

Stroke-Analysis Program for Searching Infarct/Penumbra Area from CT-Scan Images via Digital Image Processing Technique

Somchart Chokchaitam, Santichai Fueanggan and Sombat Muengtaweepongsa

Abstract— The CT scan, produces x-rays images of brain, can often show size and locations of brain abnormalities. However, with this process, a number of needed CT-scan images prolong the stroke analysis. This report applied digital-image processing technique to design stroke-analysis program for searching infarct penumbra area (mismatch area), tissue at risk. Cerebral blood flow (CBF), cerebral blood volume (CBV) and Mean Transit Time (MTT) from CT perfusion maps are used to identify mismatch area.

In our experimental results, N-Match, D-Match and Mismatch mean normal tissue areas, dead tissue areas and blood cot tissue areas, respectively. The simulation results illustrate percentages of N-Match, D-Match and Mismatch depending on their threshold. For examples, percentage of N-Match will increase when threshold of CBV and CBF are lower and threshold of MTT is higher.

Index Terms— Stroke, CT-Scan image, Infarct penumbra area, Digital image processing

I. INTRODUCTION

Stroke is the rapidly developing loss of brain functions and can cause permanent neurological damage, complications and death if not promptly diagnosed and treated. Therefore, strokes are medical emergencies that require immediate medical attention. A CT (Computed Tomography) scan [1-6] is usually one of the first test done in stroke evaluation. This is because CT scan, produces x-rays images of brain, can often show size and locations of brain abnormalities caused by tumors, blood vessel defect, blood clots and other problem. In CT perfusion maps, Cerebral blood flow (CBF), Cerebral blood volume (CBV), Mean transition time (MTT) and Time To Peak (TTP) are normally used to diagnose brain tissue. To specify Ischemic Stroke Area on the CT scan images, neurologists normally consider CBV and CBF images to identify the location of infarct penumbra area.

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In our previous research [7-8], we applied digital image processing for automatically searching infarct penumbra and infarct core areas of patients based on CBV and CBF images. In our previous results, infarct penumbra and infarct core areas are closed to the areas defined by neurologists but there are some problems because the brain structure of each person is different. Therefore, we propose to improve our method for searching infarct penumbra and infarct core areas by adding MTT images for indentifying those areas.

In this report, we apply digital-image-processing technique for separating brain into 6 areas based on CT Perfusion images such as CBV, CBF and MTT images. The simulation results illustrate percentages of each area depending on their thresholds. Therefore, neurologists can be adjusted the threshold of each parameters for solving the problem of different brain structure.

II. CT Perfusion

The CT scan, produces x-rays images of brain, can often show size and locations of brain abnormalities. In some cases, they're required CT perfusion, used a contrast material injected in brain vessels, for tracing the blood flows in cerebral vessels along time [1-6]. Using various mathematical algorithm, cerebral perfusion is represented in term of color-decoded images such as CBV, CBF, MTT and TTP.

CBV represents the percentage of blood per unit volume of tissue as illustrated in Fig. 1 (A). CBF represents the time a certain amount of blood takes to pass the cerebral blood vessels and arrive to the veins as illustrated in Fig. 1 (B). MTT represents the average of the transit time of blood through a given brain region as illustrated in Fig. 1 (C). For Normal brain, its CBV and CBF are high while MTT is low. For infarct penumbra area, we find that its CBV is normal but its CBF is low and MTT becomes high. However, when infarct penumbra turns into infarct core, both CBV and CBF of those areas are low while MTT is high.

