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Image processing-based mTICI grading after endovascular treatment for acute ischemic stroke

Abstract: **Introduction:** The grade of reperfusion after endovascular treatment of ischemic stroke e.g. mechanical thrombectomy is determined based on the mTICI score. The mTICI score shows significant interrater variability; it is usually biased towards better reperfusion results if self-assessed by the operator. We therefore developed a semi-automated image processing technique for assessing and evaluating the degree of reperfusion independently, resulting in a more objective mTICI score. **Methods:** Fifty angiography datasets of patients who were treated with mechanical thrombectomy for middle cerebral artery (MCA) occlusion were selected from our database. Image datasets were standardized by adjustment of field of view and orientation. Based on pixel intensity features, the internal carotid artery (ICA) curve was detected automatically and used as a starting point for identifying the target downstream territory (TDT) of the MCA on the DSA series. Furthermore, a grid with predefined dimensions was used to divide the TDT into check-zones and be classified as perfused or unperfused. **Results:** The algorithm detected the TDT and classified each zone of the grid as perfused or unperfused. Lastly, the percentage of the perfused area in the TDT was calculated for each patient

and compared to the grading of experienced clinical users. **Conclusion:** A semi-automatic image-processing workflow was developed to evaluate perfusion rate based on angiographic images. The approach can be used for the objective calculation of the mTICI score. The semi-automatic grading is currently feasible for MCA occlusion but can be extended for other brain territories. The work shows a starting point for a machine learning approach to achieve a fully automated system that can evaluate and give an accurate mTICI score to become a common AI-based grading standard in the coming near future.

Keywords: Stroke, image processing, automatic mTICI grading, endovascular treatment, perfusion.

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1 Introduction

Stroke is known as the second leading cause of death worldwide [1, 2], 87% of the strokes are classified as ischemic stroke, which are generated by the cerebral artery occlusion. Moreover, 50% of the ischemic strokes are thrombotic ischemic strokes [2]. Thrombotic ischemic strokes are more common for elderly people, in which it happens for 80% of the patients without any symptoms before they occur [2]. Nowadays, acute ischemic strokes are treated by endovascular therapy [1, 3, 4, 9]. Various grading scales were invented to evaluate the endovascular therapy outcomes, one of the most used grading scales is the Thrombolysis in Cerebral Infarction (TICI) score, which was modified (mTICI) and lastly extended (eTICI). The TICI score is based on the final digital subtraction angiography (DSA) images after endovascular treatment. The score reflects the percentage of the perfused treated area in the brain. The mTICI score is defined as: mTICI=0; no perfusion in the TDT, mTICI=1; minimal brain tissue perfusion in the TDT, mTICI=2a; lower than 50% perfusion in the TDT, mTICI=2b; more than 50% perfusion in the TDT, mTICI=2c; nearly complete perfusion in the TDT, and mTICI=3; complete perfusion in the TDT [1, 3]. However,

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the TICI score is facing several limitations; several studies indicated the need of increasing the resolution for a more precise treatment assessment [5-7], another limitation is overestimation of TICI gradings by operators during endovascular therapy when compared to core-lab raters [8]. Lastly, when self-assessed by the operator, the mTICI score shows high interrater variability; it is frequently biased towards better reperfusion results.

This work aims to develop a semi-automated image processing technique that evaluates the percentage of reperfusion in the TDT after an endovascular therapy independently, resulting in a more proper mTICI score.

2 Methods

The following flow chart (Figure 1) represents the main steps used in the semi-automated image processing technique for the reperfusion assessment.

Figure 1: Flowchart of the semi-automatic image processing technique.

2.1 Dataset preparation

For this work, a dataset of fifty DSA series of treated patients with mechanical thrombectomy for MCA occlusion were collected from our database. The datasets were converted to binary format by automatic thresholding, in which all values that are equal or greater than a threshold are set to one and indicate that it belongs to the contrast agent, in other words it means that the area is perfused. The threshold was selected above the maximum grey value of the DSA background. Zero values of the binary format belong to the unperfused. An example of a binary format image can be seen in figure 2. Furthermore, the field of view was reduced to the brain area only in order to have comparable ROI of the lateral image. Lastly, two frames from each DSA series were automatically detected to be used for the following steps: the first frame is the first fill image which shows the frame with internal carotid artery only (illustrated in Figure 2a), the second detected frame is capillary fill phase frame which shows the spread of contrast in soft tissue (shown in Figure 2b).

