ORIGINAL ARTICLES

Significance of Abnormal Q Waves in the Electrocardiograms of Adults Less than 40 Years Old

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Background: Abnormal Q waves (AQW) in the electrocardiogram are commonly ascribed to underlying myocardial infarction (MI). As an imperfectly specific sign of MI, the usefulness of AQW in identifying MI depends on its incidence in the population studied.

Methods: Eighty-two subjects under 40 years of age with AQW were compared with 82 subjects from the same institution aged ≥ 40 years with similar AQW to determine the presence or absence of cardiac disease or MI.

Results: Cardiac disease was present in 90.2% and 92.7% of the younger and older subjects, respectively, whereas MI was present in only 15.9% of younger subjects and in 68.3% of older subjects. Etiologies of cardiac disease differed between younger and older subjects. Some types of AQW were more useful than others in ruling MI in or out.

Conclusions: AQW were a strong indicator of organic heart disease in both adult age groups, but their utility to indicate MI was age-dependent. In the population studied, MI was present in only a small minority of subjects under 40 years of age with AQW, but was usually present in older subjects with similar AQW.

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Q wave abnormality; young adults; electrocardiography; myocardial infarction

The incidence of myocardial infarction (MI) is very small in youth but increases with age.^{1,2} Abnormal Q waves (AQW) are the electrocardiographic hallmark of the chronic stage of MI, but are not necessarily specific for that pathology. Despite attempts to apply age- and gender-related standards, when AQW are present, computerized algorithms for interpretation of the electrocardiogram (ECG) still tend to diagnose MI even in young adults.³ Physicians formally interpreting ECGs tend to acquiesce in such interpretations.

This study was designed to ascertain the significance of pathologic Q waves in subjects under 40 years of age having ECGs at a large academic medical center. It is hoped that the results described will allow physicians who read ECGs on similar groups of patients to include in their interpretations more precise assessments of the significance of these AQW.

METHODS

ECGs processed through the Electrocardiography Laboratory of the UCLA Medical Center in the years 1997–2004 were reviewed by the author to select those with AQW in subjects between ages 18 and 40 years. In this laboratory, about two-thirds of ECGs come from outpatients. Most tracings were recorded by Marquette Models MAC6, MAC8, MAC15, or MACVU ECG machines (GE Marquette Electronics, Milwaukee, WI, USA), and printed out for inspection at paper speed of 25 mm/s and amplitude of 1 mV = 10 mm. The review from 1997 to 2002 was not systematic, and some cases were missed. During 2002–2004 all cases were systematically reviewed. Cases were excluded for the following reasons: age under 18 years; age equal to or greater than 40 years; absence of clinical information sufficient to render a cardiac diagnosis and

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to rule in or out MI; technical inadequacy sufficient to obviate interpretation; abnormal ventricular activation due to incomplete or complete left bundle branch block, ventricular preexcitation, ventricular pacing, idioventricular rhythms, or ventricular tachycardia; obviously incorrect lead placement; and patient duplication. Eighty-two cases meeting these criteria were found (Group 1). Medical records of these cases were reviewed to determine the cause of the AQW and the presence or absence of MI. Particular attention was paid to myocardial imaging studies such as echocardiography, myocardial nuclear scintillation scans, cardiac magnetic resonance imaging, prior ECGs, coronary arteriography, and ventriculography. A random sample of 82 cases was taken during the same years of ECGs from subjects over age 40 years who had similarly defined AQW and adequate imaging or serial ECG information to document the presence or absence of MI (Group 2). Their medical records were similarly reviewed so incidences of MI associated with the AQW could be compared in the two age groups.

