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Original article

Beginning of Ventricular Entrainment for Differentiation Between AVNRT and AVRT

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Abstract

Background: Differentiation between atrioventricular nodal reentry tachycardia (AVNRT) and accessory pathway-mediated atrioventricular reentrant tachycardia (AVRT) is challenging even during electrophysiological testing.

Objective: To test the use of the beginning of right ventricular entrainment to differentiate between AVRT and AVNRT as an independent criterion with high sensitivity and specificity.

Methods: We studied 50 patients with supra-ventricular tachycardia. Right ventricle (RV) pacing was performed 10-40ms faster than tachycardia. Once a fixed QRS morphology was observed in 12-leads ECG, we determined after which beat the atrial perpetuation had been achieved.

Results: In all the 19 patients who had AVRT, atrial perpetuation occurred from the first beat. However, in all 31 cases of AVNRT atrial perpetuation occurred after the first beat.

Conclusion: Analyzing the beginning of ventricular entrainment can indeed differentiate between AVRT and AVNRT cases easily with a high positive predictive value.

***Keywords*:** Supra-ventricular tachycardia; Atrio-ventricular reentry tachycardia; AV Reentry tachycardia; Entrainment.

INTRODUCTION

Differentiation between atrioventricular nodal reentry tachycardia (AVNRT) and accessory pathway-mediated atrioventricular reentrant tachycardia (AVRT) is challenging even during electrophysiological study, and it becomes crucial when the arrhythmia is resistant to treatment and catheter ablation is being considered.(1) In any given case, several criteria are usually applied to reach a diagnosis, for example the return cycle after entrainment, (3,4) tachycardia resetting with fusion,(4,5) and the response to a single ventricular extra-stimulus.(6) But it should be noted that approximately 15-20% of the tachycardias could be terminated while attempting entraining it. (6)

Because some of these criteria do not apply in all instances, we hypothesize that analyzing the response of SVT to the first several cycles of overdrive pacing may help in differentiating AVRT from AVNRT. This is due to the nature of the circuits that are involved in the arrhythmia. Our aim is to look at the behavior of the tachycardia once full right ventricular (RV) capture (presumed pure RV capture in AVNRT cases or fixed fusion in AVRT cases) is achieved during SVT and to formulate criteria that would help differentiate the two forms of SVT with high sensitivity and specificity.

Methods

Our cross-sectional study was conducted in the Cardiology department, Faculty of Medicine, Zagazig University Hospitals, during the period from January 2019 to September 2019 with an estimated sample size of 50 patients. A written

informed consent was obtained from all participants. The study was done according to the World Medical Association (Declaration of Helsinki). This study included (50) patients with SVT with age range from 17-55 years, 19 were males and 31 were females, who were admitted to our Cath-lab for Electro-physiological study and possibly ablation of the tachycardia. All patients underwent successful ablation of SVT and were free of arrhythmia follow-up (3 months).

Two ECGs were obtained for each patient: one with the evidence of SVT attack and one showing sinus rhythm with detection of any pre-excitation (Delta wave) if present. An ECG machine Fukuda VX8100 Digital 3 Channel was used. Each patient was subjected to echocardiographic examination to exclude any structural heart disease (any valvular affection, ventricular myopathy) with the standard views taken with a machine like the GE Vivid E9.

Intracardiac bipolar electrograms along with the 12-lead surface ECG were recorded and stored digitally on a computerized multichannel system using a Biosense-Webster mapping system and a Micropace III pacing system in Zagazig Electro-physiology Cath-Lab.

The intracardiac tracings of the 50 patients were studied. Thirty-one patients had AVNRT, and 19 patients had AVRT (13 left lateral, 2 left posterior, 6 septal, 5 right free wall). The intracardiac electrogram of each patient was stored.

