Application of Vessel Exclusion for Development of Computer-Aided Diagnosis for Breast MRI

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Background and purpose:

One major procedure in the development of breast MRI CAD (computer-aided-diagnosis) is the search for suspicious lesions based on contrast enhancement [1-3]. While most malignant lesions show enhancements, blood vessels also show strong contrast enhancement, and may be picked up by CAD systems, which highlights suspicious tissue areas based on a pre-set enhancement threshold. The enhancement in the blood vessel decreases rapidly with time, thus the time course measured from vessel often shows wash-out in the enhancement kinetics, which is a suspicious pattern for malignancy (normally highlighted using the red color on CAD). The vessels can be identified on the maximum intensity projection (MIP) and can be easily excluded by radiologists. While this may not be a big problem for the radiologists who only use CAD for imaging processing, this is a major challenging problem for development of an automated CAD that not only identifies the suspicious lesions but also characterizes the lesion to indicate its suspicious level of malignancy. In automated CAD, the suspicious areas can be searched using the hot spot approach. The purpose of the present work was to implement a vessel exclusion procedure in conjunction with hot-spot search to identify suspicious breast lesions. We have developed a computer algorithm for identification of blood vessels on breast MRI (details reported in another abstract). In this study we evaluated the improvement of lesion detection after excluding vessels. The exclusion rate of false positive detection from vessels is reported.

Methods:

Eleven breast MRI studies were analyzed. The MRI was performed using a Phillips Eclipse 1.5T scanner. These patients were selected from a cohort receiving neoadjuvant chemotherapy. Only the pre-treatment MRI study was analyzed. Bilateral DCE-MRI was acquired using a 3D gradient echo pulse sequence, 32 axial partitions with 4-mm thickness. Sixteen frames (4 pre and 12 post) were acquired. The contrast agent (Omniscan®, 0.1 mmol/kg) was injected in about 15 sec followed by a saline flush, at start of the 5th frame acquisition. For analysis, we first subtracted pre-contrast frame #3 from post-contrast frame #6, and then a hot-spot search using a kernel of 3x3 pixels was performed in all 32 slices. For each case the threshold to identify hot-spots were determined empirically. After the hot-spot search, the contamination from subtraction artifacts and noises were excluded based on analysis of contrast enhancement time course using all 16 frames. While these false areas may be identified on the subtraction images, they will not show a well-defined enhancement before and after contrast injection, and can be excluded. Further, the enhancements outside the breast area were excluded. Figure 1 illustrates the step-by-step procedures. **Fig.1a** presents the original Maximum Intensity Projection (MIP), and **Fig.1b** shows the original result of hot-spot search after artifact clean-up. The red color indicates pixels showing wash-out pattern in the kinetics; the green color indicated pixels showing plateau, and the blue color indicates pixels showing persistent enhancement pattern in the time course. For vessel identification, we have already developed the procedures, and results validated with radiologists' drawing. Firstly the overall structure of blood vessels were identified on 2-D MIP by applying a filter bank based on Wavelet Transform and Hessian Matrix [4]; and then the vessels in the 3-D space were identified based on thresholding and morphological operations. The vessels found in 2-D and 3-D processing were combined to obtain the final results. **Fig.1c** shows the remaining hot-spot search results after removing the vessels from Fig. 1b. **Fig.1d** and **Fig.1e** provide the 3-D rendering of the detected blood vessels.

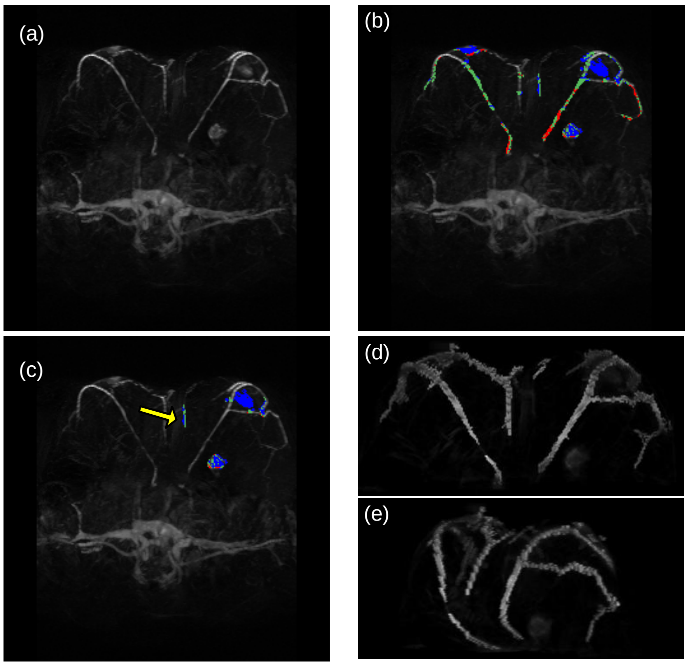

Fig.1 Blood vessels exclusion for search of suspicious breast lesions on DCE-MRI. (a) original MIP showing tumor, nipple, vessels, and artifacts. (b) original hot-spot search results. The color coding indicates the kinetic pattern: red-washout, green-plateau, blue-persistent. (c) after vessel exclusion. The vessels and some artifacts were removed, only the tumor, nipple and one tissue enhancement (indicated by yellow arrow) were visible. (d) axial view of the detected blood vessels, (e) rendering of (d) with horizontal rotation.

Table 1: Quantitative assessment for the test set.

	Mean	Range
Initail hot spot pixels	8,086	1,461 ~ 19,960
Post-exclusion pixels	7,187	649 ~ 18,381
Excluded vessel pixels	899	234 ~ 2,450
Percentage of exclusion	15.5%	2.6% ~ 55.6%

Results:

As shown in Fig.1c, most blood vessels and other false positive tissues are excluded while the tumors are well preserved. However, some false positive enhancements still exist, probably resulting from the strong background tissue enhancements (indicated by yellow arrow) and the miss-detection of blood vessels. How the vessel exclusion can enhance the hot-spot search for identifying the true suspicious tumors was evaluated using 11 cases. We calculated the total number of hot-spot pixels before and after excluding blood vessels. The number of excluded false positive vessel pixels and the percentage were also calculated, summarized in Table 1. The smallest percentage of exclusion (2.6%) was obtained from a subject with a very large tumor, with pre-exclusion of 17,337 pixels and post-exclusion of 16,370 pixels. The largest percentage of exclusion (55.6%) was obtained from a patient with a small tumor, with pre-exclusion of 1,461 and post-exclusion of 649 (the case shown in Figure 1). Since the CAD is normally applied for initial lesion detection and diagnosis of early stage disease with small lesions, the exclusion of vessels can eliminate a high percentage of false positive pixels.

Discussion:

The result demonstrates that our vessel exclusion algorithm can be used to reduce false positive enhancements coming from blood vessels. While this can be very helpful for automated CAD, this method can also be implemented for the CAD system that provides information for radiologists to make interpretations. For example, a vessel that runs perpendicular into the 2D MIP, will show as an enhancement hot spot on the MIP, and that may raise a suspicion that whether this hot spot represents a small tumor focus, especially when it is very close to the primary lesion. Our vessel exclusion algorithm also detects vessels based on 3-D images, and can be applied to find this vessel and exclude it on the 2D MIP. This clinical utility of this method will be further tested in a diagnostic dataset.

Reference: [1] Turnbull NMR Biomed 2008;DOI:10.1002/nbm.1273. [2] Levman et al. IEEE TMI 2007;27(5):688-696. [3] Koh et al. JMRI 2008;28:271-277. [4] Nakayama et al. IEEE TBME 2006;53:273-283.