FORM 2

THE PATENTS ACT, 1970

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The Patent Rules, 2003

COMPLETE SPECIFICATION

(See sections 10 & rule 13)

1. TITLE OF THE INVENTION

METHOD AND APPARATUS FOR ENHANCING ACCURACY OF TUMOUR RESPONSE THERAPY EVALUATION WITH REDUCED EXAMINATION TIME

2. APPLICANTS (S)

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3. PREAMBLE TO THE DESCRIPTION

COMPLETE

The following specification particularly describes the invention and the manner

in which it is to be performed.

METHOD AND APPARATUS FOR ENHANCING ACCURACY OF TUMOUR RESPONSE THERAPY EVALUATION WITH REDUCED EXAMINATION TIME

FIELD OF INVENTION

[0001] The present disclosure relates to medical image analysis, and more particularly, to a method and apparatus for reducing examination time and enhancing accuracy for response therapy evaluation in a tumor.

BACKGROUND OF THE INVENTION

[0002] The background description includes information that may be useful in understanding the present disclosure. It is not an admission that any of the information provided herein is prior art or relevant to the presently claimed invention, or that any publication specifically or implicitly referenced is prior art.

[0003] Functional imaging using single photon emission computed tomography (SPECT) and positron emission tomography (PET) is extremely valuable in the diagnosis of various medical disorders. Uncertainty in the anatomic definition on SPECT and PET images, however, sometimes limits their usefulness. To overcome this, a combination of magnetic resonance images (MRI) and X-ray computed tomography (CT) images with functional SPECT or PET images of the same sections of the body is sometimes used. This provides complementary anatomic (MRI or CT) and physiological (SPECT or PET) information that is of great importance to research, diagnosis and treatment.

[0004] Magnetic resonance imaging ("MRI") is a well-known, highly useful technique for diagnosing abnormalities in biological tissues. MRI can detect abnormalities that are difficult or impossible to detect by other techniques, without the use of x-rays or invasive procedures.

[0005] Functional body images and structural images are two types of medical images used by medical practitioners for the diagnosis of certain medical disorders. Functional body images such as those derived from SPECT or PET scans, provide physiological information, whereas structural images such as those derived from CT or MRI, provide an anatomic map of the body. Different medical imaging techniques may provide scans with complementary and occasionally conflicting information. For

example, the combination of such images (via image fusion or image registration) using picture archiving communications systems (PACS) can often lead to additional clinical information not apparent in the separate images. Thus, by imposing a structural anatomic framework on a set of functional images, the position of a tumor or other lesion in a later functional image may be determined even where there is insufficient anatomic detail.

[0006] Although the construction of a composite, overlapping medical image with image registration has been primarily used in the fusion of functional and anatomical images, it has also been applied to a series of the same modality of images. Examples of this are registration of SPECT images of the same subject in follow-up studies or in a comparison of an image with normal uptake properties to an image with suspected abnormalities. In addition, image registration of SPECT and PET images and the registration of SPECT and PET images with anatomic atlases provide an important means to evaluate comparative uptake properties of SPECT and PET radiopharmaceuticals, and to correlate uptake properties with anatomy.

[0007] Advancements in the digital image acquisition techniques such as ultrasound (US), computed tomography (CT), magnetic resonance (MR), positron emission tomography (PET), positron emission tomography-computed tomography (PET-CT) and single photon emission computed tomography (SPECT) that allow detecting and visualizing tumour lesions are still ongoing. The overall objective is to increase the accuracy of the images acquired. The main motivation therefore is that residual hot spots in malignant lesions can still remain undetected, possibly leaving one or more very aggressive tumoural cells in the patient, even in case of regressive therapy response. The detection of such hot spots through improved image acquisition and post-processing is important because patients with residual hot spots are not tumour-free as a result of which their prognosis has not improved meaningfully. The patient's prognosis improves meaningfully only if all tumoural cells are destroyed.