First, we tested for atrio-ventricular node (AVN) duality through the presence of a jump with or without an echo beat by an atrial extrasystole or atrial pacing. After tachycardia induction, we observed features like: atrial activation sequence and the ventricular to atrial activation interval (VA time). The diagnosis of a typical AVNRT is reached if the VA interval (the interval between the ventricular electrical activity to tha atrial one) <70ms plus one or more of these features; if there is an anterograde functional dual AV nodal pathways or concentric atrial activation sequence during SVT like that during RV pacing and an VAV response after entrainment with RVP and corrected post pacing interval (cPPI) >115ms (the time required for the last stimulus to reach the circuit, to travel around the circuit, and to return to the pacing site) and Delta VA >85ms. (8)

On the other hand, a final diagnosis of Orthodromic reentrant tachycardia is met if the VA interval >70ms with one or more of the following features: an eccentric atrial activation sequence or an 'VAV' response after entrainment with a cPPI < 115ms and ΔVA < 85ms. (8)

During tachycardia, the Tachycardia cycle length plus the VA time was calculated and documented. In each subject, we performed RV pacing 10-40ms faster than the tachycardia in attempt for entrainment. Once the tachycardia entrainment was achieved, the VA time was calculated. Analyzing the beginning of the entrainment, after a fixed QRS complex was observed on surface ECG (either fixed fusion or pure pacing) then the number of beats until the achievement of atrial perpetuation were counted. After entrainment termination, the PPI was calculated. (7)

Statistical analysis

Data collected throughout; history, ECG features and EPS measures coded, entered and analyzed using Microsoft Excel software. Data was then imported into Statistical Package for the Social Sciences (SPSS version 20.0) (Statistical Package for the Social Sciences) software for analysis. According to the type of data, qualitative data is represented as number and percentage, quantitative and continuous group data are represented by mean ± SD. Differences between quantitative independent groups by t test. Chisquare test was used for differences between groups. P value was set at <0.05 for significant results. Furthermore, ROC curve was used to determine the sensitivity and the specificity of the parameters. (9)

Results

Comparing the tachycardia features

In comparison of the AVNRT group with the AVRT group, there was no statistical difference between the age of the two groups (34.8 ±9 vs 33 ±7; P 0.549). In comparison with AVRT group, the AVNRT group had a female predominance while AVRT group had no significant sex predominance (P 0.04 vs 0.23). Comparing the tachycardia cycle length (TCL), there was a statistical difference between the two groups; 360.81± 42.624ms in AVNRT vs 331.84 ±49.531ms in AVRT. (P 0.033). Comparing the VA time, there was a statistical difference between the two groups; 37.84 ± 14.00ms in AVNRT and 92.37 ± 35.56ms in AVRT. (P < 0.001) All these data are shown in table (1).

Responses to Entrainment:

Comparing the Delta VA time, there was a statistical difference between the two groups; 111.39± 21.416ms in AVNRT vs 51.11 ±19.872ms in AVRT. (P < 0.001) According to the ROC curve

it had sensitivity and specificity of 100% for differentiation between AVNRT and AVRT cases.

Comparing the cPPI, there was a statistical difference between the two groups; 178.58 ± 34.178msin AVNRT vs 77.63 ±24.116ms in AVRT. (P < 0.001) Plus, according to the ROC curve it had sensitivity and specificity of 100% for differentiation between AVNRT and AVRT cases.

In all cases with accessory pathway mediated tachycardia, atrial perpetuation was achieved from the first beat with fixed QRS morphology. Figure (1) While, in all cases of AVNRT atrial perpetuation never happened from the first beat with a mean of 3.71 ±1.071beats. Figure (2)

This criterion is highly specific and sensitive with 100% positive predictive value according to the ROC curve below. Figure (3)

Table 1 : Variables between AVRT and AVNRT group collected during EPS.

Variables	Mean ± SD		t-test	P
	AVRT	AVNRT		
VA time	92.37 ± 36.567	37.84 ± 14.005	7.492	0.000*
TCL	331.84 ±49.531	360.81± 42.624	-2.193	0.033
Delta VA	51.11 ±19.872	111.39± 21.416	-9.923	0.000*
cPPI	77.63 ±24.116	178.58 ± 34.17	-11.252	0.000*
Atrial perpetuation after how many beats	1.00 ± 0.0	3.71 ±1.071	-10.988	0.000*

* high significance**.**

AVRT= atrio-ventricular reentrant tachycardia. AVNRT= Atrio-ventricular Reentrant tachycardia.
TCL= tachycardia cycle length. cPPI= corrected post-pacing interval.

