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Original Article

Prognosis Value of Gray-White-Matter Ratios in Comatose Survivors After In-Hospital Cardiac Arrest

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Background: The gray-white-matter ratio (GWR) measured on cerebral non-contrasted computed tomography (NCCT) has been reported to help the prognostication of mortality or comatose status of out-of-hospital cardiac arrest (OHCA) victims. Since the etiologies and resuscitative process differ significantly between patients with OHCA and in-hospital cardiac arrest (IHCA), the predictive ability of GWR in IHCA survivors remains unclear.
Methods: This retrospective observational study conducted in a single tertiary medical center in Taiwan enrolled all the non-traumatic IHCA adults with sustained return of spontaneous circulation (ROSC) and had received cerebral NCCT examination within 24 hours following cardiac arrest. The GWR of survivor and non-survivor as well as good and poor neurological outcome were analyzed.
Results: A total of 79 IHCA patients with 68.4% in male gender and mean age of 66-year-old were enrolled in the current study. Thirty-four patients (43.0%) survived to hospital discharge and 20 patients (25.3%) were discharged with good neurological outcome. The median GWR of patients with good and poor outcomes in either aspect of survival or neurological function did not show significant difference. The area under the plotted receiver of characteristic curves of each GWR did not also show satisfactory predictive performance.
Conclusion: The use of GWR for outcome prognosis of patients in emergency department who progressed to circulatory failure did not show promising result.

Key words: *brain computed tomography, gray-white-matter ratio, in-hospital cardiac arrest, prognosis*

Introduction

The catastrophic consequence of cardiac arrest, hypoxic-ischemic brain injury in particular, heralded a major health burden to the family member and medical professional. Accessible and reliable predictive tools are crucial to make an appropriate medical decision in order to avoid prolonged futile medical care. Others than the traditional neurologic examination, the evolution of various biochemical markers and electrophysiologic tests have been proposed to help the prediction of survival and neurological outcomes. Absence of pupillary light reflex and corneal reflex,[1] bilateral absence of N20 somatosensory evoked potential,[2,3] as well as lower level of serum neuron-specific enolase and S100 calcium-binding protein B at

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72 hours,[4] predicted poor outcome in cardiac arrest with substantial evidence. However, these tests are not always trustworthy during the early phase of post-arrest status. Besides, some of the tests are not readily available in the majority of institutes. Brain non-contrasted computed tomography (NCCT) evolved as a useful method in evaluating the severity of ischemic brain injury since last two decades as reflected by the extent of the loss of distinction of gray and white matter. Edematous change of brain especially at the gray matter results in the attenuation of its density.[5] The measurement of gray-white-matter ratio (GWR) helps to quantify the edematous intensity in which lower value indicates more extensive damage. These values predict the unfavorable survival and neurological outcomes with 100% specificity with various cut-off values and acceptable sensitivities.[6-13] However, the mechanism of arrest, the interval of arrest to intervention and the total cardiopulmonary resuscitation (CPR) duration differed significantly between the out-of-hospital cardiac arrest (OHCA) and in-hospital cardiac arrest (IHCA) patients.[14,15] The predictive value of GWR may have large discrepancy in these two cohorts. The predictive ability of GWR in patients with IHCA remains unclear. Therefore, we would like to evaluate the utility of GWR in predicting outcome of IHCA patient who regained circulating rhythm.

Methods

Study Population

This retrospective, single-center observational study enrolled adult patients (> 18-year-old) who had IHCA in emergency department of the National Taiwan University Hospital, and received NCCT within 24 hours after cardiac arrest following regained sustained return of spontaneous circulation (ROSC) during 2006–2014 (n = 354). Patients with previous history of severe intracranial pathology (n = 47), including 20 patients with intracerebral hemorrhage, 8 patients with pre-existing severe old insult, 2 patients with brain tumor, 1 patient with ventriculoperitoneal shunt, and 16 patients with severe CT artifact were excluded. 228 patients who had arrested outside of the healthcare facilities were further omitted. Finally, 79 IHCA patients with sustained ROSC and had received brain NCCT examination within 24 hours without significant intracranial abnormalities were eligible to our study (Fig. 1). This study was approved by the Institutional Board Review with a waiver of informed consent.

