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Characteristics, predictors and outcomes of new-onset QT prolongation in sepsis: a multicenter retrospective study

Weizhuo Liu[1,2†], Rongjiao Shao[1,2†], Shen Zhang[1†], Lei Jin[1], Rongchen Liu[3], Peidong Chen[4], Jintao Hu[5], Haocheng Ma[5,6], Bangwei Wu[3], Weiguo Liang[3], Xinping Luo[3], Jian Li[3], Weiming Chen[5*], Nanqing Xiong[3*] and Bin He[1*]

Abstract

Background Sepsis-induced myocardial injury is a serious complication of sepsis. QT prolongation is a proarrhythmic state which reflects myocardial injury in a group of heterogeneous disorders. However, the study on the clinical value of QT prolongation in sepsis is limited.

Methods We aimed to investigate the clinical characteristics and predictors of new-onset QT prolongation in sepsis and its impact on the outcome in a multicenter retrospective cohort study. Electrocardiographic and clinical data were collected from patients with sepsis from the wards and intensive care units of four centers after exclusion of QT-influencing medications and electrolyte abnormalities. Clinical outcomes were compared between patients with and without QT prolongation (QTc > 450 ms). Multivariate analysis was performed to ascertain whether QT prolongation was an independent predictor for 30-day mortality. The factors predicting QT prolongation in sepsis were also analyzed.

Results New-onset QT prolongation occurred in 235/1024 (22.9%) patients. The majority demonstrated similar pattern as type 1 long QT syndrome. Patients with QT prolongation had a higher 30-day in-hospital mortality ($P < 0.001$), which was also associated with increased tachyarrhythmias including paroxysmal atrial fibrillation or tachycardia ($P < 0.001$) and ventricular arrhythmia ($P < 0.001$) during hospitalization. QT prolongation independently predicted 30-day mortality ($P = 0.044$) after multivariate analysis. History of coronary artery disease ($P = 0.001$), septic shock ($P = 0.008$), acute respiratory ($P < 0.001$), heart ($P = 0.021$) and renal dysfunction ($P = 0.013$) were independent predictors of QT prolongation in sepsis.

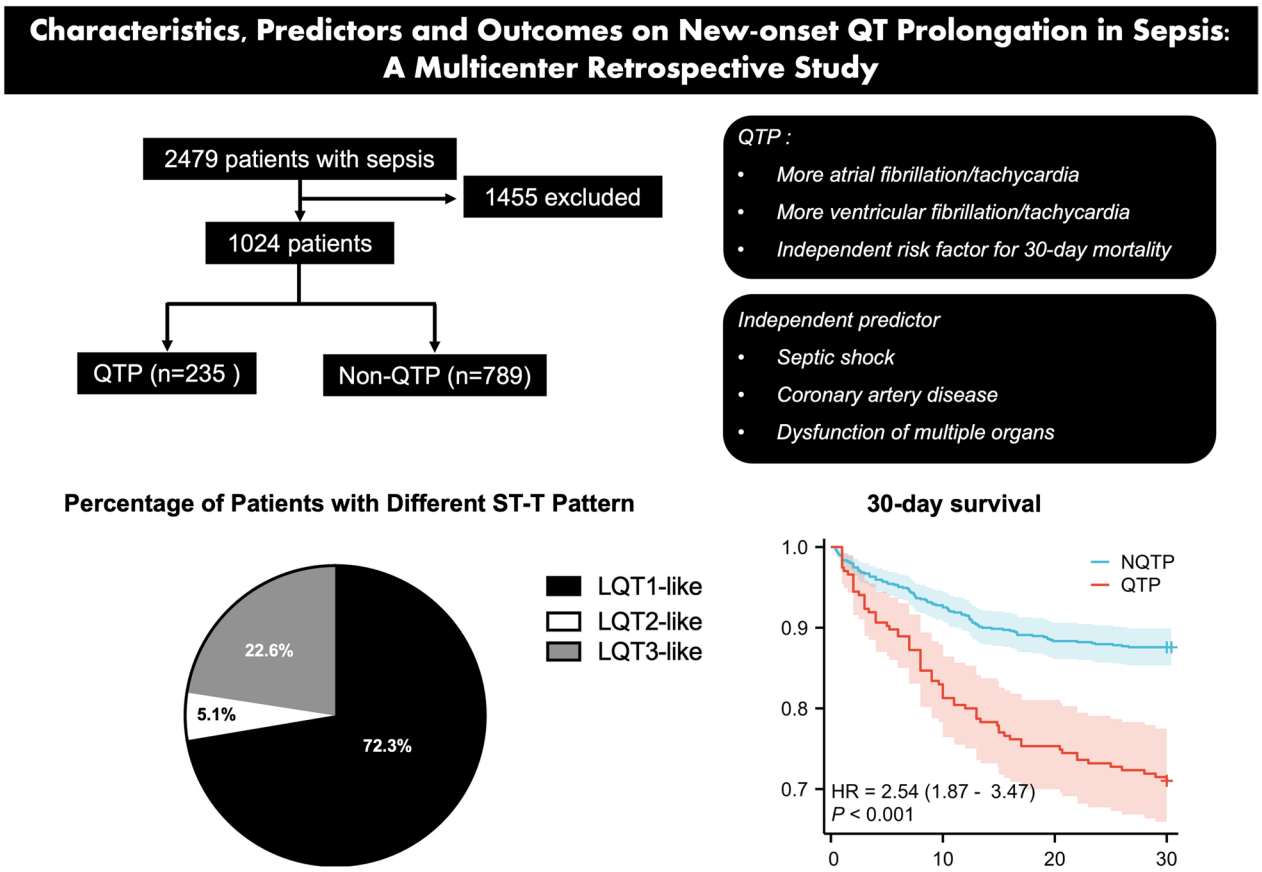
Conclusions New-onset QT prolongation in sepsis was associated with increased mortality as well as atrial and ventricular arrhythmias, which was predicted by disease severity and organ dysfunction.

