ORIGINAL ARTICLE

Prognostic Value of QT Parameters in Patients with Acute Hemorrhagic Stroke: A Prospective Evaluation with Respect to Mortality and Post-hospitalization Bed Confinement

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Background: This prospective study was performed to evaluate the prognostic prediction value of QT parameters and clinical characteristics exhibited by patients with acute hemorrhagic stroke at the time of presenting to the emergency department (ED).

Methods: One hundred and sixty-six patients admitted to the ED of Taipei Veterans General Hospital from January 2006 to October 2006 because of acute hemorrhagic stroke were enrolled. Glasgow Coma Scale (GCS) scores between 3 and 8 were taken to indicate severe neurologic deficits. QT parameters (QT max, QT min, QT dispersion, QTc max, QTc min, QTc dispersion) and other pertinent clinical variables were determined on admission. Logistic regression model was applied to evaluate prognostic prediction values.

Results: Mortality was higher among stroke patients with low GCS scores ($p < 0.01$). Leukocyte counts and systolic blood pressures were significantly higher among non-surviving patients ($p = 0.04$). No association was found between QT parameters and mortality (all $p > 0.05$). Among survivors, post-hospitalization bed confinement was required for those significantly older ($p = 0.01$) and those with higher QT max and QTc max values in multivariate analyses ($p = 0.04$ and $p < 0.01$, respectively).

Conclusion: Low GCS scores, increased leukocyte counts, and elevated systolic blood pressures predict increased mortality for subjects with acute hemorrhagic stroke. Advanced age and prolongations in QTc and QT max at the time of stroke predicted poor functional recovery for these subjects. [*J Chin Med Assoc* 2009;72(3):124–132]

Key Words: hemorrhagic stroke, prognosis, QTc dispersion, QT parameters

Introduction

Despite the high mortality rate associated with hemorrhagic stroke, approximately 50% of patients who survive appear to make a full functional or neurologic recovery, whereas 26–45% of such patients develop neurologic deficits or require assistance with daily activities.[1,2] Early predictors of mortality and poor functional outcome are crucial for planning the level of care and optimizing resource utilization. Nonetheless, rapid and noninvasive methods for assessing the prognosis of patients with acute hemorrhagic stroke in the emergency department (ED) are currently lacking.

A relationship between an altered QT parameter and poor prognosis has been observed for patients with chronic heart failure[3,4] and diabetes,[5] and for those on dialysis.[6] The QT interval and QT interval dispersion were both found to predict all-cause and cardiac

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mortality and morbidity in a population of Danish citizens.[7] QTc intervals (QT intervals corrected for heart rate) in excess of 429 msec and QTc dispersion measurements in excess of 65 msec are considered significant elevations that place such populations at risk.[6,8] Acute intracranial pathology may signal a variety of electrocardiographic (ECG) abnormalities, including QT interval prolongation.[9] These abnormalities are observed within 12–24 hours in 50% of patients with intracerebral hemorrhage (ICH).[10] In patients with acute subarachnoid hemorrhage (SAH), cardiac involvement can also be significant. Central nervous system-mediated increases in sympathetic and vagal tone are proposed to mediate the observed cardiac abnormalities. Acute stroke is reported to increase QT dispersion within 24 hours in patients without preexisting cardiovascular disease.[11] In patients hospitalized with cerebrovascular accidents, QT dispersion may reflect either neurologic injury or underlying heart disease and is proposed to serve as a predictor of functional outcome and mortality following acute neurologic events.[12]

In a recent retrospective examination of Taiwanese patients with acute ICH, increased QTc dispersion was found to be an independent predictor for inhospital mortality.[13] The present study was conducted to evaluate in a prospective manner the predictive value of QT parameters of Taiwanese patients who present in the ED with acute hemorrhagic stroke due to ICH or SAH with respect to both functional outcome and mortality. Low Glasgow Coma Scale (GCS) scores, increased leukocyte counts, and elevated systolic blood pressures were found to predict increased mortality among these subjects, and advanced age predicted poor functional recovery. A unique finding was that elevations in QTc and QT max at the time of stroke also predicted poor functional recovery for these subjects.

