POLITECHNIKA BYDGOSKA
im. Jana i Jędrzeja Śniadeckich

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Interpretable Fuzzy Rule-Based System for Fatal Ventricular Arrhythmia Risk Level Estimation due to QT-Prolonging Treatments

Sebastián García Galán
sgalan@ujaen.es
Telecommunications Engineer, PhD
Telecommunications Engineering Department
EPS de Linares – Universidad de Jaén. Spain

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Escuela Politécnica Superior de Linares

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CONTENT

PARTICIPANTS

TWO UNIVERSITIES

UNIVERSIDAD DE JAÉN

EPSL

POLITECHNIKA BYDGOSKA
im. Jana i Jędrzeja Śniadeckich

FOUR HOSPITALS

Hospital Universitario quirónsalud Madrid

GENERALITAT VALENCIANA
CONSELLERIA DE SANITAT

Hospital General Universitari d'Elda

JUNTA DE ANDALUCIA
Servicio Andaluz de Salud
CONSEJERÍA DE SALUD
HOSPITAL SAN AGUSTIN DE LINARES

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Servicio Andaluz de Salud
CONSEJERÍA DE SALUD
COMPLEJO HOSPITALARIO DE JAÉN

INTRODUCTION

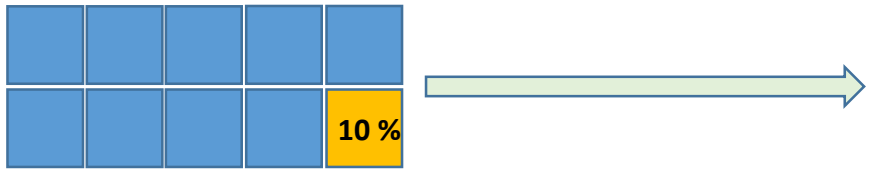
HEALTH CONDITION

TORSADES DE POINTES (FATAL VENTRICULAR ARRHYTHMIA) - SUDDEN DEATH

Chloroquine and hydroxychloroquine have been in increased use globally as a potential, albeit unproven, treatment option for coronavirus disease 2019 (COVID-19)

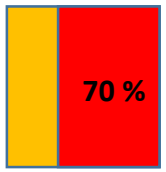
Jankelson L, Karam G, Becker ML, Chinitz LA, Tsai MC. QT prolongation, torsades de pointes, and sudden death with short courses of chloroquine or hydroxychloroquine as used in COVID-19: A systematic review. *Heart Rhythm*. 2020;17(9):1472-1479. doi:10.1016/j.hrthm.2020.05.008

COVID-19 PATIENTS
Treated with Chloroquine



MORPHOLOGICAL CHANGES IN ECG
(QT Interval Prolongation)

