Gray Matter to White Matter (GM/WM) Density Ratio Prediction on Computed Tomography in Cardiac Arrest Patients

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Abstract

Introduction: Hypoxic-ischemic brain damage is brought on by cardiac arrest or severe hypoxia, which causes patients unconscious and increases their mortality rate by 70 percent. The loss of the gray-white junction in the brain's computed tomography can be seen, which has a poor prognosis and prevents the brain from returning to normal.

Objectives: To determine the correlation between the gray-to-white matter (GM/WM) density ratio from computed tomography and the prognosis following cardiac arrest.

Material and Method: Forty-three patients who resuscitated from cardiac arrest and had performed CT brain within 60 hours were retrospectively investigated. Prognosis has divided 2 group: Glasglow outcome scale (GOS) 1-2 for poor prognosis, GOS 3-5 for good prognosis. Hounsfield units (HU) were measured at the basal ganglion, ganglionic, and surpraganglionic levels.

Results: Total 43 patients, with 8 having good prognosis and 35 having poor prognosis. The mean age of patients was 62.1 years. The average Hounsfield after post-cardiac arrest in Basal ganglion, ganglionic and supraganglionic level is not significant difference.

Conclusion: There was no statistically significant difference in the GW-WM ratio for determining the prognosis of death or vegetative state in the post-cardiac arrest patients in our study.

Introduction

Hypoxic-ischemic brain damage is brought on by cardiac arrest or severe hypoxia, which causes patients unconscious and increases their mortality

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rate by 70 percent. Cell-brain damage and cerebral edema are the main causes of death following cardiac arrest.[1-2] After cardiac arrest, treatment can prevents brain damage, which lowers mortality and disability rates. Therapeutic hypothemia prevent brain ischemia and brain hypoxia.[3,4] Cardiopulmonary resuscitation and post-cardiac arrest prognostication have numerous applications. Eg. Brainstem reflexs, somatosensory evoked potential, high-specific neurospecific enolase, and brain computed tomography or magnetic resonance imaging. There is no apparent exact ratio in the post-cardiac arrest guidelines for computed tomography brain ratio following cardiac arrest.[2]

After a cardiac arrest, brain imaging using computed tomography can predict the prognosis, but if the diagnosis is made within 24 hours, everything may return to normal. The loss of the gray-white junction in the brain's computed tomography can be seen three to five days after a cardiac arrest, which has a poor prognosis and prevents the brain from returning to normal.[1] There are several advantages for brain computed tomography, and it is economical for predicting outcomes after cardiac arrest.[1] We are interested in employing computed tomography to assess the gray-white junction ratio and forecast prognosis after cardiac arrest.gray

To determine the relationship between the gray-to-white density ratio from computed tomography for post-cardiac arrest prognostication.

Objectives

To determine the correlation between the gray-to-white matter (GM/WM) density ratio from computed tomography and the prognosis following cardiac arrest.

Material and Method

Study design

This study was designed as a retrospective observational cohort at Phramongkutklao Hospital

Study population

Patients at the Phramongkutklao Hospital who experienced cardiac arrest and were successfully revived between 1 June 2557 and 30 April 2021. A total of 77 individuals who experienced cardiac arrest were retrospectively reviewed. We retrospectively evaluated 43 patients who underwent computed tomography of the brain with complete resuscitation in 5 days and were comatose (Glasgow coma scale 8 or unresponsiveness to internal and external stimuli with total lack of alertness) at least 6 hours later were included and older than 18 years old. The following were the grounds for exclusion: traumatic brain injury, history of brain surgery following successful resuscitation, insufficient computed tomography brain imaging results, inability to follow up with a clinician for six months, and an incomplete patient history medical record. (Figure 1)

