**FORM 2**

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The Patent Rules, 2003

**COMPLETE SPECIFICATION**

(See sections 10 & rule 13)

**1. TITLE OF THE INVENTION**

**SYSTEM AND APPARATUS FOR CALIBRATING IMAGING OF LIVING TISSUE**

**2. APPLICANT (S)**

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**3. PREAMBLE TO THE DESCRIPTION**

**COMPLETE SPECIFICATION**

The following specification particularly describes the invention and the manner in which it is to be performed.

# SYSTEM AND APPARATUS FOR CALIBRATING IMAGING OF LIVING TISSUE

## TECHNICAL FIELD

**[0001]** The present disclosure relates, in general, to imaging of living tissue using MRI and PET imaging. In particular, the present disclosure relates to calibrating imaging of living tissue using a phantom apparatus.

## BACKGROUND

**[0002]** Background description includes information that may be useful in understanding the present invention. 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]** Ktrans is a measure of capillary permeability obtained using DCE-MRI perfusion. It is calculated by measuring the accumulation of gadolinium-based contrast agent in the extravascular-extracellular space. Ktrans is a pharmacokinetic parameter that is used to quantitatively measure neovascularization of tumours or cancerous tissue to assist in classification of malignant tissue and to monitor state of the tissue during and post therapy. Ktrans reflects the efflux rate of gadolinium contrast from blood plasma into the tissue extravascular extracellular space (EES). Ktrans depends on three factors: plasma blood flow (F), vascular permeability (P), and capillary surface area (S) per unit mass. In practice, the individual contributions of permeability and surface area cannot be clearly separated, and it is therefore common to consider them together as the so-called PS product.

**[0006]** During image acquisition process in DCE-MRI, a radiofrequency (RF) pulse is emitted from the scanner. When tuned to the Larmor frequency, the RF pulse is at resonance: it creates a phase coherence in the precession of all the proton spins. The duration of the RF pulse is chosen such that it tilts the spin magnetization perpendicularly to the magnetic field. When a receiving coil (an electrical conductor) is put in the vicinity of the tissue, the transverse magnetization, that still rotates as the Larmor precession, will generate an electric current in the coil by Faraday induction: this is the nuclear magnetic resonance (NMR) signal.

**[0007]** The NMR signal is attenuated due to two simultaneous relaxation processes. The loss of coherence of the spin system attenuates the NMR signal with a time constant called the transverse relaxation time (T2). Concurrently, the magnetization vector slowly relaxes towards its equilibrium orientation that is parallel to the magnetic field: this occurs with a time constant called the spin-lattice relaxation time (T1). The contrast in MR images originates from the fact that different tissues have, in general, different T1 and T2 relaxation times; as this is especially true for soft tissues, it explains the excellent soft tissue contrast of MRI.

**[0008]** However, inhomogeneities in measured T1 values can result in inaccuracy in computation of Ktrans, leading to inaccurate assessment of tissue characteristic and affecting reproducibility.

**[0009]** There is, therefore, a requirement in the art for a means to provide for homogeneous calibration of T1 relaxation time.

**[0010]** 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.

## OBJECTS OF THE INVENTION

**[0011]** A general object of the present invention is to provide a system and a method for calibrating imaging of a living tissue.

**[0012]** Another object of the present invention is to provide a phantom apparatus for calibration of imaging of living tissue.

**[0013]** Another object of the present invention is to provide for improved globalised accuracy of images obtained of living tissue using MRI, PET and DCE-MRI images.

## SUMMARY

**[0014]** The present disclosure relates, in general, to imaging of living tissue using MRI and PET imaging. In particular, the present disclosure relates to calibrating imaging of living tissue using a phantom apparatus.

**[0015]** In an aspect, the present disclosure provides a system for calibrating imaging of living tissue. The system includes: an apparatus for calibrating imaging of living tissue, the apparatus configured to provide, on being imaged, a plurality of data points for calibrating tissue parameters for the living tissue; an imaging device configured to capture images of the apparatus; and a control unit operatively coupled with the imaging device, said control unit comprising a processor operatively coupled with a memory, said memory storing instruction executable by the processor to: measure, from the captured images, one or more imaging parameters for each plurality of data points for the tissue parameters for the living tissue. The control unit is configured to determine a correction factor for each of the measured one or more imaging parameter based on deviation of the measured one or more imaging parameters from corresponding reference values of the one or more imaging parameters for the living tissue.

**[0016]** In an embodiment, the apparatus for calibrating imaging of living tissue includes: a support surface adapted to mimic an outer surface of the living tissue to be imaged by the imaging device; and a plurality of closed tubes arranged on the support surface, each closed tube filled with a mimetic material to mimic an inside of the living tissue to be imaged by the imaging device. Each of the closed tubes on the support surface provides a data point from which one or more imaging parameters is measured for the living tissue.

**[0017]** In another embodiment, the mimetic material can include, any of partially and fully, a contrast material.

**[0018]** In another embodiment, the one or more imaging parameters can be T1 relaxation time.

**[0019]** In another embodiment, the tissue parameters is Ktrans.

**[0020]** In another embodiment, the tissue parameters are kep and VE.

**[0021]** In another embodiment, the tissue parameters is ADC.

**[0022]** In another embodiment, the tissue parameters are SUV and attenuation coefficient from PET.

**[0023]** In another embodiment, the imaging device can be any of an MRI, a Dynamic Contrast Enhanced MRI (DCE-MRI) and a PET apparatus.

