensional dataset can be more precisely registered to an x-ray. This forms a "floating" reference system, in that manipulations of a treatment device extended from microcatheter would always be relative to the "local reference point", and thus positions during the heartbeat and respiration could be more precisely established. In an ideal embodiment, the treatment device and catheter positions would be localized extremely precisely through a system such as Mediguide (http://www.mediguide.co.il/). The computation of the position relative to the catheter could be used to compute a relevant CT image of the vessel cross-section, allowing the user to know whether the treatment device is off center of the vessel lumen, and also to show what is ahead and behind the treatment device as it moves across an occlusion. In another embodiment, the position of the catheter and treatment device can be localized by x-ray image processing and used to compute the deviation of the treatment device from the vessel lumen. However, with the x-ray image processing technique, the user would still have to move the x-ray c-arm about the vessel axis in order to monitor the centering in three dimensions.

OPERATION

[0030] In operation the occluded portion of a blood vessel can be quickly and accurately identified by identifying the location of the occluded portion of the blood vessel on each of a series of displayed two dimensional images derived from the three dimensional image data in planes substantially transverse to the direction of the occluded portion of the vessel. The locations identified on each of the images can be used to determine the path of the occluded vessel, even if it not readily visible in three dimensional imaging. This location information can be used to facilitate the operation of medical navigation system and to facilitate procedures for removing the occlusion and opening the vessel. The raw data can be used, or the data can be used to derive and display a construction of the occluded vessel on the three dimensional angiogram, although the display would preferably differentiate between actual portions and constructed portions of the images.

[0031] A prediction of the path of the occluded portion is preferably made, and the displayed two dimensional images are taken from planes that are perpendicular to the displayed path. The predicted path can be derived from the locations of the start and end of the occluded portion, or a more accurate prediction can be made by taking into account the directions of the non-occluded portions of the blood vessel adjacent the occluded portion of the blood vessel. Furthermore, the predicted path of the occluded portion of the blood vessel can be updated as information about the location of the occluded portion of the blood vessel identified on the displayed two dimensional images is obtained.

[0032] Depending upon user preference and how the information about the location of the occluded portion will be used, the user can identify a point near the center of the occluded portion of the blood vessel or purposely identify another point away from bending walls of the vessel or through a partial occlusion in the vessel. Rather than identifying a point in the occluded vessel, the user could identify the vessel itself, for example drawing a loop around the vessel or drawing two or more intersecting chords to identify the vessel walls.

[0033] The displayed images can be from a series of parallel planes or they can be from planes of different orientations according to the contour of the occluded vessel. The orientation can be made adjustable, or a plurality of alternative planes can be displayed to facilitate the identification of the occluded portion of the vessel.

[0034] Of course some or all of the process can be automated, including the determination of the planes in which to take images, the processing of the imaging data in each plane to identify the occluded portion of the blood vessel, and the processing of the individual locations in the occluded vessel to determine the overall path of the occluded vessel.

CLAIMS:

What is claimed is:

1. A method of finding the location of an occluded portion of a blood vessel relative to a three-dimensional angiographic image of a subject's vasculature, the method comprising:

identifying the location of the occluded portion of the blood vessel on each of a series of displayed two dimensional images derived from the three dimensional image data in planes substantially transverse to direction of the occluded portion of the vessel; and

displaying the identified locations on the three-dimensional angiographic image to indicate the location of the occluded portions.

2. The method according to claim 1 further comprising predicting the path of occluded portion, and wherein the displayed two dimensional images are from planes perpendicular to the displayed path.

3. The method according to claim 1 wherein predicting the path of the occluded portion takes into account the locations of the start and end of the occluded portion.

4. The method according to claim 3 wherein predicting the path of the occluded portion takes into account the direction of the non-occluded portions of the blood vessel adjacent the occluded portion of the blood vessel.

5. The method according to claim 2 wherein the predicted path of the occluded portion of the blood vessel is updated at least once using information about the location of the occluded portion of the blood vessel identified on the displayed two dimensional images.

6. The method according to claim 1 wherein the step of identifying the location of the occluded portion of the blood vessel comprises identifying a point near the center of the occluded portion of the blood vessel.

7. The method according to claim 1 wherein the step of identifying the location of the occluded portion of the blood vessel comprises identifying the cross-section of the occluded portion blood vessel.

8. The method according to claim 7 wherein the step of identifying the cross section of the occluded portion of the blood vessel comprises making a closed loop around the periphery of the occluded portion of the blood vessel.