[0008] US 8712130 discloses evaluating evolution of tumoral lesions by providing a first image of the tumoral lesions at a first time instance, and a second image of the tumoral lesions at a second time instant that is later than the first time instant, and then delineating a border of the tumoral lesions in the first image and the second image and registering the tumoral lesions in the first image the second image to finally segment the tumoral lesions in the first image and the second image into

concentric areas and quantify changes of at least one functional parameter between the concentric areas in the first image and respective corresponding concentric areas in the second image, which can help visualize changes in a two-dimensional or three-dimensional model of the tumoral lesions. As the '130 reference performs a voxel by voxel comparison by means of the step of voxel registration, the overall process takes a much longer time, is computationally expensive, and even affects the accuracy of therapy response evaluation. Furthermore, chances of mis-registration are also possible, which can affect the accuracy of result/outcome.

[0009] Apart from the step of registration, existing solutions also suffer from other limitations relating to, for instance, image resolution, determination of parameter for evaluating tissue, sampling tissue of interest due to change in attribute representative volume/area/size/parameter, among other like issues. Even the examination time during the MR required in current architectures is much higher, making the process uncomfortable for the patient.

[00010] There is therefore a need in the art for a method and apparatus that reduces examination time and enhances accuracy for response therapy evaluation in a tumor.

[00011] All publications herein are incorporated by reference to the same extent as if each individual publication or patent application were specifically and individually indicated to be incorporated by reference. Where a definition or use of a term in an incorporated reference is inconsistent or contrary to the definition of that term provided herein, the definition of that term provided herein applies and the definition of that term in the reference does not apply.

[00012] In some embodiments, the numbers expressing quantities of ingredients, properties such as concentration, reaction conditions, and so forth, used to describe and claim certain embodiments of the invention are to be understood as being modified in some instances by the term "about." Accordingly, in some embodiments, the numerical parameters set forth in the written description and attached claims are approximations that can vary depending upon the desired properties sought to be obtained by a particular embodiment. In some embodiments, the numerical parameters should be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of some embodiments of the

invention are approximations, the numerical values set forth in the specific examples are reported as precisely as practicable. The numerical values presented in some embodiments of the invention may contain certain errors necessarily resulting from the standard deviation found in their respective testing measurements.

[00013] As used in the description herein and throughout the claims that follow, the meaning of "a," "an," and "the" includes plural reference unless the context clearly dictates otherwise. Also, as used in the description herein, the meaning of "in" includes "in" and "on" unless the context clearly dictates otherwise.

[00014] The recitation of ranges of values herein is merely intended to serve as a shorthand method of referring individually to each separate value falling within the range. Unless otherwise indicated herein, each individual value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g. "such as") provided with respect to certain embodiments herein is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention otherwise claimed. No language in the specification should be construed as indicating any non-claimed element essential to the practice of the invention.

OBJECTS OF THE INVENTION

[00015] An object of the present disclosure is to reduce examination time and enhance accuracy for response therapy evaluation in a tumor.

[00016] An object of the present disclosure is to make the MRI process comfortable for patient.

[00017] An object of the present disclosure is to make assessment of tissue classification easy and efficient through color-coding.

SUMMARY

[00018] The present disclosure relates to medical image analysis, and more particularly, to a method and apparatus for reducing examination time and enhancing accuracy for response therapy evaluation in a tumor.

[00019] In an aspect, method of the present disclosure can include the steps of obtaining a first set of volume images before contrast and a second set of volume images after contrast, and then subtracting first set of volume images from the second set of volume images to obtain a third set of images that focus on enhanced tumor tissue. Method of the present disclosure can further include the step of drawing a region of interest (ROI) on each slice of the third set of images, and voxel-wise calculating a pharmacokinetic parameter value for each slice of the third set of MR images. Method of the present disclosure can further include the step of comparing pharmacokinetic parameter value for each voxel of each slice with respect to one or more threshold values, and classifying the voxel based on the output of the comparison step. In an aspect, based on the classification, a color code and/or a symbol and/or any other unique representation (collectively referred to as color code or simply as color hereinafter) can be associated with the voxel to enable easier and quicker interpretation of the ROI.

[00020] It is to be appreciated that although color-coding is being referred to in the instant disclosure, any other unique representation can be associated with each voxel to efficiently/visibly determine the classification/type of each voxel, and therefore all such representations are well within the scope of the present disclosure.