**[0024]** In an aspect, the present disclosure provides a method for calibrating imaging of living tissue. The method includes the steps of: measuring, at a computing device, from

captured images of an apparatus adapted for calibration of living tissue, one or more imaging parameters for each of a plurality of data points for tissue parameters for the living tissue; and determining, at the computing device, a correction factor for each of the measured one or more imaging parameter based on deviation of the measured one or more imaging parameters from corresponding reference values of the one or more imaging parameters for the living tissue.

**[0025]** In an embodiment, the apparatus is adapted for calibrating imaging of the living tissue, the apparatus configured to provide, on being imaged, the plurality of data points for calibrating the tissue parameters for the living tissue.

**[0026]** In another embodiment, the one or more imaging parameters can be T1 relaxation time.

**[0027]** In another embodiment, the tissue parameters is Ktrans.

**[0028]** In another embodiment, the tissue parameters are kep and VE.

**[0029]** In another embodiment, the tissue parameters is ADC.

**[0030]** In another embodiment, the tissue parameters are SUV and attenuation coefficient from PET.

**[0031]** 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 DRAWINGS

**[0032]** The accompanying drawings are included to provide a further understanding of the present invention and are incorporated in and constitute a part of this specification. The drawings illustrate exemplary embodiments of the present invention and, together with the description, serve to explain the principles of the present invention.

**[0033]** FIG. 1A illustrates an exemplary view of a phantom apparatus for imaging of a tissue sample, in accordance with an embodiment of the present disclosure.

**[0034]** FIG. 1B illustrates an exemplary representation of a phantom tube, in accordance with an embodiment of the present disclosure.

**[0035]** FIG. 1C illustrates an exemplary representation of use of the proposed phantom apparatus in a mMR breast coil, in accordance with an embodiment of the present disclosure.

**[0036]** FIG. 2 illustrates an exemplary view of synchronised patient and phantom apparatus study, in accordance with an embodiment of the present disclosure.

**[0037]** FIGs. 3A and 3B illustrate exemplary box plot of non – corrected and corrected T1 values for fibro-glandular tissue and fat respectively, in accordance with an embodiment of the present disclosure.

**[0038]** FIG. 4 illustrates an exemplary flow diagram to calibrate imaging of a living tissue, in accordance with an embodiment of the present disclosure.

## DETAILED DESCRIPTION

**[0039]** The following is a detailed description of embodiments of the disclosure depicted in the accompanying drawings. The embodiments are in such detail as to clearly communicate the disclosure. However, the amount of detail offered is not intended to limit the anticipated variations of embodiments; on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the present disclosure as defined by the appended claims.

**[0040]** If the specification states a component or feature "may", "can", "could", or "might" be included or have a characteristic, that particular component or feature is not required to be included or have the characteristic.

**[0041]** 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.

**[0042]** Exemplary embodiments will now be described more fully hereinafter with reference to the accompanying drawings, in which exemplary embodiments are shown. These exemplary embodiments are provided only for illustrative purposes and so that this disclosure will be thorough and complete and will fully convey the scope of the invention to those of ordinary skill in the art. The invention disclosed may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Various modifications will be readily apparent to persons skilled in the art. The general principles defined herein may be applied to other embodiments and applications without departing from the spirit and scope of the invention. Moreover, all statements herein reciting embodiments of the invention, as well as specific examples thereof, are intended to encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents as well as equivalents developed in the future (i.e., any elements developed that perform the same function, regardless of structure). Also, the terminology and phraseology used is for the purpose of describing exemplary embodiments

and should not be considered limiting. Thus, the present invention is to be accorded the widest scope encompassing numerous alternatives, modifications and equivalents consistent with the principles and features disclosed. For purpose of clarity, details relating to technical material that is known in the technical fields related to the invention have not been described in detail so as not to unnecessarily obscure the present invention.

**[0043]** 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.

**[0044]** The present disclosure relates, in general, to imaging of living tissue using MRI and PET imaging. In particular, the present disclosure relates to calibrating imaging of living tissue using a phantom apparatus.

**[0045]** In an aspect, the present disclosure provides a system for calibrating imaging of living tissue. The system includes: an apparatus for calibrating imaging of living tissue, the apparatus configured to provide, on being imaged, a plurality of data points for calibrating tissue parameters for the living tissue; an imaging device configured to capture images of the apparatus; and a control unit operatively coupled with the imaging device, said control unit comprising a processor operatively coupled with a memory, said memory storing instruction executable by the processor to: measure, from the captured images, one or more imaging parameters for each plurality of data points for the tissue parameters for the living tissue. The control unit is configured to determine a correction factor for each of the measured one or more imaging parameter based on deviation of the measured one or more imaging parameters from corresponding reference values of the one or more imaging parameters for the living tissue.

**[0046]** In an embodiment, the apparatus for calibrating imaging of living tissue includes: a support surface adapted to mimic an outer surface of the living tissue to be imaged by the imaging device; and a plurality of closed tubes arranged on the support surface, each closed tube filled with a mimetic material to mimic an inside of the living tissue to be imaged by the imaging device. Each of the closed tubes on the support surface provides a data point from which one or more imaging parameters is measured for the living tissue.