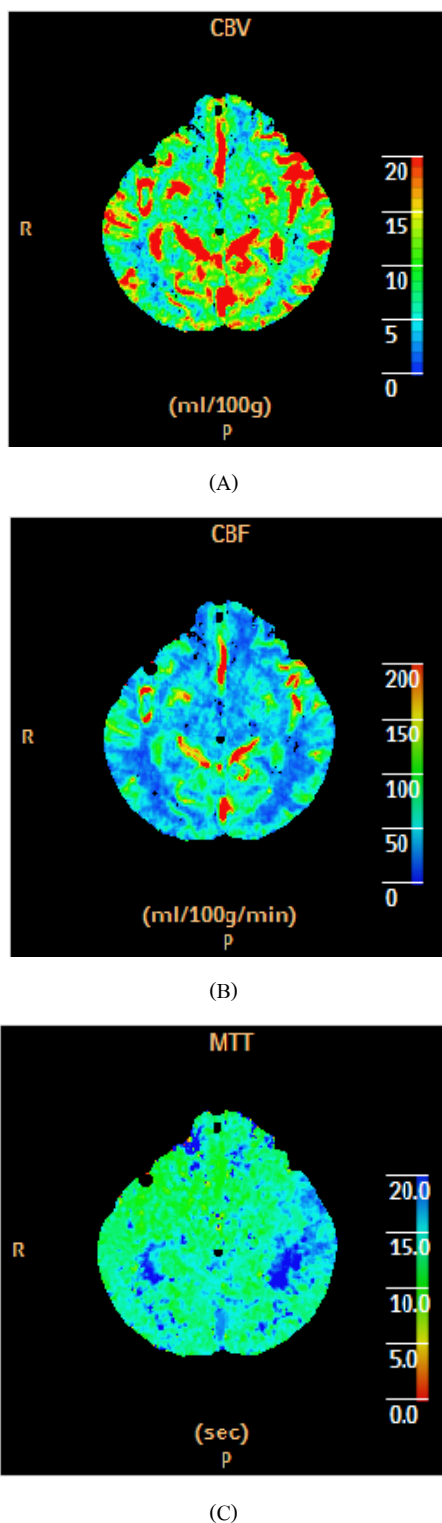


Fig. 1 represents CT perfusion images: (A) CBV (B) CBF (C) MTT

III. CRITERIA FOR IDENTIFYING PENUMBRA/INFARCT AREA

In our previous report, only CBV and CBF are applied to identify brain map as illustrated in Fig. 2. If both CBV and CBF are high, we called “N-Match” for normal brain area. When both CBV and CBF are low, we called “D-Match” for dead area (infarct core area). If CBV is high but CBF is low, we called “Mismatch” meaning infarct penumbra area.

Final, if CBV is low but CBF is high, we called “undefined” since this case is rare happen.

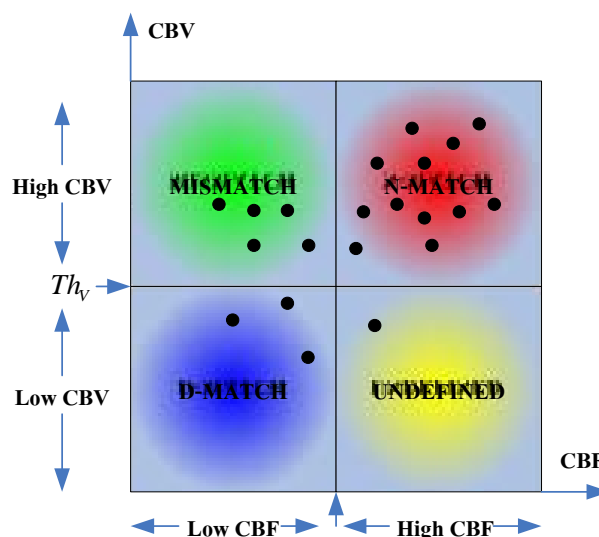


Fig. 2 Criteria for identifying brain map in our previous report

In this report, MTT is considered as a new parameter to identify brain map. If CBV is high, it means brain in that area is still not dead. In opposite, if CBV is low, it's high possibility that brain may loss functions in the future. Therefore, we design the criteria shown in table 1 as the follows:

1. When CBV and CBF are both high and MTT is low, it's surely that brain in the area works normally. This area is defined as N-Match (area 3).
2. However, when CBV and CBF are both high but MTT is high, it's a high risk to become penumbra area in the future. Therefore, this area is defined as N-Match (area 2).
3. When CBV is high but CBF is low, this area is defined as Mismatch (area 1).
4. If CBV, CBF and MTT are low, it's high possibility to be infarct area. This area is defined as D-Match (area 5)
5. If CBV and MTT are low but CBF is high, it's rare happen. This area is defined as Undefined (area 6).
6. However, when CBV is low and MTT is high, it's surely infarct area. This area is defined as D-Match (area 4). Fig. 3 illustrates criteria for identifying brain map in this report

Table 1. Criteria for identifying penumbra infarct area

	CBV	CBF	MTT
N-Match (area 3)	High	High	Low
N-Match (area 2)	High	High	High
Mismatch (area 1)	High	Low	Any
D-Match (area 5)	Low	Low	Low
Undefined (area 6)	Low	High	Low
D-Match (area 4)	Low	Any	High

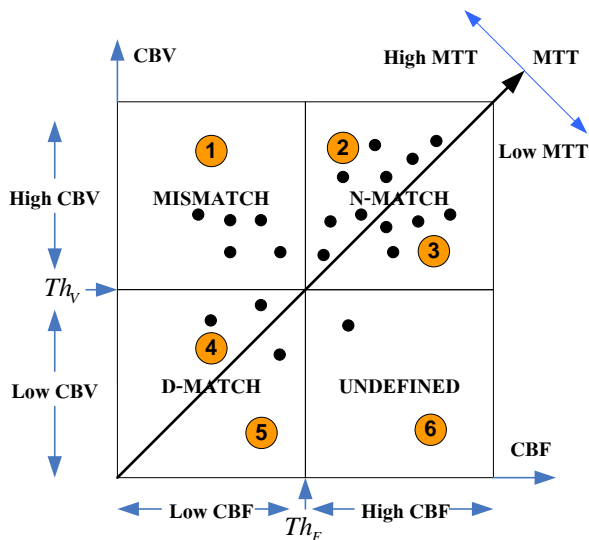


Fig. 3 Criteria for identifying brain map in this report

IV. THE DESIGNED PROGRAM

The designed program is mainly divided into 3 main parts as illustrated in Fig. 4: 1) Adjusting threshold and identifying area, 2) Finding N-Match, D-Match and Mismatch areas, and 3) Calculating volume

