Utility of Inferior Lead Q-waveforms in diagnosing Ventricular Tachycardia

Clinical Medicine Insights: Cardiology
Volume 14: 1–5

DOI: 10.1177/1179546820953416

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ABSTRACT

BACKGROUND: Electrocardiogram (ECG) differentiation of wide complex tachycardia (WCT) into ventricular tachycardia (VT) and supraventricular tachycardia with aberration (SVT-A) is often challenging.

OBJECTIVE: To determine if the presence of Q-waveforms (QS, Qr, QRs) in the inferior leads (II, III, aVF) can differentiate VT from SVT-A in a WCT compared to Brugada algorithm. We studied 2 inferior lead criteria namely QWC-A where all the inferior leads had a similar Q wave pattern and QWC-B where only lead aVF had a Q-waveform.

METHODS: A total of 181 consecutive cases of WCT were identified, digitally separated into precordial leads and inferior leads and independently reviewed by 2 electrophysiologists. An electrocardiographic diagnosis of VT or SVT-A was assigned based on Brugada and inferior lead algorithms. Results were compared to the final clinical diagnosis.

RESULTS: VT was the final clinical diagnosis in 24.9% of ECG cohort (45/181); 75.1% (136/181) were SVT-A. QWC-A and QWC-B had a high specificity (93.3% and 82.8%) and accuracy (78.2% and 71.0%), but low sensitivity (33.3% and 35.6%) in differentiating VT from SVT-A. The Brugada algorithm yielded a sensitivity of 82.2% and specificity of 68.4%. Area under the curve in ROC analysis was highest with Brugada algorithm (0.75, 95% CI 0.69-0.81) followed by QWC-A (0.63, 95% CI 0.56-0.70) and QWC-B (0.59, 95% CI 0.52-0.67).

CONCLUSION: QWC-A and QWC-B criteria had poor sensitivity but high specificity in diagnosing VT in patients presenting with WCT. Further research combining this simple criterion with other newer diagnostic algorithms can potentially improve the accuracy of the overall diagnostic algorithm.

KEYWORDS: Ventricular tachycardia, electrocardiogram

RECEIVED: April 28, 2020. **ACCEPTED:** July 31, 2020.

TYPE: Original Research

FUNDING: The author(s) received no financial support for the research, authorship, and/or publication of this article.

DECLARATION OF CONFLICTING INTERESTS: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Introduction

Wide complex tachycardia (WCT), defined as a cardiac rhythm with a QRS width of >120 ms and heart rate of >100 bpm, often presents as a diagnostic challenge. The differential diagnosis for WCT includes ventricular tachycardia (VT), supraventricular tachycardia with aberration (SVT-A) and pre-excited tachycardia. Different algorithms and criteria have been developed to aid electrocardiographic differentiation of VT and SVT-A.[1] The most commonly used criteria include the Brugada algorithm,[2] the aVR 'Vereckei' algorithm,[3] the lead II R-wave-peak-time criterion[4] and Griffith algorithm.[5] Recently, mathematical logistic regression models (The WCT formula, The WCT formula II, VT prediction Model)[6-8] for implementation in computerized ECG interpretation software have also been developed. We had observed in our patient population that presence of 'pathologic' Q waves (Q wave >40 ms in width and >25% of the QRS amplitude) in inferior leads (II, III and aVF) in a WCT correlated with a diagnosis of VT. But comparative accuracy with other well-established algorithms have not been rigorously studied. We sought to examine 2 Q-wave criteria (QWC-A and QWC-B) in differentiating WCTs using the presence or absence of specific Q wave patterns in inferior leads. We also compared its diagnostic accuracy to the well-validated Brugada algorithm.

Methods

Data collection and study design

In a retrospective design, we studied all the ECGs that were labelled as wide complex tachycardia (WCT) by the MUSE ECG reporting system (GE HealthCare) of the University of Arkansas for Medical Sciences, Little rock, AR, U.S.A from June 2009–December 2016. Only adult subjects (age >18 years) were included in the study. We manually excluded ECGs that were