**[0047]** In another embodiment, the mimetic material can include, any of partially and fully, a contrast material.

**[0048]** In another embodiment, the one or more imaging parameters can be T1 relaxation time.

**[0049]** In another embodiment, the tissue parameters is Ktrans.

**[0050]** In another embodiment, the tissue parameters are kep and VE.

**[0051]** In another embodiment, the tissue parameters is ADC.

**[0052]** In another embodiment, the tissue parameters are SUV and attenuation coefficient from PET.

**[0053]** In another embodiment, the imaging device can be any of an MRI, a Dynamic Contrast Enhanced MRI (DCE-MRI) and a PET apparatus.

**[0054]** In an aspect, the present disclosure provides a method for calibrating imaging of living tissue. The method includes the steps of: measuring, at a computing device, from captured images of an apparatus adapted for calibration of living tissue, one or more imaging parameters for each of a plurality of data points for tissue parameters for the living tissue; and determining, at the computing device, a correction factor for each of the measured one or more imaging parameter based on deviation of the measured one or more imaging parameters from corresponding reference values of the one or more imaging parameters for the living tissue.

**[0055]** In an embodiment, the apparatus is adapted for calibrating imaging of the living tissue, the apparatus configured to provide, on being imaged, the plurality of data points for calibrating the tissue parameters for the living tissue.

**[0056]** In another embodiment, the one or more imaging parameters can be T1 relaxation time.

**[0057]** In another embodiment, the tissue parameters is Ktrans.

**[0058]** In another embodiment, the tissue parameters are kep and VE.

**[0059]** In another embodiment, the tissue parameters is ADC.

**[0060]** In another embodiment, the tissue parameters are SUV and attenuation coefficient from PET.

**[0061]** FIG. 1A illustrates an exemplary view of a phantom apparatus for imaging of a tissue sample, in accordance with an embodiment of the present disclosure. The phantom apparatus 100 (hereinafter, also referred to as “phantom”) can include a support surface with contours to mimic the tissue sample to be imaged. The support surface can be made of a material such as porous polystyrene (such as thermacol). In an embodiment, the support surface can be made of other tissue mimicking materials such as silicone, PMMA, epoxy resins etc.

**[0062]** The present disclosure, in an exemplary implementation, can relate to human breast tissue imaging using an MRI scan, and the proposed phantom apparatus 100 can be for breast tissue imaging. In particular, the present disclosure can relate to imaging of cancerous breast tissue, with imaging done using a contrast material. It would be appreciated that a similar

phantom apparatus, with appropriate modifications can be used for imaging of other tissues within a human body.

**[0063]** The proposed phantom apparatus 100, in an implementation of the present disclosure, is used to determine a global normalisation of T1 values sensed across the breast coil. The use of a plurality of phantom tubes 104 facilitates better normalisation of measured T1 values as a plurality of data points for the normalisation is available after imaging. The normalised T1 value allows for applying a correction factor to more accurately image the breast tissue during MRI scans.

**[0064]** The phantom 100 can include two support surfaces (102-1, 102-2; hereinafter, individually and collectively designated 102), one for each breast. A plurality of phantom tubes (104-1, 104-2…1-4-n; hereinafter, individually and collectively designated 104) can be installed in each of the support surfaces 102. Each phantom tube 104 is installed with a predetermined gap between any two phantom tubes 104. In an exemplary embodiment, the predetermined gap can be about 2cm.

**[0065]** In an exemplary embodiment, nineteen phantom tubes 104 are used on each support surface 102, with the nineteen phantom tubes 104 on each support surface 102 being arranged in four rows containing, 3, 4, 5, 4 and 3 phantom tubes, respectively. This arrangement provides full and uniform coverage of the support surfaces 102 with the phantom tubes 104.

**[0066]** FIG. 1B illustrates an exemplary representation of a phantom tube, in accordance with an embodiment of the present disclosure. The phantom tube 104 can have dimensions such as length of about 16 cm, and a dimeter of about 4 cm.

**[0067]** FIG. 1C illustrates an exemplary representation of use of the proposed phantom apparatus in a mMR breast coil, in accordance with an embodiment of the present disclosure. The phantom apparatus 100 including the support surfaces 102 and the phantom tubes 104 on each support surface 102 are placed horizontally such that the imaging field of each cuff space of the breast coil 106 is fully and uniformly covered with phantom tubes 104. Each phantom tube 104 is filled with a contrast material 108 such as, but 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. In an exemplary embodiment, the contrast material used can be a mixture of water and 0.1mmol Gd-DTPA (diethylenetriamine penta-acetic acid gadodiamide (Omniscan) in the ratio 10:1.

**[0068]** Ktrans is a measure of capillary permeability obtained using DCE-MRI perfusion. It is calculated by measuring the accumulation of gadolinium-based contrast agent in the extravascular-extracellular space. Ktrans is a pharmacokinetic parameter that is used to quantitatively measure neovascularization of tumours or cancerous tissue to assist in classification of malignant tissue and to monitor state of the tissue during and post therapy. Ktrans reflects the efflux rate of gadolinium contrast from blood plasma into the tissue extravascular extracellular space (EES). Ktrans depends on three factors: plasma blood flow (F), vascular permeability (P), and capillary surface area (S) per unit mass. In practice, the individual contributions of permeability and surface area cannot be clearly separated, and it is therefore common to consider them together as the so-called PS product.