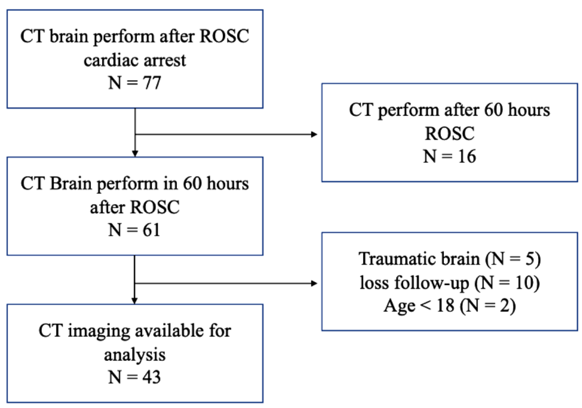

Figure 1 Subjects included in the study

Note : ROSC : return of spontaneous circulation

All data were collected through review CT brain, age, sex, cause of death, out of hospital arrest, in hospital arrest, co-morbid, presentation of ECG on admission, time to CT brain, times to resuscitations, hypothermia, Glasgow coma outcome after successful resuscitation and 6 months follow up and discharge status. Every CT scan of the brain is read by a neuroradiologist. The neurologist assessed the clinical result at post-cardiac arrest and at the 6-month follow-up. The comatose patients were divided into 2 groups; good prognosis (GOS 3-5), poor prognosis (GOS 1-2).

Definition

Therapeutic hypothermia has proven neuroprotective effects in global cerebral ischemia. Indications for hypothermia induction include cardiac arrest and neonatal asphyxia. The two general methods of induced hypothermia are either surface cooling or endovascular cooling. Hypothermia should be induced as early as possible to achieve maximum neuroprotection and edema blocking effect.[14]

The Glasgow outcome score is a scale of patients with brain injuries, such as cerebral traumas that groups victims by the objective degree of recovery.[13]

GOS	Glasgow outcome scale (Neurological outcome)
GOS 1	Death
GOS 2	Persistent vegetative state (unable to interact with environment)
GOS 3	Severe disability (unable to live independently but able to follow commands)
GOS 4	Moderate disability (able to live independently but unable to return to work)
GOS 5	Mild or no disability (able to return to work)

Poor: consisted of patients who died of any cause or remained in a persistent vegetative state (GOS 1-2).
Good: consisted of patients who regained consciousness (GOS 3-5).

Density measurement of gray matter and white matter

CT brain imaging data were collected by Canon Aquilion Prime were used of all CT studies with 5 mm slice thickness. All brain imaging procedures used non-contrast, standardized protocol imaging. Two investigators, who were blinded on clinical data assess CT scan in basal ganglion site defined as imaging in which; caudate (CN), putamen (PU), posterior limb of internal capsule (PIC) and corpus callosum (CC) and two level of superior cortex ; (1) medial cortex centrum semiovale that defined as the image 5 mm above the lateral ventricular system (MC1, MWM1), (2) medial white matter that defined high convexity area that defined next 5 mm above centrum semiovale (MC2, MWM2)

$$\text{Grey} - \text{white matter density ratio of basal ganglion (GWR} - \text{BG)} = \frac{(\text{CN} + \text{PU})}{(\text{CC} + \text{PIC})}$$

$$\text{Grey} - \text{white ratio in cortical (GWR} - \text{CO)} = \frac{(\text{MC1} + \text{MC2})}{(\text{MWM1} + \text{MWM2})}$$

$$\text{Grey} - \text{white ratio average} = \frac{(\text{GWR} - \text{BG}) + (\text{GWR} - \text{CO})}{2}$$

Figure 2 Basal Ganglion area; CC : corpus callosum, C: caudate, P: putamen, PIC: posterior limb of internal capsule

Figure 3 Medial cortex centrum semiovale; MC1 : medial cortex, MWM1 : medial white matter

Figure 4 High convexity area; MWM2 : medial white matter, MC2 : medial cortex

Statistical analysis

The information will be validated and get saved in the form of a data file. The data was processed with the STATA/MP 12 program and then analyzed using the following statistics.

