

Automatic Bolus Detection in Breast MRI: a method to improve accuracy and reliability?

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Introduction:

In diagnostic breast imaging, usually a dynamic scan is performed which consists of a native scan and a number (typically 3-10) of post contrast-administration (CA) scans of the identical volume. Despite the use of automatic power injectors, the timing of the contrast media related to the scan protocol is operator and patient dependent due to pause durations, patient weight and circulation time and the location of the injection site. Additionally technical problems can occur such as incomplete injections. As the speed of contrast media uptake is a crucial diagnostic criterion [1-3], variations from a rigid protocol can potentially impair the reliability of the exam. Moreover, due to the use of CAD workstations that work with a fixed uptake threshold for a defined time point (such as 50 or 100% at the first post-CA time point), timing variations can significantly influence the appearance of enhancement maps, as shown in Fig. 1. The goal of this work was to implement a bolus detection method for breast MRI in a routine clinical situation that eliminates many patient and operator dependent variations, helps to avoid re-scans due to injection problems and thus potentially could improve the accuracy of dynamic breast protocols.

Methods:

The automatic bolus detection method was tested on 23 consecutive patients on a Siemens MAGNETOM Verio 3T system using a 16ch breast coil. The dynamic scan consisted of 6 axial T1-weighted 3D gradient-echo scans of 70s temporal resolution. Following the native scan, the operator adjusted the position of a 2x2 cm ROI on the right ventricle. Subsequently a very fast, axial 2D gradient-echo measurement with 8cm slice thickness at 1s temporal resolution was started. During a learning phase in the first cycles prior to the injection (T_{pre}), the algorithm computes a baseline average intensity (b) and standard deviation (s) over time. During the sensitive phase of bolus detection (T_{thresh}), the algorithm checks if the signal intensity within the ROI exceeds a threshold level of $b+n*s$. If the signal exceeds this threshold, a feedback is sent to the sequence to stop the acquisition and trigger the first post-CA 3D. In order to match the peak of a given uptake curve with the center of k-space (T_{ctr}), the timing and/or k-space acquisition strategy of the post-CA needs to be adjusted.

Results and Discussion:

The algorithm triggered the following scans correctly and successfully in 23 patients. The planning and user interaction was evaluated as very user-friendly by 5/5 radiographers. Fig. 3 shows example bolus detection scans from two patients. T_{thresh} varied from 20-35s for all patients.

In contrast to other bolus detection applications, the main feeding artery (internal thoracic artery) was not used as trigger vessel, because it is difficult to detect from a native axial scan and its position might be breathing dependent. Therefore the ROI was positioned in the right ventricle. This manual positioning adjustment clearly leaves a certain amount of variability for the threshold time. While bolus detection methods are commonly used in other body MR applications, to our knowledge the use in breast MRI has not been described so far. It appears that especially protocols with temporal resolutions of ~30-90s could profit from this approach. The current concept appears inappropriate for low temporal resolution protocols with acquisition times of 2 min or longer. In that case the long time-to-center of approx. 60s or more requires an early start of the post-CA scan.

Further investigations are required in order to quantify the reduction of user dependent errors and to assess the amount of remaining operator dependency, e.g. ROI positioning. Moreover the additional advantages of this method in high temporal resolution protocols need to be analyzed such as the potential to assess the time-to-peak of a lesion more precisely.

References:

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3. Jansen, S.A. u. a. Kinetic curves of malignant lesions are not consistent across MRI systems: need for improved standardization of breast dynamic contrast-enhanced MRI acquisition. AJR Am J Roentgenol 193, (2009)

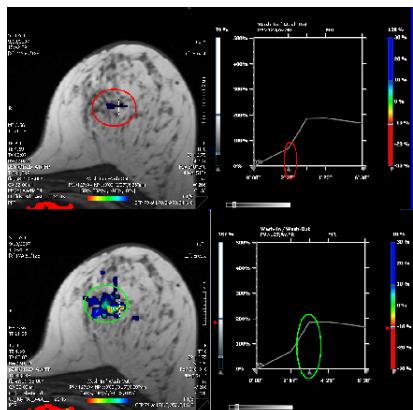


Fig 1: enhancement maps of an exam with too early injection start with a) wrong (top) and b) corrected reference time point assigned

Fig 2: protocol diagram with bolus detection scans prior to post-CA dynamic scans; T_{pre} : learning phase; T_{thresh} : time from start of injection to threshold level; T_{ctr} : time to center of k-space

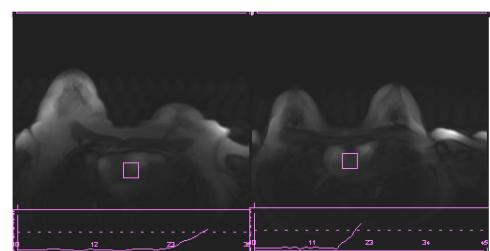


Fig 3: examples of bolus detection scans of two patients at timepoint of threshold crossing