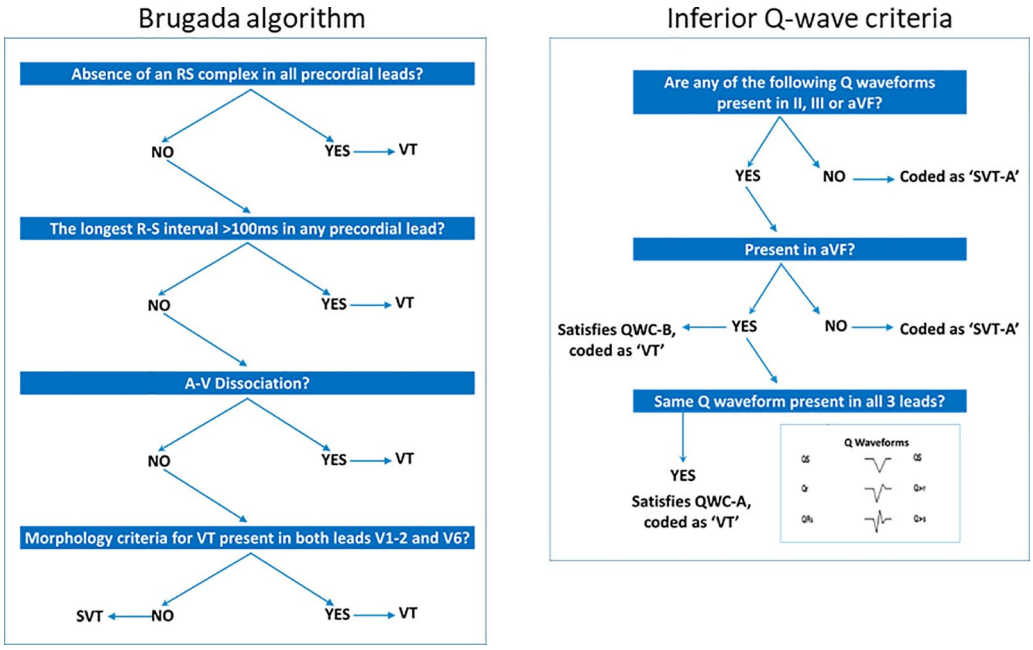

Figure 1. Description of the algorithms used in the study for interpreting WCTs.
Abbreviation: QWC, Q wave criteria.

incorrectly labelled by the reporting system as wide complex tachycardia (if QRS duration was <120 ms or heart rate <100 bpm), ECGs with paced rhythms, artifacts and duplications. The study protocol was approved by institutional review board.

We sought to analyze the predictive value of the 2 Q waveform criteria (QWC), namely QWC-A and QWC-B in differentiating VT from SVT in a WCT and compare it with the well-established Brugada algorithm. The presence of same kind of Q wave morphology in all the 3 inferior leads (II, III and aVF) was defined as the QWC-A criteria, whereas the presence of Q wave in aVF alone, among the inferior leads, satisfied the QWC-B criteria (Figure 1). We digitally separated the inferior lead images (IL set) and precordial lead images (PL set) from the selected ECGs and then distributed, in a random fashion, to 2 independent electrophysiologists who were blinded to the clinical and demographic information of the patients. They, in an open book fashion, applied the QWC criteria and Brugada criteria for interpreting the IL sets and PL sets respectively and categorized the wide complex rhythm into VT or SVT. The ECG leads were digitally separated to blind the reviewers from the ECG leads not involved in the respective algorithms and thereby reduce observer bias. Electronic medical records were then reviewed for demographic information and clinical interpretation of the ECGs. The final diagnosis reached by the consultant electrophysiologist who cared for the patient and had access to all available clinical and electrophysiologic data was considered the standard.

Statistical analysis

Continuous variables were represented as mean and standard deviation and categorical variables as frequencies and percentages. The kappa statistic was used to establish inter-observer concordance. Overall inter-observer agreement was defined as good if kappa>0.6, moderate if 0.6>kappa>0.4 and poor if kappa<0.4. Sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio, negative likelihood ratio and accuracy of each diagnostic algorithm was calculated using final clinical diagnosis as the standard. Receiver operating characteristic (ROC) curves were created for each of the diagnostic criteria. The area under the curve (AUC) were calculated and compared using Delong test. Statistical Analysis was conducted using SPSS 18.0 (SPSS Inc., Chicago, IL) and MedCalc Statistical Software version 19.2.1 (MedCalc Software Ltd, Ostend, Belgium)

Results

Of the 438 ECGs that were labelled as WCT by the ECG reporting system, ECGs of 181 unique patients met the inclusion and exclusion criteria and were included in the analysis (Figure 2). Mean age of patients were 65.0 ± 17.4 years and 43.6% were woman. Among the ECGs studied, 24.9% (45 cases) had a final clinical diagnosis of VT. Among the SVTs (136/181; 75.1%), the most common type was Atrioventricular nodal reentrant tachycardia (AVNRT) (28.7%) followed by sinus tachycardia (13.3%), atrial flutter (11%), atrial tachycardia 9.4% and atrial fibrillation (3.9%). 9.4% of the WCT were unclassified SVT with aberrant conduction (Table 1). Inter-observer agreement between the 2 electrophysiologists reviewing the ECG was good with QWC-A (k statistic = 0.64, $P < .001$) and Brugada algorithm (k statistic = 0.65, $P < .001$). QWC-B criteria showed moderate interobserver concordance (k statistic = 0.46, $P < .001$).