**[0069]** During image acquisition process in DCE-MRI, a radiofrequency (RF) pulse is emitted from the scanner. When tuned to the Larmor frequency, the RF pulse is at resonance: it creates a phase coherence in the precession of all the proton spins. The duration of the RF pulse is chosen such that it tilts the spin magnetization perpendicularly to the magnetic field. When a receiving coil (an electrical conductor) is put in the vicinity of the tissue, the transverse magnetization, that still rotates as the Larmor precession, will generate an electric current in the coil by Faraday induction: this is the nuclear magnetic resonance (NMR) signal.

**[0070]** The NMR signal is attenuated due to two simultaneous relaxation processes. The loss of coherence of the spin system attenuates the NMR signal with a time constant called the transverse relaxation time (T2). Concurrently, the magnetization vector slowly relaxes towards its equilibrium orientation that is parallel to the magnetic field: this occurs with a time constant called the spin-lattice relaxation time (T1). The contrast in MR images originates from the fact that different tissues have, in general, different T1 and T2 relaxation times; as this is especially true for soft tissues, it explains the excellent soft tissue contrast of MRI.

**[0071]** In particular, Ktrans measurement requires accurate values of T1 time to be observed. Using breast coils present in the art, inhomogeneity in T1 values across the surface of the breast coil is observed, which causes a consequent error in computation of Ktrans.

**[0072]** In the present implementation of the disclosure, the DCE-MRI technique can use the contrast material for improving the visibility of internal body structures. The proposed system 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 a population of data obtained from the DCE-MRI technique.

**[0073]** Referring to FIGs. 1A – 1C, the phantom apparatus 100 is placed in the breast coils 106 and T1 relaxation times are measured at the phantom tubes 104. Reference T1 times for the contrast material used (Omniscan) is known for different spatial locations across the support surface 102 where the phantom tubes 104 are placed, and the measured T1 relaxation times are compared with the reference times.

**[0074]** In another embodiment, a control unit (not shown in figure) operatively coupled with the MRI device can determine correction factors for T1 based on deviation of measures T1 times from the reference T1 values and the correction factors are applied at the different spatial locations to achieve homogeneity in accuracy of measured T1 values across the coil support surface 102.

**[0075]** The correction factor is calculated as,

$$\boldsymbol{Cf_n = \frac{Pht1 - t1_n}{Pht1}}$$

$Cf_n$ is the correction factor for phantom tube n;

$t1_n$ is the reference T1 value at the phantom tube n; and

Pht1 is the measured T1 value by the phantom tube.

**[0076]** The corrected T1 relaxation time is given by,

$$\boldsymbol{Ct1_n = UCt1_n + (UCt1_n * Cf_n)}$$

Ct1n is the corrected value of T1 relaxation time; and

UCt1n is the non-corrected value of T1 relaxation time.

**[0077]** FIG. 2 illustrates an exemplary view of synchronised patient and phantom apparatus study, in accordance with an embodiment of the present disclosure.

**[0078]** Table – 1 below provides a distribution of T1 values using the proposed phantom apparatus 100 before and after correction factors are applied at the different spatial locations on both sides of the breast coil. A p value of less than 0.05 is observed.

| **Tube No.** | **Non – Corrected T1 values** | | **Corrected T1 values** | |
|---|---|---|---|---|
| | **Right Side** | **Left Side** | **Right Side** | **Left Side** |
| 1 | 6.79 | 5.54 | 6.25 | 6.20 |
| 2 | 6.24 | 6.38 | 6.29 | 6.29 |
| 3 | 4.80 | 5.80 | 5.94 | 6.25 |
| 4 | 6.80 | 5.99 | 6.25 | 6.28 |
| 5 | 6.85 | 7.08 | 6.24 | 6.19 |

| | | | | |
|---|---|---|---|---|
| 6 | 6.71 | 6.82 | 6.26 | 6.24 |
| 7 | 4.77 | 6.25 | 5.92 | 6.29 |
| 8 | 7.08 | 5.29 | 6.19 | 6.13 |
| 9 | 7.61 | 6.90 | 6.01 | 6.23 |
| 10 | 7.07 | 7.33 | 6.19 | 6.12 |
| 11 | 5.98 | 7.36 | 6.27 | 6.11 |
| 12 | 4.19 | 5.42 | 5.59 | 6.17 |
| 13 | 7.59 | 5.92 | 6.02 | 6.27 |
| 14 | 7.34 | 6.63 | 6.11 | 6.27 |
| 15 | 6.79 | 7.09 | 6.25 | 6.19 |
| 16 | 5.48 | 6.71 | 6.19 | 6.26 |
| 17 | 6.34 | 5.17 | 6.29 | 6.09 |
| 18 | 6.33 | 5.74 | 6.29 | 6.24 |
| 19 | 5.12 | 6.31 | 6.07 | 6.29 |
| 20 | 6.24 | 4.76 | 6.29 | 5.92 |
| 21 | 6.18 | 4.72 | 6.29 | 5.90 |
| 22 | 5.19 | 4.45 | 6.10 | 5.75 |
| 23 | 6.44 | 5.39 | 6.29 | 6.16 |
| 24 | 7.01 | 5.60 | 6.21 | 6.21 |
| 25 | 5.75 | 5.88 | 6.24 | 6.26 |
| 26 | 4.71 | 5.51 | 5.89 | 6.19 |
| 27 | 7.34 | 5.18 | 6.12 | 6.09 |
| 28 | 6.76 | 6.56 | 6.26 | 6.28 |
| 29 | 7.05 | 6.01 | 6.20 | 6.28 |
| 30 | 5.73 | 5.68 | 6.24 | 6.23 |
| 31 | 3.13 | 4.52 | 4.70 | 5.79 |
| 32 | 6.89 | 5.29 | 6.23 | 6.13 |
| 33 | 7.01 | 5.50 | 6.21 | 6.19 |
| 34 | 6.26 | 4.97 | 6.29 | 6.01 |
| 35 | 4.48 | 5.17 | 5.77 | 6.09 |
| 36 | 6.27 | 4.62 | 6.29 | 5.85 |
| 37 | 5.83 | 5.21 | 6.26 | 6.10 |