AQW were defined as described in Table 1. These somewhat arbitrary definitions were an eclectic compilation derived from a variety of sources,⁴⁻⁶ but relied heavily on the Minnesota Code.⁷ For simplicity, leads III, aVR, and aVL were ignored in this compilation, as QR or QS complexes can occur normally in the latter two leads, and in a given case pathologic Q waves almost never are limited to lead III or aVL. A QS deflection in lead V₁ can be a normal variant and was not considered abnormal if an initial R was present in V₂. In tracings meeting criteria for left anterior fascicular block, a QS in V₂ was not considered abnormal if no other potential AQW were present. Q and R deflections were defined, and their amplitudes and durations were measured by hand and eye according to the guidelines in the Minnesota Code.⁷

Statistical differences between continuous variables were tested with analysis of variance. Mean values are expressed as $\pm$ standard deviation. Significance of differences between incidences of discrete variables that could be expressed in

Table 1. Incidence of Various Abnormal Q Wave Criteria

Criterion ^a	Age <40 Years		Age $\geq$ 40 Years	
	No MI n = 69	Yes MI n = 13	No MI n = 26	Yes MI n = 56
Lead I				
QR/QRS with Q $\geq$ 40 ms	9 (2)	1 (0)	0	5 (0)
QS	5 (0)	0	0	0
QR/QRS with Q $\geq$ 0.4 mV	10 ^d (0)	0	0	0
QR/QRS; Q $\geq$ 30 ms; R > 0.3 mV; Q:R ratio > 0.4	12 ^d (0)	3 (1)	0	2 (0)
LEAD II				
QR/QRS with Q $\geq$ 30 ms	13 (0)	5 (0)	2 (0)	10 (0)
QS	10 (0)	1 (0)	1 (0)	2 (0)
LEAD aVF				
QR/QRS; Q $\geq$ 30 ms; any Q in II	12 (0)	6 (2)	4 (2)	16 (6)
QR/QRS with Q $\geq$ 0.4 mV	12 ^d (3)	1 (0)	0	2 (0)
QS	8 (0)	2 (0)	0	8 ^b (0)
LEAD V ₂				
QS	16 (11)	3 (0)	16 ^f (12)	26 (12)
QR/QRS with Q $\geq$ 40 ms	6 (3)	1 (0)	3 (2)	5 (0)
LEADS V ₃ -V ₆ (any or all)				
QS, or QR/QRS with Q $\geq$ 40 ms	11 (1)	5 (0)	4 (2)	22 ^c (1)
LEADS V ₅ and/or V ₆				
QR/QRS with Q $\geq$ 0.4 mV	7 (0)	0	0	1 (0)
QR/QRS; Q $\geq$ 30 ms; R > 0.3 mV; Q:R ratio > 0.25	19 ^e (2)	3 (0)	0	6 (0)

^aMinimum Q depth for any criterion was 0.1 mV. Numbers in () = cases with this as only Q abnormality; Forward slash (/) separating QR and QRS indicates *either/or*. Semicolon (;) separating items indicates *and*; For intragroup comparisons ^bP < 0.05; ^cP < 0.01. For comparisons between Group 1 and Group 2 cases without MI: ^dP < 0.05; ^eP < 0.01; ^fP < 0.001.

two-by-two tables was tested by chi-square or, when numbers were small, with a 2-tailed Fisher's exact test. A P value of <0.05 was required for significant differences.

This protocol was approved by the institutional review board.

RESULTS

ECGs from 82 cases under 40 years of age were identified with AQW. In a small sampling, the incidence of AQW in tracings from all age groups was about 4%, and of this fraction about 5% occurred in subjects between ages 18 and 40 years.

Age and Gender Characteristics

The age of the Group 1 subjects averaged 29.0 ± 6.5 years (range 18.0–39.6 years). In Group 2 age averaged 68.7 ± 12.0 years (range 40.2–89.1 years). Group 1 consisted of 52 men and 30 women, and Group 2 contained a similar gender ratio of 51 men and 31 women. The men in Group 1 averaged 28.6 ± 6.5 years, and the women 29.8 ± 6.6 years, a nonsignificant difference ($P > 0.1$). In Group 2 the ages for men and women were, respectively, 67.5 ± 12.9 years and 72.8 ± 12.6 years ($P > 0.1$), also not a significant difference.