Keywords New-onset QT prolongation, Sepsis, Ventricular arrhythmia

†Weizhuo Liu, Rongjiao Shao and Shen Zhang contributed equally to this work.

*Correspondence:
Weiming Chen
cwming_qq@163.com
Nanqing Xiong
xiongnanqing@huashan.org.cn
Bin He
bin_he@sjtu.edu.cn
Full list of author information is available at the end of the article

Graphical abstract



Introduction

Myocardial injury is a serious complication of sepsis which can manifest as decreased myocardial contractility, weakened response to cardiac preload, atrial and ventricular arrhythmias [1, 2]. Prolongation of QT interval is a proarrhythmic status reflecting the increased duration of ventricular activation, which can lead to fatal ventricular arrhythmias such as polymorphic ventricular tachycardia (VT) including Torsade de Pointes VT and ventricular fibrillation (VF) [3, 4].

In addition to various types of congenital long QT syndrome, acquired QT prolongation (QTP) due to heterogeneous etiology, including myocardial ischemia, specific medications and abnormal electrolytes in different diseases, has been well described [5, 6]. QT prolongation has been considered as a consequence of myocardial injury in the setting of sepsis [7]. However, limited data have been shown with respect to the clinical value and related factors.

In this multicenter retrospective cohort study, we aimed to investigate the proportion, electrocardiogram (ECG) characteristics, clinical relevance and the risk factors of new-onset QT prolongation in patients with sepsis.

Methods

Study population

In-hospital patients diagnosed as sepsis according to the criteria of sepsis 3.0 [1] from the wards and intensive care units of four centers from 2018 to 2022, were consecutively enrolled in the study. Exclusion criteria included: (1) Patients without ECG performed at the time of diagnosis of sepsis (within 48 h); (2) history of congenital or other acquired long QT syndrome; (3) regular intake of medications affecting QT interval, e.g., types 1 and 3 antiarrhythmic agents and anti-depression agents (see Additional file 1); (4) administration of QT-influencing antibiotics before electrocardiogram (ECG) test; (5) absolute irregular rhythm, e.g., atrial fibrillation or 2nd

degree atrioventricular block and (6) extremely abnormal electrolyte level potentially causing QTP, including serum potassium level < 2.7 mmol/L and serum calcium level < 1.6 mmol/l [8, 9]. Patients with COVID-19 infection were not admitted to these centers during the study period.

Clinical data collection

ECGs were recorded with a paper speed of 25 mm/s and amplitude of 10 mm/mV and stored in digital version. QT interval was manually measured and corrected with Bazett formula (corrected QT interval (QTc) = $QT/RR^{1/2}$) when heart rate (HR) was less than or equal to 110/min, or with Hodges formula QTc = QT + 1.75(HR-60), when HR was over 110/min [10]. According to a previous study, QTP was defined as QTc > 450 ms, while T wave morphology was classified into three types as in the congenital long QT syndromes [11]: "LQT1-like morphology" denoted a long QT interval with broad T waves; "LQT2-like morphology" denoted a long QT interval with notched T waves and "LQT3-like morphology" denoted a long QT interval with small T waves separated from the QRS interval by a long isoelectric ST-segment. In patients with QTP, QT_{onset} and QT_{peak} were defined as the interval from the Q wave to the point at which the T wave departs from the flat portion of the ST-segment, and to the peak of the T wave, respectively [12, 13]. T wave duration (TWD)/QT and T_{peak}-T_{end}/QT could be, thereafter, calculated based on the above data. New-onset QTP was defined as prolongation of QT interval at the time of sepsis diagnosis without history of QTP or previously recorded ECG showing QTc > 450 ms. All the ECGs were re-analyzed by two independent cardiologists (R.L. and H.M.) with average values as results. The interpretation was carried out by clinicians without knowing the other data including the outcome of the patients.