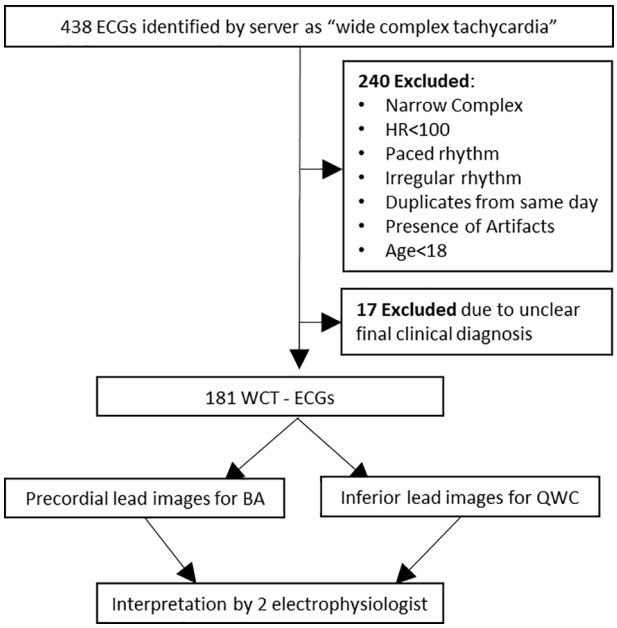

Figure 2. Selection method for ECGs with wide complex tachycardia. Abbreviations: BA, Brugada algorithm; QWC, Q wave criteria; WCT, wide complex tachycardia.

Table 1. Distribution of clinical diagnosis of WCT ECGs reviewed in the study.

TYPE OF ARRHYTHMIA	% (N)
VT	24.3% (45)
AVNRT with aberration	28.7% (52)
Atrial Flutter with aberration	11.0% (20)
Atrial Fibrillation with aberration	3.9% (7)
Sinus tachycardia with bundle branch block	13.3% (24)
Atrial Tachycardia with aberration	9.4% (17)
Unclassified SVT with aberration	9.4% (17)

Utility of diagnostic algorithms in identifying VT

The sensitivity in diagnosing VT was highest with Brugada criteria (82.8%, 95% CI 67.9%-92.0%) and classified 37 out of the 45 ECGs of VT appropriately. Both QWC-A (33.3%, 95% CI 20.0%-49.0%) and QWC-B (35.6%, 95% CI 21.9%-51.2%) had a low sensitivity and identified only 15 and 16 cases of VT respectively. However, QWC-A and QWC-B had a higher specificity, 93.3% and 82.8% respectively in diagnosing VT (Table 2). Two ECGs could not be interpreted using the inferior lead criteria as the QRS complexes were of low amplitude and wave forms were indeterminate. Table 2 describes the positive predictive value, negative predictive value, positive likelihood ratio and negative likelihood ratio of the 3 algorithms studied. Overall accuracy of QWC-A was highest (78.2%, 95%CI 71.4%-84.0%) which identified 140 out of 179 cases appropriately, followed by Brugada criteria (71.8%, 95%CI 64.7%-78.2%) and QWC-B criteria (71.0%, 95%CI 63.7%-77.5%). ROC curve analysis of each criterion in diagnosing VT is shown in Figure 3. AUC for QWC-A criteria (0.633, 95%CI 0.56-0.70) was higher than QWC-B criteria (0.592, 95%CI 0.52-0.67). Brugada criteria (0.75, 95%CI 0.69-0.81) had the highest AUC among all 3 diagnostic algorithms. Pairwise comparison of the AUC showed statistically significant difference among the AUC for each Brugada versus QWC-A ($P = .005$), Brugada versus QWC-B ($P < .001$) and QWC-A versus QWC-B ($P = .017$).