Within Group 1, the 42 subjects without congenital heart disease (CHD) were compared to the 40 patients with CHD. Neither the respective difference in mean age (29.6 ± 6.7 vs 28.4 ± 6.4 years) nor the different gender ratio (30 men/12 women vs 22 men/18 women) reached statistical significance.

Incidence of MI when AQW Present

Evidence documenting MI was present in 13 of the 82 cases in Group 1 (15.9%). In the older subjects of Group 2, the incidence of documented MI was 56 of 82 cases (68.3%), which was significantly higher than that seen in the younger subjects of Group 1 ($P < 0.0001$). The ratios of men to women in cases with MI, was not significantly different between the two groups. In neither group was there a significant difference in age between those with and without MI. Evidence allowing cardiac diagnosis in Group 1 and Group 2 subjects was cardiac angiography in 18 and 14 cases, echocardiography in 70 and 57 cases, nuclear myocardial perfusion scan in 7 and 36 cases, MRI in 2 and 0 cases, and clinical history with serial ECGs in 6 and 0 cases, respectively.

Causes of AQW Other than MI

Table 2 lists the incidence of different cardiac diagnoses in the two groups. In the younger patients of Group 1, despite the low incidence of MI, the presence of AQW was strongly indicative of organic heart disease (74 of the 82 cases or 90.2%). The high incidence of CHD and cardiomyopathies in this group reflects in part the special clinics at UCLA dealing with these ailments (The Ahmanson-UCLA Center for Adult Congenital Heart Disease, and The Ahmanson-UCLA Cardiomyopathy Center), and the institution's active program of cardiac transplantation. AQW were also a strong indicator of cardiac disease in most patients in Group

Table 2. Cardiac Conditions Associated with Abnormal Q Waves

Cardiac Abnormality	Group 1: Age < 40 (n = 82) Number of Cases with	Group 2: Age ≥ 40 (n = 82) Number of Cases with
Congenital heart disease	40 ^{c,d}	0
Other valvar heart disease	0	1
Hypertrophic cardiomyopathy	8	2
Other cardiomyopathy	8	2 ^e
Hypertensive heart disease without MI	4	14 ^a
Status postorthotopic heart transplant	4	3
Coronary heart disease with MI	10	54 ^c
Apparently normal heart	8	6

Compared with incidence in other group: ^a $P < 0.05$; ^b $P < 0.01$; ^c $P < 0.001$; ^dThree cases suffered intraoperative MI as a complication of reparative cardiac surgery, coronary angiograms were normal; ^eTwo cases had probable embolic MI, coronary arteriograms were subsequently normal.

2 subjects (76 of 82 cases or 92.7%). Not unexpectedly, the nature of cardiac disease associated with AQW differed markedly between Group 1 and Group 2. In the younger group, CHD and cardiomyopathies were significantly more common, whereas in the latter, coronary and hypertensive heart diseases were much more prevalent. The majority of CHD cases had complex lesions including d- or l-transposition of the great vessels with associated lesions (13 cases), Down syndrome with A-V canal defects and Eisenmenger physiology (six cases), tetralogy of Fallot (four cases), double outlet right ventricle (three cases), single ventricle or truncus arteriosus (two cases each), dextrocardia or tricuspid and pulmonic atresia (one case each).

There were some unusual causes for MI in Group 1. Three cases had sustained MI as an intraoperative complication of surgical repair of complex CHD despite normal coronary arteries preoperatively. In two other cases, accelerated

coronary disease in the grafted donor heart was the cause of MI after orthotopic heart transplantation. Premature coronary atherosclerosis was related to hyperhomocysteinemia and to chronic cocaine abuse in one case each.