1. Qualitative data were shown with numbers and percentages. For quantitative data, mean and standard deviation were used for data with a normal distribution, while median and interquartile range were used for data with a skewed distribution.

2. For this research, the suitable method for examining the precise prognosis of grey-to-white matter density ratio is sensitivity, specificity, positive predictive value and negative predictive value.

3. Glasgow outcome score is necessary method to distribute the data of good prognostic and poor prognostic. For good prognostic, it is GOS 3-5 while poor prognostic is 1-2 respectively.

Results

From a number of patients in the Phramongkutklao hospital who had survived cardiac arrest and were successfully revived, 43 patients met the selection criteria of the study, 8 of whom had favorable prognoses and 35 of whom had bad ones. The mean age of patients was 62.1 years, most patients were males (55.8%) as described in Table 1. Underlying disease, ECG at arrest and therapeutic hypothermia use was not significantly different between groups.

Table 1 Demographic data

	Total (n = 43) Number (%)	Good prognosis at 6 months* (n = 8) Number (%)	Poor prognosis at 6 months* (n = 35) Number (%)	p-value
Age (years): mean ± SD (range)	62.1 ± 19.9 (21-98)	57.5 ± 13.9 (27-69)	63.2 ± 21.1 (21-98)	0.178#
Gender; Male : Female	24 : 19	3 : 5	21 : 14	0.223$
Resuscitation time (minute): mean ± SD (range)	15.3 ± 12.8 (2-52)	18.0 ± 13.7 (2-40)	14.7 ± 12.7 (2-52)	0.571
Diabetes	19 (44.2%)	2 (25%)	17 (48.6%)	0.209$
Hypertension	26 (60.5%)	2 (25%)	24 (68.6%)	0.031$
Dyslipidemia	23 (53.5%)	2 (25%)	21 (60%)	0.081$
Heart disease	17 (39.5%)	1 (12.5%)	16 (45.7%)	0.088$
Stroke	4 (9.3%)	1 (12.5%)	3 (8.6%)	0.576$
Out hospital arrest	18 (41.9%)	4 (50%)	14 (40%)	0.447$
ECG at arrest: asystole or PEA	36 (83.7%)	5 (62.5%)	31 (88.6%)	0.106$
ECG at arrest: VT, VF	7 (16.3%)	3 (37.5%)	4 (11.4%)	0.106$
Therapeutic hypothermia	15 (34.9%)	3 (37.5%)	12 (34.3%)	0.583
Duration ROSC to CT brain (hour): mean ± SD (range)	12.8 ± 15.8 (1-57)	13.5 ± 16.3 (1-46)	12.6 ± 15.9 (1-57)	0.748

Data are shown as mean±standard deviation. # p-value by Mann-Whitney U test
$ p-value by Fisher-Exact test; Significant if $p<0.05$, ROSC : return of spontaneous circulation, PEA : pulseless electrical activity, VT : ventricular tachycardia, VF : ventricular fibrillation

Patients after return of spontaneous circulation (ROSC) have persistent vegetative state: minimal responsiveness (76.7%) and death at hospital discharge (65.1%). At six months, patients' Glasgow outcome scale scores were GOS 1 (Death) 69.8%. (Table 2)

After cardiac arrest, there is no statistically significant distinction in Hounsfield unit in a distinct brain area between individuals with a good prognosis and those with a bad prognosis (Table 3)

Table 2 Outcomes at different time points

		Total (n = 43) Number (%)
Glasgow outcome scale at return of spontaneous circulation (ROSC)		
1	Death	NA
2	Persistent vegetative state: Minimal responsiveness	33 (76.7%)
3	Severe disability: Conscious but disabled, dependent on others for daily	8 (18.6%)
4	Moderate disability: Disabled but independent; can work in sheltered setting	2 (4.7%)
5	Good recovery: Resumption of normal life despite minor deficits	0
Death at hospital discharge		28 (65.1%)
Glasgow outcome scale at 6-months		
1	Death	30 (69.8%)
2	Persistent vegetative state: Minimal responsiveness	5 (11.6%)
3	Severe disability: Conscious but disabled, dependent on others for daily	1 (2.3%)
4	Moderate disability: Disabled but independent; can work in sheltered setting	1 (2.3%)
5	Good recovery: Resumption of normal life despite minor deficits	6 (14%)