| | | | | |
|---|---|---|---|---|
| 38 | 4.14 | 5.50 | 5.56 | 6.19 |
| 39 | 6.69 | 5.02 | 6.26 | 6.03 |
| 40 | 6.36 | 4.23 | 6.29 | 5.61 |
| 41 | 6.79 | 4.63 | 6.25 | 5.85 |
| 42 | 5.98 | 5.96 | 6.27 | 6.27 |
| 43 | 5.69 | 4.46 | 6.23 | 5.76 |
| 44 | 5.87 | 4.65 | 6.26 | 5.86 |
| 45 | 7.09 | 5.55 | 6.19 | 6.20 |
| 46 | 4.91 | 7.26 | 5.99 | 6.14 |
| 47 | 6.10 | 5.23 | 6.28 | 6.11 |
| 48 | 4.45 | 3.59 | 5.75 | 5.13 |
| 49 | 6.93 | 5.09 | 6.22 | 6.06 |
| 50 | 8.08 | 4.69 | 5.78 | 5.88 |
| 51 | 5.22 | 3.80 | 6.11 | 5.31 |
| 52 | 5.10 | 3.68 | 6.06 | 5.20 |
| 53 | 4.86 | 4.24 | 5.96 | 5.62 |
| 54 | 7.16 | 4.79 | 6.17 | 5.93 |
| 55 | 5.49 | 2.98 | 6.19 | 4.55 |
| 56 | 5.32 | 3.43 | 6.14 | 4.99 |
| 57 | 6.30 | 3.02 | 6.29 | 4.59 |
| Mean | 6.08 | 5.38 | 6.12 | 5.98 |
| SD | 1.02 | 1.06 | 0.26 | 0.40 |
| P value | 0.00049 | | 0.031 | |

**[0079]** FIGs. 3A and 3B illustrate exemplary box plot of non – corrected and corrected T1 values for fibro-glandular tissue and fat respectively, in accordance with an embodiment of the present disclosure.

**[0080]** Table – 2 below provides a distribution of T1 values for fibro-glandular tissue and fat before and after correction factors are applied on both sides of the breast coil. A p value of less than 0.05 is observed. Here,

- NC GT T1 – non – corrected T1 value for fibro-glandular tissue;
- C GT T1 – corrected T1 value for fibro-glandular tissue;
- NC Fat T1 – non – corrected T1 value for fat;

- C Fat T1 – corrected T1 value for fat.