[00021] In an aspect therefore, a color-coded pharmacokinetic parametric map can be generated for that region by giving a cut-off threshold (obtained, for instance, from a population base data set of similar cancer patients (say having the same type of neck cancer/same type breast cancer, for instance). In an instance, red color can be associated with voxels/pixels that have a pharmacokinetic parameter value greater than A, green color can be associated with voxels/pixels that have a pharmacokinetic parameter value between A and B, and blue color can be associated with voxels/pixels that have a pharmacokinetic parameter value lower than B. In an instance, the pharmacokinetic parameter can be Ktrans, and red color can be associated with pixels/voxels that have Ktrans value > 0.6, green color can be associated with pixels/voxels that have Ktrans value between 0.3 to 0.6, and blue color can be associated with pixels/voxels that have Ktrans value < 0.3. Such a color-coded representation can therefore enable representation of near sure malignant voxels as red, probable as green, and the least as blue. In an aspect, any other pharmacokinetic parameter or a combination thereof can be incorporated, say SUV (from PET), kep,

VE, ADC, among known parameters, all of which are well within the scope of the present disclosure.

[00022] In an aspect, post color-coding/threshold based analysis of voxels/pixels, another region of interest (ROI) can be drawn on each subtracted image-set (third set of images) slice-by-slice by slicing a contour of the enhancing component of the tumor, wherein the contours can be copied in the subtracted images and pasted/moved on the corresponding slices of the color coded pharmacokinetic parametric map. Post the superimposition of the contours of each slide on the pharmacokinetic parametric map, number of red pixels (indicative of malign tissue) that are present in the slices that encompass the tumor tissue can be counted.

[00023] In an aspect, the above-mentioned steps can also be performed post-therapy (chemotherapy/ Radiotherapy)to enable a user to conduct therapy response evaluation, wherein a count of the number of red pixels post therapy when compared with the number of red pixels pre-therapy can give an absolute indication of the decrease in malignant tissues, making the therapy response evaluation easier, more accurate, and quick.

[00024] In an aspect, the proposed method is independent of volume change, which is likely to happen (increase or decrease after therapy), and hence any voxel registration error between pre and post therapy due to intrinsic volume changes and position changes are avoided in the proposed method.

[00025] In an aspect, the proposed method focuses on enhancing regions, wherein the enhancing region can be separated by subtraction of pre-contrast vs post contrast image slices at same location, and overlaid on DCR-MR study to the corresponding slice.

[00026] In another aspect, motion artifact, if any, within the same study of uncooperative patient can be removed using standard algorithm/registration methods available. Furthermore, co-registration within the same study is easier than doing voxel registration between study one (Pre-therapy) and study two (Post Therapy) (which is difficult or with errors as mentioned above).

[00027] Various objects, features, aspects and advantages of the inventive subject matter will become more apparent from the following detailed description of preferred embodiments, along with the accompanying drawing figures in which like numerals represent like components.

BRIEF DESCRIPTION OF THE DRAWINGS

[00028] FIG. 1A illustrates exemplary Ktrans images of a study of left cheek of a patient before treatment (pre) and FIG. 1B illustrates the Ktrans images post treatment (post) to demonstrate an embodiment of the present disclosure.

[00029] FIG. 2 illustrates an exemplary flow diagram in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

[00030] The present invention is not limited to the monitoring of a particular tissue region. In some embodiments, the tissue region is within a living subject (e.g., dog, cat, human, gorilla, cow, sheep, rat, mouse, etc.). In some embodiments, the tissue region is within a living human being. In some embodiments, the tissue region is a diseased tissue region (e.g., a malignant tumor, a benign tumor, an abnormal growth, an inflamed region, a cancerous region, an infected region, an organ rejection). In some embodiments, the tissue region is a body region of the subject (e.g., lung, bone, heart, leg, foot, stomach, prostate, rectum, brain, neck, liver, breast). In some embodiments, the tissue region is the entire body of the subject.

[00031] In the following detailed description of the preferred embodiment, reference is made to the accompanying drawings which form a part hereof and in which is shown by way of illustrating a specific embodiment in which the invention may be practiced. This embodiment is described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that structural or logical changes may be made without departing from the scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims.

[00032] The present disclosure relates to medical image analysis, and more particularly, to a method and apparatus for reducing examination time and enhancing accuracy for response therapy evaluation in a tumor.