Methods

From January 2006 to October 2006, 166 patients were admitted to the ED of Taipei Veterans General Hospital, Taipei, Taiwan due to acute hemorrhagic stroke and were enrolled in this study. Diagnosis was based on clinical findings and computed tomography (CT) scans obtained upon admission. Laboratory data were collected subsequently. A GCS score between 3 and 8 in the absence of paralytic agents, alcohol or sedatives was taken to indicate severity of neurologic deficits.[14] National Institutes of Health Stroke Scale (NIHSS) scores were also determined at the time of admission, and patients were grouped into the 0–24 or 25–42 category of severity.

Widely-accepted criteria for inclusion[15] and exclusion[16–19] of subjects in studies of uncomplicated acute hemorrhagic stroke were applied. Patient eligibility was determined by: (a) acute stroke of onset time within 6 hours of admission; (b) age in excess of 18 years; (c) CT scan demonstrating hemorrhagic stroke. Exclusion criteria were: (a) absence of an ECG within 6 hours of onset of stroke; (b) a T-wave that was too flat or too biphasic for accurate measurement; (c) presence of calcium abnormalities; (d) current therapy with a beta-blocker, angiotensin-converting enzyme (ACE) inhibitor, or calcium channel blocker; (e) ECG demonstrating atrial fibrillation.

QT intervals, QT dispersion, QTc, and QTc dispersion were calculated by standard methods.[6] The QT interval was defined as the period from the onset of the QRS wave to the return of the T-wave to the T-P baseline in a complete 12-lead ECG and was measured manually. If a U-wave was present, the QT interval was measured to the nadir of the curve between the T-wave and the U-wave. Three consecutive cycles in each of the 12 leads were measured and subsequently analyzed. Because the QT interval differed within each lead, maximal and minimal QT intervals were taken as the longest and shortest QT intervals, respectively, observed within these 12 leads. QT dispersion was defined as the difference between the longest and the shortest QT interval (QT dispersion = QT max – QT min). QT intervals were corrected for heart rate (QTc) using Bazett's formula ($QTc = QT\ interval/\sqrt{R\text{-}R}$, where R-R is the previous RR interval in seconds). QTc dispersion was calculated as the difference between the maximal and the minimal QTc interval occurring within the 12 leads (QTc dispersion = QTc max – QTc min).

QT parameter outcomes (QT max, QT min, QT dispersion, QTc max, QTc min, QTc dispersion) were available for 93 of the 166 enrolled patients. The remaining 73 patients were excluded from the study on the basis of inclusion ineligibility or a poorly-resolved or unreadable ECG. Information regarding inclusion and exclusion of patients is summarized in Figure 1. The following clinical parameters were also determined on admission: heart rate, white blood cell count, and systolic and diastolic blood pressures, as well as serum calcium, creatine phosphokinase, glucose and creatinine concentrations. All patients were followed for 28 days. Mortality was defined as death due to brain failure. Bed confinement was defined as the need for regular aid and attendance for daily life and Barthel index < 20 points.[20]

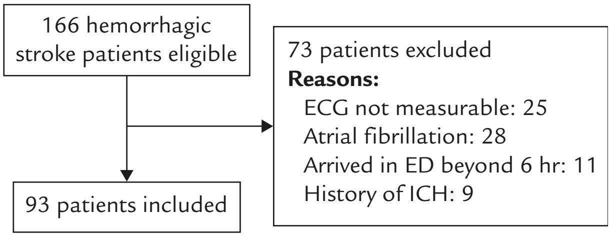

Figure 1. General information on patients' inclusion and exclusion.

Data are presented as mean ± standard deviation or median (range) for continuous variables and as number (%) for categorical variables. Pearson correlation coefficients were computed to investigate the relationships between GCS and ECG parameters. For continuous factors, the two groups were compared with the two-sample *t* test; however, the Wilcoxon rank sum test was used when data were highly skewed. The χ^2 test or Fisher's exact test was employed when comparing categorical factors. Multivariate logistic regression was conducted to examine the relationship between various ECG parameters and prognosis after adjusting for other confounders. A p value < 0.05 was considered statistically significant, and all analyses were performed using SAS version 8.0 (SAS Institute Inc., Cary, NC, USA).

