

Respiratory Arrest and Cardiovascular Collapse in a Young Autistic Woman



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Case report

This is a 28 year old female with history of autism and seizures who suffered a respiratory arrest at home after a short febrile illness. She was found unresponsive in bed at 14:00 by her parents who initiated mouth to mouth ventilation. The paramedics arrived 10 minutes later and performed endotracheal intubation and ventilation. Her pulse was weak, her blood pressure was 60/40 mm Hg, and her core temperature was 31.0 °C.

Personal antecedents: She is adopted, and we have no information of the biological family.

Although she had a history of seizures as a child, she was not taking any medication when she suffered the respiratory arrest.

Her initial ECG is shown in the next slide. She was started on vasopressors and transported by helicopter to the hospital.

She received intravenous fluids, norepinephrine, vasopressin, and was slowly rewarmed with thermal blankets. After blood cultures, cefepime 2 grams was given intravenously for possible sepsis. Drug screening was negative. The only blood test abnormality was a low potassium of 2.9 mm/L. Head CT showed diffuse cerebral edema with effacement of the sulci and basilar cisterns, and ventricular compression without uncal transtentorial downward brain herniation. Her brain function has not improved after 3 days of medical support. The second ECG was performed 1 day later.

Questions:

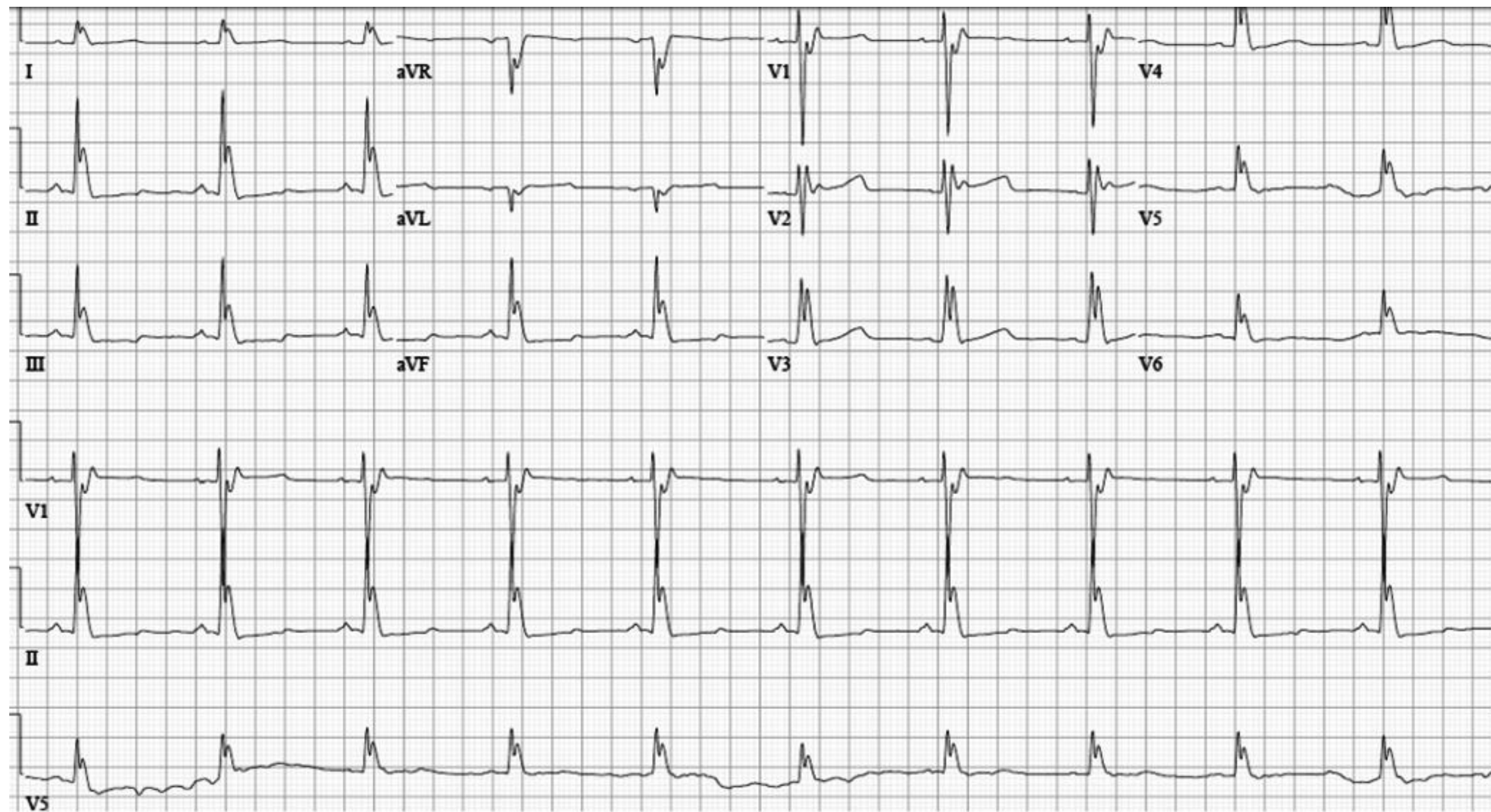
1. How do you explain the abnormality observed in the initial ECG?
2. Why did the QRS normalize in the second ECG?
3. What are the following diagnostic steps?

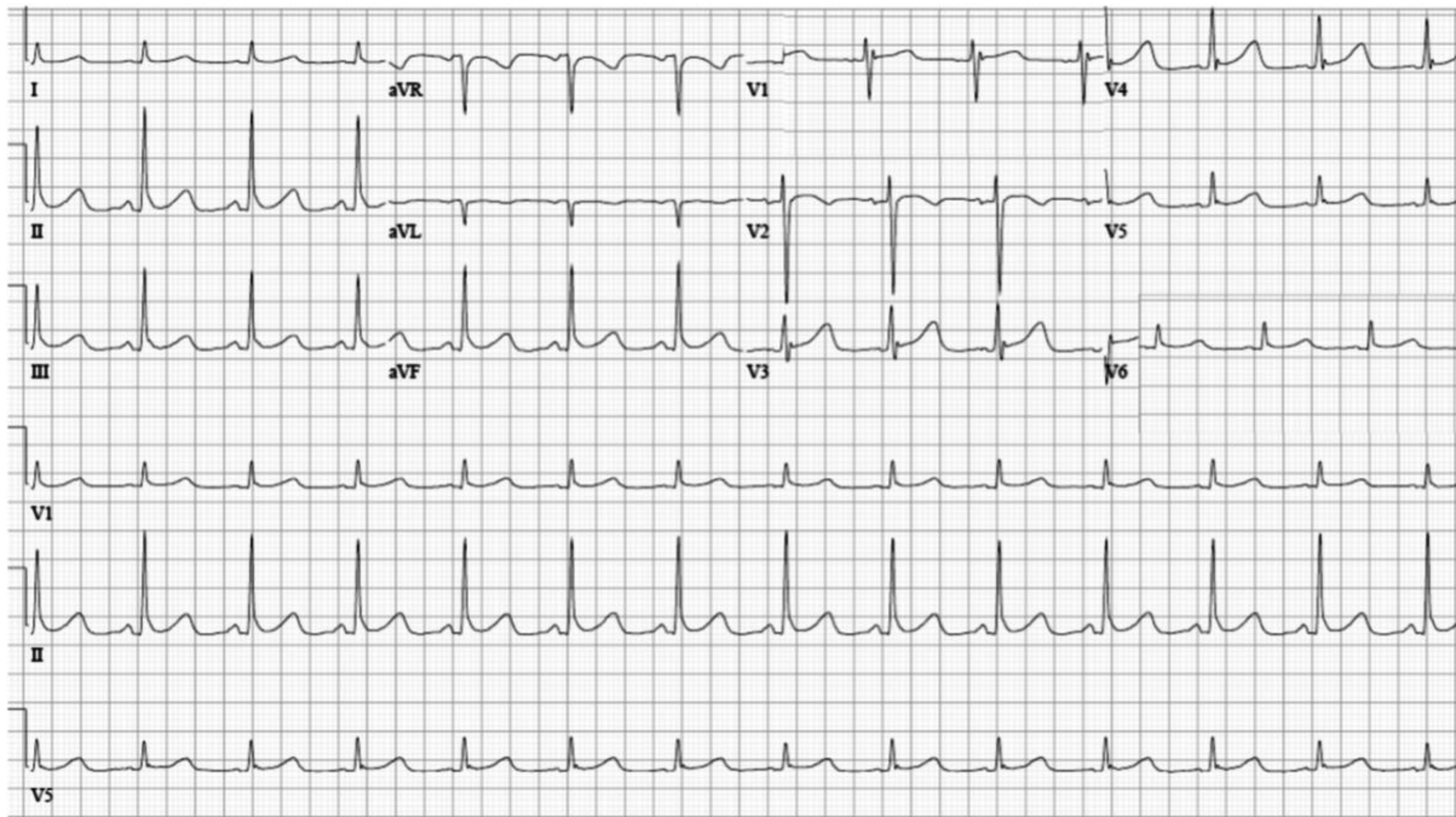
Dr Mario **Gonzalez MD PhD.**

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Colleagues opinions

Hi Thanks Mario for this incredible ECG and case!

1. The first ECG resembles the one from hypothermia with diffuse Osborn waves
2. It would be nice to determine whether hypokalemia presented along with acidosis, as some of the "J-waves" seen in the limb leads resemble acidosis too. So my question is:
3. Are we assisting to an ECG of the recovery phase of something else than spontaneously terminated?
4. QT is quite prolonged: is this the initial event? Long QT syndrome, self-terminated VF, hypothermia and hypokalemia and acidosis?
5. Is this a primary neurological event?
6. My plan from the CV perspective
 - Echo: to R/O structural heart disease and;
 - Cardiac MRI to visualize the RV (R/O ARVD) and check the septum
 - If neurological recovery, Epinephrine test (long QT) and Procainamide/Ajmaline test (Brugada)
 - I do not think that this is primarily ischemic (young woman) but the echo will help in determining whether we need to R/O CAD.
 - Renal function, filtration etc with sodium and potassium in urine to determine whether there is a structural reason for hypokalemia; playing a role on possible self limited VF...

I would like to hear other opinions

Thanks for sharing this case AB



Dear Andres, Mario, and friends,

The first ECG from this sad case of autism and seizures shows the characteristic changes of hypothermia with large J (Osborn) waves in all leads. The QT interval (~500 ms) is also prolonged which is another finding in hypothermia. Since the clinical story does not suggest that the patient was exposed to an unusually cold external environment, the likely cause of the hypothermic condition is impaired central nervous system temperature regulation perhaps related the abnormalities seen on her brain scan. It is possible that sepsis also played a role. Workup should rule out other endocrine abnormalities that might be associated with impaired temperature regulation and decreased heat production (hypothyroidism, hypopituitarism, and hypoadrenalism). The second ECG shows resolution of the large J waves as the patient was warmed.

I will be interested in the valuable opinions of other contributors in this case.

Best regards,

Frank G. **Yanowitz**, M.D. Professor of Medicine University of
Utah School of Medicine Medical Director,
ECG Services Intermountain Healthcare. Alan Lindsay. ECG Outline.
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If the first ECG was taken prior to hypothermia it is classic for the J wave syndrome with tall J waves in the inferolateral leads and likely cause of cardiac arrest especially if she was at rest or sleeping. The drug of choice would be Quinidine, consider ICD if co morbidities are not contraindication.

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Boa noite Professor, primeiramente obrigado por me incluir em seus contatos e me enviar esse caso. Vou dar minha humilde opinião com um mero R1 de clínica médica (desculpe-me se estiver errado)

O primeiro ECG tem características de hipotermia, com ondas J (de Osborn) evidentes e aumento do intervalo QT.