[00033] In an aspect, method of the present disclosure can include the steps of obtaining a first set of volume images before contrast and a second set of volume images after contrast, and then subtracting first set of volume images from the second set of volume images to obtain a third set of images that focus on enhanced tumor

tissue. Method of the present disclosure can further include the step of drawing a region of interest (ROI) on each slice of the third set of images, and voxel-wise calculating a pharmacokinetic parameter value for each slice of the third set of MR images. Method of the present disclosure can further include the step of comparing pharmacokinetic parameter value for each voxel of each slice with respect to one or more threshold values, and classifying the voxel based on the output of the comparison step. In an aspect, based on the classification, a color code and/or a symbol and/or any other unique representation (collectively referred to as color code or simply as color hereinafter) can be associated with the voxel to enable easier and quicker interpretation of the ROI.

[00034] It is to be appreciated that although color-coding is being referred to in the instant disclosure, any other unique representation can be associated with each voxel to efficiently/visibly determine the classification/type of each voxel, and therefore all such representations are well within the scope of the present disclosure.

[00035] In an aspect therefore, a color-coded pharmacokinetic parametric map can be generated for that region by giving a cut-off threshold (obtained, for instance, from a population base data set of similar cancer patients (say having the same type of neck cancer/same type breast cancer, for instance). In an instance, red color can be associated with voxels/pixels that have a pharmacokinetic parameter value greater than A, green color can be associated with voxels/pixels that have a pharmacokinetic parameter value between A and B, and blue color can be associated with voxels/pixels that have a pharmacokinetic parameter value lower than B. In an instance, the pharmacokinetic parameter can be Ktrans, and red color can be associated with pixels/voxels that have Ktrans value > 0.6, green color can be associated with pixels/voxels that have Ktrans value between 0.3 to 0.6, and blue color can be associated with pixels/voxels that have Ktrans value < 0.3. Such a color-coded representation can therefore enable representation of near sure malignant voxels as red, probable as green, and the least as blue. In an aspect, any other pharmacokinetic parameter or a combination thereof can be incorporated, say SUV (from PET), kep, VE, ADC, among known parameters, all of which are well within the scope of the present disclosure.

[00036] In an aspect, post color-coding/threshold based analysis of voxels/pixels, another region of interest (ROI) can be drawn on each subtracted image-set (third set

of images) slice-by-slice by slicing a contour of the enhancing component of the tumor, wherein the contours can be copied in the subtracted images and pasted/moved on the corresponding slices of the color coded pharmacokinetic parametric map. Post the superimposition of the contours of each slide on the pharmacokinetic parametric map, number of red pixels (indicative of malign tissue) that are present in the slices that encompass the tumor tissue can be counted.

[00037] In an aspect, the above-mentioned steps can also be performed post-therapy (chemotherapy/ Radiotherapy) to enable a user to conduct therapy response evaluation, wherein a count of the number of red pixels post therapy when compared with the number of red pixels pre-therapy can give an absolute indication of the decrease in malignant tissues, making the therapy response evaluation easier, more accurate, and quick.

[00038] In an aspect, the proposed method is independent of volume change, which is likely to happen (increase or decrease after therapy).

[00039] In an aspect, the present disclosure further provides an optimized Ktrans Dynamic Contrast Enhanced MRI (DCE-MRI) method to optimize patient examination time. For instance, the present method can use an improved and accurate pharmacokinetic parameters such as K^{trans} (transfer constant across capillary membrane; a pharmacokinetic parameter of tissue perfusion), K_{ep}, and V_e using T1W Fast DCE-MRI technique to distinguish between malignant, benign and normal tissue. Although the present disclosure has been made with respect to breast cancer detection, the proposed method and technique can be applied to any imaging system used for tissue classification. Optimization of the selected pharmacokinetic parameter can be performed by using, for instance, a phantom and a contrast agent in the proposed MRI system for computing accurate T_1 value of a tissue after the contrast is injected based on intrinsic T_{10} value the tissue, wherein the intrinsic T_{10} value is adjusted and/or normalized to improve accuracy of the T_1 value computed, which in turn is used for computation of the pharmacokinetic parameter such as K^{trans}. In another aspect, a phantom having a predefined T_1 value from the manufacturer can be first placed in the MRI system and a modified T_1 value T_{1M}can be computed for the image of the phantom when in the MRI system such that difference between the modified value T_{1M} and the known/predefined T_1 value gives a deviation factor that is caused by variation in machine parameters such as coil, magnet, and sequence, among other parameters.