Results

One hundred and sixty-six patients with hemorrhagic stroke were eligible, and 73 patients were excluded. Criteria for exclusion (Figure 1) were: the ECG was not measurable (25 patients); atrial fibrillation was present (25 patients); time of arrival at the ER exceeded 6 hours following stroke (11 patients); a history of ICH was present (9 patients). The ECG was not measureable in 25 patients for the following reasons: the T-wave was too flat to measure (12 patients); the T-wave was too biphasic to measure (8 patients); or tremor or another artifact was present (5 patients). Descriptive characteristics of the 93 stoke patients included in this study are presented in Table 1. The mean age was 61.7 ± 16.1 years, and 63% of included patients were male. The major form of hemorrhage was ICH (64.52%). Six patients (6.45%) were diagnosed with hemorrhage at the brain stem, and 27 patients (29.03%) were diagnosed with SAH. The GCS score was classified as severe in 1 third of patients. Upon determination of the NIHSS score, 37.6% of patients were classified into the 0–24 category, whereas 62.4% of patients were classified into the 25–42 category. Mean values for QT max and QTc max were 448.3 ± 66.8 and 527.3 ± 54.0, respectively. A modest relationship between GCS and 6 ECG parameters was observed, with all Pearson correlation coefficients determined to be < 0.2 (all $p > 0.05$; data not shown). Mean systolic and diastolic blood pressures, mean white blood cell counts, and median creatine phosphokinase values were elevated. Other clinical features were unremarkable.

Surviving and non-surviving patients were compared with respect to demographics, ECG parameters and other clinical features, and findings are presented in Table 2. Patients exhibiting severe GCS scores were less likely to survive ($p < 0.01$); the odds ratio was 4.08 (95% confidence interval [CI], 1.60–10.43), supporting the statistically significant difference between the 2 groups. Patients with higher NIHSS scores were also less likely to survive ($p = 0.02$). Additionally, white blood cell counts and systolic blood pressures were significantly higher among non-surviving patients

Table 1. Demographics, ECG parameters and other clinical features of 93 stroke patients at the time of stroke*

Age, yr	61.8 ± 16.1
Gender	
Male	59 (63.4)
Female	34 (36.6)
Type of hemorrhage	
Intracerebral	60 (64.5)
Brain stem	6 (6.5)
Subarachnoid	27 (29.0)
GCS score	
9–15 (mild–moderate)	61 (65.6)
3–8 (severe)	32 (34.4)
NIHSS score	
0–24	35 (37.6)
25–42	58 (62.4)
ECG parameters	
QT max	448.4 ± 66.9
QT min	344.7 ± 55.1
QT dispersion	104.1 ± 42.5
QTc max	527.4 ± 54.1
QTc min	395.1 ± 45.6
QTc dispersion	132.5 ± 51.9
Heart rate (beats/min)	78.9 ± 16.6
White blood cell count ($\times 10^3/\mu L$)	12.0 ± 4.4
Calcium (mg/dL)	8.3 ± 0.5
Systolic blood pressure (mmHg)	178.7 ± 31.0
Diastolic blood pressure (mmHg)†	96 (62–183)
Creatine phosphokinase (U/L)†	89 (8–4,730)
Glucose (mg/dL)†	139 (71–417)
Creatinine (mg/dL)†	1.1 (0.5–9.8)

Data presented as mean ± standard deviation or n (%); †data expressed as median (range) due to prominent skewing of the data.

Table 2. Examination of demographics, ECG parameters and other clinical features of stroke patients at the time of stroke for factors with significant contribution to survival*