O segundo ECG é um ritmo sinusal, com atraso final de condução tipo III e padrão de repolarização precoce, com normalização do QRS após o aquecimento da paciente.

Os próximos passos diagnósticos devem ser voltados para a avaliação neurológica: punção lombar se possível, DNM e pesquisa de causas metabólicas.

Espero receber mais casos interessantes como esse.

Um abraço cordial,

Gabriel Afonso Dutra Kreling R1 de clinica Medica

English

Good evening, Professor,

First, thank you for including me in your contacts and for sending me this case.

I will express my modest opinion as a mere 1st year resident in clinical practice (I apologize if I am mistaken).

The first ECG has characteristics of hypothermia, with evident J waves (Osborn waves) and increase in QT interval.

The second ECG is sinus rhythm, with type III end conduction delay and early repolarization pattern, with QRS normalization after warming up the patient.

The next diagnostic steps should be sent to a neurological evaluation: spinal tap if possible, NMR and research of metabolic causes.

I hope you receive more interesting cases like this one.

Cordially,

Gabriel Kreling R1 de clinica Medica

Querido Potro: En el ECG inicial las típicas Ondas J de Osborn descriptas por hipotermia con temperaturas menores a 32,2 grados, además se encuentra la bradicardia sinusal, asociada a prolongación progresiva del intervalo PR, el complejo QRS y el intervalo QTc. Asimismo la hipokalemia severa es causa de falla muscular e insuficiencia respiratoria, también anormalidades del fósforo y magnesio, causando Insuficiencia respiratoria aguda.

En el segundo electrocardiograma mejoro la FC a 75 latidos por minutos pero presenta un QTC prolongado, refiere no se utilizo ningún medicamento previo. El mismo autismo puede asociarse con QT prolongado (El síndrome del QT largo SQTl 8 o síndrome de Timothy de carácter genético, pero se asocia a cardiopatías congénitas, sindactilia, hipoglucemia intermitente, desarrollo tardío y autismo. De está paciente solo refieren autismo, así que supongo que el QT prolongado debe ser por la hipopotasemia, o hipomagneemia asociada.

Que la MS se haya presentado en el contexto de un Síndrome febril obviamente obliga a descartar una canalopatía, luego de la reanimación presenta un Supra ST elevado y ondas J en cara inferior y de V3 a V6.

Asimismo la fiebre causa un estado catecolaminérgico similar al ejercicio, que puede contribuir a la aparición de arritmias como la taquicardia ventricular polimorfa.

Por lo referido presenta hipertensión endocraneana por encefalitis o por la hipoxia en la reanimación dado por el edema intersticial que presenta también puede ser secundaria a la utilización de soluciones salinas hipertónicas y manitol en su tratamiento o su uso en la reanimación cardiopulmonar. Creo una RNM de cerebro brindaría mejor definición que una TAC y realizaría con cuidado una punción de LCR para su análisis y cultivo.

Descartó virus de la inmunodeficiencia? dado que desconocen antecedentes dado que puede dar meningitis por criptococo que suele ocasionar edema difuso cerebral e hipertensión endocraneana además del síndrome febril.

Un abrazo

Martín Ibarrola

Dear Pony: In the initial ECG typical Osborn J waves described by hypothermia with temperatures below 32.2 degrees, plus sinus bradycardia associated with progressive prolongation of the PR interval, QRS complex and QTc interval. Also severe hypokalemia causes muscle and respiratory failure, also phosphorus and magnesium abnormalities, causing acute respiratory failure.

In the second ECG the HR normalizes (75 beats per minute) but remains the prolonged QTc, it refers any previous medication was not used. The same autism may be associated with prolonged QT (the long QT syndrome LQTS 8 or Timothy genetic character syndrome, but is associated with congenital heart defects, syndactyly, intermittent hypoglycemia, late and autism development. This patient only refer autism, so I guess prolonged QT should be by hypokalemia, or hypomagnesemia associated.

The event has been presented in the context of a febrile syndrome must be ruled obviously a channelopathy after resuscitation has ST segment elevation in inferior leads and V3 to V6.

Fever also causes a similar exercise catecholaminergic state, which may contribute to the onset of arrhythmias such as polymorphic ventricular tachycardia.

It has referred encephalitis intracranial hypertension or hypoxia in resuscitation given by interstitial edema that presents can also be secondary to the use of hypertonic saline and mannitol solutions treatment or use in cardiopulmonary resuscitation. I think an MRI brain would provide a better definition TAC and perform carefully puncture for CSF analysis and culture.

Did you rule out immunodeficiency virus? as unknown background can give as cryptococcal meningitis usually cause diffuse cerebral edema and intracranial hypertension in addition to the febrile syndrome.

Hugs

Martín Ibarrola, MD from Argentina



Final comments by.....



I also have the right to have my "Yoko Ono". This is my wife Helena Akemi.



Possible diagnosis sequence: Autism spectrum disorder (ASD) → Mitochondrial dysfunction → dysautonomia (or autonomic neuropathy) → Impaired thermogenesis → moderate hypothermia (remember that her core temperature was 31.0 °C.) → Respiratory Arrest → Cardiovascular Collapse.

- I. Mild hypothermia: 32-35°C or 90°-95°F;
- II. Moderate hypothermia: (28-32°C or 82°-90° F);
- III. Severe hypothermia: less than 28°C.

Autism spectrum disorder (ASD) is a devastating neurodevelopmental disorder. Evidence has emerged that some children, adolescents and young adults with ASD suffer from undiagnosed comorbid medical conditions. One of the medical disorders that has been consistently associated with ASD is **mitochondrial dysfunction**. Individuals with mitochondrial disorders without concomitant ASD manifest dysfunction in multiple high-energy organ systems, such as the central nervous, muscular, and gastrointestinal systems. Interestingly, these are the identical organ systems affected in a significant number of patients with ASD. Mitochondrial dysfunction may lead to the emergence of dysautonomia.

What is dysautonomia? For many, it is a one word description that explains some of the most troublesome and puzzling symptoms that adults and children with mitochondrial disease experience. The autonomic nervous system functions to moderate and allow adaption of the body to everything in our environment. The autonomic nervous system, when functioning properly, regulates the response to very basic changes such as body temperature, walking, sitting, sleeping, eating, desiring, and digesting food, thirst, etc. Dysfunction of the autonomic nervous system, also known as dysautonomia, can present some of the greatest daily quality of life challenges for people who are affected. This finding increases the possibility that mitochondrial dysfunction may be one of the keys that explains the many diverse symptoms observed in some individuals with ASD. Frye et al (**Frye 2011**). Mitochondria are a predominant source of reactive oxygen species (ROS), especially in the context of abnormal

electron transport chain function (**Trushina2007**). Individuals with ASD have been shown, as a group, to be under higher oxidative stress and have reduced levels of antioxidants as compared to controls (**James 2009**). It is likely that mitochondrial dysfunction could be the cause of abnormally high levels of oxidative stress found in ASD individuals. Mitochondrial function can also contribute to abnormalities in neuronal function that have been reported in ASD. For example, an imbalance in the excitatory (glutamate) and inhibitory (gamma-aminobutyric acid) neurotransmitter systems has been implicated in the pathogenesis of ASD, with a relative increase in the excitatory-to-inhibitory ratio. Mitochondrial dysfunction can lead to reduced synaptic neurotransmitter release in neurons that have high firing rates, such as inhibitory gamma-aminobutyric acid interneurons. Thus, mitochondrial dysfunction can result in a reduction in inhibition and the relative increase in the excitatory-to-inhibitory ratio observed in ASD. Furthermore, calcium signaling is essential for the integrity of synaptic function and abnormal calcium signaling has also been implicated in ASD. Mitochondria are well known to have a pivotal role in the regulation of plasma membrane calcium channels and transporter activities.

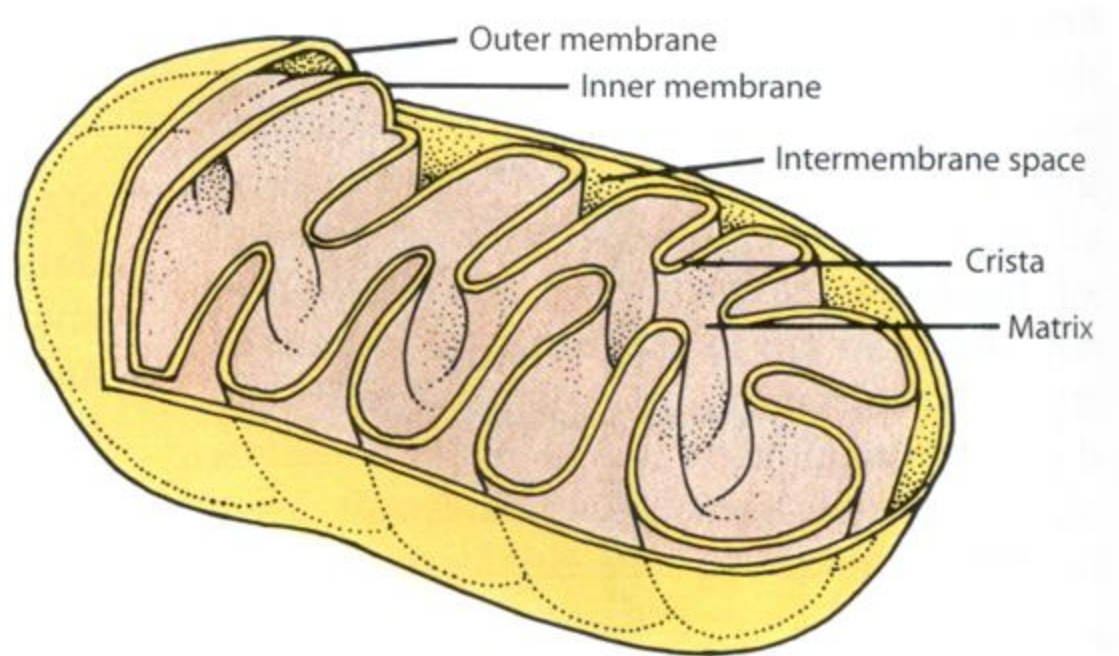
This new understanding of ASD should provide researchers a pathway for understanding the etiopathogenesis of ASD and clinicians the potential to develop medical therapies. Disorders of energy metabolism have been associated with ASD. Children with autism were more likely to have mitochondrial dysfunction, mtDNA over replication, and mtDNA deletions than typically developing children (**Giulivi 2010**).