When a patient is then placed in the MRI system, intrinsic value T_{10} of the tissue under consideration can be computed without insertion of the contrast. As was the case with the T_1 value of the phantom, the computed intrinsic T_{10} value of the tissue can also be influenced by machine parameters and therefore a correct intrinsic T_{10C} value can be computed by normalizing the computed intrinsic T_{10} value by the deviation factor computed using the phantom.

[00040] In an aspect, DCE-MRI technique of the present disclosure can use contrast agents/tracers for improving the visibility of internal body structures. The contrast agents/tracers can include but are not limited to Gadolinium (Gd), Gadopentate dimeglumine Gd-DTPA and other FDA approved Gd based contrast agents such as Omniscan, Multihance, Magnevist, Prohance, OptiMARK, Dotarem. Supermagnetic iron oxide compounds are also typically used as MRI contrast agents for example Cliavist, Combidex, Feridex, Resovist etc. Supermagnetic iron platinum and paramagnetic manganese compounds also serve as MRI contrast agents.

[00041] In another aspect, the proposed method works on tumor tissue volume and can compare disease tumor volume pre therapy and post therapy. In another aspect, the proposed method is configured to find Ktrans threshold value based on experimental data performed on population of data. In yet another aspect, the proposed method eliminates the requirement for co-registration of images that is otherwise required between pre-therapy and post-therapy (voxel by voxel), and therefore there is no registration of error. In yet another aspect, subtracted images can be used to demarcate the tumor volume in pre-therapy as well as post therapy but no registration is required on image data before and after the therapy on voxel by voxel. Furthermore, demarcated tumor enhancing volume may increase after therapy, but assessing response due to therapy by measuring the number of voxels above threshold gives a better picture. This has been verified based on patient physical condition.

[00042] In an aspect, the first set of volume images and the second set of volume images can be acquired using fast Dynamic Contrast Enhanced MRI such that the images are taken every n seconds. In an aspect, n seconds can be increased or decreased based on resolution and signal to noise ratio of image data to calculate correctly the Ktrans in temporal study. According to one embodiment, method of the present disclosure can be configured to first obtain a first set of volume images before contrast. Such first set of volume images can be received, say every 4 seconds for a

minute, giving 14 images/data points through a high temporal resolution scan, making the examination time extremely quick for the patient. The method can then include obtaining a second set of volume images after contrast. Such second set of volume images can also be received, say every 4 seconds for a minute, giving 14 images through a high temporal resolution scan. Such high temporal resolution scan can be configured by means of a hardware unit that enable quick and high resolution image scans of a target tissue to be taken, wherein the hardware unit can be part of the MRI device being used and attributes thereof can be configured to enable such quick and high resolution scans to be taken. In an aspect, reducing the acquisition time for the Ktrans (or any other pharmacokinetic parameter such as v_e) yields strong accuracy.

[00043] In an aspect, the method can then include subtracting first set of volume images from the second set of volume images to obtain a third set of images that focus on enhanced tumor tissue. Method of the present disclosure can further include the step of drawing a region of interest (ROI) on each slice of the third set of images, and voxel-wise calculating a pharmacokinetic parameter value (such as Ktrans) for each slice of the third set of MR images.

[00044] Method of the present disclosure can further include the step of comparing pharmacokinetic parameter value for each voxel of each slice with respect to one or more threshold values, and classifying the voxel (indicative of whether the voxel is malignant, benign, or normal, for instance) based on the output of the comparison step. In an aspect, based on the classification, a color code and/or a symbol and/or any other unique representation (collectively referred to as color code or simply as color hereinafter) can be associated with the voxel to enable easier and quicker interpretation of the ROI.

