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(54) Title: METHOD OF CORRECTING INHOMOGENEITIES / DISCONTINUITIES IN MR PERFUSION IMAGES

(57) Abstract: The invention relates to a method of correcting inhomogeneities / discontinuities in MR perfusion images of the myocardium of a patient, which perfusion images relate time-sequentially to a preliminary phase which precedes the administration of a contrast medium and to an examination phase which succeeds the administration of the contrast medium, the perfusion images from the examination phase being corrected, in a correction step, for a detected intensity variation of the perfusion images from the preliminary phase, the perfusion images from the preliminary phase being transformed, prior to the correction step, in such a manner that pixels or groups of pixels thereof register with corresponding pixels or groups of pixels of the perfusion images from the examination phase.

METHOD OF CORRECTING INHOMOGENEITIES / DISCONTINUITIES IN MR PERFUSION IMAGES

The invention relates to a method of correcting inhomogeneities in MR perfusion images of the myocardium of a patient, which perfusion images relate time-sequentially to a preliminary phase which precedes the administration of a contrast medium and to an examination phase which succeeds the administration of the contrast medium, the perfusion images from the examination phase being corrected, in a correction step, for a detected intensity variation of the perfusion images from the preliminary phase.

MR perfusion images of the myocardium of a patient are formed so as to enable determination of the perfusion thereof. The actual image acquisition takes place after the injection of the contrast medium so as to enable suitable evaluation as to which parts, if any, of the myocardium exhibit insufficient perfusion.

From practice it is known to correct the perfusion images acquired after the administration of the contrast medium in the examination phase for the intensity variation detected in the preceding preliminary phase. This is because the acquired perfusion images exhibit an intensity variation which is dependent inter alia on the position occupied by the heart relative to the acquisition coils of the relevant MR scanner during the exposure. The intensity variation of the perfusion images from the preliminary phase preceding the administration of the contrast medium then serves as a starting point for the correction of the intensity variation of the perfusion images in the examination phase.

In practice, however, the above step often has an effect to the contrary, because the patient is allowed to inhale deeply a few times just before having to hold his or her breath during the administration of the contrast medium. Consequently, the position of the heart in the examination phase changes relative to the position occupied by the heart during the preliminary phase. The correction step executed in conformity with the state of the art, consequently, may give rise to incorrect correction of the intensity of the perfusion images from the examination phase.

It is an object of the invention to solve the latter problem.

To this end, the method of correcting inhomogeneities in MR perfusion images in accordance with the invention is characterized in that, prior to the correction step, the perfusion images from the preliminary phase are transformed in such a manner that pixels

or groups of pixels thereof register with corresponding pixels or groups of pixels, that is, pixels or groups of pixels relating to the same position in the heart of the patient, of the perfusion images from the examination phase. The correction step can thus be related each time to the correct pixels or groups of pixels.

In conformity with a first version of the method in accordance with the invention, the correction step is preferably carried out for each pixel separately. This results in a comparatively accurate correction of the brightness of the various pixels constituting the perfusion images.

When the number of operations and the calculation time required for these operations must be controlled so as to enable fast transformation, in conformity with a second preferred version of the method of the invention the correction step is preferably carried out each time for a group of pixels, which group is selected from the set formed by:

- a series of pixels situated on one or more contours within the myocardium,
- the pixels situated each time within a segment of the myocardium,
- the pixels situated each time within a part of a segment of the myocardium.

The invention will be described in detail hereinafter with reference to an embodiment which, however, does not limit the appended claims in any way whatsoever.

During a first step of the method there is determined a transformation which relates the perfusion images from the preliminary phase, in which no contrast medium has been administered to the patient yet, to the perfusion images from the examination phase which succeeds the administration of the contrast medium.

Various methods can be used to carry out such a transformation. A method of this kind is described, for example, in the article "Validation of Non-Rigid Registration using Finite Elements Methods" by J. Schnabel et al. which is to be presented during the IPMI 2001.

The next step may be the determination of the intensity variation of the perfusion images from the preliminary phase by averaging this intensity in different positions or in different segments of the myocardium. Without intent to exclude any other methods, in this respect the following methods may be mentioned by way of example:

- an intensity determination for each pixel in the myocardium separately,
- an intensity determination for all pixels situated on one or more contours within the myocardium;
- an intensity determination which is valid each time for a segment of the myocardium;
- an intensity determination each time for a part of a segment of the myocardium.