Data Collection and Outcome Measurement

From the individual medical charts, we retrospectively collected the following information: preexisting comorbidities, the neurological function before cardiac arrest (evaluated as Cerebral Performance Category, CPC), initial electrocardiographic (ECG) rhythm, the presence of witnessed collapse, resuscitative details, CPR duration, the highest Acute Physiology and Chronic Health Evaluation (APACHE) II score in the first 24 hours after ROSC, mean blood pressure 30 minutes after ROSC, medical treatment at resuscitation, post-arrest care (e.g., percutaneous coronary intervention and therapeutic hypothermia), laboratory and radiological findings. Initial shockable rhythm included ventricular fibrillation and ventricular tachycardia. ROSC was defined as a palpable pulse with measurable blood pressure and sustained ROSC as ROSC persisted for more than 20 minutes. Causes of cardiac arrest were classified as cardiogenic or noncardiogenic. The cardiogenic causes included acute coronary syndrome and fatal arrhythmia without electrolyte imbalance. The noncardiogenic causes included respiratory event, infectious etiology, massive gastrointestinal bleeding, central nervous system lesion, and others. Repeated laboratory examinations, 12-leads ECG, and additional selective examinations such as brain NCCT, transthoracic echocardiography, abdominal sonography, and coronary angiography were performed to determine the cause of cardiac arrest in survivors. The etiology of cardiac arrest was determined by the physician-in-charge and was reviewed by the study physicians. The controversy was resolved after discussion among the physicians. The survival to discharge was defined as patient's survival to hospital discharge, including return to home or relocate to a nursing residence. The neurological status was dichotomized to two groups according to the CPC. Those who could recover to live with an independent live at discharge fell into the group with favorable outcome (CPC level 1 or 2) whereas those did not were denoted as unfavorable outcome (CPC level 3–5).

Computed Tomography Measurements

The brain NCCT was performed with 64-rows multi-detector scanner (LightSpeed VCT) in axial mode by the technician on duty who was not involved

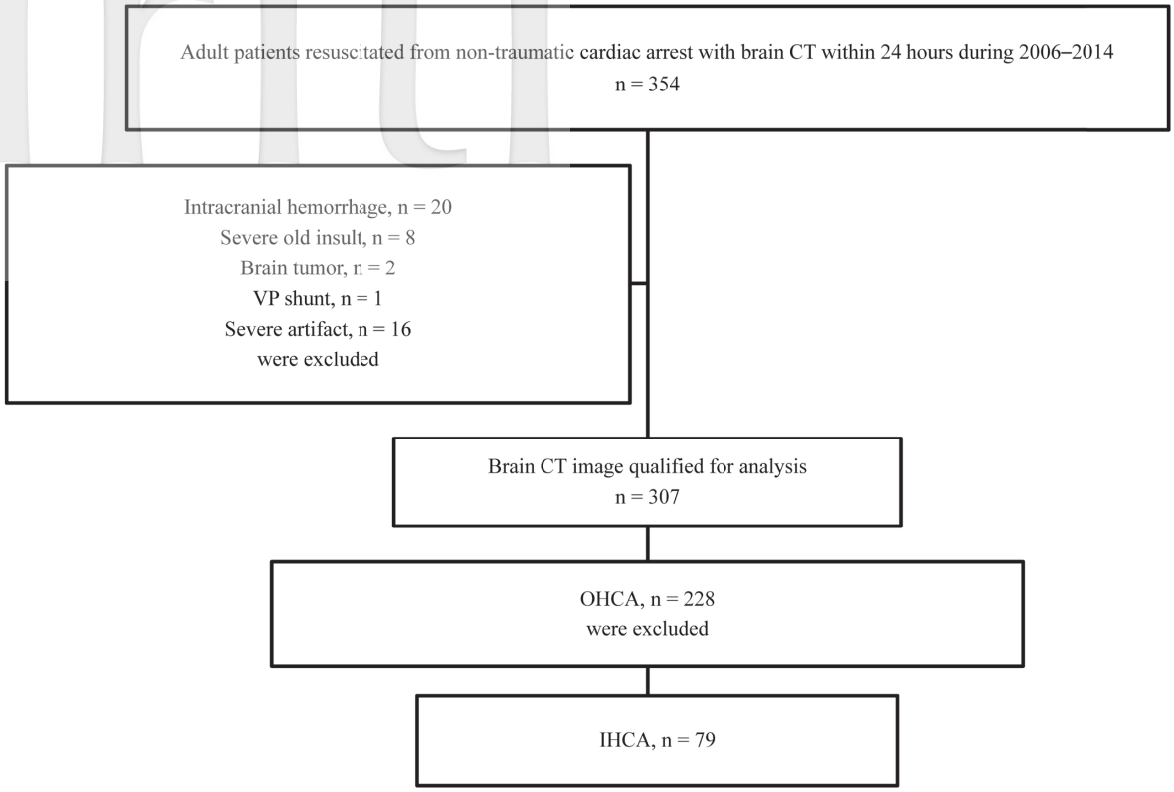

Fig. 1. Flowchart of patient enrollment.
CT: computed tomography; IHCA: in-hospital cardiac arrest; OHCA: out-of-hospital cardiac arrest; VP shunt: ventriculoperitoneal shunt.

in our study. Two senior residents from emergency medicine and radiology department respectively evaluated the image parameters independently through Picture Archiving and Communication System. Both of the physicians went through a course of self-training for landmark identification on computed tomography (CT) images prior to the study initiation. They were blinded to the patient's clinical information.