[00045] In an aspect therefore, a color-coded pharmacokinetic parametric map can be generated for that region by giving a cut-off threshold (obtained, for instance, from a population base data set of similar cancer patients (say having the same type of neck cancer/same type breast cancer, for instance). In an instance, red color can be associated with voxels/pixels that have a pharmacokinetic parameter value greater than A, green color can be associated with voxels/pixels that have a pharmacokinetic parameter value between A and B, and blue color can be associated with voxels/pixels that have a pharmacokinetic parameter value lower than B. In an instance, the pharmacokinetic parameter can be Ktrans, and red color can be associated with

pixels/voxels that have Ktrans value > 0.6, green color can be associated with pixels/voxels that have Ktrans value between 0.3 to 0.6, and blue color can be associated with pixels/voxels that have Ktrans value < 0.3. Such a color-coded representation can therefore enable representation of near sure malignant voxels as red, probable as green, and the least as blue. In an aspect, any other pharmacokinetic parameter or a combination thereof can be incorporated, say SUV (from PET), kep, VE, ADC, among known parameters, all of which are well within the scope of the present disclosure. In an aspect, calculation of pharmacokinetic parameters such as K^{trans}, k_{ep}, and $v_e$can be done using the following formula:

$$V_e = C_{gdtissue} / C_{gdplasma}$$
$$K_{ep} = 1/ (ttP_{tissue} - ttP_{plasma})$$
$$K^{trans} = V_e * K_{ep}$$

[00046] In an aspect, post the color-coding/threshold based analysis of the voxels/pixels, another region of interest (ROI) can be drawn on each subtracted image-set (third set of images) slice-by-slice by slicing a contour of the enhancing component of the tumor, wherein the contours can be copied in the subtracted images and pasted/moved on the corresponding slices of the color coded pharmacokinetic parametric map. Post the superimposition of the contours of each slide on the pharmacokinetic parametric map, number of red pixels (indicative of malign tissue) that are present in the slices that encompass the tumor tissue can be counted.

[00047] In an aspect, the above-mentioned steps can also be performed post-therapy (chemotherapy/ Radiotherapy) to enable a user to conduct therapy response evaluation, wherein a count of the number of red pixels post therapy when compared with the number of red pixels pre-therapy can give an absolute indication of the decrease in malignant tissues, making the therapy response evaluation easier, more accurate, and quick.

[00048] In an aspect, although the present disclosure has been made with respect to head and neck cancer detection, the proposed method and technique can be applied to any imaging system used for tissue classification.

[00049] FIG. 1A illustrates exemplary Ktrans images of a study of left cheek of a patient before treatment (pre) and FIG. 1B illustrates the Ktrans images post treatment

(post) to demonstrate an embodiment of the present disclosure. In an aspect, within FIG. 1A, image 102 illustrates a first image that is taken before the contrast is injected, 104 illustrates a second image that is taken post the contrast, 106 illustrates a third image showing subtracted (pre 102 from post 104) with region of interest (ROI) drawn on the boundary of the tumor in a representative section showing largest tumor dimension. In an aspect, ROI in the subtracted image can be copy pasted on the Ktrans map to obtain the fourth image(color image) 108, wherein the red pixels are counted from a text file generated in the background showing the pixel Ktrans value with X and Y coordinates covering the drawn ROI.

[00050] In an aspect, the same process can be done post-treatment (after Radiotherapy and concurrent Chemotherapy) to obtain images as shown in 150 (152 (pre-contrast), 154 (post-contrast), 156(subtracted image), and 158 (color-coded superimposed image)), and comparison of the fourth images 158 vs. 108 can be done to evaluate the therapy effect.

[00051] In the present example, it can be noted that the volume of disease has decreased between the studies. By counting the number of red pixels (which are above a threshold value (say >.6 in case the pharmakinetic parameter is Ktrans), the number of near sure malignant voxels can be determined and compared between the two images to compute/evaluate the change pre- and post-therapy. In an aspect, by counting the number of red pixel, the change in volume is ignored, and is not allowed to influence the change in tumor behavior, unlike if we take parameters like % of red pixels in the volume etc. This is significant as the volume may be bigger in the post therapy due to intratumor hemorrhage, necrosis oedema etc. without actually increase due to the tumor (cancer) cells.

[00052] In an aspect, the subtracted image can be used for better demarcation of tumor boundary. Post contrast images can serve the purpose. In this way, image registration of pre and post images series is not required before subtraction to achieve positional accuracy. In an aspect, in the proposed method, the images do not need to participate in the Ktrans change in pixel values between pre and post treatment images as has been tried in the conventional method. In the proposed method, if there is gross motion between pre-contrast and post-contrast images, the tumor boundary could be marked in the post-contrast images without resorting to subtraction.