The clinical variables were retrieved from the hospital information system. The baseline data including age, sex, body mass index, body surface area, history of chronic diseases and recent surgery were collected. Charlson score was used to assess the general comorbidity conditions. Structural heart diseases included ischemic cardiomyopathy, severe valvular heart diseases (with or without surgical repair) and non-ischemic (dilated, hypertrophic, restrictive or arrhythmogenic) cardiomyopathies. Renal insufficiency was defined as stage 4+ chronic kidney disease.

The complications including septic shock and dysfunction of organs were evaluated at the diagnosis time. Septic shock was defined as a state of acute circulatory failure due to sepsis manifest as hypotension (mean arterial pressure < 65 mmHg) and raised lactate level, requiring adequate fluid resuscitation and/or vasopressor therapy [14]. Acute heart failure was defined as rapid or gradual onset of symptoms and/or signs and imaging evidence of heart failure requiring urgent treatment, with an NT-proBNP level > 300 pg/ml [15]. Acute renal failure was defined as an increase in serum creatinine by ≥ 0.3 mg/dl (26.5 μmol/l) within 48 h, or increase in creatinine to ≥ 1.5 times baseline occurring within the prior 7 days, or urine volume < 0.5 ml/kg/h for 6 h [16]. Acute respiratory failure was defined as new or acutely worsening respiratory symptoms following a known clinical insult lasting less than a week and PaO_2/FiO_2 less than or equal to 300 mmHg while receiving additional oxygen by a standard facial mask [17]. Acute liver failure was defined in the study as an acute liver function deterioration with or without preexisting liver diseases, manifesting as jaundice, coagulopathy, ascites and/or hepatic encephalopathy within 4 weeks [18, 19]. The results of laboratory tests were also recorded. Sequential organ failure assessment (SOFA) and quick sequential organ failure assessment (qSOFA) scores could, therefore, be calculated based on the data [14].

During hospitalization, any episodes of atrial fibrillation (AF), atrial tachyarrhythmia (AT), VT and VF demonstrated in ECG tracing, Holter or telemetry were counted as tachyarrhythmias. AF was defined as the absence of P wave replaced by fibrillatory atrial activities with irregular R–R intervals. AT was defined as regular atrial rhythm, including focal and macro-reentrant atrial tachycardia (flutter) but not junctional tachycardia, at a constant rate of > 100/min with discrete P or F waves and atrial activation sequences originating outside of the sinus node [20]. Ventricular tachycardia was defined as more than three consecutive ventricular beats with a rate > 100/min, independent from atrial and AV nodal conduction. Ventricular fibrillation was defined as chaotic rhythm with undulations that are irregular in timing and morphology, without discrete QRS complexes on the surface ECG [21]. The study was approved by the Ethics Committee of Shanghai Chest Hospital, Shanghai Jiaotong University School of Medicine (IRB No. KS22024).

Statistical analysis

Clinical variables were expressed as a percentage (%) for categorical variables, mean with standard deviation for normally distributed continuous variables and median with interquartile rate for discontinuous variables. To compare categorical variables, Chi-square test or Fisher's exact test was used; to compare continuous variables, an unpaired two-tailed *t*-test or Mann–Whitney *U*-test was used. In laboratory verification, data were presented as the mean ± SEM at least three duplications of different samples. Student's *t*-test was applied for analysis between two groups, and one-way analysis of variance was used

for comparisons between multiple groups. Multivariate analysis was performed to ascertain whether QTP was an independent predictor for prognosis and to explore the predictors of QTP using logistics regression, which adjusted for all variables showing statistical differences in univariate analysis and of vital importance in clinical practice. Correlated variables with collinearity were not repetitively taken into analysis in one model. Multiple regression models were established for further validation. Statistical analysis was performed with Stata 16.0 software. GraphPad Prism 7.0 (GraphPad Software Inc., USA) was used to analyze and illustrate the data. Differences with p-values < 0.05 were considered statistically significant.

Results

Clinical characteristics and the incidence of new-onset QTP

A total of 2479 patients matched the diagnosis of sepsis during the study period. After exclusion of QTP history, QT-influencing medications, electrolyte abnormalities, irregular rhythm and lack of timely ECGs, a total number of 1024 subjects, including 382 (37.3%) patients from the intensive care units, were enrolled and divided into QTP and non-QTP groups (Fig. 1). The distribution of QTc is shown in Fig. 2A. The mean QTc in the whole cohort was 430.1 ± 35.3 ms, in which QTP occurred in 235 (22.9%) individuals.

QTP was found statistically related to higher age ($P=0.002$), lower body surface area ($P=0.013$), hypertension ($P=0.044$), coronary artery disease ($P<0.001$), structural heart disease ($P<0.001$), renal insufficiency ($P=0.002$) and chronic occlusive pulmonary disease ($P<0.001$). QTP was associated with septic shock ($P<0.001$), multiple organ dysfunction (all $P<0.01$) and a higher SOFA ($P<0.001$) and qSOFA score ($P<0.001$). Patients with QTP had an increased 30-day mortality ($P<0.001$), but without difference in hospital stay (Table 1).