The Hounsfield Unit (HU) of selective region of interest was measured according to the precedent publications. Circular region of interest with measurement of 0.11 cm^2 was placed at the selective area of gray matter and white matter at both of the basal ganglia and cerebral hemispheres. At basal ganglia level, the density of bilateral putamen (PU), head of caudate nuclei (CN), posterior limb of internal capsule (PIC) and corpus callosum (CC) were measured (Supplement Fig. 1). The gray matter to white matter ratio of basal ganglia (GWR-BG) was calculated as follow:

$$GWR\text{-}BG = (PU + CN) / (PIC + CC)$$

The density of bilateral medial gray matter and medial white (MW) matter were determined at two levels, centrum semiovale and high convexity area respectively. The centrum semiovale is located 5 mm just above the last lateral ventricle whereas the high convexity area is located 5 mm just cranial to it. The division of the sum of all gray matter and white matter constitutes the GWR of cerebrum (GWR-C) as shown by the formula below:

GWR-C = (medial cortex at centrum semiovale level [MC1] + medial cortex at high convexity area [MC2]) / (MW matter at centrum semiovale level [MW1] + MW matter at high convexity area [MW2])

The average of GWR-BG and GWR-C gave rise to the average GWR of the brain (GWR-AVE):

$$GWR\text{-}AVE = (GWR\text{-}BG + GWR\text{-}C) / 2^{9}$$

In addition, the simplified version of GWR with inclusion of PU and PIC only was also calculated for comparison:

GWR-PUPIC = PU / PIC[11,12]

The GWR calculation was went through twice by the first interpreter at different interval in order to estimate the intra-rater consistency. Both of the results of the two interpreters were compared for the determination of inter-rater reliability. The image interpretation performance was evaluated by a third party.

Statistical Analysis

Demographic and clinical characteristics of enrolled patients were reported as frequencies and percentages for categorical variables, as means and standard deviations for continuous variables. The values of GWR were presented as medians and interquartile ranges. The group comparisons in terms of survival to discharge (survivor vs. non-survivor) and neurological outcome at hospital discharge (good neurological outcome vs. poor neurological outcome) in demographic characteristics, resuscitative events, and GWR prognostication were also analyzed, using chi-square or Fisher's exact test for categorical variables, Student's t-test or Mann-Whitney U test for continuous variables.

Receiver of characteristic (ROC) curves were plotted to evaluate the GWR performance of outcome prediction as shown by the area under the curve (AUC). Optimal cutoff value with 100% specificity was obtained from the ROC curve. The corresponding sensitivity and positive predictive value were estimated with their 95% confidence interval (95% CI). A *p*-value less than 0.05 was considered as statistically significant. All analyses were performed by using SPSS version 21.0 software.

Results

Table 1 demonstrated the demographic characteristics of the patients. The mean age of the patients was 66-year-old and the majority of them were male in gender (68.4%). There were 34 patients (43.0%) survived to hospital discharge and 45 patients deceased (57.0%). 20 (25.3%) and 59 (74.7%) patients were discharged with good and poor neurological outcome respectively. There was no significant difference in demographic characteristic, except a higher proportion of patients with premorbid cerebrovascular accident did not survive the cardiac arrest event (29.4% vs. 11.1%, $p = 0.04$).

The important resuscitative variables were

Table 1. Comparison of demographic characteristic between patients with good and poor survival and neurological outcomes

	Total patients (n = 79)	Survival to discharge		*p*-value	Neurological outcome		*p*-value
		Survivor (n = 34)	Non-survivor (n = 45)		Good (n = 20)	Poor (n = 59)	
Age	66.0 ± 15.4	67.0 ± 16.8	65.2 ± 14.3	0.621	61.1 ± 17.6	67.6 ± 14.3	0.101
Gender (male)	54 (68.4)	22 (64.7)	32 (71.1)	0.544	14 (70.0)	40 (67.8)	0.855
DM	27 (34.2)	11 (32.4)	16 (35.6)	0.766	7 (35.0)	20 (33.9)	0.928
HTN	36 (45.6)	17 (50.0)	19 (42.2)	0.492	10 (50.0)	26 (44.1)	0.645
CAD	19 (24.1)	9 (26.5)	10 (22.2)	0.662	4 (20.0)	15 (25.4)	0.767
HF	4 (5.1)	1 (2.9)	3 (6.7)	0.630	1 (5.0)	3 (5.1)	1.000
COPD/asthma	3 (3.8)	2 (5.9)	1 (2.2)	0.574	2 (10.0)	1 (1.7)	0.156
ESRD	9 (11.4)	4 (11.8)	5 (11.1)	1.000	2 (10.0)	7 (11.9)	1.000
Cirrhosis	4 (5.1)	1 (2.9)	3 (6.7)	0.630	0	4 (6.8)	0.567
CVA	15 (19.0)	10 (29.4)	5 (11.1)	0.040	4 (20.0)	11 (18.6)	1.000
Dementia	8 (10.1)	4 (11.8)	4 (8.9)	0.720	1 (5.0)	7 (11.9)	0.672
Malignancy	24 (30.4)	9 (26.5)	15 (33.3)	0.511	4 (20.0)	20 (33.9)	0.277
CPC = 1–2	60 (75.9)	24 (70.6)	36 (80.0)	0.332	20 (100.0)	40 (67.8)	0.004

Data given as number (%) or mean (standard deviation). $p < 0.005$ defined as statistical significance. Pre-arrest cerebrovascular accident associated with poorer survival outcome.