	Survivors ($n=65$)	Non-survivors ($n=28$)	$p^{‡}$
Age, yr	61.8 ± 16.3	61.6 ± 16.0	0.94
Gender			0.41
Male	43 (66.2)	16 (57.1)	
Female	22 (33.9)	12 (42.9)	
Systemic disease history			
Diabetes mellitus	25 (38.5)	11 (39.3)	1.00
Hypertension	57 (87.7)	24 (85.7)	0.09
Dialysis	0 (0)	2 (7.1)	0.75
Type of hemorrhage			0.14
Intracerebral	44 (67.7)	16 (57.1)	
Brain stem	2 (3.1)	4 (14.3)	
Subarachnoid	19 (29.2)	8 (28.6)	
GCS score			< 0.01§
9–15 (mild–moderate)	49 (75.4)	12 (42.9)	
3–8 (severe)	16 (24.6)	16 (57.1)	
NIHSS score			0.02§
0–24	30 (46.2)	5 (17.9)	
25–42	35 (53.8)	23 (82.1)	
ECG parameters			
QT max	448.9 ± 66.8	447.1 ± 68.3	0.91
QT min	346.9 ± 57.1	339.6 ± 50.9	0.56
QT dispersion	102.7 ± 41.2	107.5 ± 46.1	0.62
QTc max	527.3 ± 54.9	527.5 ± 53.1	0.99
QTc min	395.8 ± 48.3	393.4 ± 39.1	0.82
QTc dispersion	131.8 ± 54.2	134.10 ± 47.1	0.85
Heart rate (beats/min)	79.3 ± 15.0	78.1 ± 20.2	0.77
White blood cell count ($\times 10^3/\mu$L)	11.41 ± 3.95	13.44 ± 5.01	0.04§
Calcium (mg/dL)	8.30 ± 0.51	8.23 ± 0.44	0.57
Systolic blood pressure (mmHg)	174.3 ± 31.3	188.8 ± 28.2	0.04§
Diastolic blood pressure (mmHg)†	92 (62–183)	100 (62–175)	0.19
Creatine phosphokinase (U/L)†	91 (8–4,560)	79 (25–4,730)	0.33
Glucose (mg/dL)†	139 (71–371)	139.5 (103–417)	0.37
Creatinine (mg/dL)†	1.1 (0.5–3.1)	1.25 (0.70–9.80)	0.17

*Data presented as mean ± standard deviation or n (%); †data expressed as median (range) due to prominent skewing of the data; ‡Student's t or Wilcoxon rank sum test for continuous variables and χ^2 or Fisher's exact test for categorical variables; §$p < 0.05$.

($p=0.04$). However, no association was found between various ECG parameters and death (all $p>0.05$). Patient demographics and clinical features other than white blood cell count and systolic blood pressure were not significantly associated with survival (all $p>0.05$).

Attempts were made to record the numbers of patients with ischemic heart disease, heart failure and left ventricular hypertrophy to examine the contribution of these conditions to survival. However, 14 patients without a history of heart disease exhibited ST segment depression. These patients were followed, and 4 were later diagnosed with ischemic heart disease.

Surviving stroke patients were examined for factors contributing to functional outcome as defined by post-hospitalization bed confinement (Table 3). A significant association was observed between patient age and post-hospitalization bed confinement ($p=0.01$). Bedridden survivors were also found to have had higher QT max and QTc max values following stroke as compared to non-bedridden survivors ($p=0.04$ and $p<0.01$, respectively). Of the other demographic factors, clinical features, and ECG parameters examined, none were significantly associated with post-hospitalization bed confinement (all $p>0.05$). Table 4 presents examination

Table 3. Examination of demographics, ECG parameters and other clinical features of stroke patients at the time of stroke for factors with significant contribution to post-hospitalization bed confinement*

	Confinement not needed ($n=52$)	Confinement needed ($n=13$)	$p^{‡}$
Age, yr	59.3 ± 15.9	73.0 ± 13.3	0.01§
Gender			
Male	35 (67.3)	8 (61.5)	0.75
Female	17 (32.7)	5 (38.5)	
Type of hemorrhage			
Intracerebral	37 (71.2)	7 (53.9)	0.25
Brain stem	1 (1.9)	1 (7.7)	
Subarachnoid	14 (26.9)	5 (38.5)	
GCS score			
9–15 (mild–moderate)	41 (78.9)	8 (61.5)	0.28
3–8 (severe)	11 (21.2)	5 (38.5)	
NIHSS score			
0–24	23 (44.2)	7 (53.9)	0.76
25–42	29 (55.8)	6 (46.2)	
ECG parameters			
QT max	437.7 ± 56.4	493.9 ± 87.0	0.04§
QT min	341.7 ± 54.2	367.7 ± 65.6	0.14
QT dispersion	98.3 ± 38.3	120.0 ± 49.0	0.09
QTc max	516.2 ± 49.3	571.7 ± 55.3	< 0.01§
QTc min	392.4 ± 47.1	409.5 ± 52.5	0.26
QTc dispersion	126.2 ± 53.1	154.2 ± 54.8	0.10
Heart rate (beats/min)	79.8 ± 14.8	77.3 ± 16.3	0.60
White blood cell count ($\times 10^3/\mu L$)	11.37 ± 3.81	11.58 ± 4.63	0.87
Calcium (mg/dL)	8.25 ± 0.51	8.46 ± 0.48	0.19
Systolic blood pressure (mmHg)	174.6 ± 30.3	173.5 ± 36.4	0.91
Diastolic blood pressure (mmHg)†	93 (62–183)	85 (67–147)	0.40
Creatine phosphokinase (U/L)†	95 (8–4,560)	89 (13–761)	0.83
Glucose (mg/dL)†	139.5 (77–371)	135 (71–211)	0.74
Creatinine (mg/dL)†	1.0 (0.5–3.1)	1.2 (0.7–1.9)	0.42