Table 3 Hounsfield at different brain areas after cardiac arrest

	Total (n = 43) mean ± SD	Good prognosis at 6 months* (n = 8) mean ± SD	Poor prognosis at 6 months* (n = 35) mean ± SD	p-value#
Caudate	36.9 ± 4.8	36.8 ± 2.3	36.9 ± 4.8	0.058
Putamen	36.6 ± 4.7	39.2 ± 4.7	36.6 ± 4.7	0.109
Posterior internal capsule	30.3 ± 3.8	31.2 ± 4.7	30.3 ± 3.8	0.381
White matter	30.6 ± 3.2	31.5 ± 4.1	30.6 ± 3.2	0.471
High convexity gray matter	34.9 ± 5.3	35.9 ± 2.3	34.9 ± 5.3	0.915
High convexity white matter	28.4 ± 2.8	29.5 ± 2.5	28.4 ± 2.8	0.317
Centrum semiovale gray matter	34.9 ± 4.2	37.2 ± 3.5	34.9 ± 4.2	0.109
Centrum semiovale white matter	27.2 ± 3.9	29.4 ± 5.1	27.2 ± 3.9	0.199

Good prognosis = GOS 3-5, Poor prognosis = GOS 1-2

p-value by Mann-Whitney U test

The average gray-to-white matter density ratio in the basal ganglion and cortex, as well as when they are combined, does not significantly differ. (Table 4)

Table 4 GWR after arrest

	Total (n = 43) mean ± SD	Good prognosis at 6 months* (n = 8) mean ± SD	Poor prognosis at 6 months* (n = 35) mean ± SD	p-value#
Basal ganglia GWR (BG-GWR)	1.2 ± 0.2	1.3 ± 0.1	1.2 ± 0.2	0.530
Cortex GWR (C-GWR) (frontal + centrum semiovale)	1.3 ± 0.2	1.2 ± 0.1	1.3 ± 0.2	0.247
Combined BG-GWR + C-GWR	1.2 ± 0.2	1.3 ± 0.1	1.2 ± 0.2	0.866

Discussion

There are numerous algorithms to predict poor neurological outcomes in comatose patients. The main CT finding of global anoxic-ischemic cerebral insult following cardiac arrest is cerebral edema, which appears as reduction in the depth of the cerebral sulci and decreased attenuation of the grey-to-white matter density. Guidelines for the prognostication of cardiac arrest do not include the ratio of a bad neurological outcome in the CT brain. The finding of this study shows that the density of gray-white ratio on CT brain in 60 hours after cardiac arrest patients. The 24-hour CT brain imaging of a cardiac arrest patient's gray-white matter ratio, according to Choi SP[1], is poorly favorable at less than 1.22 predicted vegetative state or death with sensitivity of 63% and a specificity of 100%.

The results show no significant difference of gray-white matter ratio in the basal ganglion, cortex and combined in good prognosis and poor prognosis groups. Patients with positive prognoses were likely to have higher Hounsfield gray-white matter ratios than patients with bad prognoses, according to Hounsfield's caudate but there was no significant difference.

There are several limitations to the study. First, this was retrospective cohort study at a single institution. The number of good prognostics was relatively than poor prognosis. The CT scans were performed at different times, and this could have influenced the CT density changes in anoxic-ischemic cerebral disease. Therefore, a well-designed prospective study on a larger number of patients is needed to predict and confirm the GW-WM density ratio cutoff value for the prediction of vegetative state or death.

Conclusion

The GW-WM ratio did not significantly differ in the post-cardiac arrest patients in our investigation for determining prognosis of death or vegetative state

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Institutional review board statement

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