CAD: coronary artery disease; COPD: chronic obstructive pulmonary disease; CPC: Cerebral Performance Category; CVA: cerebrovascular accident; DM: diabetes mellitus; ESRD: end-stage renal disease; HF: heart failure; HTN: hypertension.

shown in the Table 2. Most patients (86.1%) collapsed with witness but only 17.7% of patients presented with the initial shockable rhythm. Half of the patients with presumed cardiogenic arrest received primary PCI (15.2%). Nine patients (11.4%) received ECMO support during resuscitation and 18 patients (22.8%) received therapeutic hypothermia with target temperature of 33°C. No significant discrepancy of resuscitative variables between the survivors and non-survivors. In contrary, the patients with favorable neurological outcome had a higher proportion of first monitored shockable rhythm (35.0% vs. 11.9%, p = 0.019) and required relatively larger amount of defibrillation times (1.2 ± 2.1 vs. 0.3 ± 0.9, p = 0.087). They also had a higher rate of primary revascularization therapy with percutaneous coronary intervention (30.0% vs. 10.2%, p = 0.033) and therapeutic hypothermia (40.0% vs. 16.9%, p = 0.034) after ROSC. The status of witnessed arrest, etiology of cardiac arrest, CPR duration, involvement of extracorporeal CPR and APACHE II score were similar in both of the good and poor neurological outcomes groups.

GWR Contributions to the Outcome Predictions

All of the estimated GWR included the conventional method (GWR-BG, GWR-C, and GWR-AVE) and simplified version (GWR-PUPIC) were shown in Table 3. Although most of the patients with positive outcomes had relatively higher GWR values, they did not reach statistical significance. After excluding the individuals with poor pre-arrest CPC level, the poor predictive performance of GWRs still hold true (Supplement Table 1).

The test-retest and inter-rater reliability were excellent as shown by their intra-class correlation co-efficiencies with 0.932 and 0.908, respectively.

Receiver of operating characteristic curve was plotted to evaluate the predictive performance of the GWR. The AUC for predicting 100% mortality with GWR-BG, GWR-C, GWR-AVE and GWR-PUPIC were 0.51 (95% CI: 0.38–0.64, p = 0.866), 0.57 (95% CI: 0.44–0.70, p = 0.294), 0.57 (95% CI: 0.44–0.70, p = 0.322) and 0.49 (95% CI: 0.36–0.62, p = 0.851), respectively (Fig. 2 and Table 4). Similar trend was found for making prediction of poor neurological outcome (CPC: 3–5) with 100% specificity as presented by their

Table 2. Comparison of resuscitative events between good and poor survival and neurological outcomes

	Total patients (n = 79)	Survival to discharge		p-value	Neurological outcome		p-value
		Survivor (n = 34)	Non-survivor (n = 45)		Good (n = 20)	Poor (n = 59)	
Cause of arrest				0.740			0.279
Cardiac	24 (30.4)	11 (32.4)	13 (28.9)		8 (40.0)	16 (27.1)	
Respiratory	32 (40.5)	17 (50.0)	15 (33.3)		9 (45.0)	23 (39.0)	
Septic	16 (20.2)	4 (11.8)	12 (26.7)		1 (5.0)	15 (25.4)	
Others	7 (8.9)	2 (5.9)	5 (11.1)		2 (10.0)	5 (8.5)	
Witnessed collapse	68 (86.1)	29 (85.3)	39 (86.7)	0.861	15 (75.0)	53 (89.8)	0.098
Initial shockable rhythm	14 (17.7)	9 (26.5)	5 (11.1)	0.077	7 (35.0)	7 (11.9)	0.019
Defibrillation (times)	0.51 ± 1.34	0.7 ± 1.7	0.3 ± 1.0	0.188	1.2 ± 2.1	0.3 ± 0.9	0.087
CPR duration (min)	12.35 ± 11.19	11.6 ± 9.2	11.2 ± 11.1	0.866	11.2 ± 9.8	11.4 ± 10.5	0.941
PCI after ROSC	12 (15.2)	8 (23.5)	4 (8.9)	0.112	6 (30.0)	6 (10.2)	0.033
ECMO during CPR	9 (11.4)	3 (8.8)	6 (13.3)	0.725	3 (15.0)	6 (10.2)	0.685
TH	18 (22.8)	10 (29.4)	8 (17.8)	0.222	8 (40.0)	10 (16.9)	0.034
Highest APACHE II within 24 hour	23.57 ± 7.18	22.90 ± 7.50	24.57 ± 6.84	0.510	23.00 ± 8.24	23.87 ± 6.76	0.740
GCS after ROSC	3.48 ± 1.59	3.84 ± 2.08	3.22 ± 1.06	0.128	4.50 ± 2.62	3.17 ± 0.93	0.048