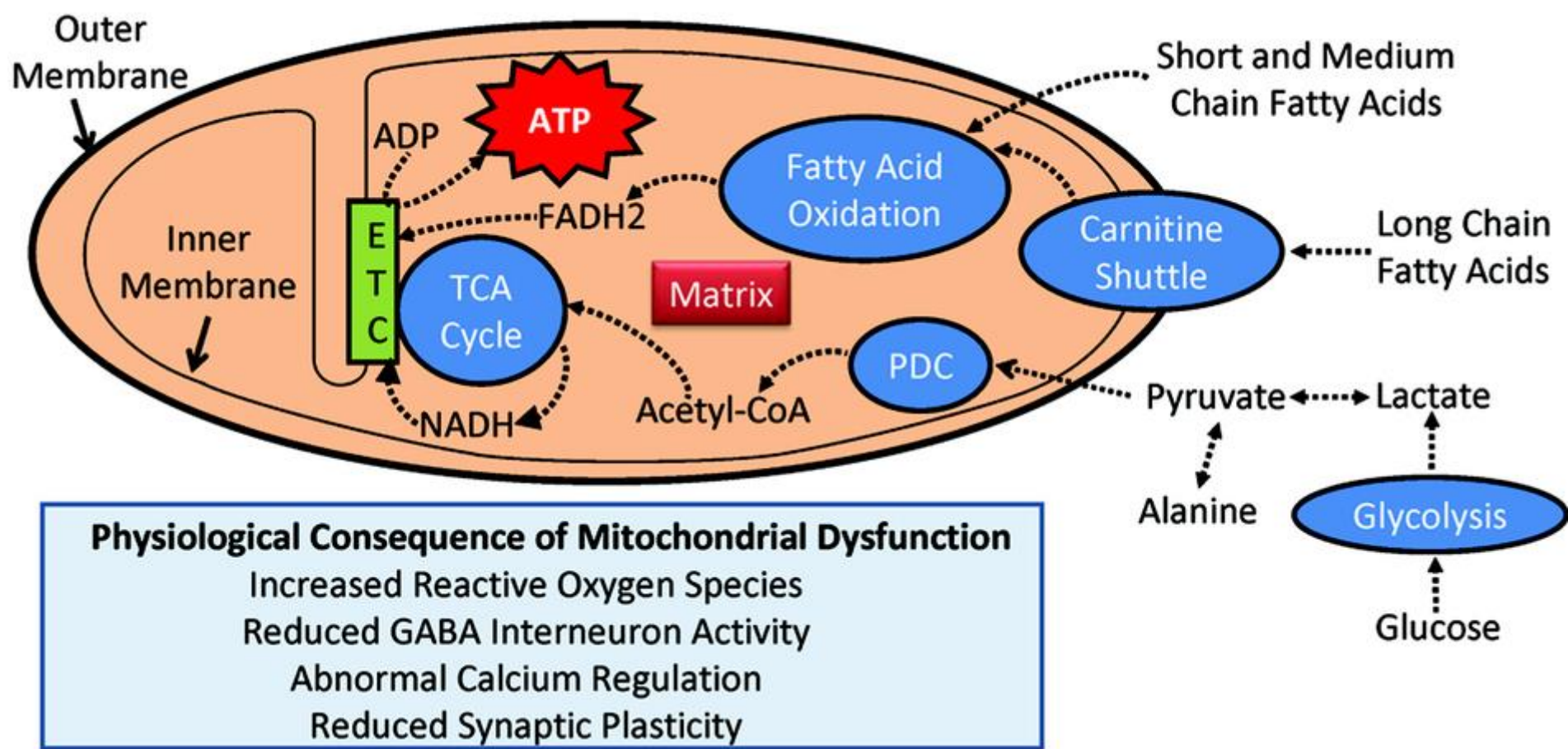
Mitochondria are the main intracellular source of oxygen free radicals, which are very reactive and can harm cellular structures and DNA. Cells can repair typical levels of oxidative damage. However, in the children with autism the cells produced more free radicals and were less able to repair the damage, and as a result experienced more oxidative stress. The free radical levels in the blood cells of children with autism were 1 ½ times greater than those without the disorder.

The role of the mitochondria

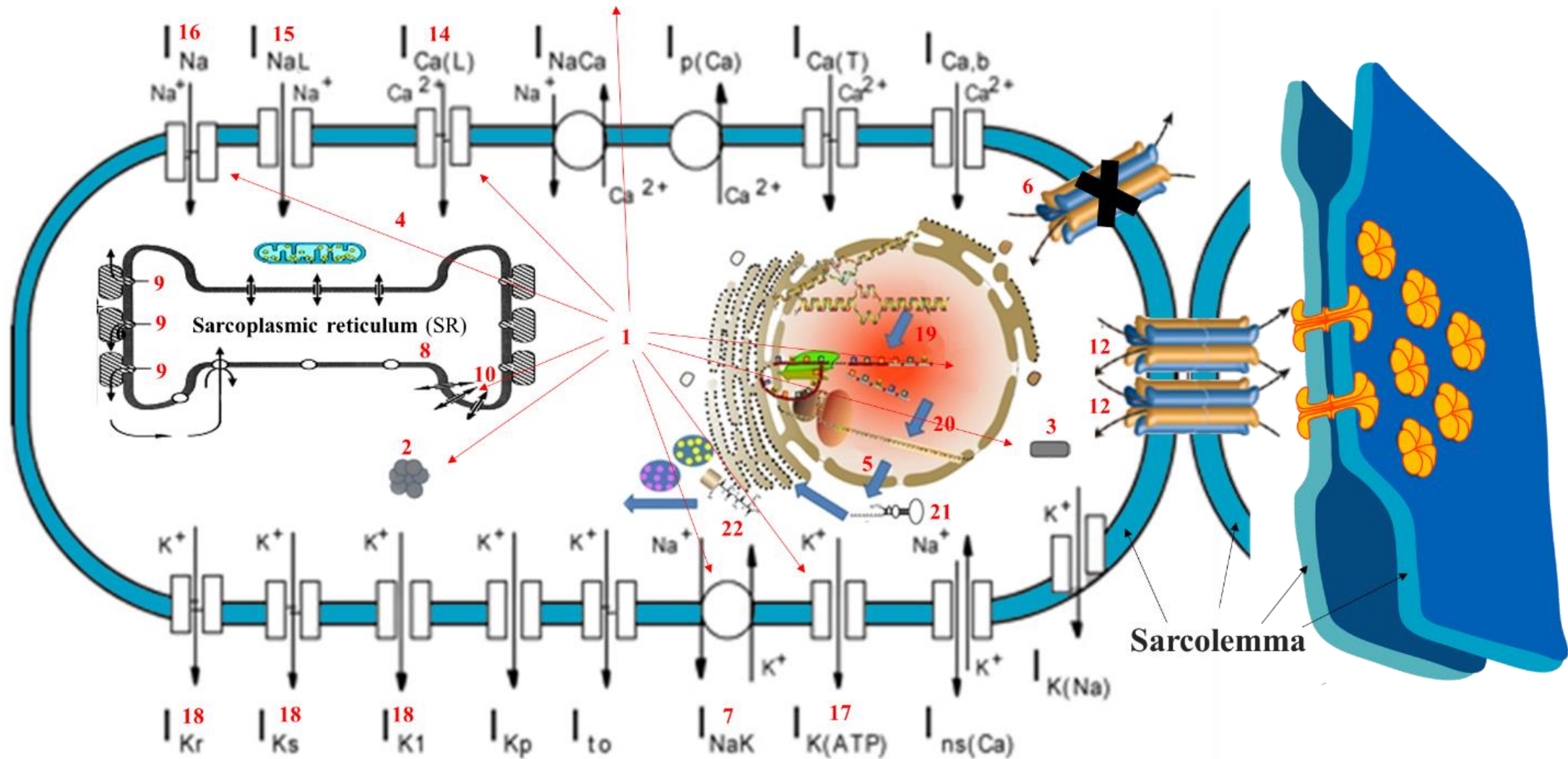
The healthy function of mitochondria is essential to life sustaining metabolic processes including:

- I. Regulating ion concentrations such as calcium buffering critical to intracellular communication
- II. Maintain roles in fluctuating lipid levels
- III. Synthesizing products necessary for the transportation of glucose and insulin
- IV. Providing sufficient energy for blood flow to and within the heart
- V. Regulating the removal of cellular damage or apoptosis if condition is deleterious enough to the mitochondrion's function
- VI. Energy powerhouse of the cell
- VII. Produces cellular energy – ATP
- VIII. Maintains glutathione levels
- IX. Protects DNA
- X. Signals cell reproduction
- XI. Activates cell apoptosis
- XII. Maintains cell electrochemical integrity



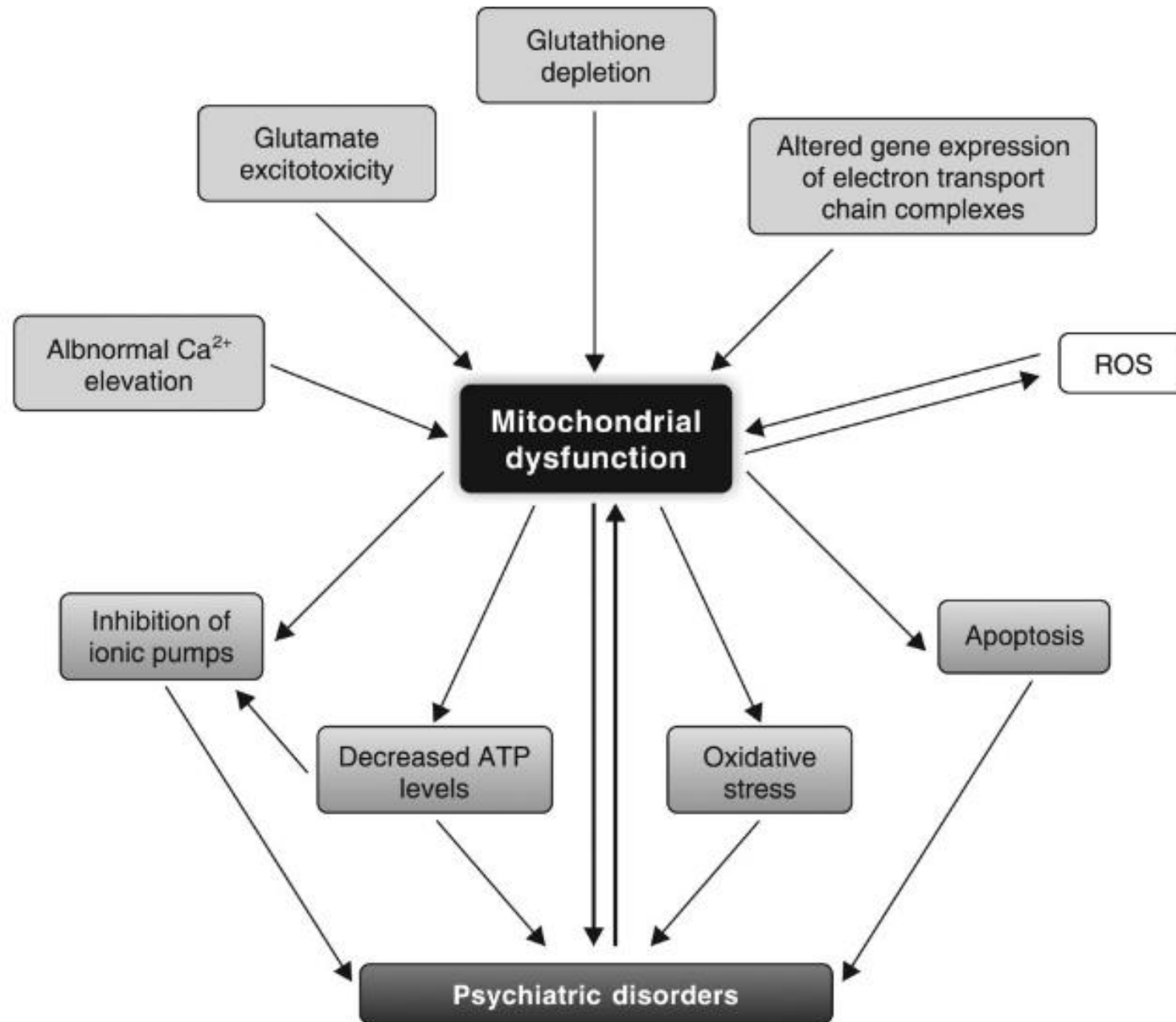


The mitochondrion is represented diagrammatically in the figure. Glucose and fatty acids are processed through separate but overlapping pathways to create ATP. The fatty acid oxidation pathway, tricarboxylic acid (TCA) cycle, and the pyruvate dehydrogenase complex (PDC) are located within the mitochondrion matrix, which is located inside the inner mitochondrial membrane. Long-chain fatty acids require the carnitine shuttle to enter the mitochondrial matrix, whereas medium- and short-chain fatty acids do not require the carnitine shuttle. One of the enzymes for the TCA cycle, succinate dehydrogenase, is complex II of the electron transport chain (ETC). Electron carriers, NADH and FADH₂, transfer energy from the TCA cycle, and fatty acid oxidation pathway to the ETC. The ETC is the final common pathway for the generation of ATP from ADP. The *panel* lists some of the physiological consequences of mitochondrial dysfunction. **Increased reactive oxygen species (ROS)** has several consequences on cells and extracellular space. See next slide.