Description and comparison of ECG parameters

In terms of morphology, the majority of the patients (72.3%) had an LQT-1-like T wave, followed by LQT-3- (22.6%) and LQT-2-like (5.1%) configuration (Fig. 2A–B). TWD/QT and T_{peak}-T_{end}/QT were 59.1 ± 11.5% and 27.1 ± 7.0%, respectively. TWD/QT was lower in LQT-3 (43.3 ± 7.2%) than in LQT-1 (63.6 ± 7.9%) and LQT-2 (64.2 ± 8.7%) pattern (both $P<0.001$), without difference in the latter two (LQT-1 vs. LQT-2, $P>0.999$). T_{peak}-T_{end}/QT was highest in LQT-2-like pattern (36.4 ± 8.2%), followed by LQT-1- (27.6 ± 6.2%) and LQT-3-like pattern (23.7 ± 6.9%) with statistical significance (all $P<0.001$) (Fig. 2C–D). Patients with new-onset QTP had a higher sinus heart rate (97.9 ± 24.4 bpm vs. 90.0 ± 21.3 bpm, $P<0.001$) and a wider QRS width (98.7 ± 23.3 ms vs. 89.8 ± 13.0 ms, $P<0.001$) in baseline ECG compared to non-QTP patients (Table 2).

Relationship between new-onset QTP and clinical outcome in sepsis

Kaplan–Meier survival curve showed that new-onset QTP was associated with a higher 30-day mortality compared to those without QTP (both $P<0.001$, Fig. 3). After multivariate analysis adjusted for indicators showing significant difference in univariate analysis,