Illustrative examples of ECGs from Group 1 with AQW in the absence of MI are shown in Figures 1 and 2. For comparison, the last tracing in the latter figure is from a patient with an MI. In reference to Figure 1C, the association of Duchenne's muscular dystrophy with AQW in lateral leads and prominent anterior forces has been well documented.⁸

A QS complex limited to V_1 - V_2 was the only Q abnormality in 11 of the 69 Group 1 subjects without MI, and in 12 of the 26 Group 2 cases without MI (15.9% vs 46.2%; $P < 0.005$). In the 12 Group 1 subjects with AQW but either an apparently normal heart or hypertensive heart disease, the Q abnormality was a QS complex limited to V_1 - V_2 in 9 cases, but this was the only Q abnormality in 12 of

Figure 1. Examples of ECGs from patients with abnormal Q waves due to cardiac disease other than MI. (A) An 18-year-old woman with d-transposition of the great vessels. Her cardiac lesions had been treated with a Mustard procedure. She had a normal-sized left ventricle (LV) with normal wall motion and an ejection fraction (EF) of 57%. The right ventricle (RV) was dilated with an EF of 45%. (B) A 23-year-old man with Down syndrome, a large ostium primum atrial septal defect, ventricular septal defect, Eisenmenger physiology with cyanosis and clubbing, and estimated RV systolic pressure of 75 mmHg. The interventricular septum was 1.7-cm thick, and posterior left ventricular wall only 0.9-cm thick. There also was RV dilation and hypertrophy. (C) A 20-year-old man with Duchenne's muscular dystrophy. The LV was dilated with globally reduced wall motion and an EF of 20%. There also was biatrial enlargement. (D) An 18-year-old man with hypertrophic cardiomyopathy, asymmetrical septal hypertrophy, but normal LV size and wall motion.

Figure 2. Additional examples of abnormal Q waves caused by diverse cardiac conditions. (A) A 28-year-old woman with l-transposition of the great vessels (TGA), congenitally corrected TGA, but no associated defects. The systemic ventricle with right ventricular anatomy was dilated with a 33% ejection fraction. The pulmonary ventricle had LV morphology, normal size, and wall motion, with an EF of 75%. (B) A 37-year-old diabetic woman with atypical chest pain. Rest and adenosine stress sestamibi myocardial perfusion scans were entirely normal. Multiple ECGs mostly showed initial R waves in V_2 , indicating importance of high lead placement in producing the abnormal Q wave. (C) A 25-year-old man with a dilated cardiomyopathy associated with spinocerebellar atrophy. LV was dilated with globally reduced wall motion and EF of 30%. Pathologic examination of the heart, after its removal for heart transplantation, showed normal coronary arteries, no area of focal scarring, and histology consistent with idiopathic dilated cardiomyopathy. (D) A 35-year-old woman with hyperhomocysteinemia, was a smoker, had hypertension and an elevated cholesterol level. She had suffered two MIs, had occluded left obtuse marginal and right posterior descending coronary arteries, with an inferoposterior LV aneurysm and LVEF of 40%.

the 21 similar Group 2 cases (75% vs 57.1%; $P < 0.05$). None of the Group 1 cases in which this was the only Q wave abnormality had an MI.

Differences in ECG Abnormality in Group 1 and Group 2 and in Cases with and without MI

Table 1 shows that in subjects without MI the following criteria were significantly more common in Group 1 than in Group 2: a Q ≥ 0.4 mV in a QR or QRS complex in leads I or aVF; a Q wave depth $>40\%$ of the height of the following R wave in lead I; and a Q depth $>25\%$ of R wave height in V_5 or V_6 . QS complexes in V_1 - V_2 were more common in cases without MI in Group 2 than in Group 1. In general, criteria incorporating Q >0.4 mV or relatively high Q/R ratios in any lead were more common in Group 1 subjects, but small numbers of cases precluded achievement of statistical

significance for leads other than those mentioned above.

In Group 2 subjects, two criteria were significantly more common in those with an MI than in those without: a QS deflection in lead aVF, and a QS or QR/QRS with Q wave duration ≥ 40 ms in any of leads V_3 - V_6 .