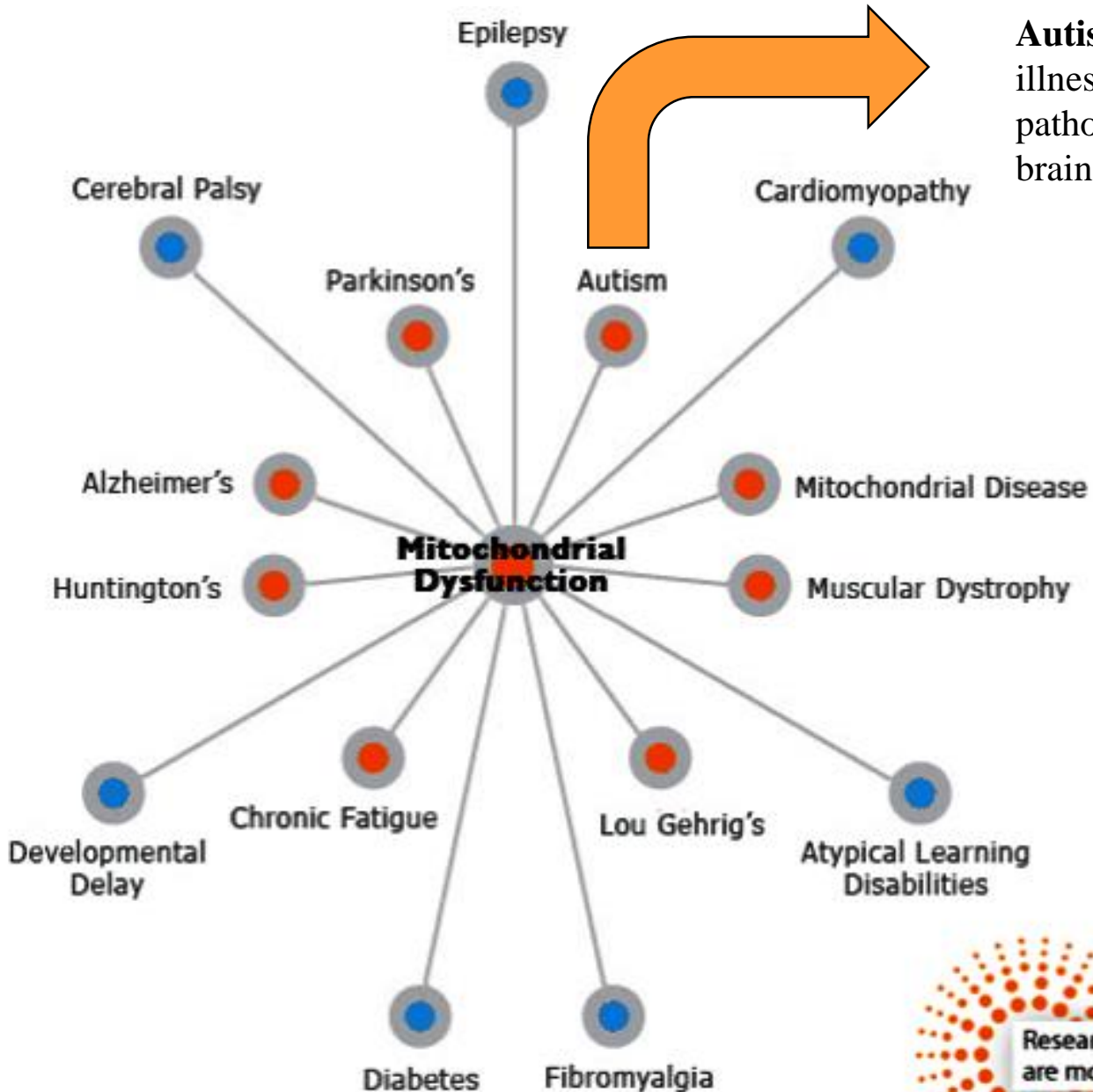
- 1) Excess of reactive oxygen species (ROS);
- 2) CaMKII activation or Ca²⁺/calmodulin-dependent protein kinases II;
- 3) c-Src activation (SRC proto-oncogene, non-receptor tyrosine kinase);
- 4) PKC (Protein kinase C) enzymes play important roles in several signal transduction cascades. Abnormal splicing, activation of CaMKII, c-Src, and PKC are among emerging new antiarrhythmic;
- 5) mRNA of Na⁺ current;
- 6) Impair gap junction CX43 conduction resulting in reduced myocyte coupling;
- 7) NCX: Na⁺/Ca²⁺ exchanger. The NCX removes a single Ca²⁺ ion in exchange for the import of three Na⁺ ions. It is considered one of the most important cellular mechanisms for removing Ca²⁺;
- 8) Phospholamban (PLB): It is a 52-amino acid integral membrane protein that regulates the Ca²⁺ pump in cardiac muscle and skeletal muscle cells;
- 9) Ryanodine receptor (RyR) participates in different signaling pathways involving Ca²⁺ release from intracellular organelles. It is the major cellular mediator of Ca²⁺ induced Ca²⁺ release (CICR) in animal cells. RyR2 is primarily expressed in myocardium;
- 10) Sarco-/endoplasmic reticulum Ca²⁺-ATPase (SERCA) resides in the sarcoplasmic reticulum (SR) within myocytes. It is a Ca²⁺ ATPase that transfers Ca²⁺ from the cytosol of the cell to the lumen of the SR at the expense of ATP hydrolysis during muscle relaxation;
- 11) Transforming Growth Factor- β (TGF- β) leads to the activation of different downstream substrates and regulatory proteins, inducing transcription of different target genes that function in differentiation, chemotaxis, proliferation, and activation of many immune cells;
- 12) Zonula Occludens-1 (ZO-1) or tight junction protein. It is located on a cytoplasmic membrane surface of intercellular tight junctions. The encoded protein may be involved in signal transduction at cell–cell junctions;
- 13) Extracellular fibroblasts activation and collagen deposition;
- 14) Increase in L-type Ca²⁺ current;
- 15) Increase in late Na⁺ current. Selective inhibition of cardiac late I_{Na} with eleclazine confers dual protection against vulnerability to ischemia-induced AF and reduces atrial and ventricular repolarization abnormalities before and during adrenergic stimulation without negative inotropic effects.
- 16) Na⁺ current reduction;
- 17) ATP-sensitive K⁺ channel (KATP channel) inhibition;
- 18) I_{to} , I_{Ks} and I_{Kr} inhibition;
- 19) Transcription;
- 20) Splicing;
- 21) microRNA;
- 22) Translation.

Consequence of mitochondrial dysfunction



Entities where mitochondrial dysfunction have some role

Autism: Free radical production and damage is not the only factor to blame in illnesses associated with mitochondria dysfunction. A major implication in the pathogenesis of autism is the transfer of inflammatory signal across the blood brain barrier (**Stolp 2013**).



Research shows the orange ones are more significantly influenced

Clinical Abnormalities Found in Mitochondrial Disease

Not Typically Clinically Abnormal in ASD

Ophthalmoplegia	Stroke-like
Facies myopathica	episodes
Hematology, Vision	Migraine
Hearing, Brainstem	Cortical
abnormalities	blindness

Clinically Abnormal in Some ASD Individuals

Development Delay	Abnormalities in
Loss of Skills	Endocrine/Growth,
Seizures	Gastrointestinal
Muscle Weakness	System, Lactate,
Peripheral Neuropathy	Pyruvate, Alanine

Mitochondrial function, features associated with mitochondrial disease, and the features and consequences of mitochondrial dysfunction in ASD. The *panel* outlines we show some of the features and metabolic markers used to diagnose mitochondrial disease. The features are divided up into those that are not typically clinically abnormal in ASD and those found to be clinically abnormal in some individuals with ASD. Features in which the association with ASD is unclear are not listed in this panel.

Hypothermia concept

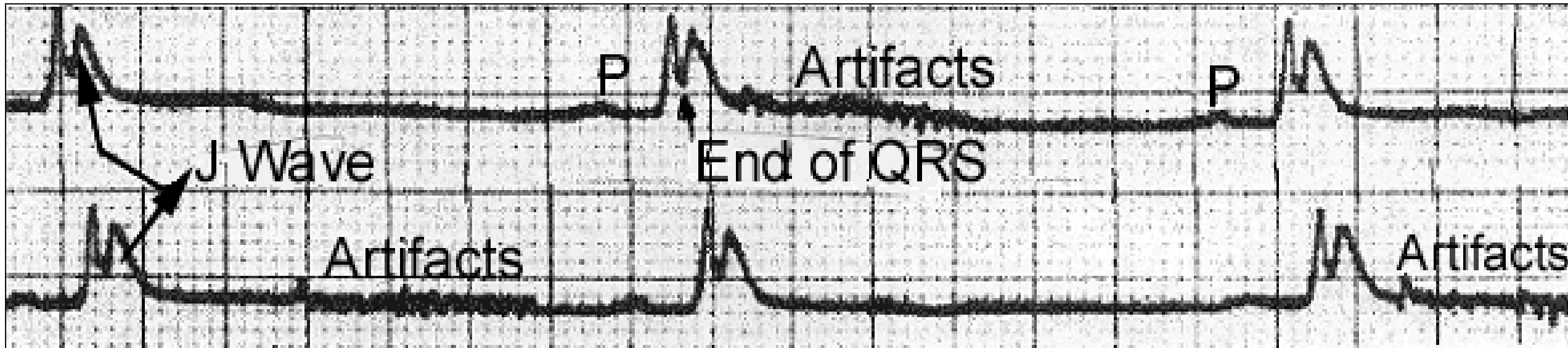
Concept: hypothermia is defined as the condition where central temperature (rectal, esophageal or tympanic) is below 35°C. Hypothermia may be accidental, metabolic, or therapeutic.

Accidental hypothermia is more frequent in countries with cold weather, during winter season. Hypothermal state is characterized by drop in basal metabolism, decrease in O₂ consumption and greater production of CO₂ (**Reuler 1978**).

During hypothermia, gradual decrease of heart rate is observed and systolic volume, with progressive drop of blood pressure later, which becomes significant when central temperature values close to 23°C are reached (**Gebauer2006**).

Electrocardiographic main features in hypothermia

1. **Rhythm:** sinus or AF present in 50-60% of the cases, when temperature is lower than 32°C (**Reuler 1978**). Less frequently, atrial flutter may be found, junctional rhythm and even degeneration into VF. These events appear in the second phase of hypothermia (out of exhaustion) when temperature is between 27°C and 34°C. Idioventricular rhythm and total AV block are described.
2. **Artifacts:** frequent fluctuation in the baseline as a consequence of artifact caused by the muscular trembling of the patient. This fact is found only in the initial phase (of struggle), when body temperature is between 36 and 32°C (**Okada 1984**).