A. Adjusting threshold and identifying area

For CBV, CBF and MTT, we identify area from eq. (1)

$$F_T [i, j] = \begin{cases} 255 & \text{if } F[i, j] = 0 \\ 1 & \text{if } F[i, j] \geq T \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Whereas $F[i, j]$ represents an original image and $F_T[i, j]$ represents an output image. T represents threshold to classify high or low. Value “255”, “1” and “0” represent “don’t count area”, “high area” and “low area”, respectively.

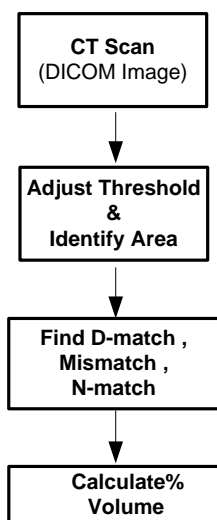


Fig. 4 Block Diagram of the designed program

B. Finding N-Match, D-Match and Mismatch areas

We apply criteria in Table 1 to identify N-Match, D-Match and Mismatch areas (6 areas). The normal areas are located in area 2 and area 3; whereas, the abnormal areas are located in area 1, area 4, area 5 and area 6.

C. Calculating volume

We calculate percentage volume of each area from eq. (2)

$$\text{Volume Segment (\%)} = \frac{\text{Pixel Segmen}}{\text{Pixel Brain}} \times 100 \quad (2)$$

Whereas “Pixel Segment” represents number of pixel in interested area, “Pixel Brain” represents number of pixel in the whole brain and “Volume Segment” represents percentage of interested area.

V. Experimental Results

In simulation results, four CT perfusion images are used to test our designed program. We also vary 4 threshold levels to illustrate how the threshold affects distribution of the areas. In this report, threshold 1 sets threshold for CBV, CBF and MTT as “4”, “20” and “12”, respectively. Threshold 2 sets threshold for CBV, CBF and MTT as “6”, “24” and “15”, respectively. Threshold 3 sets threshold for CBV, CBF and MTT as “7”, “30” and “14”, respectively. Threshold 4 sets threshold for CBV, CBF and MTT as “5”, “20” and “15”, respectively.

From the simulation results, we can conclude the follows:

1. Percent Distribution of each area depends on threshold
2. Each image has a different sensitivity to the same threshold.
3. When we increase threshold of CBV or CBF, percentage of N-match will decrease.
4. Percentage of area 3 and area 5 are close to 0%

Finally, we hope that neurologist can use the designed program by adjusting threshold to automatically analyze the infarct penumbra area. Resulted image to illustrate the area will be added in camera ready version.

Table 2 Simulation results for the first CT perfusion image

	Th 1	Th2	Th3	Th4
Area 1	10.3%	24.5%	32.8%	46.8%
Area 2	80.3%	66.1%	47.3%	23.6%
Area 3	0%	0%	0%	0%
Area 4	8.8%	9.3%	19.7%	29.0%
Area 5	0%	0%	0%	0%
Area 6	0.6%	0.1%	0.2%	0.6%

Table 3 Simulation results for the second CT perfusion image

	Th 1	Th2	Th3	Th4
Area 1	8.7%	20.0%	31.0%	42.7%
Area 2	83.7%	72.4%	52.6%	31.0%
Area 3	0%	0.1%	0.1%	0.1%
Area 4	7.2%	7.4%	16.1%	25.7%
Area 5	0%	0%	0%	0.1%
Area 6	0.4%	0.1%	0.2%	0.6%

Table 4 Simulation results for the third CT perfusion image

	Th 1	Th2	Th3	Th4
Area 1	18.0%	30.7%	32.9%	38.7%
Area 2	72.1%	59.4%	46.1%	29.9%
Area 3	0%	0%	0%	0%
Area 4	9.6%	9.8%	20.9%	31.0%
Area 5	0%	0%	0%	0%
Area 6	0.3%	0.1%	0.1%	0.3%

Table 5 Simulation results for the forth CT perfusion image

	Th 1	Th2	Th3	Th4
Area 1	9.7%	20.2%	27.2%	38.4%
Area 2	83.6%	73.1%	58.0%	37.9%
Area 3	0%	0%	0%	0%
Area 4	6.5%	6.6%	14.7%	23.2%
Area 5	0%	0%	0%	0%
Area 6	0.2%	0.1%	0.1%	0.5%

V. CONCLUSION

In this report, we presented a new stroke-analysis program for searching penumbra infarct area. The designed program applies CBV, CBF and MTT to divide brain areas into 6 areas. The simulation results illustrated an effectiveness to basically classify stroke patients.

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