9. The method according to claim 7 wherein the step of identifying the cross section of the occluded portion of the blood vessel comprises marking two intersecting chords across the cross section.

10. A method of locating an occluded portion of a blood vessel relative to a three-dimensional angiographic image of a subject's vasculature, the method comprising:

successively displaying two dimensional images derived from the three dimensional image data of a plane substantially transverse to the expected local direction of the vessel that includes the occluded potion of the vessel;

identifying the location of the occluded portion of the vessel on the displayed two dimensional images; and

displaying the identified locations on the three-dimensional image to indicate the location of the occluded portions.

11. The method according to claim 10 further comprising identifying the starting point of the occluded portion of the blood vessel.

12. The method according to claim 11 further comprising determining a predicted path of the occluded portion of the blood vessel based upon the direction of the non-occluded portion adjacent the starting point of the occluded portion, and wherein the orientation of the plane of at least the first two dimensional image is perpendicular to the predicted path.

13. The method according to claim 2 further comprising determining a predicted path of the occluded portion or the blood vessel based upon the direction of the non-occluded portion adjacent the starting point of the occluded portion, and wherein the orientation of the plane of the first two dimensional image is perpendicular to the predicted direction, and wherein the orientation of the successive planes is perpendicular to the predicted path of the occluded portion based at least in part upon a location of the occluded portion identified on one of the previous displayed two dimensional image.

14. The method according to claim 10 wherein the step of identifying the location of the occluded portion of the blood vessel comprises identifying a point near the center of the occluded portion of the blood vessel.

15. The method according to claim 10 wherein the step of identifying the location of the occluded portion of the blood vessel comprises identifying the cross-section of the occluded portion blood vessel.

16. The method according to claim 15 wherein the step of identifying the cross section of the occluded portion of the blood vessel comprises making a closed loop around the periphery of the occluded portion of the blood vessel.

17. The method according to claim 15 wherein the step of identifying the cross section of the occluded portion of the blood vessel comprises marking two intersecting chords across the cross section.

18. The method according to claim 10 further comprising identifying the starting and ending points of the occluded portion of the blood vessel, and wherein the planes are perpendicular to a straight line connecting the starting and ending points.

19. The method according to claim 10 further comprising identifying the starting and ending points of the occluded portion of the blood vessel, and wherein the planes are perpendicular to a curve connecting the staring and ending points derived in part from the direction of the non-occluded portions of the blood vessel adjacent the occluded portion.

20. The method according to claim 10 further comprising adjusting the orientation of the plane of the displayed two dimensional image before at least some identification steps.

21. The method according to claim 10 further comprising displaying a plurality of two dimensional images at different angular orientations, and wherein the step of identifying the location of the occluded portion of the lumen comprises identifying the occluded portion of the lumen on one of the displayed images.

22. A method of locating an occluded portion of a blood vessel in a three-dimensional angiographic image of a subject's vasculature, the method comprising:

predicting the path of the occluded potion of the blood vessel;

displaying two dimensional images derived from the three dimensional image data of a plane substantially transverse to the predicted path of the occluded portion of the vessel that includes the occluded potion of the vessel;

identifying the location of the occluded portion of the vessel on the displayed two dimensional image; and

displaying the identified locations on the three-dimensional image to indicate the location of the occluded portions.

23. The method according to claim 22 further comprising updating the predicted path of the occluded portion of the blood vessel based in part on at least one of the locations of the occluded potion identified on a displayed two-dimensional image.

24. A method of identifying a navigation path through an occluded portion of a blood vessel that is difficult to see on a three-dimensional angiographic image, the method comprising:

identifying the location of the occluded portion of the blood vessel on each of a series of displayed two dimensional images derived from the three dimensional image data in planes substantially transverse to direction of the occluded portion of the vessel; and

determining the navigation path by connecting the identified locations.

25. The method according to claim 21 further comprising positioning imaging equipment to image in a direction substantially perpendicular to the navigation path.