Discussion

Electrocardiographic diagnosis of WCT continues to be challenging and most algorithms that seek to tackle this are multistep and complicated. In this study we describe a simple and essentially single-step Q-wave criteria which assesses the presence of Q waveforms in the inferior leads to diagnose VT in a WCT and compared it with the well-established Brugada algorithm. Our study showed high accuracy and specificity for the QWC-A criteria (78.2% and 93.3% respectively). However, its sensitivity was low (33.3%). The highest sensitivity in diagnosing VT was with Brugada criteria (82.2%). But, the specificity of Brugada criteria was low (68.4%). AUC in ROC analysis was also highest with the Brugada algorithm.

It has been recognized that VT is more common than SVT-A in a WCT. In older series, the prevalence of VT among WCT was cited to be >85%.[9,10] Newer studies had a prevalence of VT between 70% and 75%.[3,4,11] Unlike similar studies, VT accounted for only 24.9% cases in the current study. The most common SVT was AVNRT with aberrant conduction followed by sinus tachycardia with a bundle branch block.

Unlike the original study of Brugada algorithm which showed a high specificity (96.5%), our study had a relatively low specificity (68.4%) in diagnosing VT using Brugada algorithm. This finding was similar to other independent reports which evaluated Brugada criteria in WCT and had observed a lower specificity.[12-14] The QWC-A offered more accuracy in our sample population likely due to its high specificity, albeit poor sensitivity, in a sample with relatively low prevalence of VT. Thus, the diagnostic value of each of these algorithms may be influenced by the prevalence of the types of WCTs. In addition, all 3 algorithms, QWC-A, QWC-B and Brugada, had moderate to high inter-observer concordance, which suggests to the ease of reproducibility of results with different observers.

Q waves in the inferior leads during VT could reflect the presence of a remote inferior myocardial infarction that could serve as a substrate for VT. In addition, negative Q waves in inferior leads reflect a caudo-crainal activation sequence reflective of a ventricular origin of the rhythm.[15] Inferior lead Q waveforms have previously been analyzed in predicting VT. Griffith et al. published a multivariate analysis of 102 consecutive patients to determine independent predictors of VT in a WCT.[16] ECG waveforms in various leads were studied in

Table 2. Comparison of the 2 inferior lead algorithms in diagnosing VT in a WCT.

VARIABLE	QWC-A	QWC-B	BRUGADA
Sensitivity (%)	33.3 (20.0-49.0)	35.6 (21.9-51.2)	82.2 (67.9-92.0)
Specificity (%)	93.3 (87.6-96.9)	82.8 (75.4-88.8)	68.4 (59.9-76.1)
Positive predictive value (%)	62.5 (43.9-78.0)	41.0 (28.8-54.5)	46.3 (39.4-53.3)
Negative predictive value (%)	80.6 (77.1-83.7)	79.3 (75.2-82.8)	92.1 (86.0-95.7)
Positive likelihood ratio	5.0 (2.3-10.6)	2.0 (1.2-3.6)	2.6 (2.0-3.5)
Negative likelihood ratio	0.7 (0.6-0.9)	0.8 (0.6-1.0)	0.3 (0.1-0.5)
Accuracy (%)	78.2 (71.4-84.0)	71.0 (63.7-77.5)	71.8 (64.7-78.2)

Abbreviations: QWC, Q-waveform criteria; VT, ventricular tachycardia; WCT, wide complex tachycardia.

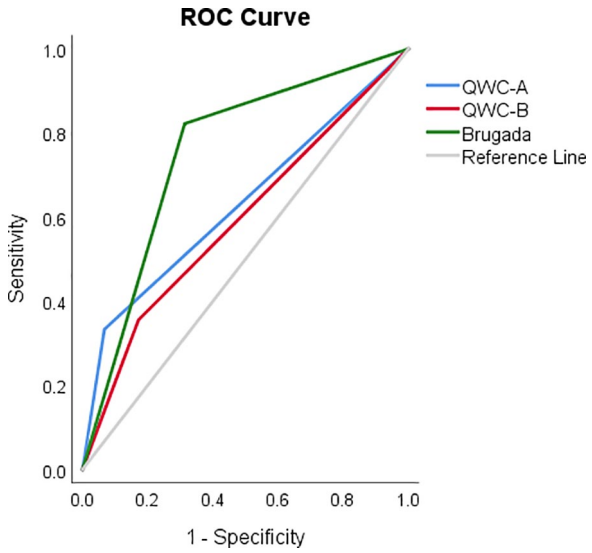

Figure 3. Results of ROC curve analysis of the diagnostic algorithms.
Abbreviations: QWC, Q wave criteria; ROC, receiver operating curve.

detail. Among the 4 leads studied (I, aVF, V1 and V6), certain waveforms (Q, QS, Qr or qR waveforms) in aVF was found to be the most useful with a 72% predictive accuracy for VT. Our findings were in congruence with this study and we noted a 78.2% accuracy in diagnosing VT based on the presence of a similar Q-wave pattern in all 3 inferior leads.