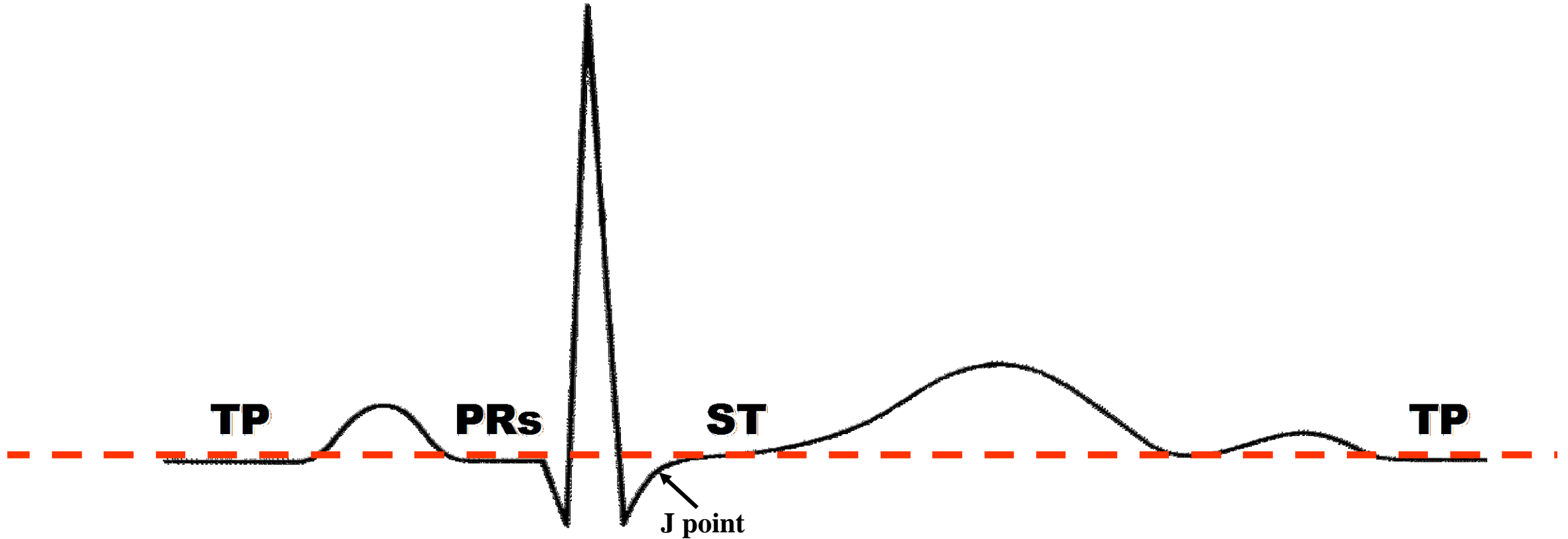


3. **Heart rate:** in the initial phase there may be tachycardia by release of adrenaline, and later sinus bradycardia in 30% of the cases, in patients since hypothermia in the struggle phase. Characterized by being progressive, with intensification of hypothermia¹. There is no linear correlation with the intensity in body temperature drop. Bradycardia is due to decrease in the ascending ramp in phase 4 in the P cells of the sinus node (decrease of diastolic depolarization, rhythmicity or automatism) by increased vagal reflex, even coexisting with increase of circulating catecholamine's. Hypothermia constitutes one of the three causes for chronic metabolic bradycardia; the other two being **obstructive jaundice** (by bradycardizing effect of biliary salts on the sinus node) (**Bashour 1985**) and **myxedema** (**Lida 2011**). On the other hand, hypothyroidism is one of the causes for metabolic hypothermia.
4. **P -wave:** voltage decrease is described (**de Souza 2007**). Also widening of P wave (consequence of decreasing of the velocity of intra-atrial conduction).
5. **PR interval:** it tends to be prolonged as body temperature decrease (**Chhabra 2013**).
6. **QRS complex:** decrease in voltage and widening of the QRS-complex (**Bjørnstad 1991**). The latter may be mistakenly considered to be increased, by the presence of the so-called J wave (see item as belonging to QRS), resembling branch block or intraventricular disorder of the stimulus. The explanation for QRS broadening is in the decrease of rest potential and consequently, phase 0 rise velocity and negative dromotropism. The J wave “per se” is not significant for ventricular fibrillation (VF) appearance, since QRS complex duration prolongation constitutes a reliable sign for VF appearance. When rapidly induced hypothermia for heart surgery causes QRS prolongation, it causes VF in almost all patients (**Fleming 1957**).
7. **J wave or Osborn wave:** it is a dome-like or hump in the same direction of precedent R wave immediately following the QRS complex of the surface ECG which is observed as late delta wave following the QRS complex or the small secondary pseudo-R wave (pseudo-R') in ECG constitutes the most typical electrocardiographic element; however, not pathognomonic, since it may be found in other clinical circumstances (**Antzelevitc 2010**). It is located at the point where QRS ends (late δ wave) and the initial part of ST segment (J point). It corresponds to phases 1 and 2 of action potential. The J wave is due to different densities in the Ito channels concentration (phase 1) in ventricular myocardium thickness. These channels of the initial potassium outflow are very numerous in the epicardium and scant or absent in the endocardium. This fact justifies phase 1 of AP in the epicardium showing a notch. On the contrary, phase 1 of endocardial cells lacks a notch (**Yan 1996**). J waves and ST elevation usually return to normal as body temperature increases and hypoxia and acidosis regress. Localized epicardial cooling of the RVOT could be an in vivo experimental model of Brugada syndrome (**Nishida 2004**). J wave is a deflection with a dome or hump morphology in the same direction as the R wave.



- I. **The J-wave:** also referred to as the J deflection (**Patel 1994**), "the camel's hump"/ camel-hump sign (**Abbot 1976**), "late delta wave" (**Sentürk 2013**), elevated J-point, hat hook junction, hypothermic wave, prominent J wave, K wave, H wave, current of injury, Osborn wave (**Alhaddad 2000**), hypothermal or cool wave (**Ortak 2007**). J wave is a repolarization phenomenon.
- II. **J-point:** Approximate point of convergence between the end of QRS complex and the onset of ST segment. It is considered the point at which the QRS complex finishes and the ST segment begins. The J-point is an essential landmark for measuring QRS duration and ST segment elevation and/or depression. J-point represents approximate the end of depolarization and the beginning of repolarization as determined by the surface ECG. There is an overlap of ≈ 10 milliseconds (**Mirvis 1982**). The J point is used to measure the degree of ST elevation or depression present. It is very important in *ACS-ST segment elevation myocardial infarction* (STEMI). The TP segment of precedent beat and the PRs or PQs segment (PRs), are used as reference as the isoelectric line. See next slide.

Correlation of levels between PRs or PQ, ST segment and TP (Riera 2008)



Usually, PR segment (end of P wave up to QRS complex onset), ST segment (from J point or the end of QRS up to the beginning of the T wave) and TP segment (from the end of the T wave up to the P wave of the following cycle) are at the same level. The figure shows a normal ECG and a line of dots pointing out the level of the three segments: PR, ST and TP.

PR (PRs) or PQ segment: it stretches from the end of P wave to the onset of QRS complex. The PR segment is leveled when it is at the same level of the PR segment of the beat being studied. If the PR segment falls below the baseline (TP segment of precedent beat), then it is said to be depressed.

ST segment: it stretches from the from the J point (union of ST with the end of QRS complex) up to the onset of the T wave.

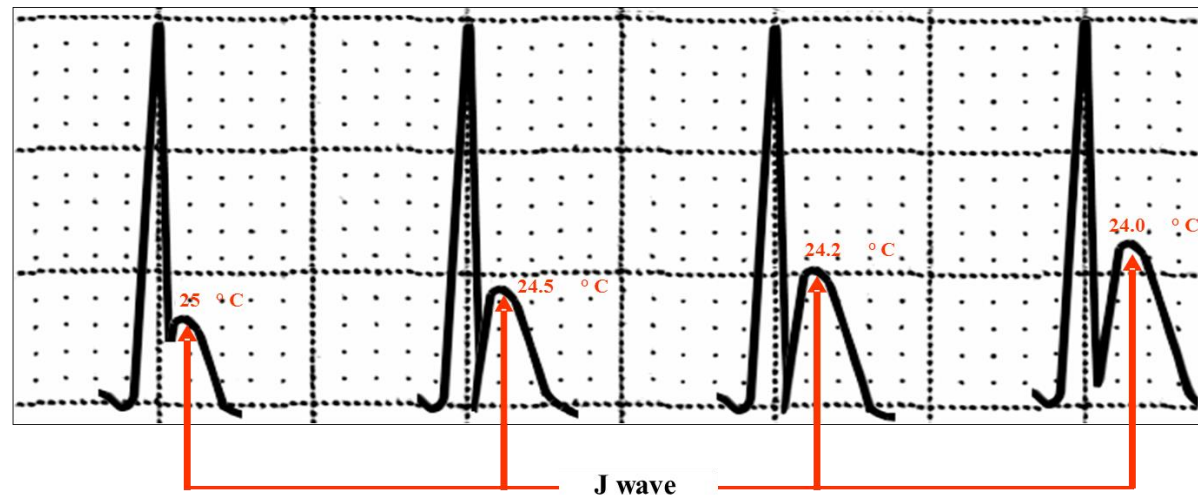
TP segment: it stretches from the end of T wave to the onset of the P wave of the next cycle. TP segment is between the end of the T wave and the beginning of the next P wave. It is the true isoelectric interval in the electrocardiogram. In other words the PR segment changes are relative to the baseline formed by the precedent TP segment of anterior beat.

Electrocardiographic J wave of hypothermia characteristics

J wave presents the following features:

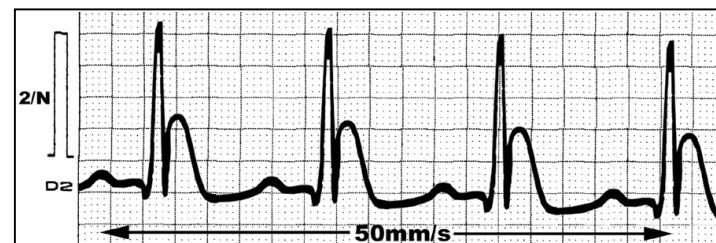
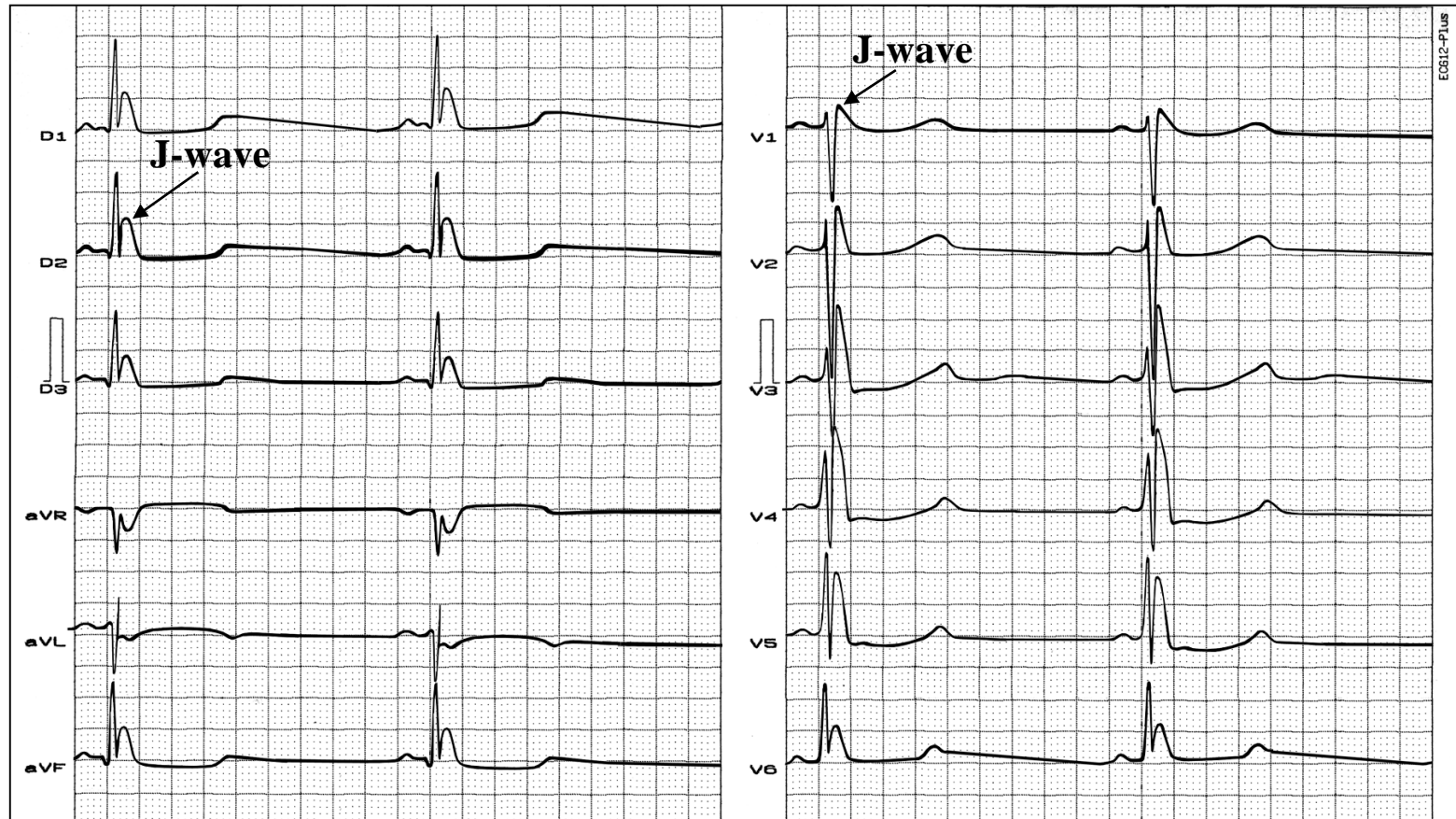
- I. Location:** the J wave is located at the point where the QRS complex ends (late δ wave) occupying the initial part of the ST segment, corresponding to phase 1 and 2 of monophasic action potential (**Alsafwah 2001**).
- II. Polarity:** always positive and prominent in the leads that face the left ventricle: V_5 and V_6 and possibly and mainly in hearts in a vertical position in inferior wall leads (**Sgobba 1982**), unlike J wave found in Brugada syndrome, located in right precordial leads V_1 to V_2 or V_3 .
- III. Aspect:** it may appear resembling small secondary R wave (R'), falsely mimicking RBBB (see next slide). The J wave is characteristic of hypothermia; however, not pathognomonic, since it may be observed in normothermal circumstances (**Burali 1991; Patel 1994**).
- IV. Voltage:** slow and lasting inscription, and voltage greater in left leads V_5 and V_6 and inversely proportional to the severity of hypothermia, i.e. the lower the central temperature, the greater the voltage of J wave. The presence and size of the Osborn waves in hypothermic patients appear to be a function of temperature. The magnitude of the Osborn waves is inversely correlated with the temperature (**Vasallo 1999**). In certain cases, J wave acquires a great voltage associated to superior convexity, mimicking the acute phase of myocardial infarction: "evolving myocardial infarction", which reverses with central temperature normalization. There is inverse and significant correlation between J wave voltage (mm) and central temperature in hypothermia. However, the amplitude of the J wave in the admission ECG of hypothermic patients may not accurately predict the core body temperature (**Omar 2015**). Figure below.

Inverse and significant correlation between J wave voltage (mm) and central temperature in hypothermia



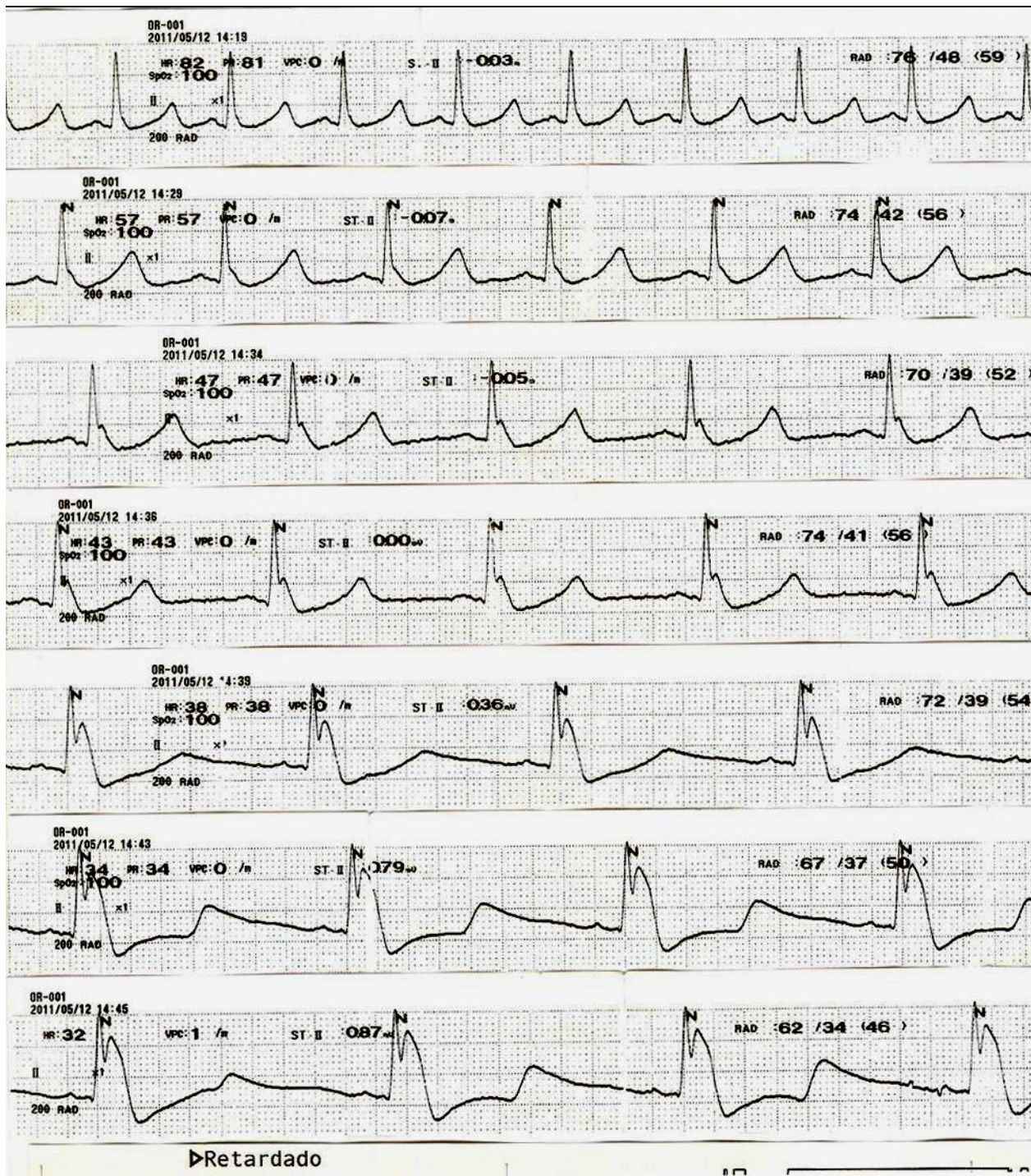
Characteristic ECG of patient in severe hypothermia

Name: ADS; **Gender:** M; **Age:** 32 y/o; **Ethnic group:** mulatto; **Weight:** 68 Kg; **Height:** 1.64 m; **Date:** 03/04/2002; Steps to increase body temperature.



ECG diagnosis: sinus bradycardia of 30 bpm, prominent J wave, very evident in inferior leads and I, as well as in all precordial leads. Pseudo CRBBB determined by J wave, which is not part of the QRS complex.

Normothermia



Hypothermia

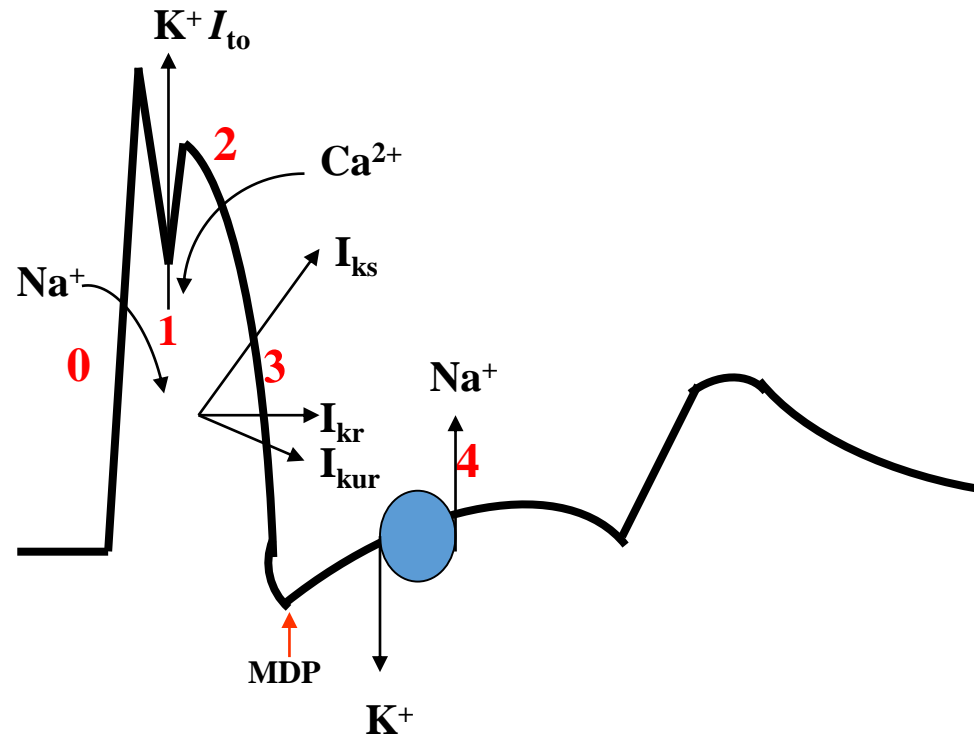
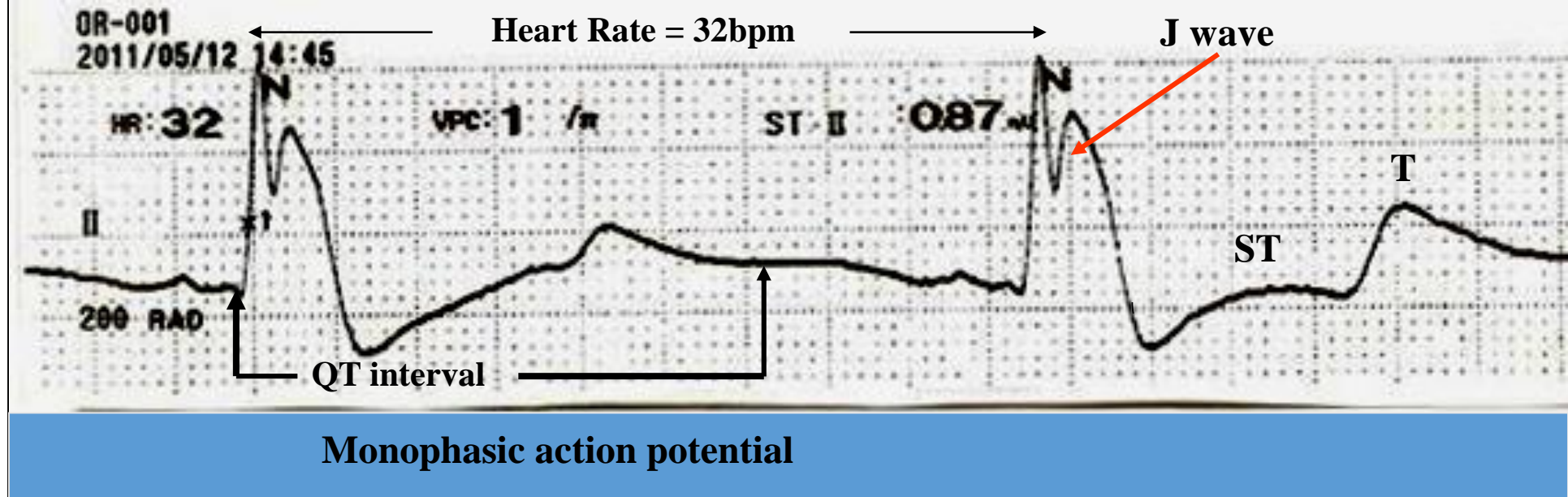
The tracing was obtained during cooling of the blood before a surgical procedure of the heart.