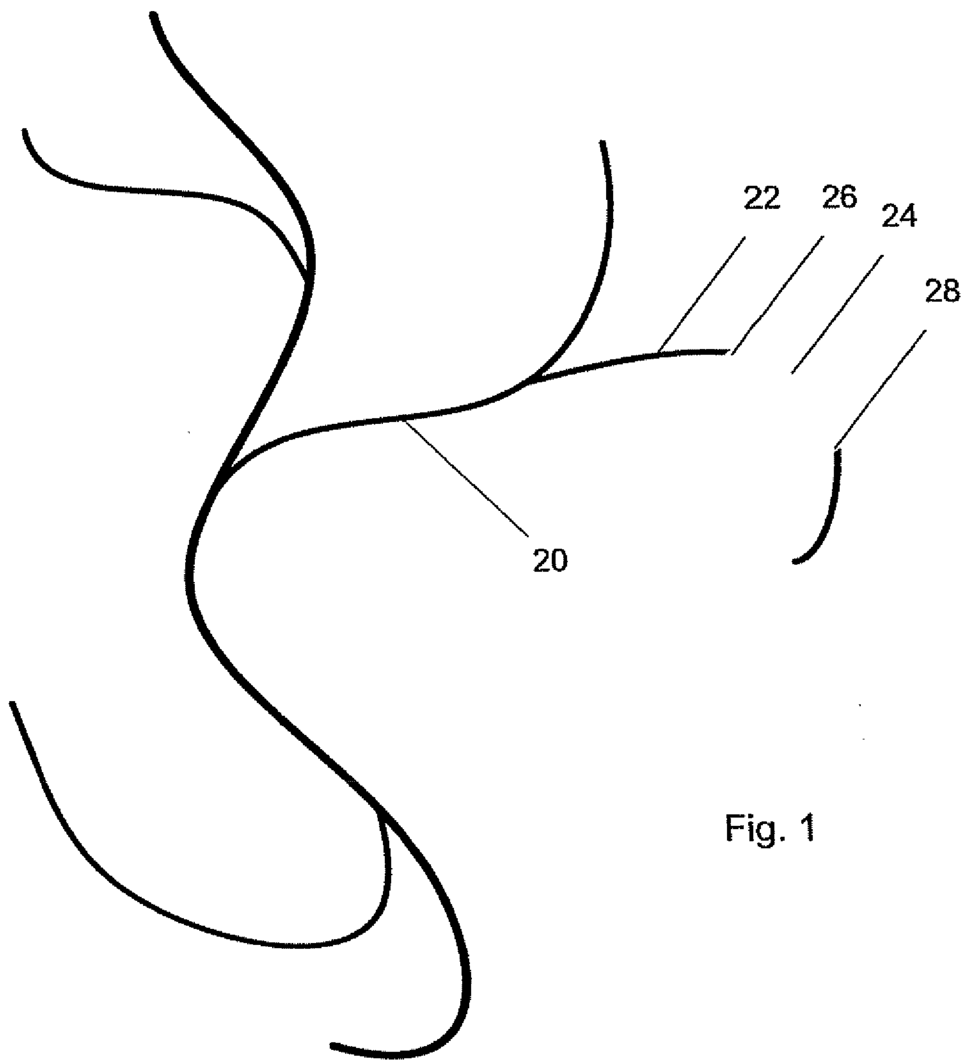

Fig. 1

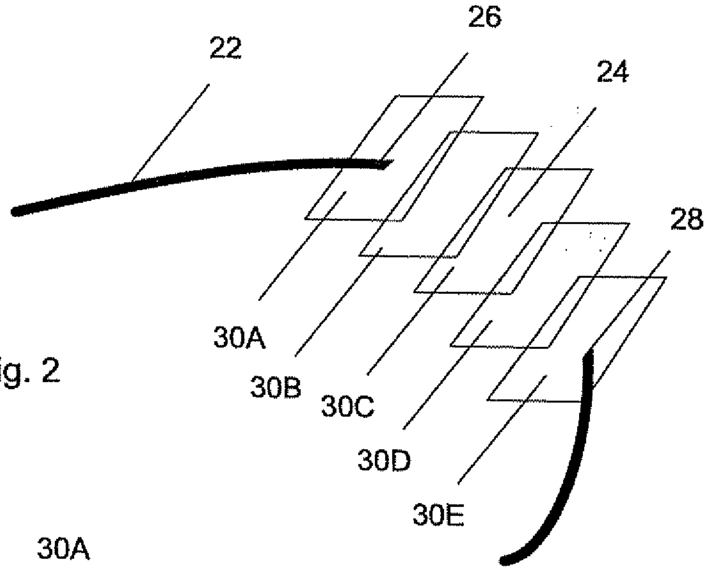

Fig. 2

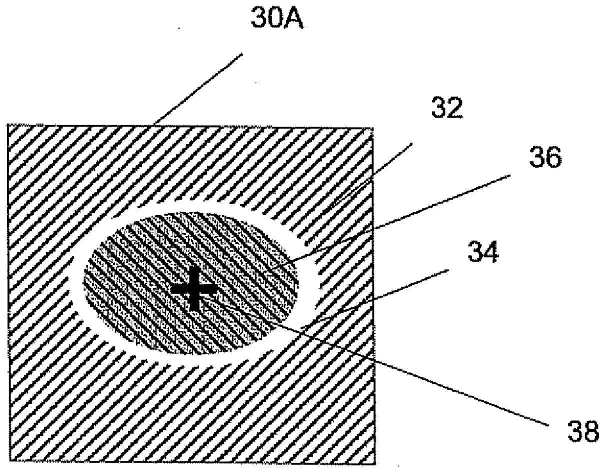

Fig. 3