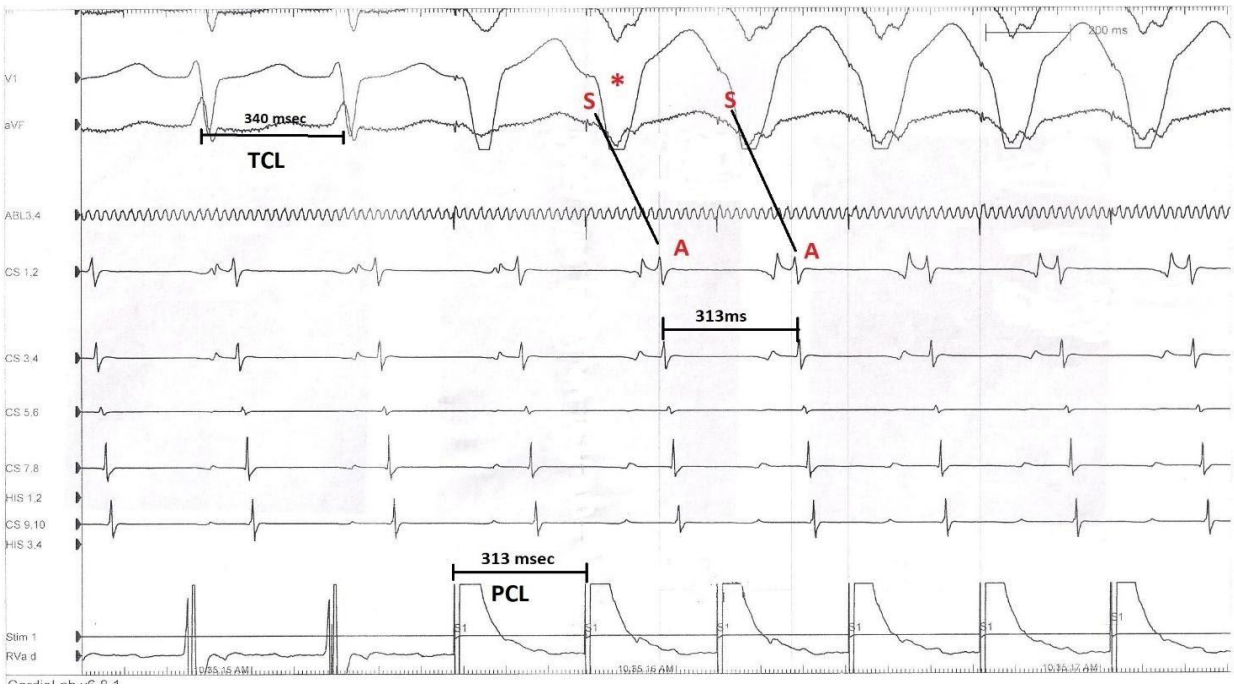

Figure 1.

Entrainment of case of left free wall mediated orthodromic reentry tachycardia. Right ventricular pacing at rate of 192 BPM (PCL 313ms) faster than tachycardia in trial to entrain the tachycardia. Asterisk donates the first beat with fixed QRS complex. Atrial perpetuation to the PCL occurred from the first beat. A= atrial electrogram. S= Right ventricle produced stimulus. CS= coronary sinus. RVa = Right ventricle apex.