**Data presented as mean ± standard deviation or n (%); †data expressed as median (range) due to prominent skewing of the data; ‡Student's t or Wilcoxon rank sum test for continuous variables and χ^2 or Fisher's exact test for categorical variables; §$p < 0.05$.*

of demographics, ECG parameters and other clinical features of ICH patients at the time of stroke for factors with significant contribution to survival. The distribution of NIHSS score shows significant difference between survivors and non-survivors ($p=0.003$). Non-survivor patients had lower NIHSS score.

Since QT max and QTc max following stroke were highly correlated with post-hospitalization bed confinement, separate multivariate logistic regressions were performed to confirm these associations. After adjusting for age, gender, NIHSS score and GCS score, both ECG parameters remained important factors associated with a need for bed confinement. For QT max, the findings were: adjusted odds ratio (aOR), 1.01; 95% CI, 1.00–1.03; $p=0.02$ (Table 5). For QTc max, findings were: aOR, 1.03; 95% CI, 1.01–1.04; $p=0.01$ (Table 6).

Discussion

A low GCS score is currently a well-accepted predictor of mortality for stroke patients in Western countries. Using the ICH score as a measure of outcome risk, a low GCS score was found to be the most important independent predictor of 30-day mortality of ICH patients in Western countries.[21] The present study, which was conducted with Taiwanese subjects who experienced acute stroke due to ICH, brain stem hemorrhage or SAH, provides evidence that low GCS scores are also prognostic indicators of mortality from stroke in Taiwan. Although ICH scores were not determined for ICH patients, stroke patients with GCS scores of 9–15 (mild–moderate) were found to be more likely to survive than those with GCS scores

Table 4. Examination of demographics, ECG parameters and other clinical features of intracerebral hemorrhage patients at the time of stroke for factors with significant contribution to survival*

	Survivors ($n = 44$)	Non-survivors ($n = 16$)	p‡
Age, yr	62.3 ± 16.7	62.5 ± 13.0	0.98
Gender			0.38
Male	35 (79.6)	11 (68.7)	
Female	9 (30.45)	5 (31.3)	
Systemic disease history			
Diabetes mellitus	18 (40.9)	11 (43.8)	0.84
Hypertension	39 (88.6)	13 (81.3)	0.46
Dialysis	0 (0)	0 (0)	–
GCS score			0.23
9–15 (mild–moderate)	32 (72.7)	9 (56.3)	
3–8 (severe)	12 (27.3)	7 (43.8)	
NIHSS score			0.03§
0–24	25 (56.8)	2 (12.5)	
25–42	19 (43.2)	14 (87.5)	
ECG parameters			
QT max	444.6 ± 68.5	451.3 ± 54.6	0.73
QT min	340.6 ± 55.4	349.4 ± 57.4	0.59
QT dispersion	104.4 ± 43.9	101.9 ± 36.6	0.84
QTc max	523.4 ± 55.4	520.4 ± 58.5	0.85
QTc min	386.7 ± 46.9	400.0 ± 40.1	0.32
QTc dispersion	138.1 ± 59.3	120.3 ± 38.5	0.18
Heart rate (beats/min)	99.5 ± 122.9	82.8 ± 19.4	0.59
White blood cell count ($\times 10^3/\mu L$)	11.10 ± 4.09	11.55 ± 4.38	0.72
Calcium (mg/dL)	8.31 ± 0.51	8.36 ± 0.48	0.73
Systolic blood pressure (mmHg)	179.1 ± 31.1	180.3 ± 24.0	0.88
Diastolic blood pressure (mmHg)†	92.0 (88.0–108.0)	99.5 (82.5–110.5)	0.98
Creatine phosphokinase (U/L)†	103.5 (70.5–200.0)	99.00 (75.5–122.5)	0.97
Glucose (mg/dL)†	140.0 (119.5–179.0)	136.50 (122.00–171.0)	0.99
Creatinine (mg/dL)†	1.15 (0.90–1.45)	1.15 (0.90–1.50)	0.58