| | NC GT T1 | | C GT T1 | | NC Fat T1 | | C Fat T1 | |
|---|---|---|---|---|---|---|---|---|
| | **Right** | **Left** | **Right** | **Left** | **Right** | **Left** | **Right** | **Left** |
| 1 | 1703.91 | 1511.26 | 1460.54 | 1446.14 | 394.27 | 363.25 | 373.72 | 380.38 |
| 2 | 774.69 | 550.73 | 764.73 | 769.34 | 350.64 | 345.57 | 381.90 | 388.60 |
| 3 | 1985.58 | 1285.73 | 1538.76 | 1538.03 | 386.25 | 332.90 | 390.92 | 398.05 |
| 4 | 667.67 | 475.22 | 659.09 | 663.86 | 406.49 | 348.56 | 383.06 | 394.31 |
| 5 | 1620.75 | 1498.11 | 1605.58 | 1620.39 | 352.99 | 332.22 | 398.65 | 405.24 |
| 6 | 2173.91 | 1608.68 | 2145.95 | 2167.43 | 473.06 | 310.57 | 394.46 | 398.86 |
| 7 | 681.88 | 1141.61 | 1054.30 | 1092.42 | 333.24 | 327.38 | 392.89 | 387.22 |
| 8 | 1923.71 | 1104.26 | 1426.35 | 1476.98 | 329.20 | 245.83 | 394.41 | 375.47 |
| 9 | 1236.72 | 700.60 | 1184.11 | 985.31 | 313.09 | 243.64 | 391.81 | 362.59 |
| 10 | 1294.17 | 682.91 | 1197.78 | 1043.07 | 388.68 | 297.58 | 393.39 | 381.14 |
| 11 | 1445.67 | 1430.20 | 1432.14 | 1494.15 | 373.01 | 261.62 | 405.18 | 389.34 |
| 12 | 1450.88 | 848.37 | 1284.45 | 1252.14 | 343.05 | 308.55 | 381.95 | 380.40 |
| 13 | 2267.71 | 1366.46 | 1808.16 | 1846.17 | 359.19 | 283.90 | 405.13 | 388.99 |
| 14 | 3414.93 | 1455.28 | 1549.85 | 1523.91 | 409.67 | 287.41 | 380.17 | 387.24 |
| 15 | 1445.43 | 1319.47 | 1600.99 | 1626.74 | 361.38 | 311.43 | 393.59 | 390.60 |
| 16 | 1638.69 | 1418.55 | 1544.81 | 1592.42 | 343.83 | 304.49 | 405.37 | 396.88 |
| 17 | 429.88 | 518.95 | 556.85 | 589.33 | 385.06 | 304.44 | 393.14 | 386.64 |
| 18 | 2345.13 | 1377.66 | 1933.87 | 1924.52 | 374.45 | 306.58 | 385.49 | 374.58 |
| 19 | 1725.40 | 466.54 | 1250.31 | 712.58 | 351.02 | 256.97 | 401.96 | 382.42 |
| 20 | 864.09 | 449.74 | 769.74 | 686.92 | 418.70 | 313.35 | 382.15 | 391.41 |
| 21 | 1297.20 | 802.67 | 1189.75 | 1150.07 | 371.47 | 315.11 | 388.40 | 377.72 |
| 22 | 1381.18 | 685.69 | 1176.27 | 1047.32 | 436.12 | 298.99 | 389.42 | 389.70 |
| 23 | 959.44 | 1280.86 | 1131.17 | 1178.35 | 341.22 | 343.88 | 390.36 | 390.75 |
| 24 | 3354.35 | 1406.06 | 2487.11 | 2075.26 | 522.22 | 335.05 | 395.29 | 400.80 |
| 25 | 2307.16 | 1486.32 | 1831.25 | 1858.03 | 461.53 | 289.57 | 390.10 | 390.15 |
| 26 | 1343.63 | 1365.45 | 1326.35 | 1359.12 | 428.67 | 373.13 | 381.58 | 399.45 |
| 27 | 446.96 | 573.95 | 485.59 | 516.47 | 437.87 | 311.94 | 373.65 | 376.57 |
| 28 | 1613.30 | 1602.57 | 1707.13 | 1746.54 | 396.36 | 351.22 | 381.95 | 399.09 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 29 | 1015.40 | 1221.65 | 1250.59 | 1240.93 | 341.11 | 292.69 | 390.61 | 391.49 |
| 30 | 1298.82 | 1539.51 | 1623.34 | 1683.77 | 392.74 | 365.68 | 387.40 | 395.59 |
| 31 | 2457.37 | 2149.68 | 2353.52 | 2431.84 | 398.17 | 394.97 | 394.44 | 405.66 |
| 32 | 1736.94 | 945.44 | 1663.04 | 1444.05 | 462.31 | 327.99 | 390.75 | 389.87 |
| 33 | 2597.19 | 1383.24 | 2195.22 | 2041.58 | 370.61 | 293.32 | 365.95 | 373.60 |
| 34 | 1622.16 | 992.23 | 1413.88 | 1377.28 | 396.86 | 320.16 | 383.63 | 400.12 |
| 35 | 2111.79 | 1425.81 | 2083.09 | 2065.23 | 413.92 | 302.56 | 383.09 | 397.02 |
| 36 | 1683.74 | 1507.27 | 1801.90 | 1847.94 | 477.63 | 279.45 | 363.25 | 377.55 |
| 37 | 1245.96 | 855.62 | 1234.30 | 1187.66 | 403.27 | 288.09 | 380.38 | 378.04 |
| 38 | 872.38 | 461.16 | 807.40 | 667.97 | 380.08 | 346.45 | 384.68 | 396.17 |
| 39 | 1895.63 | 905.24 | 1762.49 | 1336.08 | 363.02 | 905.24 | 394.32 | 458.45 |
| 40 | 1539.70 | 1141.13 | 1342.00 | 1399.05 | 485.26 | 271.42 | 400.16 | 397.86 |
| 41 | 1958.51 | 1636.82 | 1854.17 | 1851.67 | 419.78 | 307.46 | 374.82 | 394.83 |
| 42 | 1909.47 | 1218.05 | 1828.24 | 1738.71 | 463.39 | 273.17 | 396.35 | 381.61 |
| 43 | 544.71 | 561.58 | 642.21 | 732.51 | 420.70 | 345.32 | 396.45 | 398.82 |
| 44 | 888.46 | 826.60 | 981.89 | 1017.25 | 429.62 | 355.13 | 380.77 | 387.87 |
| 45 | 1707.04 | 1357.30 | 1685.56 | 1670.37 | 459.38 | 321.56 | 388.28 | 378.32 |
| 46 | 549.14 | 417.12 | 647.43 | 586.97 | 418.33 | 341.66 | 386.69 | 388.04 |
| Mean | 1552.79 | 1107.81 | 1418.98 | 1376.17 | 398.67 | 326.90 | 388.31 | 390.34 |
| SD | 684.47 | 420.14 | 483.67 | 482.61 | 47.38 | 93.41 | 9.41 | 13.91 |
| P Value | 0.0003* | | 0.542 | | 0.00001* | | 0.414 | |