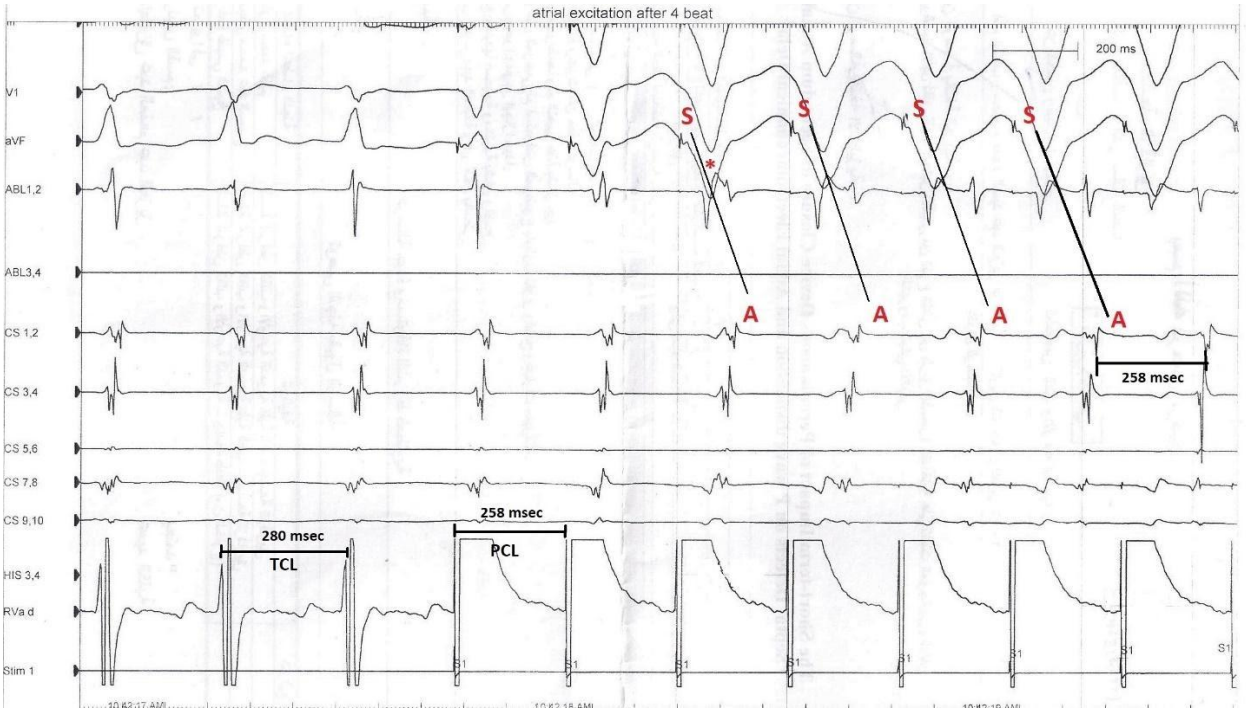

Figure 2.

Entrainment of Atrio-ventricular Reentrant tachycardia (AVNRT). Right ventricular pacing at rate of 232 BPM (PCL 258ms) faster than tachycardia in trial to entrain the tachycardia. Asterisk donates the first beat with a fixed QRS complex. Atrial perpetuation to the PCL occurred from the fourth beat. A= atrial electrogram. S= Right ventricle produced stimulus. CS= coronary sinus. RVa = Right ventricle apex.

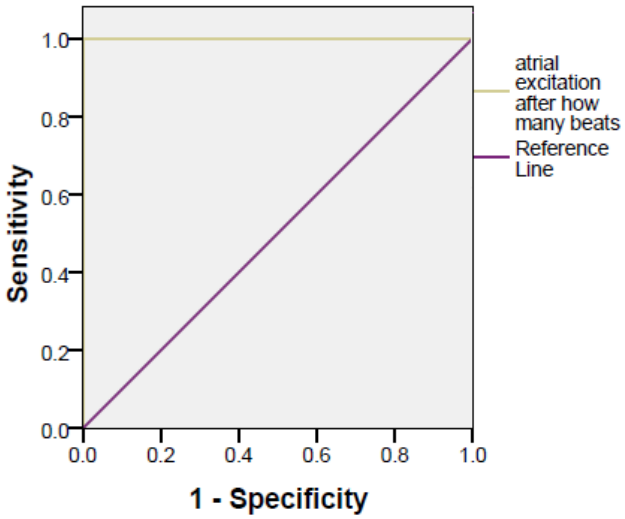

Figure 3. *ROC curve of sensitivity and specificity.*

ROC curve shows the sensitivity and specificity of number of beats before the achievement of atrial perpetuation in differentiation between AVNRT and AVRT as 100%.

Discussion

The need for a new criterion for differentiation between AVNRT and AVRT arises from the fact that there is no single criteria that has the ultimate sensitivity and specificity. (7) Moreover, most criteria used for differentiation can't be met in all cases because they couldn`t be achieved or because tachycardia was terminated after pacing. (10) So, we went on with our study in trial to signify the use of beginning of entrainment for differentiation between AVRT and AVNRT. In addition, some of the entrainment criteria for differentiation depends on the continuity of the tachycardia afterward which is not a necessity for our criterion. This criterion is also not so difficult to apply during EPS. Also, it doesn't depend on difficult technique or special equipment. Plus, in comparison to other studies it isn`t retrospective. (7)

As our results showed that this criterion could differentiate between AVNRT and AVRT with 100% positive and negative predictive values. While in all cases of AVRT, atrial perpetuation to the pacing cycle length was achieved from the first beat with the fixed QRS morphology. While, in all cases of AVNRT it never occurred from the first beat but from the second beat or more. So, the cutoff point must be equal to more than 2 for diagnosis of AVNRT. between the two mechanisms of the tachycardia is one.