*Data presented as mean ± standard deviation or n (%); †data expressed as median (range) due to prominent skewing of the data; ‡Student's t or Wilcoxon rank sum test for continuous variables and χ^2 or Fisher's exact test for categorical variables; §$p < 0.05$.

Table 5. Effect of adjustments for age and gender on the relationship between QT max and requirement of acute stroke survivors for post-hospitalization bed confinement ($n = 65$)

	OR*	95% CI	OR†	95% CI
Age	1.08‡	1.02, 1.14	1.07‡	1.01, 1.14
Gender				
Male	Reference	–	Reference	–
Female	1.07	0.21, 5.34	0.86	1.15, 4.96
NIHSS score	–	–	1.02	0.95, 1.09
GCS score	–	–	0.87	0.73, 1.08
QT max	1.01‡	1.00, 1.03	1.01‡	1.00, 1.03

*Model adjusted by age, gender and QT max; †model adjusted by age, gender, NIHSS score, GCS score and QT max; ‡$p < 0.05$, tested with stepwise logistic regression and presented with OR and 95% CI.

Table 6. Effect of adjustments for age and gender on the relationship between QTc max and requirement of acute stroke survivors for post-hospitalization bed confinement ($n = 65$)

	OR*	95% CI	OR†	95% CI
Age	1.08‡	1.02, 1.15	1.08‡	1.01, 1.16
Gender				
Male	Reference	–	Reference	–
Female	1.00	0.20, 5.05	1.82	0.15, 4.39
NIHSS score	–	–	1.03	0.96, 1.10
GCS score	–	–	0.93	0.77, 1.14
QTc max	1.03‡	1.01, 1.04	1.03‡	1.01, 1.04

Model adjusted by age, gender and QT max; †model adjusted by age, gender, NIHSS score, GCS score and QT max; ‡$p < 0.05$, tested with stepwise logistic regression and presented with OR and 95% CI.

of 3–8 (severe) ($p < 0.01$). These findings are consistent with those of Schwartz and colleagues,[22] who found a close correlation between mortality following stroke and GCS scores ≤7. In the present study, 2 other clinical features were found to correlate closely with survival among Taiwanese subjects with acute stroke. Non-survivors were more likely than survivors to display increased white blood cell counts and systolic blood pressures than were survivors (both $p = 0.04$). These findings are also in accord with those of other investigators. For example, Fang et al[23] recently observed that an increased white blood cell count correlates closely with increased mortality among Chinese subjects with spontaneous ICH. These investigators also reported that prothrombin time and platelet count were good early predictors of mortality in these subjects and proposed that ethnic Chinese stroke patients may exhibit profiles that differ from those in Western countries. The increased leukocyte counts and systolic blood pressures observed among non-surviving stroke patients of Chinese ethnicity are likely attributable to autoregulatory dysfunction with excessive blood flow, hypertension, venous outflow obstruction, altered hemostasis, ruptured aneurysm or arteriovenous malformation, cardiac arrhythmias, and/or eclampsia, such as are common among nontraumatic ICH patients.[24]

Although ECG abnormalities may be related to the etiology of vascular events, the relationship between cardiac arrhythmias and mortality remains controversial. Nonetheless, cardiac monitoring of acute stroke patients represents a low-cost, efficient and relatively simple method for detecting the development of cerebrum-induced dysrhythmia or cardiac injury.[25] Accordingly, Sulter and colleagues[26] have suggested that an intensive cardiac monitoring regimen consisting of ECG surveillance for acute stroke patients should lower the risk of death and subsequent functional impairment.