Data given as number (%) or mean (standard deviation). $p < 0.005$ defined as statistical significance. First monitored shockable rhythm, higher GCS shortly after ROSC and application of PCI and TH associated with favorable neurological outcome.
APACHE II: Acute Physiology and Chronic Health Evaluation II; CPR: cardiopulmonary resuscitation; ECMO: extracorporeal membrane oxygenation; GCS: Glascow Coma Scale; PCI: percutaneous coronary intervention; TH: therapeutic hypothermia.

Table 3. The grey matter-to-white matter ratio values between groups

	Survival to discharge			Neurological outcome		
	Survivor	Non-survivor	*p*-value	Good	Poor	*p*-value
GWR-BG	1.265 (1.206–1.304)	1.263 (1.200–1.305)	0.866	1.271 (1.234–1.342)	1.262 (1.195–1.303)	0.215
GWR-C	1.232 (1.189–1.366)	1.218 (1.179–1.207)	0.294	1.217 (1.199–1.282)	1.230 (1.178–1.309)	0.718
GWR-AVE	1.247 (1.214–1.321)	1.245 (1.205–1.289)	0.322	1.252 (1.221–1.311)	1.244 (1.194–1.300)	0.264
GWR-PUPIC	1.259 (1.196–1.323)	1.270 (1.191–1.344)	0.851	1.280 (1.235–1.374)	1.261 (1.180–1.328)	0.079

No significant difference of GWR values with respect to their survival and neurological outcomes.
AVE: average; BG: basal ganglia; C: cerebrum; GWR: grey matter-to-white matter ratio; PIC: posterior limb of internal capsule; PU: putamen.

corresponding AUC values: 0.59 (95% CI: 0.46–0.73, $p = 0.215$), 0.53 (95% CI: 0.39–0.66, $p = 0.718$), 0.58 (95% CI: 0.45–0.72, $p = 0.264$) and 0.63 (95% CI: 0.50–0.77, $p = 0.079$) in orderly (Fig. 3 and Table 5).

Discussion

The present study enrolled 79 adult patients resuscitated from non-traumatic IHCA and received brain NCCT within 24 hours after ROSC. It demonstrated that GWR application did not show significant benefit in predicting survival and neurological outcomes in IHCA survivors. This is the first study to evaluate the effectiveness of GWR in predicting the survival and neurological outcomes for IHCA patients.

Several preceding studies showed compelling evidence of predictive role of GWR in the OHCA patients who regained circulating rhythm.[7-9] There were multiple retrospective analyses revealed 100% specificity prediction for hospital mortality and dependent lifestyle after ROSC with different cut-off values that varied among facilities. GWR-BG < 1.18[7] and GWR-AVE < 1.14[8] had been reported to be a useful predictive threshold. Simplified version of GWR as shown in a retrospective study in which GWR-CNPIC < 1.22 helped to predict death or vegetative state with 100% specificity and 63% sensitivity.[9] The combination of laboratory and clinical examinations with GWR further improve the prediction. GWR-PUPIC in combination with neurological examination[10] and serum neuron specific enolase[11] increased the sensitivity of prognostication. The further addition of malignant electroencephalography pattern and clinical examination with Full Outline of Unresponsiveness Brainstem or Pitsburg postCardiac Arrest Category significantly improved the prognostic performance.[16] However, the discriminatory power of our GWR was indeterminate. The highest predictive performance of in-hospital mortality and poor neurological outcome are GWR-C (AUC: 0.57, 95% CI: 0.44–0.70; sensitivity: 2.2%; $p = 0.294$) and GWR-PUPIC (AUC: 0.63, 95% CI: 0.50–0.77; sensitivity: 23.7%; $p = 0.079$) respectively. An observational study involving 284 patients revealed the evidence of poor predictive performance for neurological outcome in the scenario of cardiogenic arrest.[12] Therefore, the performance of the GWR in specific subgroup need additional consideration.