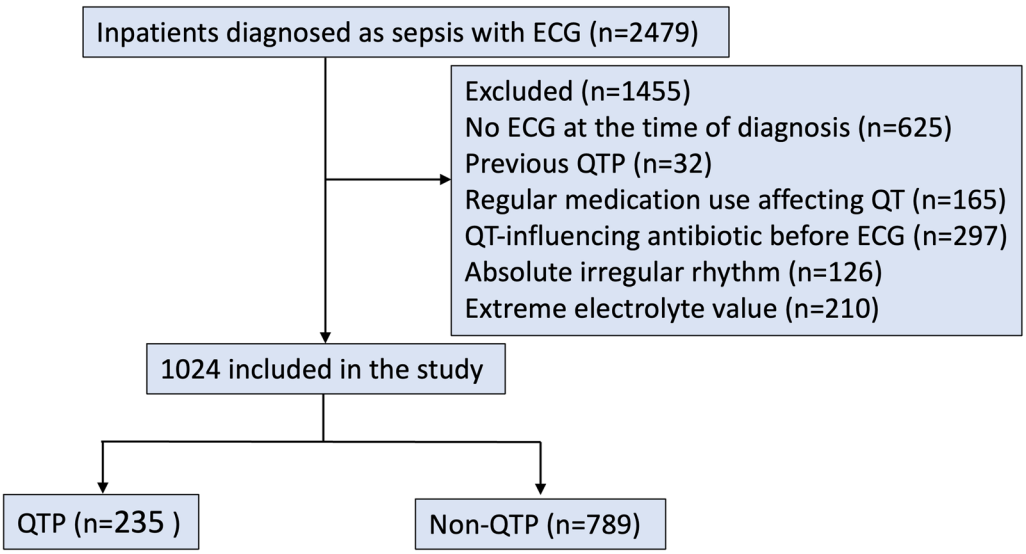


Fig. 1 Flowchart of the patient inclusion in this study. *QTP* QT prolongation

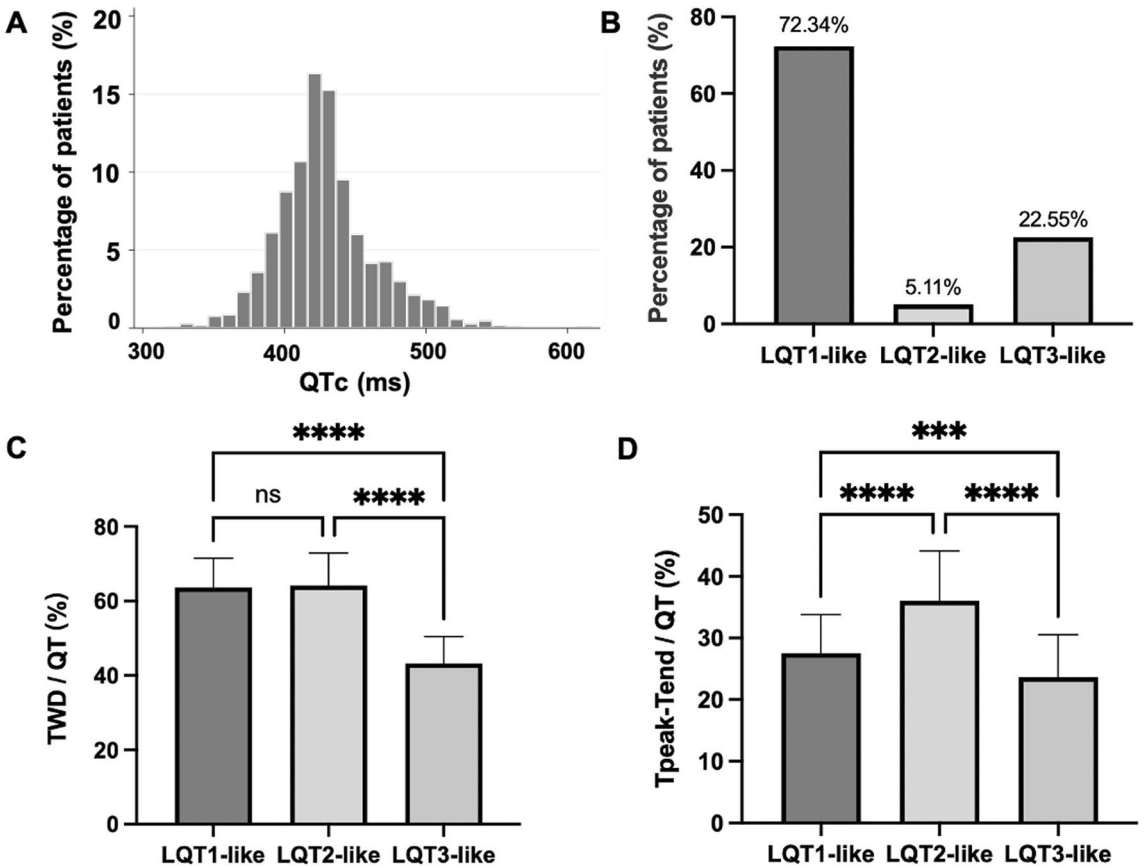


Fig. 2 **A** Distribution of the corrected QTc in the whole study cohort. **B** Proportion of different QT morphologies in patients with QT prolongation. **C** T wave duration/QT for each LQT-like phenotype. **D** T_{peak}-T_{end}/QT for each LQT-like phenotype. See text for discussion. *LQT* long QT and *QTc* corrected QT interval

QTP was an independent predictor for 30-day mortality while adjusted for age, body mass index, recent surgery, structural heart disease, Charlson score and SOFA score (Additional file 2: Table S1A–B). In addition, multiple regression models were performed to further validate the relations between QTP and the 30-day mortality (Additional file 2: Table S1C, all $P < 0.05$).

During hospitalization, patients showing QTP had a higher risk for developing tachyarrhythmias, including paroxysmal AF/AT (13.19% vs. 4.56%, $P < 0.001$), VT and VF (5.5% vs. 0.63%, $P < 0.001$). QTc in patients with AF/AT or VT/VF was longer than those without tachyarrhythmias (452.6 ± 39.6 ms, 428.14 ± 34.28, $P < 0.001$). Among patients with QTP, ECG parameters were compared between those with different outcomes during hospitalization, i.e., survived or died. Patients who died within 30 days had a higher heart rate ($P < 0.001$), a higher QTc ($P = 0.005$) and a rightward axis ($P = 0.002$). TWD/QT and T_{peak}-T_{end}/QT did not show difference in the two subgroups (Table 3).

Risk factors for new-onset QTP in sepsis

In multivariate analysis, coronary artery disease (OR 2.51, $P = 0.001$), septic shock (OR 1.71, $P = 0.008$), acute heart failure (OR 1.73, $P = 0.021$), acute kidney injury (OR 1.67, $P = 0.013$) and acute respiratory failure (OR 2.66, $P < 0.001$) were independently associated with QTP (Table 4). In addition, the relationship between QTP and all the five above factors was confirmed in different regression models (Additional file 3: Table S2).

Discussion

In the present study, we have following findings regarding the new-onset QTP in sepsis including the prevalence, ECG characteristics, prognostic value and the risk factors:

(1) QTP occurred in 22.9% patients with sepsis in this study. The morphological QT change was variable, mostly manifesting as the prolongation of T wave (LQT-1-like configuration).