COVID-19 PATIENTS
With QT Interval Prolongation



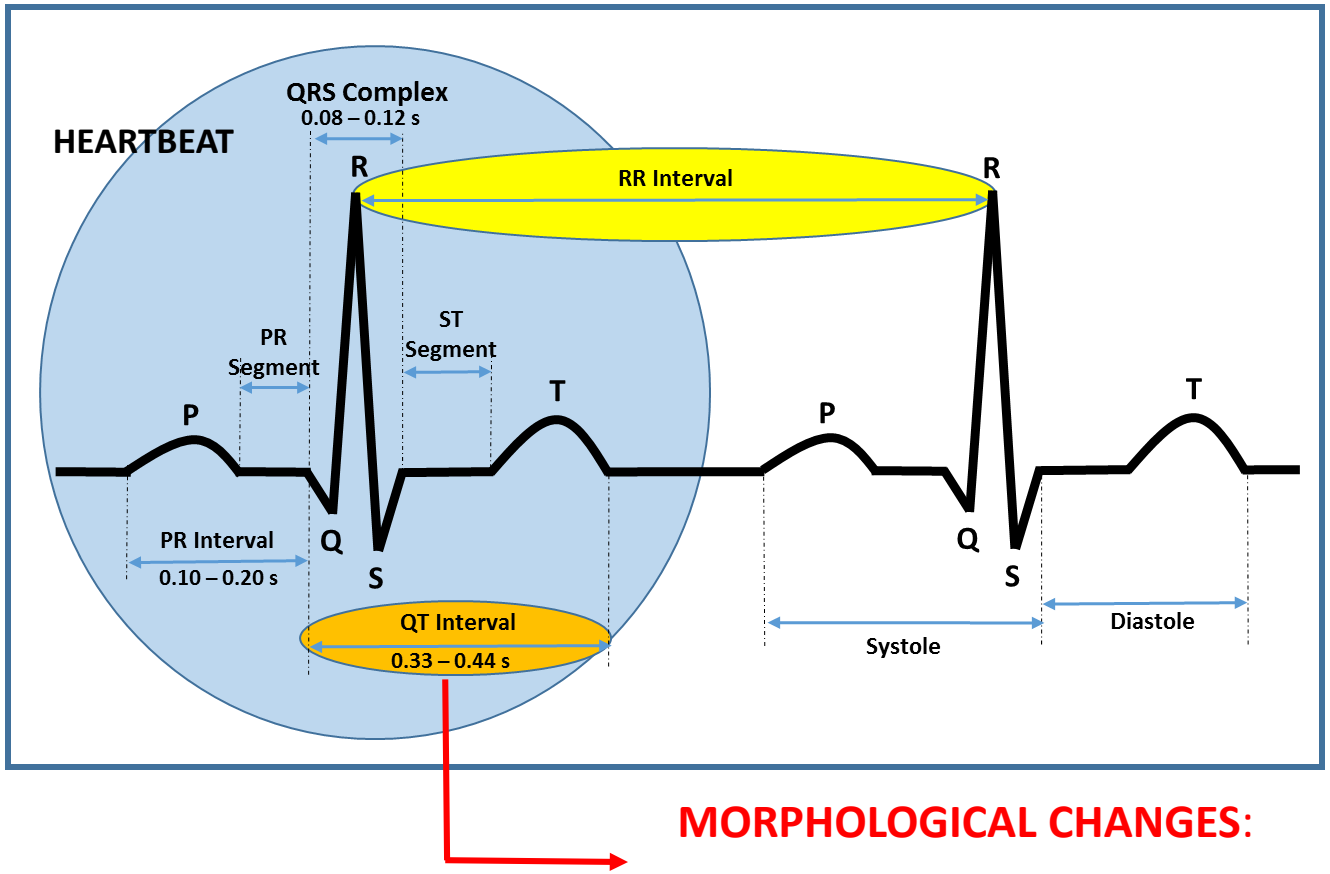
VENTRICULAR ARRHYTHMIA

Combined Treatment
+ azithromycin
+ kaletra

!!!

INTRODUCTION

MORPHOLOGICAL CHANGES IN ECG



MORPHOLOGICAL CHANGES:

QT Interval PROLONGATION

QT Interval: The QT interval is defined from the beginning of the QRS complex to the end of the T wave.

Corrected QT interval (QTc): *estimates* the QT interval at a standard heart rate of 60 bpm. This allows comparison of QT values over time at different heart rates and improves detection of patients at increased risk of arrhythmias.