Although the ECG obtained was somewhat expected, what was striking is that the progressive development and augmentation of the J wave was recorded.

Most of the hypothermia cases are published in the moment when the patient is rescued and after recovery. On the other hand, in this case we can see the time course of changes up to the simulation of a monophasic action potential.

Additionally, significant bradycardia is observed and the QT interval was too prolonged, something that usually is not given much attention in the published cases.

Courtesy of Prof. Dr. Raimundo Puerta from Cuba



MDP: the most negative transmembrane potential achieved by a cardiac cell during repolarization. Also called maximum diastolic potential.

T wave modifications and QT/QTc interval in hypothermia

T wave of hypothermia

T wave is altered, directly related with the degree of hypothermia.

When the J wave begins to show a concomitant great voltage, the T wave of the corresponding lead gets inverted.

T waves with changes in polarity or in the axis are called T wave alternans, and are observed during rapid blood transfusion in surgical hypothermia (**Navarro 1978**).

Flattening and asymmetrical inversion are described, mostly in the anterior wall.

QT/QTc interval in hypothermia

In hypothermia it is prolonged in most cases, as a consequence of appearance of extra wave in the J point, and ventricular repolarization slowing.

In all cases, the electric systole prolongation is reversible with hypothermia reversion (**Lins 2004**).

the $TpTe/\sqrt{RR}$ did not change, the $([TpTe/QTc] \times 100\%)$ decreased significantly during therapeutic hypothermia (TH). QTc prolongation without TpTe increase or abnormal J wave may not be arrhythmogenic during TH (**Kim 2014**).

Rhythm disorders in hypothermia

Hypothermia is associated with the presence of greater incidence of several arrhythmias, both supraventricular and ventricular.

Significant arrhythmias do not appear with body temperatures above 32°C. This is the reason why this is the limit of moderate hypothermia, induced with therapeutic purposes (**Marion 1997**).

Atrial fibrillation with low rate of ventricular response, is described as an arrhythmia with significant incidence in moderate hypothermia, in some series being observed in up to 50% to 60% of cases (**Strohmer 2004**).

The percentage differences found in atrial fibrillation appearance in the different series in literature, relate with the heterogeneous nature of the populations studied. Elderly patients display a greater prevalence of atrial fibrillation. Thus, when the average age of patients in hypothermia is lower, atrial fibrillation percentage will be so too.

Ventricular fibrillation has great possibilities of appearing with temperatures below 28°C. When it occurs with values above 28°C, associated myocardial disease must be suspected.

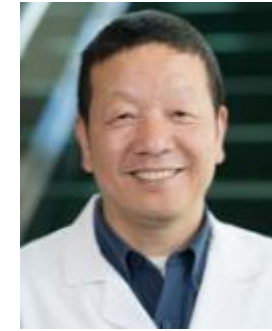
Electrophysiological substrate of J wave

Experimental evidence support the hypothesis that one heterogeneous distribution of the I_{to} channel in the ventricular wall thickness accounts for the spike-and-dome configuration in monophasic AP in the epicardium, and prominent notch in phase 1 and phase 1 shortening, which results in voltage gradient that manifests by J wave (**Antzelevitch 2005**).

Experimental studies point out that J wave appearance is the consequence of the presence of transmural gradient in ventricular wall thickness, secondary to existence in the epicardium but not the endocardium, of significant notch in phase 1, mediated by a greater activity or density of initial transient outward potassium current.

This greater activity and/or density of the I_{to} channel in epicardial cardiomyocytes, but not endocardial ones, accounts for the characteristic aspect of AP known as “*spike-and-dome configuration of the monophasic action potential*”.

Moreover, the greater initial potassium outflow in the epicardium than the endocardium, causes phase 2 shortening in the epicardium, which conditions transmural dispersion of repolarization and J wave appearance, which carried to a certain level, causes a greater tendency to appearance of ventricular arrhythmia by the mechanism called functional reentry in phase 2 (**Yan 1996**).

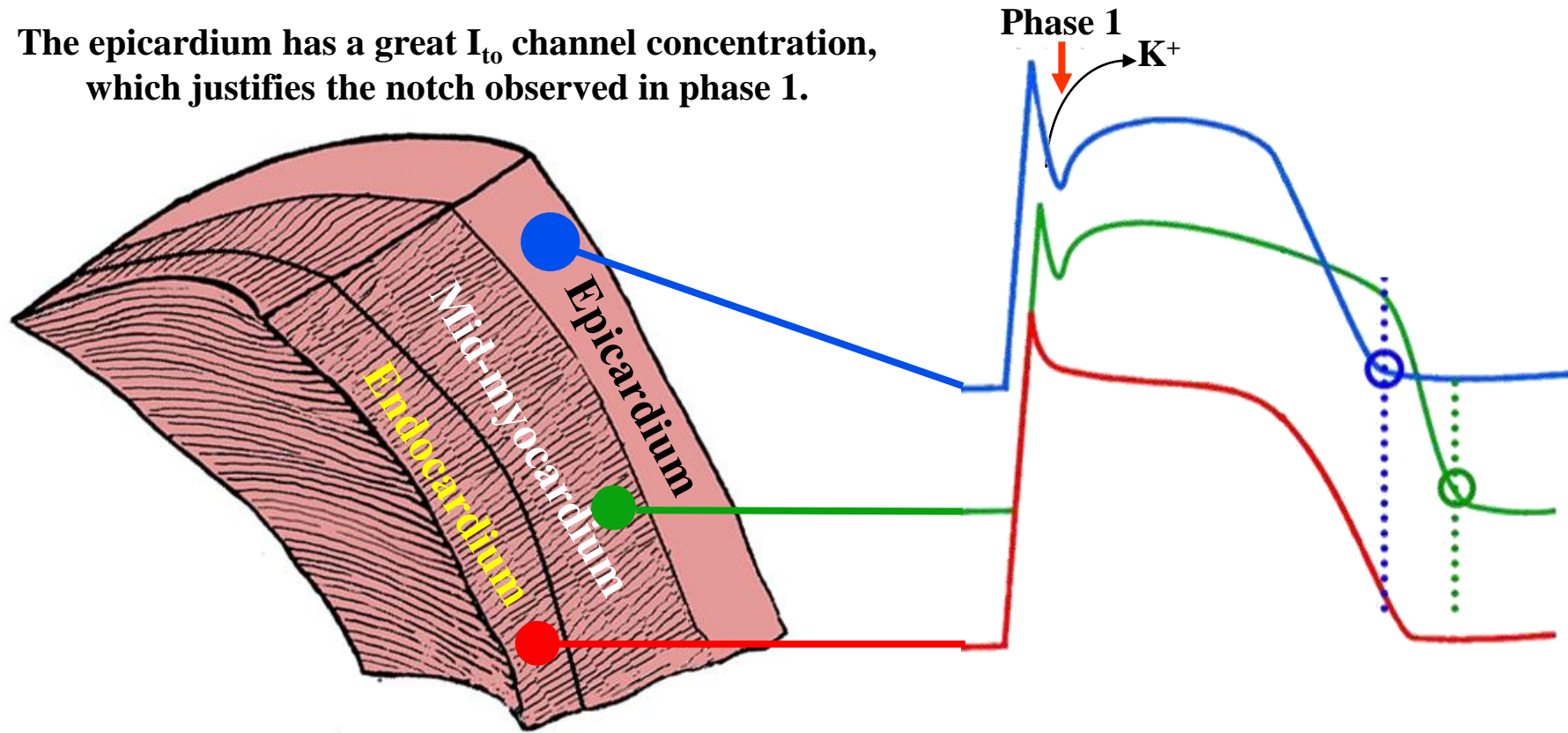


Experimental located cooling of the right ventricular outflow tract (RVOT) in vivo in dogs, resembles the electrophysiological alterations that occur in Brugada syndrome, causing J wave appearance secondary to I_{to} channel activation, and showing the classical aspect of “spike-and-dome configuration” of the monophasic action potential in the epicardial cells of the RVOT (**Nishida 2004**).

Several entities are associated to J wave appearance (J wave syndromes) that include among others (**Hlaing 2005**), early repolarization syndromes, Brugada syndrome, overlapping or atypical Brugada syndrome (**Riera 2004**), idiopathic ventricular fibrillation with prominent J wave in inferior wall, the so called concealed form of arrhythmogenic right ventricular cardiomyopathy/dysplasia (ARVC/D), hypercalcemia, acute ST segment elevation myocardial infarction, variant angina or Prinzmetal angina, intoxication by tricyclic, encephalic lesion, cocaine abuse (**Robertson 2010; El Mazloun 2015**), and tricyclic antidepressants intoxication (**Bigwood 2005**),

Outline of Electric heterogeneity within ventricular wall myocardium thickness and cellular basis of hypothermia-induced J-waves

The epicardium has a great I_{to} channel concentration, which justifies the notch observed in phase 1.