Table 1 Baseline and disease characteristics in patients with and without QTP

	Non-QTP ($n=789$)	QTP[a] ($n=235$)	*P* value
Patient characteristics			
Age, years	59.9 ± 16.2	63.6 ± 15.3	0.002
Sex, female, %	251 (31.8)	81 (34.5)	0.445
Body mass index (kg/m^2)	23.25 ± 3.55	22.97 ± 3.46	0.292
Body surface area (m^2)	1.73 ± 0.17	1.69 ± 0.19	0.013
Baseline comorbidities			
Hypertension, %	215 (27.25)	80 (34.04)	0.044
Diabetes mellitus, %	170 (21.55)	53 (22.55)	0.743
Coronary artery disease, %	44 (5.58)	37 (15.74)	< 0.001
Structural heart disease, %	38 (4.82)	30 (12.77)	< 0.001
Congenital heart disease, %	12 (1.52)	2 (0.85)	0.438
Renal insufficiency, %	35 (4.44)	23 (9.79)	0.002
COPD[b], %	35 (4.44)	35 (14.89)	< 0.001
Liver cirrhosis, %	23 (2.92)	10 (4.26)	0.307
Charlson score	1 [0, 2]	2 [1, 3]	< 0.001
Recent[c] surgery, %	129 (16.35)	42 (17.87)	0.583
Recent[c] chemo/immunotherapy, %	59 (7.48)	11 (4.68)	0.136
Clinical characteristics			
Severe sepsis/shock, %	159 (20.15)	110 (46.80)	< 0.001
qSOFA[d] score	1 [1, 2]	2 [1, 2]	< 0.001
SOFA[e] score	3 [2, 6]	6 [3, 8]	< 0.001
Acute heart failure, %	68 (8.62)	70 (29.79)	< 0.001
Acute renal failure, %	127 (16.10)	95 (40.43)	< 0.001
Acute respiratory failure, %	124 (15.72)	114 (48.51)	< 0.001
Acute liver failure, %	47 (5.96)	26 (11.06)	0.008
Laboratory results			
White blood cell count, *10^9/L	10.38 ± 8.70	13.20 ± 18.57	0.001
Neutrophil, %	75.37 ± 16.42	82.21 ± 31.64	< 0.001
Hemoglobin, g/L	106.84 ± 24.93	107.12 ± 27.22	0.880
C-reactive protein, mg/L	75.33 ± 72.59	92.14 ± 78.56	0.018
Procalcitonin, ng/mL	10.39 ± 42.88	12.39 ± 23.50	0.493
Lactate level	2.84 ± 2.33	4.03 ± 3.12	< 0.001
Pro-BNP, pg/mL	585.2 [159.4, 2520.0]	1383.7 [458.4, 4945.0]	< 0.001
Troponin T, ng/mL	0.136 ± 0.823	0.141 ± 0.758	0.958
Creatinine, μmol/L	107.75 ± 130.77	168.43 ± 210.62	< 0.001
Bilirubin, mmol/L	22.24 ± 50.94	27.70 ± 56.72	0.161
Alanine transaminase, U/L	58.70 ± 191.20	83.94 ± 305.19	0.127
Albumin, g/L	33.74 ± 6.61	32.72 ± 6.45	0.038
Serum potassium, mmol/L	3.86 ± 0.57	3.89 ± 0.72	0.457
Serum calcium, mmol/L	2.312 ± 0.19	2.12 ± 0.20	0.964
Etiology			
Positive blood culture	353 (44.74)	84 (35.74)	0.014
Gram-positive bacteria, %	139 (39.38)	23 (27.38)	0.041
Gram-negative bacteria, %	200 (56.66)	58 (69.05)	0.038
Non-bacteria, %	20 (5.67)	8 (9.52)	0.194
Portal of entry of the infection			
Lungs	306 (38.78)	122 (51.91)	0.001
Abdominal	178 (22.56)	58 (24.68)	0.498
Cardiovascular	52 (6.59)	13 (5.53)	0.559

Table 1 (continued)

	Non-QTP ($n=789$)	QTP[a] ($n=235$)	*P* value
Central nervous system	71 (9.00)	17 (7.23)	0.314
Urinary	157 (19.90)	42 (17.87)	0.491
Catheter-related	33 (4.18)	10 (4.26)	0.961
Others	87 (11.03)	25 (10.64)	0.867
Unknown	79 (10.01)	15 (6.38)	0.091
Treatment			
Antibiotic use	788 (99.87)	233 (99.15)	0.361
Vasoactive drugs	189 (23.95)	101 (42.98)	< 0.001
Mechanical ventilation	235 (29.78)	119 (50.64)	< 0.001
Tracheal intubation	139 (17.62)	89 (37.87)	< 0.001
Fluids infused	206 (26.11)	117 (49.79)	< 0.001
Outcome			
In-hospital mortality, %	118 (14.96)	77 (32.77)	< 0.001
Length of hospital stay, days	12.0 [7.0, 19.6]	11.4 [6.6, 19.0]	0.322
30-day mortality, %	98 (12.42)	67 (28.51)	< 0.001

[a] QTP = QT prolongation

[b] COPD = chronic obstructive pulmonary disease

[c] Within 30 days

[d] qSOFA = quick sequential organ failure assessment

[e] SOFA = sequential organ failure assessment

(2) New-onset QTP independently predicted 30-day mortality in sepsis.
(3) Patients with QTP had more atrial and ventricular tachyarrhythmias during hospitalization.
(4) QTP was independently predicted by disease severity and the dysfunction of multiple organs.

Acquired QTP was secondary to a group of heterogeneous diseases or pathophysiologic status. The vast majority of acquired LQT syndrome is caused by the drug effect or abnormal electrolyte [22–25]. It is not infrequent to see the phenomenon of QTP in patients with sepsis [26, 27], which is, however, less reported and often explained by the use of antibiotics [28]. In a previous study, 10.5% patients with sepsis had a QTc duration longer than 490 ms without including those treated by QT-influencing medications [29]. In our study, the patients receiving therapy with QT-affecting antibiotics have also been excluded, so were the subjects with extreme values of electrolytes, which can be proven by the similar serum potassium and calcium levels in univariate analysis.

