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ORIGINAL ARTICLE

Semi-automatic detection and segmentation algorithm of saccular aneurysms in 2D cerebral DSA images

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KEYWORDS

Digital subtraction angiography;
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Abstract *Objective:* To detect and segment cerebral saccular aneurysms (CSAs) in 2D Digital Subtraction Angiography (DSA) images.
Patients and methods: Ten patients underwent Intra-arterial DSA procedures. Patients were injected with Iodine-containing radiopaque material. A scheme for semi-automatic detection and segmentation of intracranial aneurysms is proposed in this study. The algorithm consisted of three major image processing stages: image enhancement, image segmentation and image classification. Applied to the 2D Digital Subtraction Angiography (DSA) images, the algorithm was evaluated in 19 scene files to detect 10 CSAs.
Results: Aneurysms were identified by the proposed detection and segmentation algorithm with 89.47% sensitivity and 80.95% positive predictive value (PPV) after executing the algorithm on 19 DSA images of 10 aneurysms. Results have been verified by specialized radiologists. However, 4 false positive aneurysms were detected when aneurysms' location is at Anterior Communicating Artery (ACA).
Conclusion: The suggested algorithm is a promising method for detection and segmentation of saccular aneurysms; it provides a diagnostic tool for CSAs.

1. Introduction

Medical image processing is the most challenging and emerging field now days (1). Digital Subtraction Angiography (DSA) has been the standard of reference for the detection and characterization of intracranial aneurysms (2). Cerebral saccular aneurysms (CSAs) are initially rounded, berrylike outpouchings that arise at a branching site on the parent artery (3), and more than 90% of the intracranial aneurysms are of this type (4). Fig. 1 shows an example of CSA which is located at the right middle cerebral artery.

Subarachnoid hemorrhage due to the rupture of an intracranial aneurysm is a devastating event associated with

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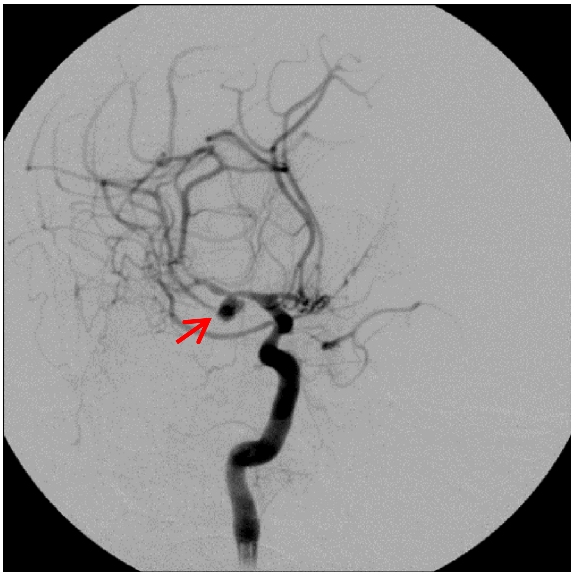

Fig. 1 2D cerebral DSA image with CSA at the right middle cerebral artery.

high rates of mortality (40–50%) and morbidity (5). At first glance, Aneurysms segmentation seems to be easy but the local inhomogeneous contrast agent distribution, patient movement as well as the smooth intensity ramp between blood vessels and background make it a difficult task (6).

Segmentation methods vary depending on the imaging modality, application domain, method being automatic or semi-automatic, and other specific factors. There is no single segmentation method that can extract vasculature from every medical image modality (7).

Intracranial vessels and aneurysms segmentation algorithms can be divided into several categories: Pattern recognition techniques, Model-based approaches, Tracking-based approaches, Artificial Intelligence-based approaches and hybrid approaches.

Pattern recognition techniques deal with the automatic detection or classification of objects or features. For vessel extraction, pattern recognition techniques are concerned with the automatic detection of vessel structures and features. Pattern recognition techniques include seven categories: (1) multi-scale approaches (8), (2) skeleton-based (centerline) approaches (9,10), (3) ridge-based approaches (11,12), (4) region growing approaches (13,14), (5) differential geometry-based approaches (15,16), (6) matching filters approaches (17,18), and (7) mathematical morphology schemes (19).

Model-Based (MB) Approaches apply explicit vessel models to extract the vasculature. MB approaches are divided into four categories: (1) deformable models (20), (2) Parametric models (21), (3) Template matching (22), and (4) Generalized cylinders (23). Active contour models or snakes are a special case of a more general technique of matching a deformable model by means of energy minimization (7).

Tracking-Based Approaches apply local operators on a focus known to be a vessel and track it. On the other hand, patter recognition approaches apply local operators to the whole image. Vessel tracking (VT) approaches, starting from an initial point, detect vessel centerlines or boundaries by analyzing the pixels orthogonal to the tracking direction. Different methods are employed in determining vessel contours or centerlines. Edge detection operation followed by sequential tracing by incorporating connectivity information is a straightforward approach (7). Fuzzy clustering is an approach to identifying vessel segments. It uses linguistic descriptions such as "vessel" and "nonvessel" to track vessels in retinal angiogram images (24).

Artificial Intelligence-Based Approaches (AIBA) utilize knowledge to guide the segmentation process and to delineate vessel structures. Different types of knowledge are employed in different systems from various sources. One knowledge source is the properties of the image acquisition technique, such as Digital Subtraction Angiography (DSA) and computed tomography (CT). Some applications utilize a general blood vessel model as a knowledge source (7).

Hybrid approaches combine one method or more of the aforementioned approaches to segment vessel structure. For instance, Hu and Hoffman (25) extracted the object boundaries by combining an iterative thresholding approach with region growing and component label analysis.

Existing approaches for vessel structures segmentation have the following limitations (26):

1. Some approaches require user interaction to initialize a vessel of interest (27,28).
2. Some deformable models assume circular vessel cross sections; this holds for healthy people, but not for patients with a stenosis or an aneurysm (29).
3. Some approaches are computationally expensive (30).

Despite the availability of many image segmentation methods, with varying approaches and algorithms, there is no dominant method in terms of effectiveness, across all areas (31). The segmentation of cerebral vasculature with aneurysms is a difficult task often due to their complex geometry as well as limited image contrast and spatial resolution, which are critical factors compared with the size of these vascular segments (32).

In this paper, CSAs are detected and segmented semi-automatically from 2D cerebral DSA images through two steps. First, potential regions of interest (potential aneurysms) are detected by pre-processing the DSA images, segmenting the vessel tree, and applying morphological processing. Second, false positive reduction method is applied on the areas highlighted in the first step, where the reduction scheme depends on the extracted features of the potential aneurysms.

2. Patients and methods

2.1. Patients

This study was approved by Damascus University and Al-Assad University hospital in Damascus/Syria. There were 6 female and 4 male patients, and their ages ranged from 38 to 64 years, with a mean age of 47.2 ± 7.7 years. Patients were clinically diagnosed for cerebral saccular aneurysms. Table 1 shows demographic characteristics of the studied patients.

2.2. DSA protocol

DSA imaging was performed by DSA modality station (Siemens/AXIOM-Artis), DSA consisted of an X-ray assembly