Heart rate variability was recently found to be a good predictor of outcome in acute severe stroke;[27] however, the instrumentation/equipment required to measure heart rate variability is complex and difficult to utilize in the ED.

QT dispersion is a non-sensitive, specific representation of abnormalities of the T-wave loop morphology[28] and of discrepancies in heart dipole projection.[29] Depression of the ST segment, which connects the QRS complex and the T-wave, and inversion of the T-wave are known predictors of increased mortality at 3 months in multivariate testing, with variability in ST segment changes likely due to cerebrogenic cardiac effects.[30] ECG-detectable cardiac abnormalities in stroke patients are now recognized to include ectopic beats, atrial fibrillation, prolonged QTc, atrioventricular block, ST segment depression, and T-wave changes.[12,31,32] In the present study, correlations between alterations in QT parameters at the time of stroke and subsequent death were found to be statistically insignificant (all $p > 0.05$). A unique finding of the present study, however, is the close correlation between increased QT max and QTc max within 6 hours of acute stroke and post-hospitalization bed confinement of survivors. This association was significant before and after performance of multivariate analyses ($p = 0.04$ and $p < 0.01$, respectively). Long-term care of survivors with elevated QTc/QTc max values at the time of stroke is therefore recommended following their discharge from hospital.

Few studies have been performed that examine the prognostic value of the ECG for subjects of non-Western countries who present with acute stroke. Findings of the present report do not agree with those of Huang et al,[13] who examined the prognostic value of QTc dispersion in Taiwanese patients with acute ICH. These investigators observed that increased QTc dispersion values correlated closely with inhospital mortality. Their study differs from the present study, however, in that the former was retrospective and not observational, involved smaller numbers of subjects, evaluated ICH but not other forms of stroke, utilized ECG measurements performed at later times after stroke occurrence, did not define mortality as death due to brain failure, did not evaluate functional outcome, and involved considerably longer follow-up periods. Large-scale studies that evaluate the importance of ECG parameters at the time of stroke to outcomes for Taiwanese patients are clearly indicated.

Terayama et al[33] reported that the mean age of patients with fatal ICH (62.5 years) was significantly greater than that of patients with non-fatal ICH (59.2 years). In the present study, however, no association between the age of stroke survivors and their mortality was observed. On the other hand, post-hospitalization bed confinement among stroke survivors (mean age, 61.83 years) was found to correlate closely with their age, an association which was observed before and after multivariate analyses were performed ($p = 0.04$ and $p < 0.01$, respectively). These findings are consistent with those of Qureshi et al,[34] who found no association between the age of stroke patients and their mortality but observed a better functional outcome at discharge among patients < 45 years of age and a poorer outcome at discharge among patients > 65 years of age. To further substantiate the prognostic value of QT parameters in stroke patients, exploration of potential interrelationships existing among QTc/QTc max values, age, and functional recovery will be required.

The limitations of the present study, besides the modest patient cohort, are evident with respect to the study design. The significance of the selected segment of the 12-lead ECG is unclear since different leads are known to have different significances. As pointed out by Calder,[35] however, well-defined guidelines for determination of QTc dispersion are lacking regarding which combination of leads to measure, how many leads to include for accuracy, and whether to correct for missing leads. In the present study, QT parameter (QT interval, QTc, QTc dispersion) abnormalities were not evaluated by prevalence or by the respective influence of each variable. Also, patients with a prior history of cardiac or vascular complications or diagnoses were indistinguishable in statistical analysis, and follow-up QT parameters were not retrieved for comparison. It was therefore not possible to determine the prognostic value of any of the QT parameters with the exception of the observed correlation between QT max/QTc max and recovery of function. Additional follow-up studies are planned to verify the significance of the findings of this report. It should be noted that the large number of patients excluded from this study may have resulted in some degree of bias.

In conclusion, low GCS scores, increased leukocyte counts, and elevated systolic blood pressures predict increased mortality among Taiwanese subjects following acute hemorrhagic stroke. Advanced age and elevations in QTc and QT max at the time of stroke predict poor functional recovery for these subjects. Measurements of QTc and QT max at the time such subjects present to the ED is therefore recommended to identify those who are more likely to exhibit subsequent functional impairment.

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