**[0081]** FIG. 4 illustrates an exemplary flow diagram to calibrate imaging of a living tissue, in accordance with an embodiment of the present disclosure. The method 400 includes the steps of:

- 402 – measuring, from captured images of an apparatus adapted for calibration of living tissue, one or more imaging parameters for each of a plurality of data points for tissue parameters for the living tissue; and
- 404 – determining a correction factor for each of the measured one or more imaging parameter based on deviation of the measured one or more imaging parameters from corresponding reference values of the one or more imaging parameters for the living tissue.

**[0082]** Thus, the present disclosure provides a phantom apparatus and a method for the phantom apparatus that significantly improves homogeneity of measured T1 values during DCE-MRI scans across breast coil for breast MRI.

**[0083]** It should be apparent to those skilled in the art that many more modifications besides those already described are possible without departing from the inventive concepts herein. The inventive patent matter, therefore, is not to be restricted except in the spirit of the appended claims. Moreover, in interpreting both the specification and the claims, all terms should be interpreted in the broadest possible manner consistent with the context. In particular, the terms "includes" and "including" should be interpreted as referring to elements, components, or steps in a non-exclusive manner, indicating that the referenced elements, components, or steps may be present, or utilized, or combined with other elements, components, or steps that are not expressly referenced. Where the specification claims refer to at least one of something selected from the group consisting of A, B, C ….and N, the text should be interpreted as requiring only one element from the group, not A plus N, or B plus N, etc. The foregoing description of the specific embodiments will so fully reveal the general nature of the embodiments herein that others can, by applying current knowledge, readily modify and/or adapt for various applications such specific embodiments without departing from the generic concept, and, therefore, such adaptations and modifications should and are intended to be comprehended within the meaning and range of equivalents of the disclosed embodiments. It is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation. Therefore, while the embodiments herein have been described in terms of preferred embodiments, those skilled in the art will recognize that the embodiments herein can be practised with modification within the spirit and scope of the appended claims.

**[0084]** While the foregoing describes various embodiments of the invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof. The scope of the invention is determined by the claims that follow. The invention is not limited to the described embodiments, versions or examples, which are included to enable a person having ordinary skill in the art to make and use the invention when combined with information and knowledge available to the person having ordinary skill in the art.

## ADVANTAGES OF THE INVENTION

**[0085]** The present invention provides a system and a method for calibrating imaging of a living tissue.

**[0086]** The present invention provides a phantom apparatus for calibration of imaging of living tissue.

**[0087]** The present invention provides for improved globalised accuracy of images obtained of living tissue using MRI, PET and DCE-MRI images.

**For House Of Diagnostics LLP et. al.**

**Tarun Khurana**

**Regd. Patent Agent [IN/PA-1325]**

**Dated: 08th May, 2020**

**We Claim:**

1. A system for calibrating imaging of living tissue, said system comprising:

   an apparatus for calibrating imaging of living tissue, the apparatus configured to provide, on being imaged, a plurality of data points for calibrating tissue parameters for the living tissue;

   an imaging device configured to capture images of the apparatus; and

   a control unit operatively coupled with the imaging device, said control unit comprising a processor operatively coupled with a memory, said memory storing instruction executable by the processor to:

   measure, from the captured images, one or more imaging parameters for each plurality of data points for the tissue parameters for the living tissue,

   wherein the control unit is configured to determine a correction factor for each of the measured one or more imaging parameter based on deviation of the measured one or more imaging parameters from corresponding reference values of the one or more imaging parameters for the living tissue.
2. The system as claimed in claim 1, wherein the apparatus for calibrating imaging of living tissue comprises:

   a support surface adapted to mimic a body of the living tissue to be imaged by the imaging device; and

   a plurality of closed tubes arranged on the support surface, each closed tube filled with a mimetic material to mimic an inside of the living tissue to be imaged by the imaging device,

   wherein each of the closed tubes on the support surface provides a data point from which one or more imaging parameters is measured for the living tissue.
3. The system as claimed in claim 2, wherein the mimetic material comprises, any of partially and fully, a contrast material.
4. The system as claimed in claim 1, wherein the one or more imaging parameters is T1 relaxation time.
5. The system as claimed in claim 1, wherein the tissue parameters is Ktrans.
6. The system as claimed in claim 1, wherein the tissue parameters are kep and VE.
7. The system as claimed in claim 1, wherein the tissue parameters is ADC.
8. The system as claimed in claim 1, wherein the tissue parameters are SUV and attenuation coefficient from PET.