The peri-arrest process of IHCA differed significantly from the OHCA patients.[14,15] In the current

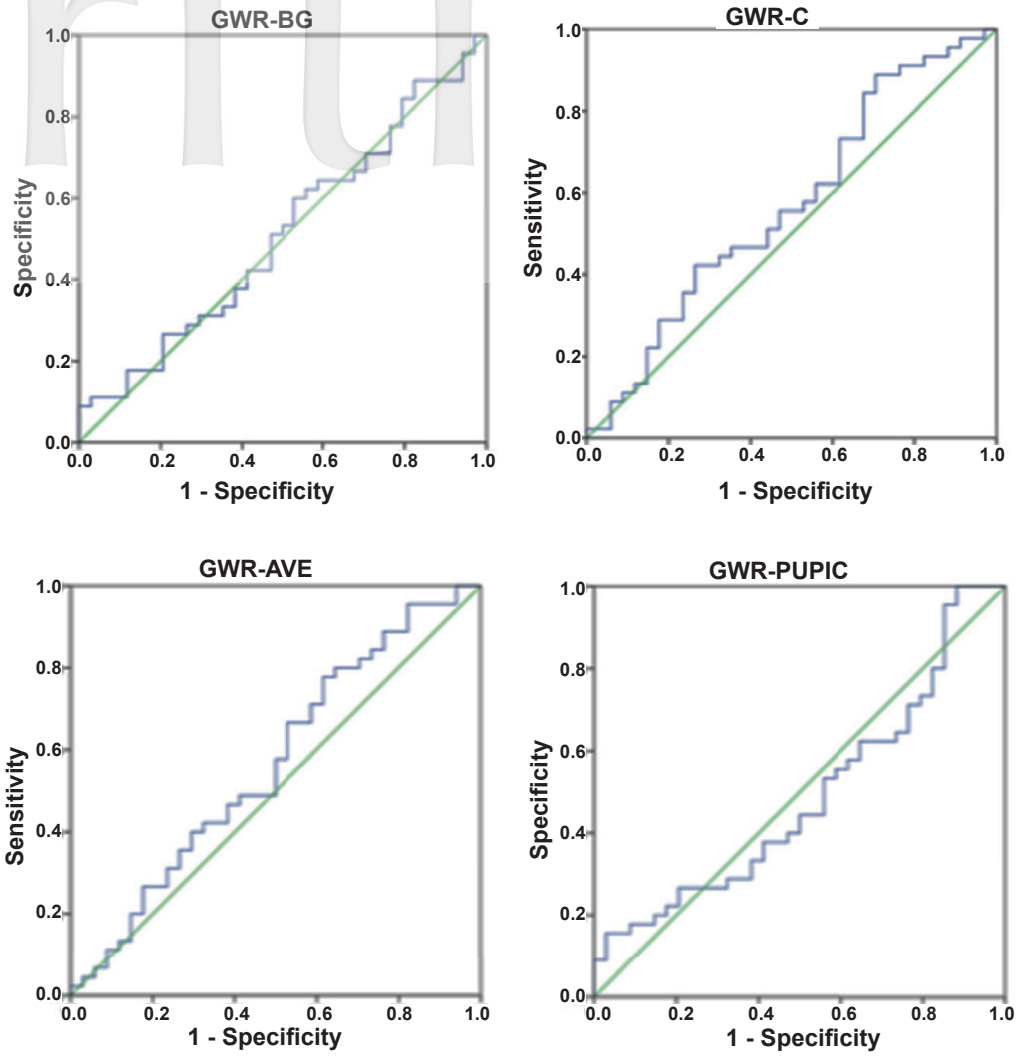

Fig. 2. The receiver of characteristic curve and predictive performance of grey matter-to-white matter ratio for in-hospital mortality.

AVE: average; BG: basal ganglia; C: cerebrum; GWR: gray matter-to-white matter ratio; PIC: posterior limb of internal capsule; PU: putamen.

Table 4. The area under the curve values of gray matter-to-white matter ratio for inhospital mortality

	AUC (95% CI)	Cut-off	Sensitivity (%)	Specificity	*p*-value
GWR-BG	0.51 (0.38–0.64)	1.101	8.9	100	0.866
GWR-C	0.57 (0.44–0.70)	0.866	2.2	100	0.294
GWR-AVE	0.57 (0.44–0.70)	0.931	2.2	100	0.322
GWR-PUPIC	0.49 (0.36–0.62)	1.134	8.9	100	0.851

Poor predictive ability of gray matter-to-white matter ratio for inhospital mortality with 100% specificity as demonstrated by their low area under the curve in the range of 0.49–0.57.

AUC: area under the curve; AVE: average; BG: basal ganglia; C: cerebrum; CI: confidence interval; GWR: gray matter-to-white matter ratio; PIC: posterior limb of internal capsule; PU: putamen.