During the subsequent correction step, an intensity correction is carried out for each pixel or each group of pixels of the perfusion images from the examination phase, which intensity correction corresponds to the intensity variation in the corresponding pixels or groups of pixels of the perfusion images from the preliminary phase. Thus, for each pixel or group of pixels a relative brightness variation is measured so as to enable more accurate diagnosis of the perfusion of the myocardium.

The invention also relates to a workstation as defined in claim 4. The workstation of the invention is in particular suitable for carrying out the method of the invention. The workstation, for example, comprises circuitry that is designed to carry out the steps of the method of the invention. The invention also relates to a computer program as defined in claim 5. The computer program of the invention can be loaded into the working memory of a workstation so as to suitably program the workstation to allow the workstation to carry out the method of the invention. The computer program of the invention may be stored on a data carrier such as a CD-ROM or may be downloaded from a data network such as the world-wide web.

CLAIMS:

1. A method of correcting inhomogeneities in MR perfusion images of the myocardium of a patient, which perfusion images relate time-sequentially to a preliminary phase which precedes the administration of a contrast medium and to an examination phase which succeeds the administration of the contrast medium, the perfusion images from the examination phase being corrected, in a correction step, for a detected intensity variation of the perfusion images from the preliminary phase, characterized in that, prior to the correction step, the perfusion images from the preliminary phase are transformed in such a manner that pixels or groups of pixels thereof register with corresponding pixels or groups of pixels of the perfusion images from the examination phase.

2. A method as claimed in claim 1, characterized in that the correction step is carried out for each pixel separately.

3. A method as claimed in claim 1, characterized in that the correction step is carried out each time for a group of pixels, which group is selected from the set formed by:

- a series of pixels situated on one or more contours within the myocardium,
- the pixels situated each time within a segment of the myocardium,
- the pixels situated each time within a part of a segment of the myocardium.

4. A workstation for correcting inhomogeneities in MR perfusion images of the myocardium of a patient, which perfusion images relate time-sequentially to a preliminary phase which precedes the administration of a contrast medium and to an examination phase which succeeds the administration of the contrast medium, the perfusion images from the examination phase being corrected, in a correction step, for a detected intensity variation of the perfusion images from the preliminary phase, characterized in that, prior to the correction step, the perfusion images from the preliminary phase are transformed in such a manner that pixels or groups of pixels thereof register with corresponding pixels or groups of pixels of the perfusion images from the examination phase.

5. A computer program for correcting inhomogeneities in MR perfusion images of the myocardium of a patient, which perfusion images relate time-sequentially to a preliminary phase which precedes the administration of a contrast medium and to an examination phase which succeeds the administration of the contrast medium, which computer program includes instructions whereby the perfusion images from the examination zone are corrected, in a correction step, for a detected intensity variation of the perfusion images from the preliminary phase, characterized in that the computer program also includes instructions for transforming, prior to the correction step, the perfusion images from the preliminary phase in such a manner that pixels or groups of pixels thereof register with corresponding pixels or groups of pixels of the perfusion images from the examination phase.

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01R33/563

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
INSPEC, WPI Data, PAJ, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	M. BREEUWER ET AL.: "Automatic quantitative analysis of cardiac MR perfusion images" PROC. SPIE, vol. 4322, February 2001 (2001-02), pages 733-742, XP008011224 the whole document ---	1-5
X	A.-OU. BOUDRAA ET AL.: "Temporal covariance analysis ..." COMPUT. BIOL. MED., vol. 31, February 2001 (2001-02), pages 133-142, XP001128158 the whole document ---	1,4,5

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[X] Further documents are listed in the continuation of box C.

[ ] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA	Authorized officer
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Int onal Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	XIN YANG ET AL: "Computer aided measurement of local myocardial perfusion in MRI" PROCEEDINGS OF THE COMPUTERS IN CARDIOLOGY CONFERENCE. LONDON, SEPT. 5 - 8, 1993, LOS ALAMITOS, IEEE COMP. SOC. PRESS, US, 5 September 1993 (1993-09-05), pages 365-368, XP010128755 ISBN: 0-8186-5470-8 the whole document ---	1,4,5
A	J.A. SCHNABEL ET AL.: "Validation of Non-rigid Registration ..." INF. PROC. IN MED. IM., vol. 2082, June 2001 (2001-06), pages 344-357, XP001128727 cited in the application the whole document -----	1-5