QT interval was composed of the entire duration of ventricular depolarization and the repolarization. The majority of the patients showed T wave prolongation similar to type 1 long QT syndrome, i.e., the prolongation occurred mainly in the T wave duration, which indicated that the decrease in potassium efflux might be an underlying reason [11, 30]. T wave patterns in congenital LQT syndrome (LQT-1/2/3 like) have been used in acquired QTP to describe the morphology. The difference in pattern indicates the functional variation of different ion channels and may lead to different outcomes in specific settings. The majority of QTP in the current study demonstrated an LQT-1-like pattern, suggesting that the downregulation of potassium channel might be an underlying reason for the lengthening of ventricular activation time.

In our study, QTP demonstrated prognostic value as indicated by the Kaplan–Meier curve and multivariate analysis. This observation aligns with the findings of a previous study [29]. For a more robust conclusion, multiple models were used in our study to confirm QTP as the independent predictor for 30-day mortality. QTP has been described as a commonly encountered ECG change in a group of heterogeneous diseases such as myocardial infarction [31], myocarditis [32] and viral infection [33]. It was associated with not only ventricular but also AT/AF despite the exclusion of persistent atrial fibrillation, suggesting the potential increase in general electrical vulnerability. This was further supported by the higher QTc in the patients experiencing those tachyarrhythmias. Considering the consequence of increased fatal arrhythmias, maintaining the serum potassium level at a normal range is of potential benefit due to its effect on potassium efflux.

Table 2 ECG parameters and arrhythmias during hospitalization in patients with and without QTP

ECG parameters	Non-QTP[a] (n = 789)	QTP (n = 235)	*P* value
ECG at diagnosis			
Heart rate, bpm	90.9 ± 21.3	97.9 ± 24.4	< 0.001
QRS duration, ms	89.8 ± 13.0	98.7 ± 23.3	< 0.001
PR interval, ms	151.9 ± 27.3	151.4 ± 28.0	0.829
QT interval, ms	346.0 ± 42.3	387.5 ± 43.5	< 0.001
Corrected QT interval[b], ms	415.3 ± 22.0	479.6 ± 25.1	< 0.001
Axis, degree	38 [13, 63]	39 [9, 68]	0.672
RV5 + SV1, MV	2.12 ± 1.13	2.03 ± 1.11	0.296
TWD[c]/QT	–	59.1 ± 11.5	–
T_{peak}-T_{end}[d]/QT	–	27.1 ± 7.0	–
U wave, %	0 (0)	9 (3.83)	< 0.001
Atrioventricular block, %	25 (3.17)	11 (4.68)	0.269
Left bundle branch block, %	1 (0.13)	3 (1.28)	0.013
Right bundle branch block, %	36 (4.56)	27 (11.49)	< 0.001
Left ventricular hypertrophy, %	38 (4.82)	16 (6.81)	0.230
Sinus tachycardia, %	234 (29.66)	84 (35.74)	0.077
Sinus bradycardia, %	22 (2.79)	2 (0.85)	0.085
ST-segment depression, %	36 (4.56)	9 (3.83)	0.630
Arrhythmic events during hospitalization			
Paroxysmal AF or AT[e], %	36 (4.56)	31 (13.19)	< 0.001
Frequent PVCs[f], %	29 (3.58)	19 (8.09)	0.005
VT or VF[g], %	5 (0.63)	13 (5.53)	< 0.001

[a] QTP = QT prolongation

[b] Corrected with Bazett formula (Corrected QT interval (QTc) = QT/$RR^{1/2}$) when heart rate (HR) was less than or equal to 110/min, or with Hodges formula QTc = QT + 1.75(HR-60), when HR was over 110/min

[c] TWD = T wave duration

[d] Defined as the time interval from the peak to the end of the T wave

[e] AF = atrial fibrillation and AT = atrial tachyarrhythmia

[f] PVC = premature ventricular contraction

[g] VT = ventricular tachycardia and VF = ventricular fibrillation

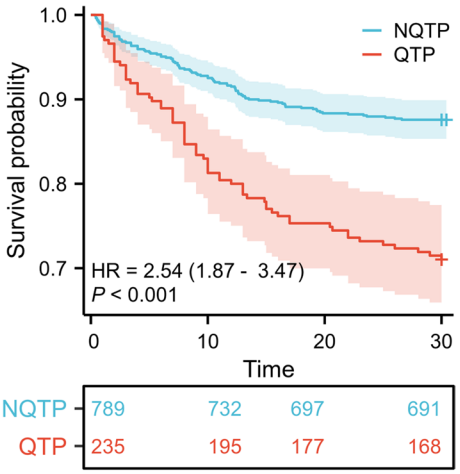


Fig. 3 Kaplan–Meier survival curve of the study cohort. Patients with QTP had a higher 30-day mortality rate compared to the controls (both $P < 0.001$). *NQTP* non-QT prolongation and *QTP* QT prolongation

Organ failure is a marker for deterioration of the disease and the compromised outcome in sepsis [34]. Several models were established in the multivariate analysis for robust evidence supporting the factors as independent predictors for QTP. Dysfunction of multiple organs, i.e., cardiac, respiratory and renal failure, was independent predictors for QTP in our study, indicating the association between the disease severity and the QT interval. We also found that coronary artery disease was a predictor for QTP, which showed similar results to a previous study conducted in cardiac care units [27]. The ratios of TWD/QT and T_{peak}-T_{end}/QT did not show significance in patients with a worse prognosis, which was different from the previous study [35].