9. The system as claimed in claim 1, wherein the imaging device is any of an MRI, a Dynamic Contrast Enhanced MRI (DCE-MRI) and a PET apparatus.
10. A method for calibrating imaging of living tissue, said method comprising the steps of:

    measuring, at a computing device, from captured images of an apparatus adapted for calibration of living tissue, one or more imaging parameters for each of a plurality of data points for tissue parameters for the living tissue; and

    determining, at the computing device, a correction factor for each of the measured one or more imaging parameter based on deviation of the measured one or more imaging parameters from corresponding reference values of the one or more imaging parameters for the living tissue.
11. The method as claimed in claim 10, wherein the apparatus is adapted for calibrating imaging of the living tissue, the apparatus configured to provide, on being imaged, the plurality of data points for calibrating the tissue parameters for the living tissue.
12. The method as claimed in claim 10, wherein the one or more imaging parameters is T1 relaxation time.
13. The method as claimed in claim 10, wherein the tissue parameters is Ktrans.
14. The method as claimed in claim 10, wherein the tissue parameters are kep and VE.
15. The method as claimed in claim 10, wherein the tissue parameters is ADC.
16. The method as claimed in claim 10, wherein the tissue parameters are SUV and attenuation coefficient from PET.

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**Dated: 08th May, 2020**

## ABSTRACT

**SYSTEM AND APPARATUS FOR CALIBRATING IMAGING OF LIVING TISSUE**

The present disclosure provides a system for calibrating imaging of living tissue. The system includes: an apparatus for calibrating imaging of living tissue. The apparatus includes: a support surface; and a plurality of closed tubes arranged on the support surface, each closed tube filled with a mimetic material to mimic an inside of the living tissue to be imaged by the imaging device. The system further includes an imaging device configured to capture images of the apparatus; and a control unit operatively coupled with the imaging device, said control unit comprising a processor operatively coupled with a memory, said memory storing instruction executable by the processor to: measure, from the captured images, one or more imaging parameters for each plurality of data points for the tissue parameters for the living tissue. The control unit is configured to determine a correction factor for each of the measured one or more imaging parameter based on deviation of the measured one or more imaging parameters from corresponding reference values of the one or more imaging parameters for the living tissue.


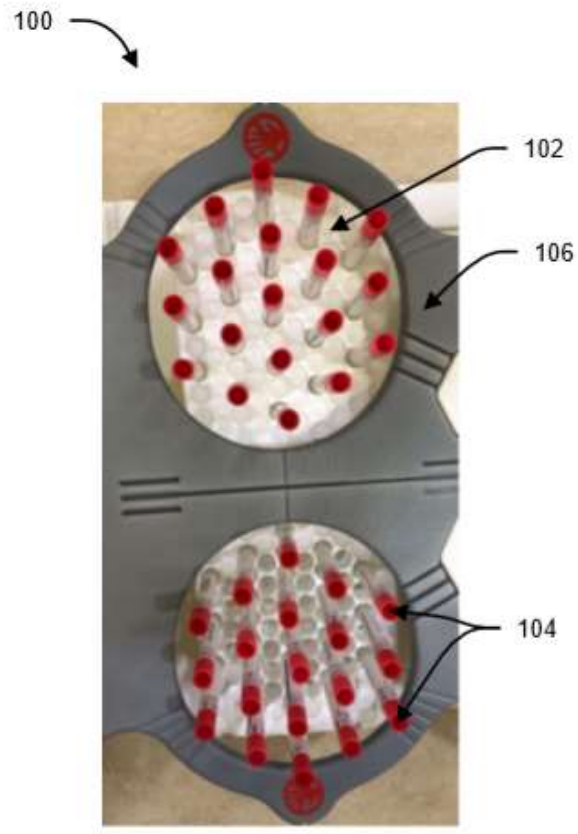


FIG. 1A


FIG. 1B

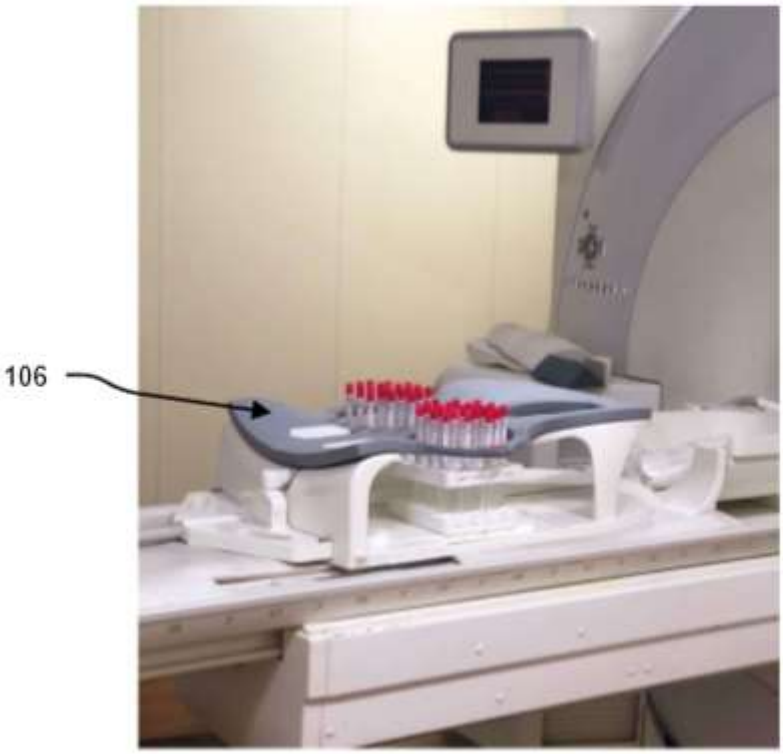


FIG. 1C

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