Recently Chen et al, published a new algorithm named limb lead algorithm (LLA) to differentiate VT from SVT in WCTs.[17] As per this algorithm, VT is diagnosed in the presence of at least 1 of the following: (1) monophasic R wave in lead aVR; (2) predominantly negative QRS in leads I, II, and III and (3) opposing QRS complex in the limb leads (OQL): concordant monophasic QRS in all 3 inferior leads *and* concordant monophasic QRS in 2 or 3 of the remaining limb leads with a polarity opposite to that of the inferior leads. LLA algorithm had a sensitivity of 87.2% and a specificity of 90.8% as reported in the study. Our QWC-A criteria share similar characteristics to the second step of the LLA and that of the OQL (third step) algorithm delineated by Chen. et al in their previous work.[14] Like the second step of the LLA algorithm, we sought to use QRS complexes that appeared as QS, Qr, qrS, but didn't count rSr' or rS even if the predominant voltage was negative. Compared to the OQL or the third step, we only included monophasic negative QRS complexes in the inferior leads (QW-A criteria) and did not account for complexes with positive polarity or consider other limb leads. Both LLA and QOL demonstrated remarkably high specificity (92.1%). QWC-A criteria had similar high specificity rates compared to the LLA and the OQL algorithms but much lower sensitivity.

Given that the QWC-A criterion is simple and reproducible, future research should be performed to assess if QWC-A criteria can be incorporated to one of the newer algorithms such as LLA to further improve the sensitivity and specificity in diagnosing VT.

Strenghts and limitations

The reference standard used in our study was the final clinical diagnosis made by an electrophysiologist who had access to all clinical and electrophysiological data. Unlike previous studies which compared diagnostic accuracy of algorithms to the final diagnosis obtained using invasive electrophysiology study as gold standard, all patients in our cohort did not undergo electrophysiologic study.[17] This may be considered both as a strength and a limitation of the study. In real world, it is difficult to justify the need for an EP study on all cases of WCT. In addition, the diagnosis of WCT can often be reached using other techniques such as vagal maneuvers, adenosine administration, reviewing older ECGs of same patient or simply by the high likelihood in specific clinical scenarios. Our patient selection evaluates a more representative patient population by including patients that are expected to be encountered in real word clinical practice–not just those having had an electrophysiology procedure. The advantage of having a definitive gold standard such as an EP study is counterbalanced by the sampling bias created by this approach. The prevalence of VT that maybe expected from

an EP lab would be unsurprisingly be higher than in clinical practice. As such, we do not exactly know how well the algorithms such as the Brugada and Vereckei algorithms perform for populations expected in actual clinical practice.

Another limitation is that our study population included a lower percentage (24.9%) of VT patients, compared to prior studies. Sensitivity and specificity of a test often vary with prevalence. The use of a highly specific criterion on study population with a lower VT prevalence may have contributed to the increased accuracy of QWC algorithms. However, this also reflects the known observation that the patient substrate is an important determinant of the etiology of WCT. Finally, the observers that interpreted the algorithms were experienced ECG readers, hence the same results may not be reproduced by other physicians such as a general practitioner or physicians of other specialties. However, given the simplicity and ease of QWC-A and QWC-B algorithms, we feel that it is probably easier for general physicians to use these newer algorithms rather than multi-step algorithms such as the Brugada algorithm that involve subtle analysis of QRS morphologies. We emphasize that while the QWC-A criteria do not serve as replacement for other validated methods for the differentiation of WCT, it may serve as an additional confirmatory tool when VT is diagnosed to be present using other methods.

Conclusion

In our study, we observed that about a third of ventricular tachycardia have a pathologic Q waveform in the inferior leads (II, III and aVF). The presence of identical QS, Qr or QRs in all 3 inferior leads was predictive of VT and had a high specificity (93%). However, due to low diagnostic specificity, the inferior lead criteria should not be used as a standalone criterion to differentiate WCTs. Clinical features or a combination with other known predictive ECG features may improve prediction rates. Further research by combining QWC-A into one of the previously established diagnostic algorithms should be considered in future as it may potentially improve the sensitivity and specificity of the overall diagnostic algorithm.

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