Additionally, individual differences were observed in the presence of QTP even in similar clinical settings, suggesting that the effect of sepsis on the expression of ion channel proteins could be heterogeneous. This necessitates further investigation.

Limitations

This work was a retrospective cohort study and needed further validation with a prospective study. Patients without timely ECG were excluded, which may alter the frequency of QTP. Serum magnesium level was not available in part of the subjects. QTP due to hypomagnesemia was, therefore, not excluded.

Conclusions

In patients with sepsis showing new-onset QTP, the majority of changes in QT morphology was manifested as T wave prolongation. New-onset QTP was associated with worse prognosis and was associated with increased atrial and ventricular arrhythmias. QTP could be predicted by the disease severity and dysfunction of multiple organs.

Abbreviations

AF	Atrial fibrillation
AT	Atrial tachyarrhythmia
ECG	Electrocardiogram
HR	Heart rate
QTc	Corrected QT interval
QTP	QT prolongation
(q)SOFA	(Quick) sequential organ failure assessment
TWD	T wave duration
VF	Ventricular fibrillation
VT	Ventricular tachycardia

Table 3 Comparison between QTP patients with different outcomes during hospitalization

ECG parameters	30-day survival ($n=168$)	30-day mortality ($n=67$)	*P* value
Heart rate, bpm	93.35 ± 19.62	109.39 ± 30.74	< 0.001
QRS duration, ms	98.16 ± 23.22	99.99 ± 23.61	0.589
PR interval, ms	152.34 (27.82)	149.16 (28.48)	0.434
QT interval, ms	390.90 (41.39)	378.96 (47.63)	0.057
Corrected QT, ms	476.70 (23.32)	486.76 (28.15)	0.005
Axis, degree	34 [3.5, 63.5]	58 [21, 76]	0.002
RV5 + SV1, ms	2.04 (1.03)	2.01 (1.32)	0.816
TWD/QT	59.88 (10.74)	57.02 (13.15)	0.085
T_{peak}-T_{end}/QT	27.63 (7.12)	25.85 (6.49)	0.077
U wave	8 (4.76)	1 (1.49)	0.238

Table 4 Multivariate analysis for prediction of new-onset QTP in sepsis

Variable	OR	95% CI for OR		*P* value
		Lower	Upper	
Coronary artery disease, %	2.51	1.46	4.30	0.001
Septic shock, %	1.71	1.15	2.53	0.008
Acute heart failure, %	1.73	1.09	2.75	0.021
Acute renal failure, %	1.67	1.12	2.50	0.013
Acute respiratory failure, %	2.66	1.77	3.99	< 0.001

Adjusted for age, body surface area, hypertension, coronary heart disease, structural heart disease, COPD, septic shock, acute heart failure, acute renal failure, acute respiratory failure and acute liver failure that show significant difference in univariate analysis

QTP QT prolongation

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13054-024-04879-2.

Additional file 1. QT-Prolonging Medications for Exclusion in the Study.

Additional file 2. **Table S1**: Predictors of 30-day mortality in patients with sepsis.

Additional file 3. **Table S2**: Multiple regression models for validate the risk factors for QTP.

Author contributions

WL and SZ analyzed data and wrote the paper. RS and WL conducted the statistical analysis. WC, NX, and BH designed and supervised the research. RL, PC, WC, JH, BW, and HM contributed to data collection and data correction. XL and JL served as the academic consultants. All authors contributed to the process and the editing of the manuscript. All authors provided critical revisions of the manuscript and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Shanghai Chest Hospital, Shanghai Jiaotong University School of Medicine (IRB No. KS22024).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Department of Critical Care Medicine, Shanghai Chest Hospital, Shanghai Jiaotong University School of Medicine, 241 Huaihaixi Road, Shanghai 200030, China. [2]Centre for Cardiopulmonary Translational Medicine, Shanghai Chest Hospital, Shanghai Jiaotong University School of Medicine, Shanghai, China. [3]Department of Cardiology, Huashan Hospital Fudan University, 12 Wulumuqizhong Road, Shanghai 200030, China. [4]Department of Infectious Diseases, Jing'an District Central Hospital of Shanghai, Fudan University, Shanghai, China. [5]Department of Cardiology, People's Hospital of Qiubei, Putan Road in Jinping Town, Qiubei 663200, Yunnan, China. [6]Department of Cardiology, First Affiliated Hospital of Kunming Medical University, Kunming, Yunnan, China.

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