The scientific explanation behind these findings depends on the understanding of the nature of the tachycardia circuit, what is entrainment and the pacing maneuvers used.

AVNRT represents an example of anatomical reentry tachycardias in which the circuit is located within the AVN itself which in turn is an atrial structure within the triangle of Koch. (8) The dual AVN physiology provides the two limbs of the circuit. So, the ventricle is not a part of the circuit at all. On the other hand, the tachycardia circuit in AVRT consists of the ventricle, the accessory pathway, the atrium and the AVN with His system. (8)

Tachycardia entrainment depends on the ability of the paced impulse to penetrate the tachycardia circuit and to accelerate the tachycardia to the pacing cycle length. And the pacing site is the RV apex. Entrainment with manifest fusion occurs in AVRT and means that when a ventricular pacing from RV apex is initiated, two waves are generated, the orthodromic one of the preceding tachycardia beat and the antidromic one of the paced impulses. If the collision between the two waves happens in the myocardium, it will result in a fusion, which is a complex of combined morphology of the tachycardia QRS and that of the fully paced. In AVNRT, entrainment occurs but without fusion as the QRS will be entirely of paced morphology. This happens due to the fact that the collision between the antidromic wave and the orthodromic wave of the proceeding beat occurs within the AVN tissue so that the antidromic beat will be the only one capturing the myocardium.

It's important to identify the first beat with a fixed QRS morphology after initiating RV pacing. This beat represents the fixed fusion in AVRT and the pure paced complex in AVNRT.

So, from the above information we conclude that entrainment and circuit penetration is easier in AVRT as the ventricle is part of the circuit, making atrial perpetuation always happens from the first beat. Penetrating the His system plus the AVN and entraining AVNRT is not as easy, making atrial perpetuation never happens from the first beat. Dandamudi et al, said that "Assessing the initial response of ORT and AVNRT to RV pacing during SVT can differentiate the two forms of SVT with very high positive and negative predictive values. Once fully captured RV pacing is achieved during SVT, using a cutoff _1 beat to accelerate TCL to PCL can identify all ORT cases and essentially exclude all cases of AVNRT with high accuracy. On the contrary, if two beats are required to accelerate SVT to the PCL once fixed morphology RV pacing is achieved, this can distinguish AVNRT from ORT with very high confidence as well." Which agrees with our findings. (7)

While Al-Mahameed et al, did something different as he studied 92 patients with SVT and performed RVP. He also defined the Transition Zone as the zone from the beginning of RVP till the first QRS with fixed morphology. Then he measured the stimulus-atrial time from the end of the Transition Zone till the end of Pacing. A fixed SA (stimulus-atrial activation interval) time was achieved within the Transition Zone (TZ) in almost all patients with ORT. Patients with atrioventricular nodal reentrant tachycardia or atrial tachycardia didn`t have a fixed S-A time within the TZ. So, he

concluded that "During RVP within 40 ms of the tachycardia cycle length, ORT is the likely mechanism when atrial timing is perturbed, or a fixed stimulus-atrial interval is established within the TZ." (5).

We concluded that AVNRT is more common than AVRT in general population, plus there was no statistical difference between the two groups regarding the age, while in term of sex difference in the AVNRT group showed female predominance but the AVRT group had no sex difference. These data agree with Porter et al, that AVNRT is more common than AVRT in the general population. Porter et al, also said that AVNRT is more common in females which is what our study concluded. (11)