[00053] Table-1 indicates change the number of voxels that are associated with each color-code over a period of time for two patients. As can be seen, with passing time and therapy, the number of red pixels/voxels have come down, which is clearly indicative of a positive therapy response.

Patient Name	Patient ID	Date	Ktrans value <0.30 (Represented through Blue Color)	Ktrans value between 0.30-0.60 (Represented through Green Color)	Ktrans value >0.60 (Represented through Red Color)
Patient 1	Pre	21082013	236	1945	2130
Patient 1	Post	25022014	216	6	0
Patient 2	Pre	17012014	198	1088	1234
Patient 2	Post1	27032014	195	1130	695
Patient 2	Post2	15072014	118	699	494
Patient 2	Post3	22082014	129	319	316

Table -1

[00054] FIG. 2 illustrates an exemplary flow diagram 200 in accordance with an embodiment of the present disclosure. As shown, at step 202,a first set of volume images before contrast are obtained, and at step 204, a second set of volume images after contrast are obtained. At step 206, first set of volume images can be subtracted from the second set of volume images to obtain a third set of images that focus on enhanced tumor tissue and, at step 208, a region of interest (ROI) can be drawn on the boundary of the tumor in a representative section showing largest tumor dimension.

[00055] At step 210, a pharmacokinetic parameter map can be generated by voxel-wise comparing pharmacokinetic parameter value for each voxel of each slice with respect to one or more threshold values, and classifying/color-coding the voxel based on the output of the comparison step. At step 212, the ROI can be superimposed on the pharmacokinetic parameter map to enable easier and quicker interpretation of the ROI. At step 214, similar steps are followed post-therapy as well, and pre-therapy ROI superimposed pharmacokinetic parameter map image can be compared with post-therapy ROI superimposed pharmacokinetic parameter map image to determine/evaluate therapy response. In an aspect, for each ROI superimposed pharmacokinetic parameter map image, a Permeability Index Count (PIC) can be computed, giving a pre-therapy PIC and a post-therapy PIC, both of which can be compared to determine/evaluate therapy response. In an aspect, the PIC can be expressed for tumor volume that comes after applying threshold value.

[00056] The foregoing has described the principles, embodiments, and modes of operation of the present invention. However, the invention should not be construed as being limited to the particular embodiments described above, as they should be regarded as being illustrative and not as restrictive. It should be appreciated that variations may be made in those embodiments by those skilled in the art without departing from the scope of the present invention.

[00057] While exemplary embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of the present invention should not be limited by the above described exemplary embodiment.

[00058] Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that the invention may be practiced otherwise than as specifically described herein.

[00059] Different embodiments of the invention are able to obtain images from a wide range of image acquisition systems such as CT, US, MR, PET, PET-CT, SPECT scanners and enables evaluation of therapy response, therapeutic methods, drug effectiveness, tumoural pathology, and hot spot identification.

[00060] Although the present invention has been illustrated by reference to specific embodiments, it will be apparent to those skilled in the art that the invention is not limited to the details of the foregoing illustrative embodiments, and that the present invention may be embodied with various changes and modifications without departing from the scope thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein. In other words, it is contemplated to cover any and all modifications, variations or equivalents that fall within the scope of the basic underlying principles and whose essential attributes are claimed in this patent application. It will furthermore be understood by the reader of this patent application that the words "comprising" or "comprise" do not exclude other elements or steps, that the words "a" or "an" do not exclude a plurality, and that a single element, such as a computer system, a processor, or another integrated unit may fulfil the functions of several means recited in the claims. Any reference signs in the claims shall not be construed as limiting the respective claims concerned. The terms "first", "second", third", "a", "b", "c", and the like, when used in the description or in the claims are introduced to distinguish between similar elements or steps and are not necessarily describing a sequential or chronological order. Similarly, the terms "top", "bottom", "over", "under", and the like are introduced for descriptive purposes and not necessarily to denote relative positions. It is to be understood that the terms so used are interchangeable under appropriate circumstances and embodiments of the invention are capable of operating according to the present invention in other sequences, or in orientations different from the one(s) described or illustrated above.