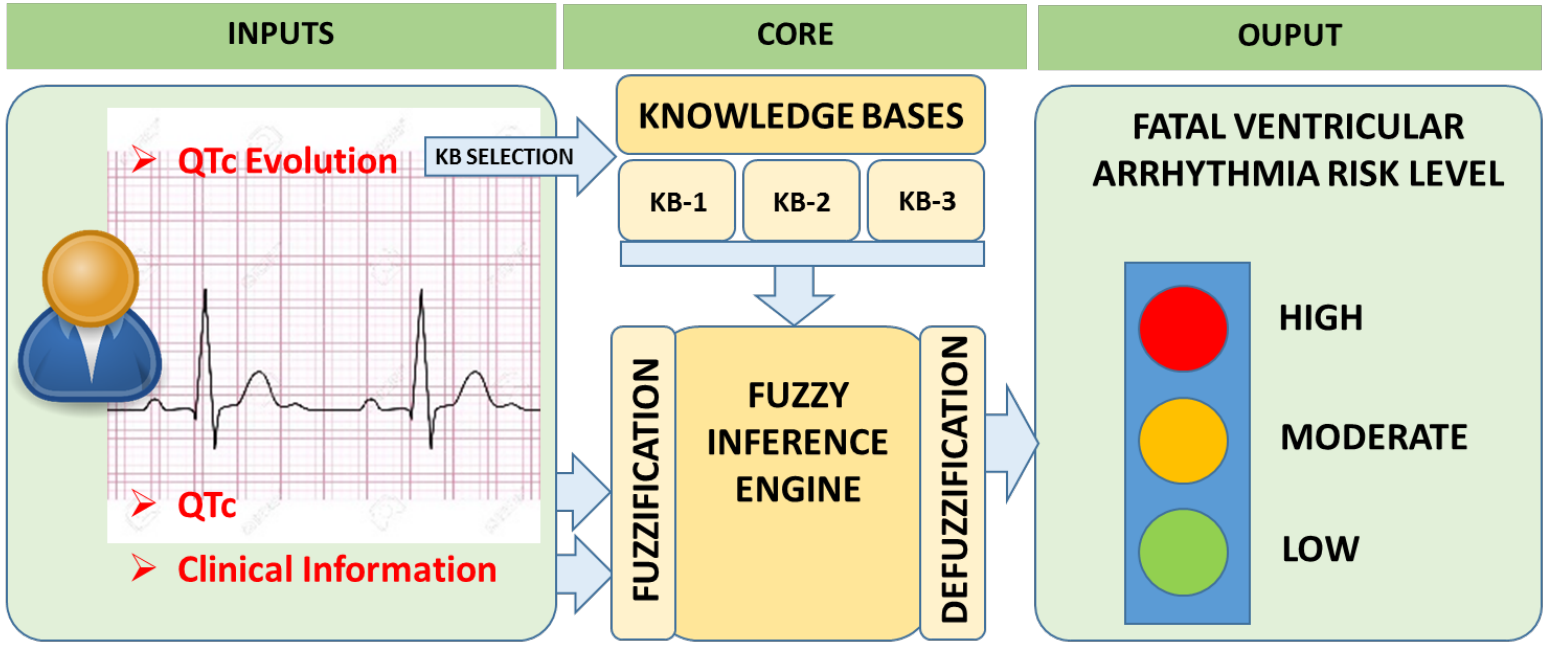
BAZETT $QTc = \frac{QT}{\sqrt{RR}}$

FRIDERICIA $QTc = \frac{QT}{\sqrt[3]{RR}}$

FRAMINGHAM $QTc = QT+0.154(1-RR)$

FUZZY RULE-BASED SYSTEM

SYSTEM STRUCTURE



INPUTS

QTc

$$QTc = QT+0.154(1-RR)$$

QTc Evolution

$$\Delta QT_C = QT_{C\ CURRENT\ ECG} - QT_{C\ BASAL\ ECG}$$

Clinical Information

- Age ≥ 68 years
- Female sex
- Loop diuretic
- Serum K+ ≤ 3.5 mEq/L
- Admission QTC ≥ 450 ms
- Acute Myocardial Infarction
- ≥2 QTc-prolonging drugs
- Sepsis
- Heart failure
- One QTc-prolonging drug

FUZZY RULE-BASED SYSTEM

KNOWLEDGE BASES

ΔQT_C	Selected Knowledge Base
ΔQT_C < 25 ms	RB1 (LOW)
25 ms ≤ ΔQT_C < 50 ms	RB2 (MIDDLE)
ΔQT_C ≥ 50 ms	RB3 (HIGH)

RULES BASE "LOW" (ΔQTc < 25ms)

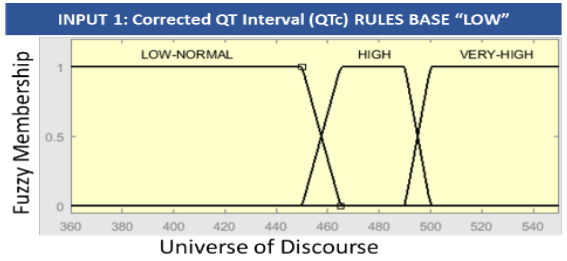
CLINUCAL INFORMATION	QTc: LOW NORMAL	MOD-HIGH HIGH	VERY-HIGH
LOW	LOW	MODERATE	HIGH
MIDDLE			
HIGH			

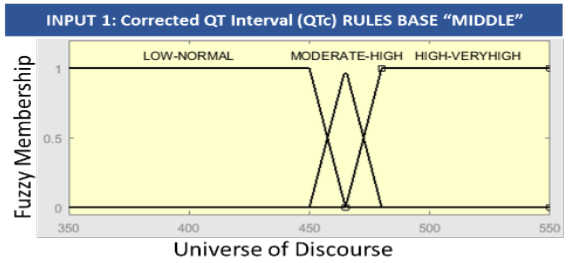
RULES BASE "MIDDLE" (25ms ≤ ΔQTc < 50ms)

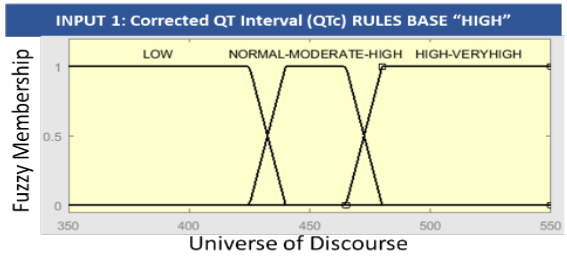
CLINUCAL INFORMATION	QTc: LOW NORMAL	MOD-HIGH	HIGH VERY-HIGH
LOW	LOW	MODERATE	HIGH
MIDDLE			
HIGH			

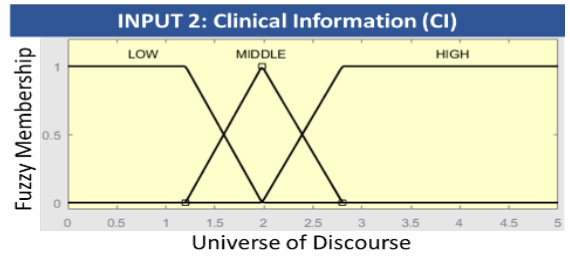
RULES BASE "HIGH" (ΔQTc ≥ 50ms)