Through our study we concluded that the VA time was greater in cases of AVRT with a mean of 92.37 ± 35.56ms, while in AVNRT it had a mean of 37.84 ± 14.00ms. This could be easily explained by the sequence of ventricular and atrial activation. In AVRT, atrial and ventricular activation always happen in sequence making VA time longer. But, in AVNRT atrial and ventricular activation happens parallelly making VA time shorter. In a previous study by **Knight et al,** AV nodal reentry tachycardia is diagnosed when the VA time is ≤ 70 m and ORT is excluded which agrees with our results. (P < 0.001) (1) While **Benditt et al,** said that a VA time of 61ms or less did not occur in patients with accessory AV pathways, but occurred frequently in patients with reentry within the AV node. (12) Also, Mills et al, came across the same finding that VA time is shorter in AVNRT than in AVRT cases. (P<0.001) (13)

In our study we concluded that the AVRT group had a shorter TCL than the AVNRT group, with a mean of 331.84 ±49.531ms in AVRT and 360.81± 42.624ms in AVNRT.

This could be explained by the fast-conductive properties of the accessory pathway. This finding was also published by ***Knight et al***, who concluded that TCL is in fact shorter in AVRT than in AVNRT. (1) ***Calvo et al***, also agrees with our result regarding AVRT cases with shorter cycle length. (14) While ***Mills et al***, concluded that the TCL was shorter in AVRT than AVNRT (329 ± 51ms vs 340 ± 60ms, P = 0.04). (13)

Through our study we concluded that Delta VA time was greater in the AVNRT group than in the AVRT group with a mean of 111.39± 21.416msand 51.11 ±19.872ms respectively. (P = 0.000) This happens due to different activation sequences in AVNRT than during pacing. During pacing, the ventricle is activated firstly then the atrium is activated in sequence making SA time long. But, during the tachycardia they are activated parallelly making the VA time short. The end result is that the Delta VA time is long. In AVRT, ventricular pacing and atrial activation occurs in sequence making stimulus to atrium time in ventricular pacing (SA) and VA time close in value and Delta VA time short. This agrees with the result that ***Calvo et al***, came across a finding that "(SA-VA) were longer for AVNRT (156±37ms versus 27.3±21ms; P<0.001)." (14) ***Michaud et al***, said that "All patients with atypical AVNRT had a SA–VA interval >85ms, and all patients with ORT using a septal accessory pathway had a SA–VA interval ,85ms (range 0 to 80)." Which agrees with our results. (2) ***Ho et al***, concluded that a ΔVA<85ms is diagnostic of orthodromic AVRT. (15)

We also concluded that cPPI was shorter in cases of AVRT than that in AVNRT with a mean of 77.63 ±24.116ms and 178.58 ± 34.178ms respectively. The post pacing interval is the time required for the last stimulus to reach the circuit, to travel around the circuit, and to return to the pacing site. (2) The farther the pacing site is from a circuit, the greater the PPI-TCL difference will be. Because the right ventricular apex is close to orthodromic AVRT circuits yet relatively far from AVNRT circuits, the PPI-TCL difference is greater in AVNRT than in AVRT. ***Gonzalez-Torrecilla et al***, said in his Electrophysiologic study demonstrated ORT in 84 patients and AVNRT in 109 patients. The mean corrected PPI-TCL difference was significantly shorter in 77 patients with ORT (66 ± 27ms) than in 104 AVNRT patients (151 ± 28ms; P <.0001) (3) ***Michaud et al***, said that "All patients with AVNRT had a PPI–TCL >115ms (range 140 to 260), and all patients with ORT using a septal accessory pathway had a PPI–TCL <115ms (range 0 to 95)." Which agrees with our conclusion. (2) ***Ho et al***, said that "PPI–TCL was shorter for ORT (118ms versus 176ms)" which agrees with our result. (15)

Study limitation

This study should be conducted on a multiple centers scale. This criterion doesn't apply to cases of AVNRT with a bystander accessory pathway because the accessory pathway can reset the tachycardia. Intra-atrial dissociation may lead to false results. (8,9) Also, this criterion doesn't help with localizing the site of the accessory pathway, but it should be noted that this isn't the main aim of it.

Conclusion

Analyzing the beginning of entrainment aiming toward the differentiation between cases of AVNRT from those with AVRT. In all cases of AVRT, atrial perpetuation occurred from the first beat after the achievement of a fixed QRS morphology on surface ECG. While, in cases of AVNRT this never occurred from the first but from the second one or more. This renders this criterion highly specific and sensitive for the differentiation between the two-tachycardia mechanism with a clear cut off value.

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