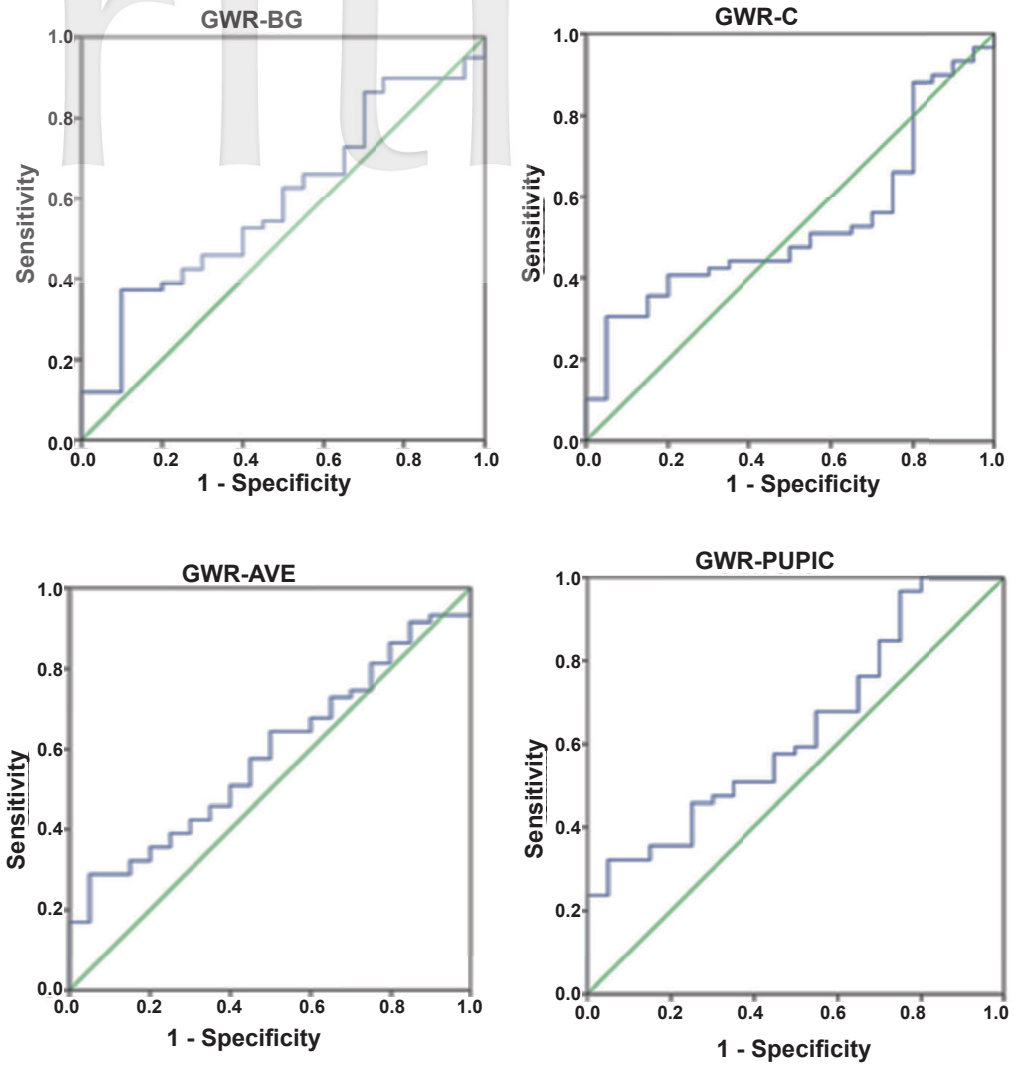

Fig. 3. The receiver of characteristic curve and predictive performance of gray-white-matter ratio for poor neurological outcome.

AVE: average; BG: basal ganglia; C: cerebrum; GWR: gray matter-to-white matter ratio; PIC: posterior limb of internal capsule; PU: putamen.

Table 5. The area under the curve values of gray matter-to-white matter ratio for poor neurological outcome

	AUC (95% CI)	Cut-off	Sensitivity (%)	Specificity	*p*-value
GWR-BG	0.59 (0.46–0.73)	1.135	11.9	100	0.215
GWR-C	0.53 (0.39–0.66)	1.138	10.2	100	0.718
GWR-AVE	0.58 (0.45–0.72)	1.179	16.9	100	0.264
GWR-PUPIC	0.63 (0.50–0.77)	1.178	23.7	100	0.079

Poor predictive ability of gray matter-to-white matter ratio for Cerebral Performance Category level 3–5 with 100% specificity as demonstrated by their low area under the curve in the range of 0.53–0.63.

AUC: area under the curve; AVE: average; BG: basal ganglia; C: cerebrum; CI: confidence interval; GWR: gray matter-to-white matter ratio; PIC: posterior limb of internal capsule; PU: putamen.

study, most of the etiologies of IHCA were presumed to be respiratory (40.5%), cardiac (30.4%) and septic etiologies (20.2%) whereas the main culprits for the OHCA patients at the same period were cardiac (48.7%), followed by respiratory (36.8%) and septic event (6.6%) (not shown). The unfavorable outcome might be an inevitable consequence of the progression of the chronic advanced illness such as malignancy. Larger amount of patients with active cancer existed in this group (30.4% vs. 13.2%) (not shown). Patients with advanced cancer expected lower survival rate after IHCA.[17] Besides, the percentage of patient with presumed septic etiology was obviously greater in IHCA survivors. Severe exacerbation of infectious disease was notorious for exempt from mortality.[15] The brain image studies may not be a reliable tool for outcome prediction in this subgroup of patient.