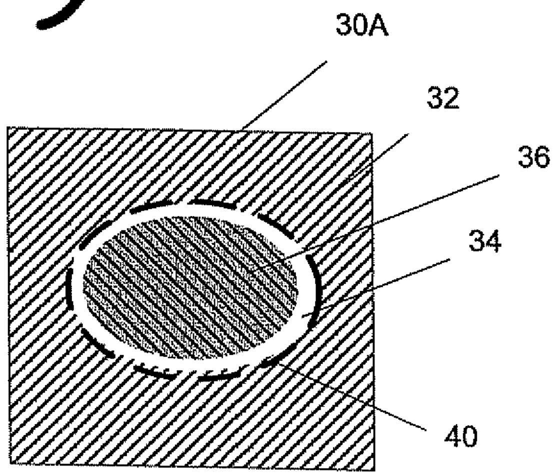

Fig. 5

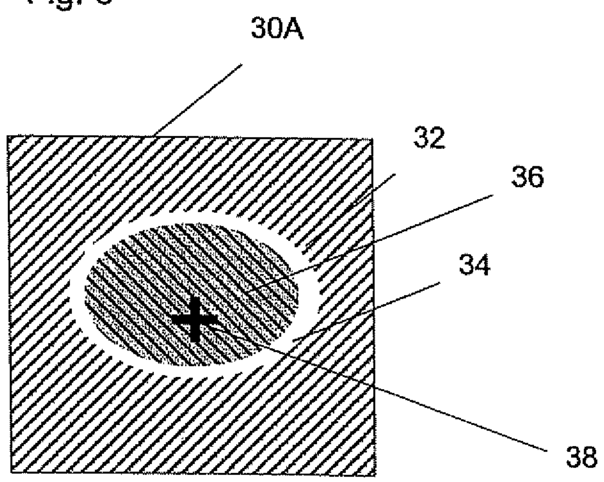

Fig. 4

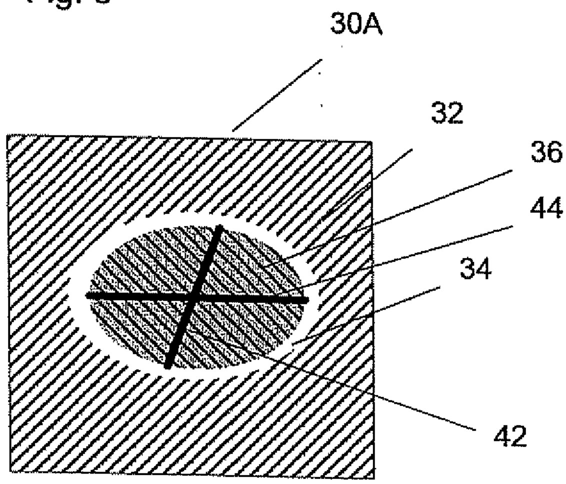

Fig. 6

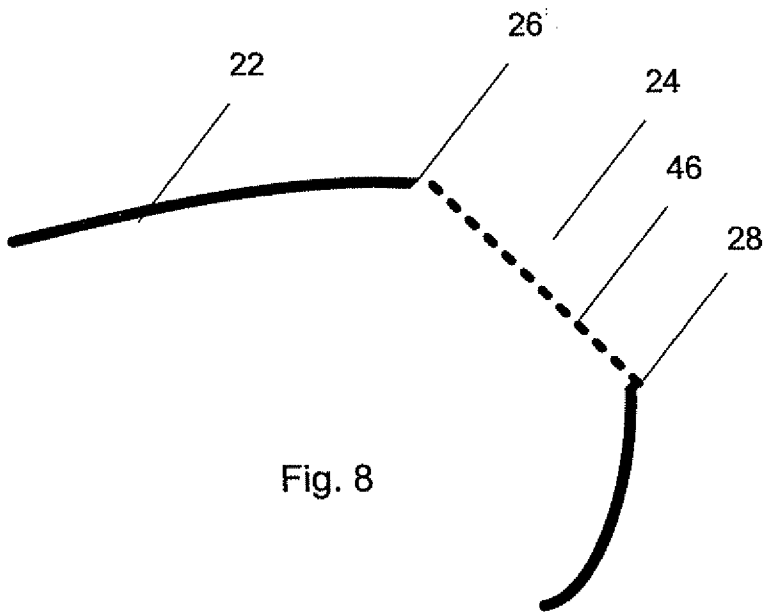