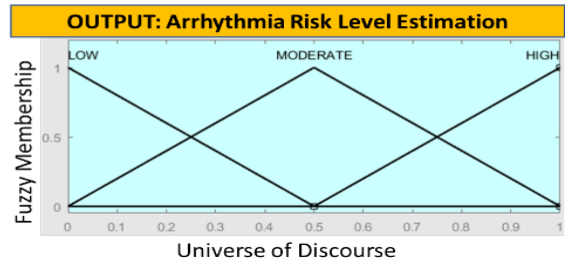
CLINUCAL INFORMATION	QTc: LOW	NORMAL MOD-HIGH	HIGH VERY-HIGH
LOW	LOW	MODERATE	HIGH
MIDDLE			
HIGH			









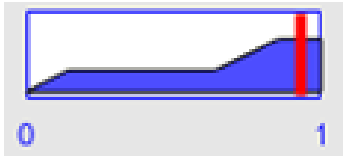
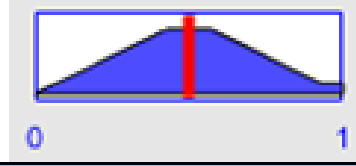
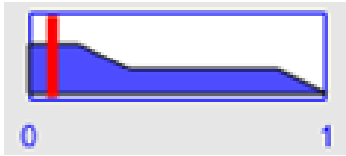


FUZZY RULE-BASED SYSTEM

THREE STUDY CASES

RISK FACTORS	PATIENT 1	PATIENT 2	PATIENT 3
Age ≥ 68 years	0,24	-	0,24
Female sex	-	-	0,24
Loop diuretic	-	-	-
Serum K^+ ≤ 3.5 mEq/L	-	0,48	-
Admission QT_C ≥ 450 ms	-	-	-
Acute Myocardial Infarction	-	0,72	-
≥2 QTc-prolonging drugs	-	-	-
Sepsis	-	0,72	-
Heart failure	-	-	-
One QTc-prolonging drug	-	-	-
RISK SCORE	0,24	1,92	0,48

	INPUTS			OUTPUT
	QTc (ms)	CI	ΔQT_C (ms)	y_0
Patient 1	476	0.24	55	0.93
Patient 2	450	1.91	30	0.50
Patient 3	455	0.48	15	0.08

Activated Rules for Patient 1	Output
If (QTc is NORMAL-MODERATE-HIGH) and (CI is not HIGH) then (RISK is ORANGE)	
If (QTc is HIGH-VERYHIGH) then (RISK is RED)	
Activated Rules for Patient 2	**Output**
If (QTc is LOW-NORMAL) and (CI is MIDDLE) then (RISK is ORANGE)	
If (CI is HIGH) then (RISK is RED)	
Activated Rules for Patient 3	**Output**
If (QTc is LOW-NORMAL) and (CI is LOW) then (RISK is GREEN)	
If (QTc is HIGH) and (CI is not HIGH) then (RISK is ORANGE)	

EXPERIMENTAL RESULTS

PRELIMINARY RESULTS

CONFUSION MATRIX

		FRBS DECISIONS		
		GREEN	ORANGE	RED
DOCTORS DECISIONS	GREEN	9	0	0
	ORANGE	1	19	1
	RED	0	1	53

ACCURACY: 96,43 %

FIELD RESULTS

Hospital Universitario quirónsalud Madrid

GENERALITAT VALENCIANA
CONSELLERIA DE SANITAT

Hospital General Universitari d'Elda

CONCLUSIONS

- FUZZY RULE-BASED SYSTEM FOR THE FATAL VENTRICULAR ARRHYTHMIA RISK LEVEL
- AIMED TO PATIENTS WITH QT PROLONGER TREATMENT (COMBINED OR NOT)
- DESIGNED BASED ON EXPERIENCE OF CARDIOLOGIST AND PULMONOLOGISTS
- SPECIALY RELEVEANT IN HEALTH CENTERS WITHOUT SPECIALIZED CLINICAL STAFF
- HIGH ACCURACY IN COMPARISON WITH DOCTORS DECISIONS
- HIGHLY INTERPRETABLE DECISON PROCESS

FUTURE WORKS

- REAL-TIME APPLICATION (Currently tested in two hospitals and in several primary care health centers)
- IMPROVEMENTS (QT Interval Obtaining, Decisions)
- DISTRIBUTION

CONCLUSIONS

Thank you all for your time and attention !!!

Sebastián García Galán
sgalan@ujaen.es
Telecommunications Engineer, PhD
Telecommunications Engineering Department
EPS de Linares – Universidad de Jaén. SPAIN