The IHCA patients also had different resuscitative details from the OHCA patients. Compared to OHCA cohort, the patients who coded in the institute had earlier accessed to medical attention and intervention. The immediate advanced cardiac life support (ACLS) intervening by the experienced health care personnel led to shorter no-flow time.[14] Our study showed that the IHCA patients had marked shorter CPR duration with smaller standard deviation when compared to the contemporary OHCA cohort as the previous study.[15] Earlier activation of chain of survival and higher quality of resuscitation in the hospital might help to re-initiate the circulating rhythm quicker compared to the out-of-hospital scenario. Therefore, the anoxic insult of brain might be lesser in severity, resulting limited attenuation of brain UH.

There were several limitations in the current study. First, this was a retrospective study and the crucial clinical information may not be retrieved completely through medical chart review. Second, the study is conducted in an urban hospital. The result of our study should not be generalized to other contexts. Besides, the enrollment of only the IHCA survivors with brain CT examination within 24 hours may prone to selection bias. Forth, the change of ACLS guideline and the improvement of resuscitative quality along in years may influent our result. Last, the sample size of the current study is relatively small. Prospective multicenter study with more patient enrollment may be necessary for better clarification of usefulness of GWR in IHCA survivors.

Conclusion

In our study, GWR application did not show promising result in predicting hospital survival and neurological outcome of patients in emergency department who deteriorated to cardiac arrest.

Conflicts of Interest Statement

None.

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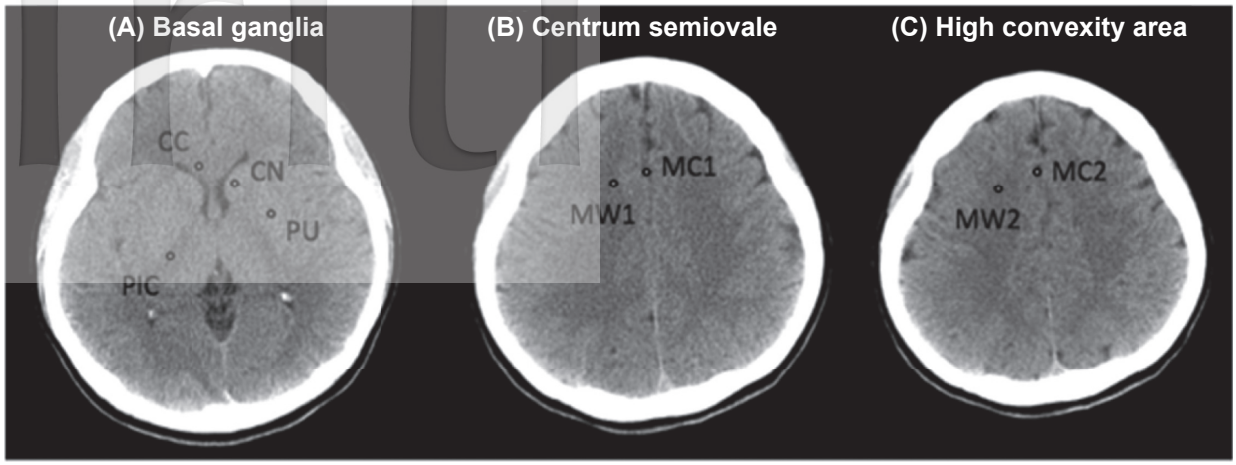

Supplement Fig. 1. Brain computed tomography of one of the eligible patient

The region of interest that computed the estimation of gray matter to white matter ratio.
CC: corpus callosum; CN: caudate nuclei; MC1: medial cortex at centrum semiovale level; MC2: medial cortex at high convexity area; MW1: medial white matter at centrum semiovale level; MW2: medial white matter at high convexity area; PIC: posterior limb of internal capsule; PU: putamen.

Supplement Table 1. The grey matter-to-white matter ratio values for predicting neurological outcome in patients with good pre-arrest Cerebral Performance Category (n = 61)

	Good neurological outcome (n = 20)	Poor neurological outcome (n = 41)	*p*-value
GWR-BG	1.271 (1.234–1.342)	1.267 (1.203–1.303)	0.442
GWR-C	1.217 (1.199–1.282)	1.218 (1.169–1.302)	0.398
GWR-AVE	1.252 (1.221–1.311)	1.241 (1.209–1.289)	0.225
GWR-PUPIC	1.280 (1.235–1.374)	1.269 (1.202–1.342)	0.256

Data given as median (interquartile range). No significant difference of GWR values between patients with good and poor neurological outcome in subset patients with pre-arrest CPC level of 1–2.
AVE: average; BG: basal ganglia; C: cerebrum; CPC: Cerebral Performance Category; GWR: grey matter-to-white matter ratio; PIC: posterior limb of internal capsule; PU: putamen.