Fig. 8

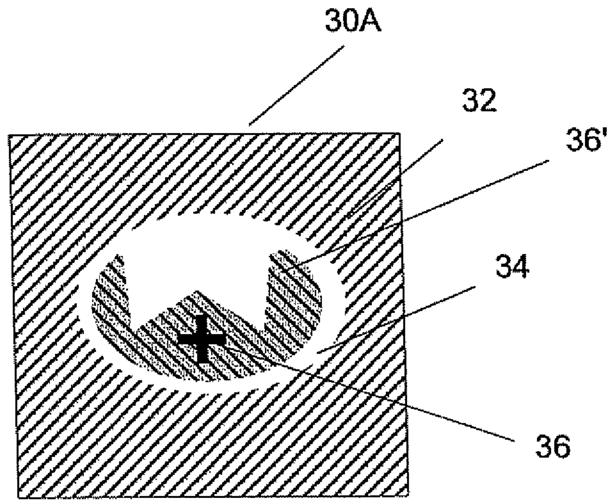

Fig. 7

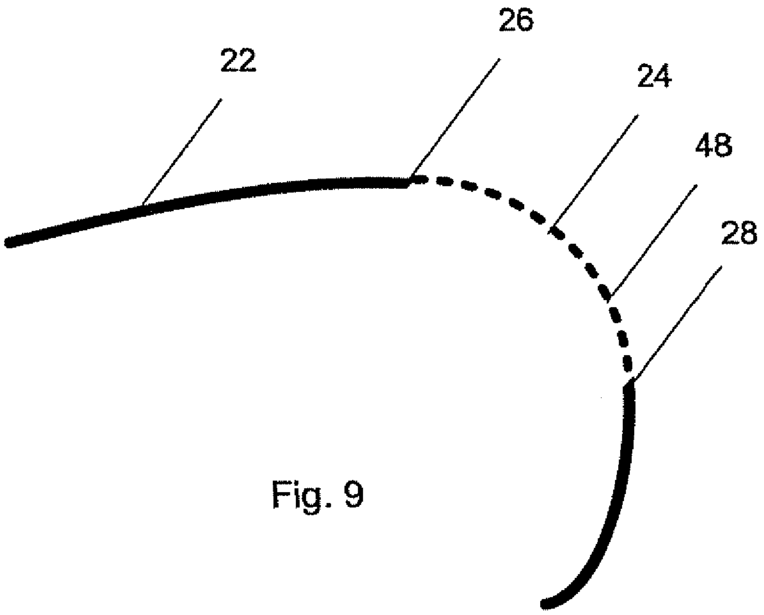

Fig. 9

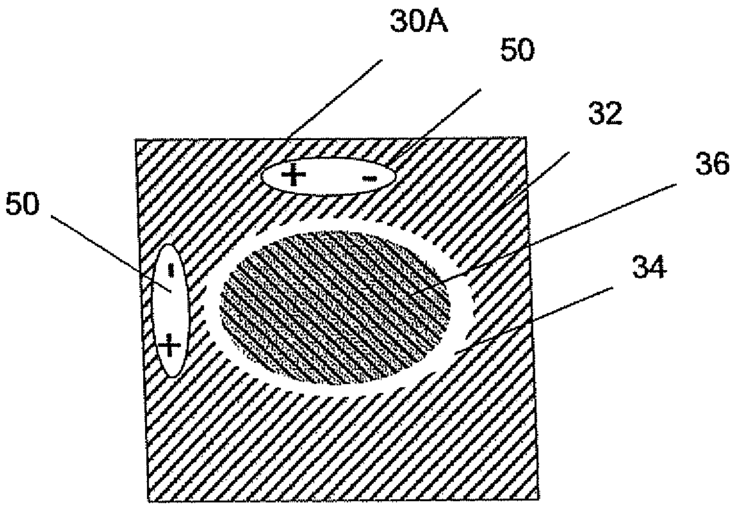

Fig. 10