In Table 3, the Q wave abnormalities that seemed likely to help differentiate patients with and without MI in Groups 1 and 2 are coupled with some other similarly useful ECG abnormalities present in these tracings. Also in this table, the subgroup of patients less than 40 years of age who did not have CHD is listed separately. A QS or QR/QRS complex with Q wave duration ≥ 40 ms in leads V_1 - V_2 as the only abnormality was more common in the absence than in the presence of an MI in both Group 1 and Group 2 cases, but this reached statistical significance only in Group 2 and in the Group 1 subjects without CHD. In Group 1, it was significantly

Table 3. ECG Differences Between Young and Older Patients and Between Those with and without Myocardial Infarction

Criterion	Age < 40 All Cases		Age < 40 Cases w/o CHD		Age ≥ 40	
	No MI n = 69	Yes MI n = 13	No MI n = 32	Yes MI n = 10	No MI n = 26	Yes MI n = 56
QS in I and/or V ₆	10	0	3	0	0	0
QS in V ₁₋₂ is only Q abnormality (or QR V ₁₋₂ if RBBB or IRBBB)	15 ^e	0	12 ^{a,e}	0	14 ^b	13
QR/QRS with 30 ms < Q < 40 ms duration	22 ^d	3	7	1	3	2
QR/QRS with Q ≥ 40 ms duration	15	9 ^b	8	6 ^a	4	25 ^b
QR/QRS with Q ≥ 0.4 mV depth	18 ^e	1	5 ^h	0	0	3
Abnormal Q wave plus: "northwest" QRS axis	14 ^d	1	3 ^f	1	0	1
Right atrial abnormality	18 ^d	1	5	1	2	1
Probable right ventricular hypertrophy	22 ^d	2	5 ^g	1	2	1
Ischemic ST-T abnormality in same lead(s) as abnormal Q wave	1	3 ^a	0	3 ^a	0	21 ^c

"/" between QR/QRS indicates *either* QR or QRS complex. CHD = congenital heart disease; MI = myocardial infarction; w = with; w/o = without; In comparing incidences of a criterion in those with and without MI *within* a major group: ^aP < 0.05, ^bP < 0.01, ^cP < 0.001; In assessing differences in criterion incidences in comparable subgroups in those w/o MI, all age < 40 versus age ≥ 40, ^dP < 0.05, ^eP < 0.01; in those both w/o and w MI, age < 40 w CHD versus age < 40 w/o CHD; ^fP < 0.05, ^gP < 0.01; age < 40 w/o CHD versus age ≥ 40, ^hP < 0.05.

more common in cases without than in those with CHD.

Other types of AQW seen in the absence of MI significantly more often in the younger Group 1 cases than in Group 2 cases were QR/QRS with Q duration >30 ms but <40 ms; QR/QRS with Q depth ≥4 mm; any abnormal Q plus a right atrial abnormality or a northwest QRS axis or probable right ventricular hypertrophy (RVH). In the absence of an MI, the latter two supplements to AQW were significantly more common in Group 1 patients with CHD than in those without CHD. In all of the 18 Group 1 cases without an MI but with a QR/QRS complex having a Q depth ≥4 mm, these deep Q waves were <40 ms in duration (e.g., Fig. 1B). They were ≥40 ms in the one Group 1 patient with an MI and in two of the three Group 2 cases with this type of Q abnormality and MI.

In both Group 1 and Group 2, the presence of a QR/QRS with Q duration ≥40 ms in one or more of the leads studied was significantly more common in the presence of an MI than in its absence. Also the presence of an ischemic-type ST-T abnormality in the lead(s) with AQW was a significant marker of MI in both groups.

In comparing cases in the subset of Group 1 without CHD to equivalent older patients of Group 2, the only criterion showing a significant difference in frequency was the presence of a QR/QRS with a

Q depth ≥4 mm, which in the absence of MI was more commonly seen in the younger patients.