2.2 Reference point detection

A reference point is needed to be used as a starting point for the ROI which represents the TDT. For that, the decision was to use the ICA curve as a reference point. The ICA curve was automatically identified by filtering the first fill image using a median filter, then skeletonization and pruning were applied and the most far point representing the middle of the ICA curve was detected and chosen to be the reference point. The red spot in Figure 2a shows the detected reference point.

2.3 Region of interest definition and classification

Starting from the detected reference point, the ROI was identified with a 45 degrees angle until the last intensity values belonging to the brain, as illustrated in Figure 3. Furthermore, grid based check zones with a size of 20*20 pixels were applied to the ROI. The grid was used to classify each zone as perfused or unperfused. A zone is considered as perfused if the number of ones in the zone is more than 25% of its total number of pixels. We chose this 25% after analysis of the arterial phase of several DSA images. The average of pixels belonging to arteries in the brain compared to pixels belonging to Background is less than 25%. After classification the percentage of perfusion was calculated as in the equation below:

Figure 2: Binary format images of **a)** The first "fill" frame and the detected reference point (in red), **b)** The capillary fill phase image.

Figure 3: Grid for "perfused" (blue) and "unperfused" (red) classification.

$$Perc = \frac{\# \text{ of perfused zones}}{\text{Total \# of zones}} \quad (1)$$

To be able to evaluate our image processing algorithm, two experienced neuroradiologists graded the dataset blindly (Without knowing the algorithm score) and independently (Without knowing the score of each other). Lastly, the semi-automatic image processing technique mTICI scores were compared to the neuroradiologists scores.

3 Results and discussion

The results showed the ability of the algorithm to detect the TDT and to classify the zones as perfused and unperfused. Table 1 below shows the results of the evaluation of fifty cases using the algorithm in comparison to the evaluation of two experienced neuroradiologists.

Table 1: The image processing algorithm results for the mTICI score in comparison to two experienced neuroradiologists scores.

% of cases received the same score from both neuroradiologists	33/50 (66 %)
% of cases received different scores from the neuroradiologists	17/50 (34%)
% of the algorithm scores matched to both neuroradiologists score	25/50 (50%)
% of the algorithm scores matched to at least one neuroradiologist	41/50 (82%)
% of the algorithm scores which did not match to the neuroradiologists score	9/50 (18%)

Table 1 shows, that the neuroradiologists gave the same score for only 66% of the cases, 75% of them received the same score from the developed algorithm. Moreover, the algorithm's score matched with at least one neuroradiologist in 82% of the total cases. However, 18% of the patient data received a different score from the algorithm than the neuroradiologists given scores. This can be due to different factors such as; high noisy images (as shown in Figure 4), wrong reference point detection (as illustrated in Figure 5), and large ROI detection (as shown in Figure 6).

Noisy images are generated mostly when a motion occurs during the acquisition, the reference point can be wrongly detected when the DSA series frame rate is slow, in which an image without the capillary fill cannot be detected. Nevertheless, large ROI can be detected when the image is not standardized perfectly because of big orientation.

Figure 4: Wrong detection for the ICA curve (Reference point).

Figure 5: Motion during acquiring the DSA series leading to a noisy image.

Figure 6: Large detected TDT; the detected ROI is the MCA and the PCA regions.

4 Conclusion

A semi-automatic image-processing technique was developed for the evaluation of reperfusion rate based on DSA series. The technique is meant to be used for the mTICI scoring. For that, fifty cases suffering from MCA occlusion were used and evaluated by the developed algorithm and two experienced neuroradiologists after EVT. The resulting scores from the algorithm were compared to the given scores from both neuroradiologists. The results show a 75 % agreement between both neuroradiologists and image-processing-based algorithm and 82% agreement between the algorithm and at least one neuroradiologist. Lastly, in 18% of the cases the algorithm's score did not match with any of the neuroradiologists' scores. The promising results show that the semi-automatic grading is feasible for the MCA occlusions and can be applied for other brain territories. Moreover, the work can be extended and used as a starting point for a machine learning approach for a fully automated approach with more accurate mTICI score. The approach can become a common AI-based grading routine in the near future.

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