Allowed Claims

1. A computer apparatus and color encoding scheme to facilitate the interpretation and analysis of a multi-echo chemical shift encoded (CSE) MRI of a vertebrate organism, comprising:

(a) a non-transitory memory storing images generated from a gradient echo (GRE containing) multi-echo CSE MRI sequence;

(b) a program stored in the non-transitory memory and operatively configured to generate a three-dimensional color space composite output image utilizing at least three stored images as inputs, wherein:

(i) the at least three input images are inherently co-registered and have at least three different image types selected from the group consisting of in-phase (IP), opposed-phase (OP), water (W), fat (F), R2* (1/T2*), and derivatives of these;

(ii) output image voxels whose MRI signal derives at least in part from water protons approach grayscale as the contribution of lipid protons and T2* signal decay approach zero;

(iii) output image voxels exhibit a color that deviates from gray based in part on lipid proton content and T2* signal decay; and

(iv) at least a portion of the output image voxels exhibit a color that includes and provides information from corresponding voxels in each of the input images; and

(c) a computer processor in communication with the non-transitory memory and configured to perform the program by executing computer executable instructions.

2. The apparatus of claim 1, wherein the at least three images include Dixon in phase (IP), opposed phase (OP), and derived water (W) images.

3. The apparatus of claim 1, wherein at least a portion of the stored images are obtained using the iterative decomposition of water with echo asymmetry and least-squares estimation (IDEAL) technique.

4. The apparatus of claim 1 wherein the color composite image is encoded in the RGB color space.

5. The apparatus of claim 4, wherein the at least three image maps include OP, IP, and W series, each of which is assigned a different color channel selected from R, G, and B in the RGB color space.

6. The apparatus and method of claim 5 wherein the OP, IP, and W series are respectively assigned to the R, G, and B channels.

7. The apparatus of claim 2, wherein the color space is CIE L*a*b*.

8. The apparatus of claim 1, wherein the color space is CIE L*a*b* and wherein:

L = IP + OP, a = (IP -OP)/ (IP + OP), and b = (IP + OP – 2W) / (IP + OP); or L = x* (IP + OP), a = y* (IP – OP), b = z* (IP + OP – 2W).

9. The apparatus of claim 8 wherein x = 50, y = 100, and z = 50.

10. The apparatus of claim 1 wherein soft tissue voxels containing both iron and fat are identified and specially encoded to enhance their conspicuity.

11. The apparatus of claim 10 wherein the soft tissue voxels are identified by the Boll technique, by comparing to reference soft tissue voxels that are not expected to contain iron or fat, or by comparison to a co-registered longer echo train CSE MRI that demonstrates the presence of both steatosis and iron overload.

12. The apparatus of claim 10 wherein the voxels are uniquely color encoded.

13. The apparatus of claim 1, wherein the color space composites generated are used as an input in an artificial intelligence application.

14. The apparatus of Claim 13, wherein the artificial intelligence application involves computer vision and relies on transfer learning of convolutional neural networks pretrained with color images.

15. The apparatus of claim 1, wherein the acquired images are selected from the group consisting of gradient echo images, spin echo images, and combinations thereof.

16. The apparatus of claim 1, wherein the derived images are selected from the group consisting of PDFF (proton density fat fraction), PDWF (proton density water fraction), R2*, T2*, W (water), F (fat), W%, or F%.

17. The apparatus of claim 1, wherein the multi-echo chemical shift encoded (CSE) MRI sequence is a dual echo (two point) Dixon sequence

18. The apparatus of claim 17, wherein the dual echoes are gradient echoes, the first being opposed phase and the second being in phase.

19. The computer apparatus of claim 1, further comprising:

a graphical user interface configured to display the color composite image on a display screen and receive input from a user for selecting one or more voxels being displayed, wherein in response to the selection, one or more values of the selected one or more voxels are displayed on the graphical user interface.

20. The computer apparatus of claim 19, wherein the one or more values are selected from one or more of the following or combinations thereof:

(i) RGB values;

(ii) an input value from which the RGB values are derived,

(iii) intensity values of a chemical shift encoded MRI's echo train;

(iv) a plot of the echo train values;

(v) derivable values from a chemical shift encoded MRI; or

(vi) intensity or derivable values from another MRI series that is co-registered to the color composite being interrogated.