DISCUSSION

In arriving at a correct conclusion about the meaning of findings in the ECG of his own patient, the clinician has the benefit of correlating many bits of information about that patient with what is contained in the ECG. The electrocardiographer, in contrast, is usually limited to knowledge of age and gender when interpreting the ECG. Extended to the matter of AQW and MI, Bayes's theorem indicates that the clinical usefulness of QWA, not perfectly specific indicators of MI, will be very limited in a population with a low incidence of MI.⁹ Adults under 40 years of age are just such a population.^{1,2} As the incidence of MI increases with age, the clinical utility of AQW as a marker for MI increases in older populations.¹⁰ The findings in this study are entirely consistent with this reasoning. On the other hand, the presence of AQW was a powerful indicator of the presence of some cardiac pathology in both younger and older populations. There were, however, significant differences between the age groups in the incidences of the various types of heart disease that were found in the population studied. This has pertinence to how ECGs with

AQW should be interpreted in younger versus older populations.

Limitations of the Study

The small number of cases with each ECG criterion listed limits the latter's clinical utility, and indicates lack of sufficient power for conclusive negative findings. The population studied is not typical of subjects having ECGs at many other facilities. The special clinics for CHD in adults, cardiomyopathies, and heart transplantation at the author's institution attract a disproportionate number of younger patients to whom these clinics offer special expertise. This certainly has biased the frequency with which AQW were found to be associated with these conditions in younger subjects. Thus, the results of this study are not necessarily applicable to other populations.

Lack of Specificity of AQW for MI

AQW mimicking MI have been described in various types of CHD, in hypertrophic cardiomyopathy, and in other varieties of cardiomyopathy.^{6,11} Certain criteria of Q abnormality were particularly useless as indicators of MI in this study. The presence of QS deflections in lead I or V₆ was not associated with MI in any of the cases studied. It was usually associated with extreme right axis deviation or "northwest" axis of the QRS, and other signs of RVH in CHD cases. QS deflections limited to V₁-V₂ were never seen associated with MI in the younger subjects of this study, and was of limited usefulness in indicating MI in older subjects. This is in accord with prior work showing the unreliability of this Q wave abnormality, and its increasing frequency with age.^{6,12} Deep but narrow Q waves were not associated with MI in the younger subjects of this population, but this exclusionary utility was lost in older patients. This is consistent with a tendency for normal Q waves in inferior and lateral leads to be of greater amplitude in the young.⁴ Q wave duration ≥ 40 ms in QR or QRS complexes was useful in suggesting MI in both age groups, but much more so in the older subjects, reflecting at least in part the much greater incidence of MI in the latter.^{1,2,13}

Usefulness of Associated ECG Abnormalities

The presence of ischemic-type ST-T wave abnormality in one or more leads with AQW not un-

expectedly improved the specificity of QWA for MI.^{6,14,15} The presence of right atrial abnormality, right axis deviation, "northwest" axis, or RVH might prove useful in suggesting an etiology other than MI for the Q wave abnormality, especially in young adults. This is because these abnormalities are much more common in CHD and cardiomyopathies than in ischemic heart disease. But larger groups of patients must be studied to confirm this suspicion. Care is needed to distinguish the prominent anterior QRS forces of RVH from those seen with posterior MI, and this distinction was not always possible.

CONCLUSIONS

In the unique population studied, AQW as defined in this study were strongly associated with organic heart disease in adult subjects under 40 years of age as well as in older persons. In subjects less than 40 years old, AQW usually indicated a pathology other than MI, whereas in older patients, MI was very likely to be present. Certain criteria for Q abnormality are more specific for MI than others, consistent with information from the work of others.^{6,7,15} Extension of these findings to other populations should be done with caution. Nevertheless, if those who interpret ECGs formally take into consideration the low prevalence of MI in young patients, they should be able to give a more precise interpretation of the significance of AQW in that population.

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