[00061] All publications and patents mentioned in the above specification are herein incorporated by reference. Although the invention has been described in connection with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments.

Indeed, various modifications of the described modes for carrying out the invention that are obvious to those skilled in the relevant fields are intended to be within the scope of the following claims.

ADVANTAGES OF THE INVENTION

[00062] The present disclosure reduces examination time and enhances accuracy for response therapy evaluation in a tumor.

[00063] The present disclosure makes the MRI process comfortable for patient.

[00064] The present disclosure makes assessment of tissue classification easy and efficient through color-coding.

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We Claim:

1. A method for evaluating therapy response in a tumor, said method comprising the steps of:

obtaining a first set of volume images before contrast;

obtaining a second set of volume images post contrast;

subtracting the first set of volume images from the second set of volume images to obtain a third set of images that focus on enhanced tumor tissue;

drawing, based on the third set of images, slice-by-slice, a region of interest (ROI) on boundary of the tumor in a representative section showing largest tumor dimension;

generating a pharmacokinetic parameter map by voxel-wise comparing pharmacokinetic parameter value for each voxel of each slice with respect to one or more threshold values, and classifying the voxel based on output of the comparison step; and

superimposing the ROI on the pharmacokinetic parameter map to enable interpretation of the ROI.

2. The method of claim 1, wherein the method is also implemented post therapy, wherein comparison of interpretation of pre-therapy ROI and interpretation of post-therapy ROI enables evaluation of therapy response.

3. The method of claim 1, wherein superimposition of the ROI on the pharmacokinetic parameter map enables generation of a fourth image.

4. The method of claim 1, wherein the pharmacokinetic parameter is selected from one or a combination of Ktrans, SUV, kep, VE, and ADC.

5. The method of claim 1, wherein the voxel is classified based on association of a color code or a symbol with the voxel.

6. The method of claim 5, wherein red color code is indicative of near-malignant tissue, green color code is indicative of benign tissue, and blue color code is indicative of normal tissue.

7. The method of claim 6, wherein, in case the pharmacokinetic parameter is Ktrans, the red color code is associated when Ktrans value of the voxel is greater than 0.6, green color code is association when Ktrans value of the voxel is between 0.3 and 0.6, and blue color code is association when Ktrans value of the voxel is less than 0.3.

8. The method of claim 1, wherein change in volume is ignored and not allowed to influence change in tumor behavior.

9. The method of claim 1, wherein the first set of volume images and the second set of volume images are acquired using fast Dynamic Contrast Enhanced MRI such that the images are taken every n seconds.

10. A system for evaluating therapy response in a tumor, said system comprising:

means for obtaining a first set of volume images before contrast;

means for obtaining a second set of volume images post contrast;

means for subtracting the first set of volume images from the second set of volume images to obtain a third set of images that focus on enhanced tumor tissue;

means for drawing, based on the third set of images, slice-by-slice, a region of interest (ROI) on boundary of the tumor in a representative section showing largest tumor dimension;

means for generating a pharmacokinetic parameter map by voxel-wise comparing pharmacokinetic parameter value for each voxel of each slice with respect to one or more threshold values, and classifying the voxel based on output of the comparison step; and

means for superimposing the ROI on the pharmacokinetic parameter map to enable interpretation of the ROI.

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ABSTRACT

METHOD AND APPARATUS FOR ENHANCING ACCURACY OF TUMOUR RESPONSE THERAPY EVALUATION WITH REDUCED EXAMINATION TIME

The present disclosure relates to a method for evaluating therapy response in a tumor. In an aspect, the method can include the steps of obtaining a first set of volume images before contrast; obtaining a second set of volume images post contrast; subtracting the first set of volume images from the second set of volume images to obtain a third set of images that focus on enhanced tumor tissue; drawing, based on the third set of images, slice-by-slice, a region of interest (ROI) on boundary of the tumor in a representative section showing largest tumor dimension; generating a pharmacokinetic parameter map by voxel-wise comparing pharmacokinetic parameter value for each voxel of each slice with respect to one or more threshold values, and classifying the voxel based on output of the comparison step; and superimposing the ROI on the pharmacokinetic parameter map to enable interpretation of the ROI.

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