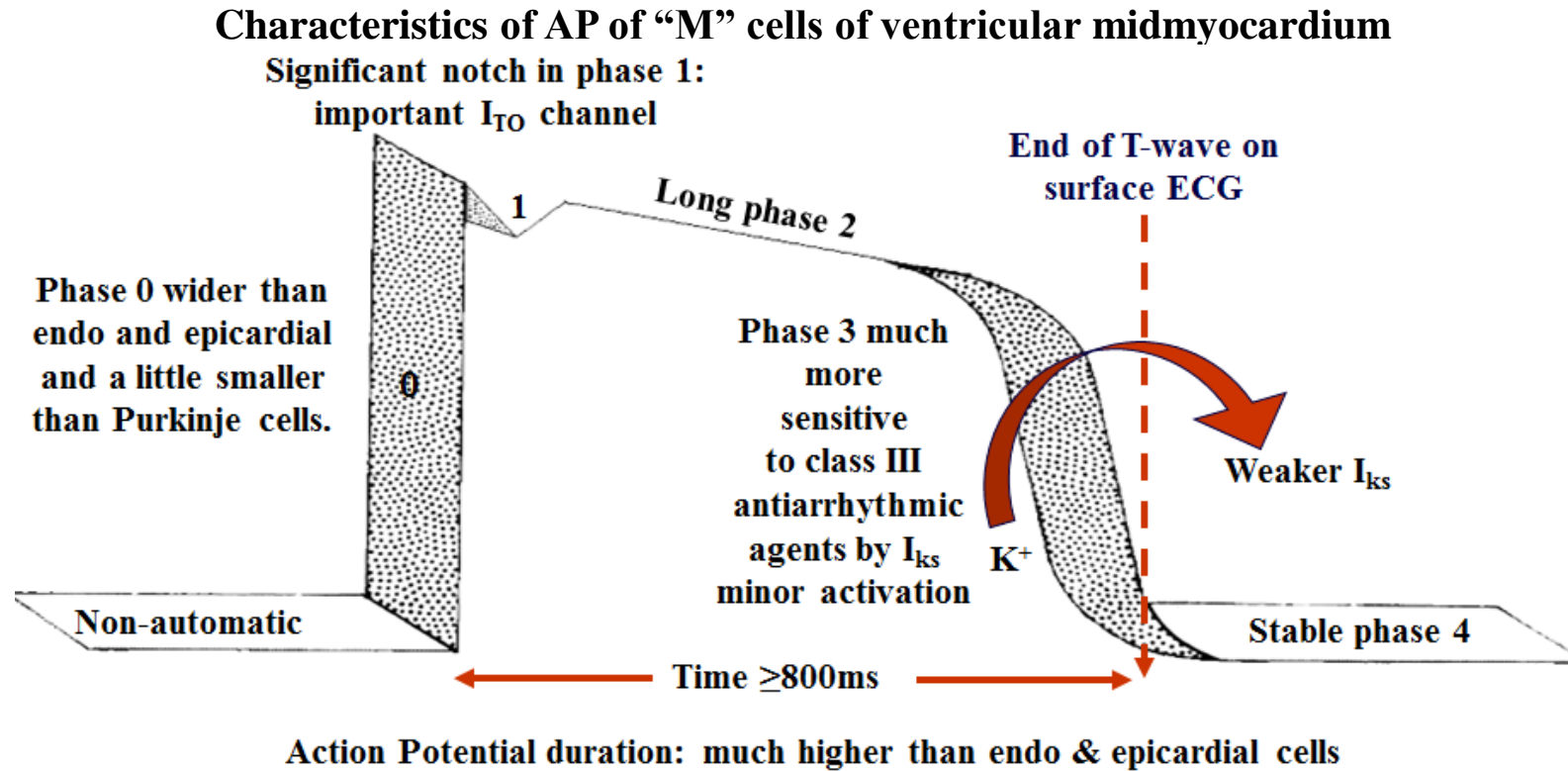
Camel-hump wave



The endocardium does not have I_{to} channels, which conditions absence of notch in phase 1 of AP in these cells.

The proposed cellular basis of hypothermia-induced J waves is the accentuation of the spike-and-dome morphology of the action potential of M and epicardial cells. This epicardial accentuation is mediated by a transient outward current (I_{to}) that does not occur in the endocardium, originating in a transmural voltage gradient responsible for the appearance of a **camel-hump wave** at the end of the QRS complex (Yan 1996).

Ventricular myocardium in larger mammals has been shown to be comprised of three distinct cell types: epicardial, M, and endocardial. Epicardial and M cell action potentials differ from endocardial cells with respect to the morphology of phase 1. These cells possess a prominent I_{to} mediated notch responsible for the "spike and dome" morphology of the epicardial and M cell response. M cells are distinguished from the other cell types in that they display a smaller $I(K_s)$, but a larger late $I(Na)$ and $I(Na-Ca)$. These ionic distinctions underlie the longer action potential duration (APD) and steeper APD-rate relationship of the M cell.

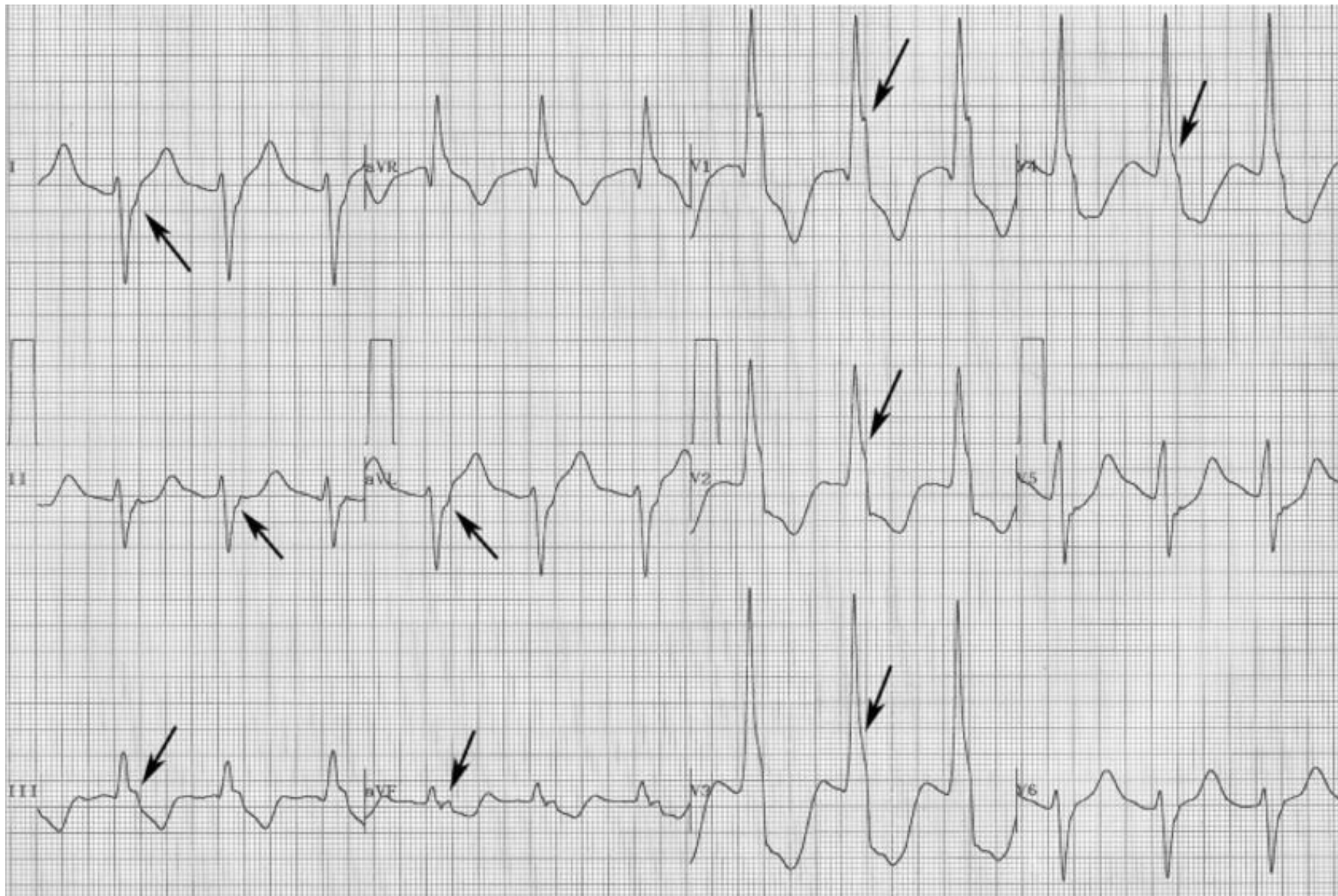


Difference in the time course of repolarization of phase 1 and phase 3 are responsible for the inscription of the electrocardiographic J wave and T wave, respectively. These repolarization gradients are sensitively modulated by electrotonic communication among the three cell types, $[K(1)](o)$, and the presence of drugs that either reduce or augment net repolarizing current. A reduction in net repolarizing current generally leads to a preferential prolongation of the M cell action potential, responsible for a prolongation of the QT interval and an increase in transmural dispersion of repolarization (TDR), which underlies the development of torsade de pointes arrhythmias.

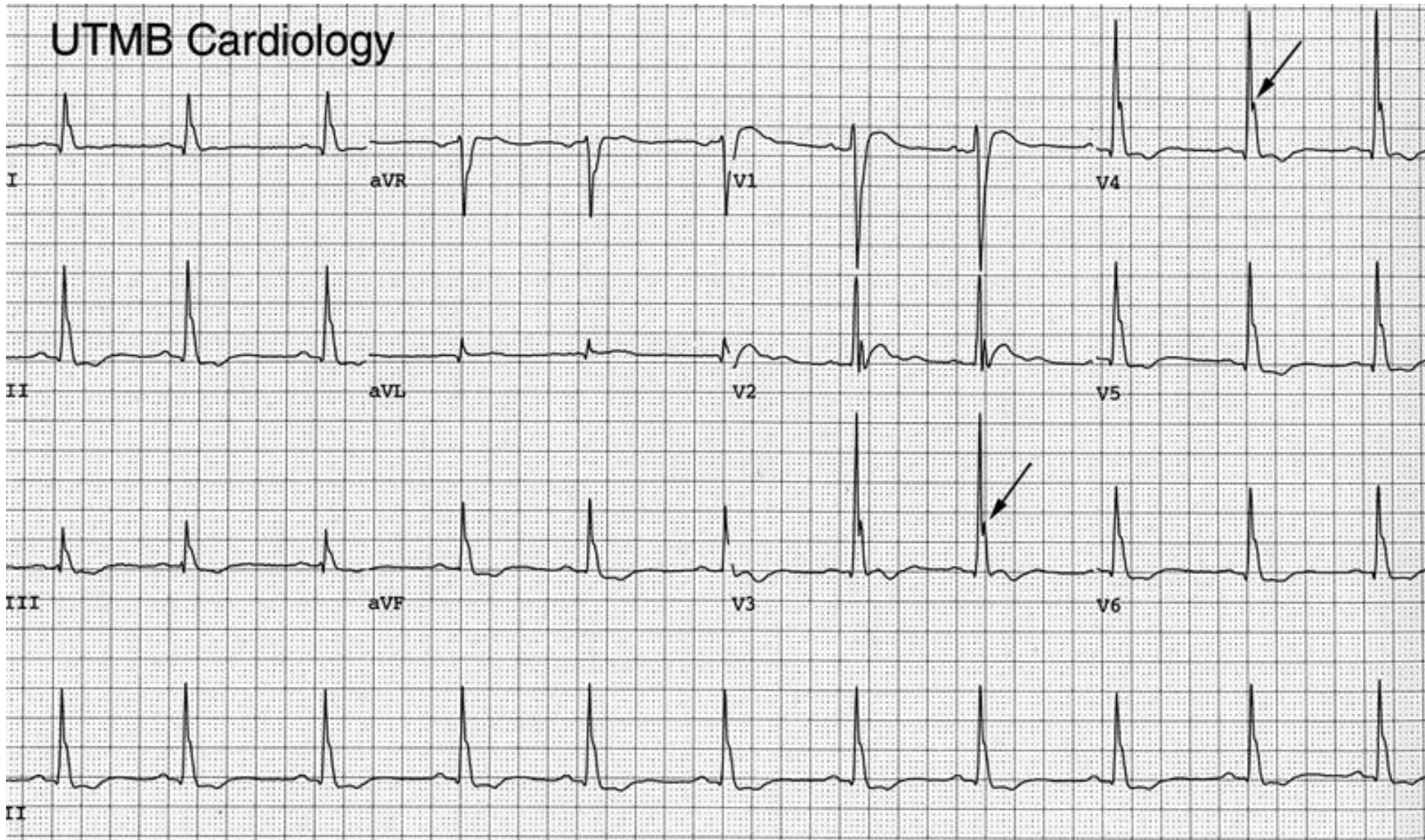
Name: PASA; **Gender:** M; **Age:** 47 y/o; **Ethnic group:** Afro-descendent; **Weight:** 61Kg; **Height:** 1.68 m; **Date:** 03/07/2008; Central body temperature 29°C.



Severe hypothermia. Atrial fibrillation with slow ventricular response. Left posterior fascicular block pattern. Gussak wave or lambda wave.

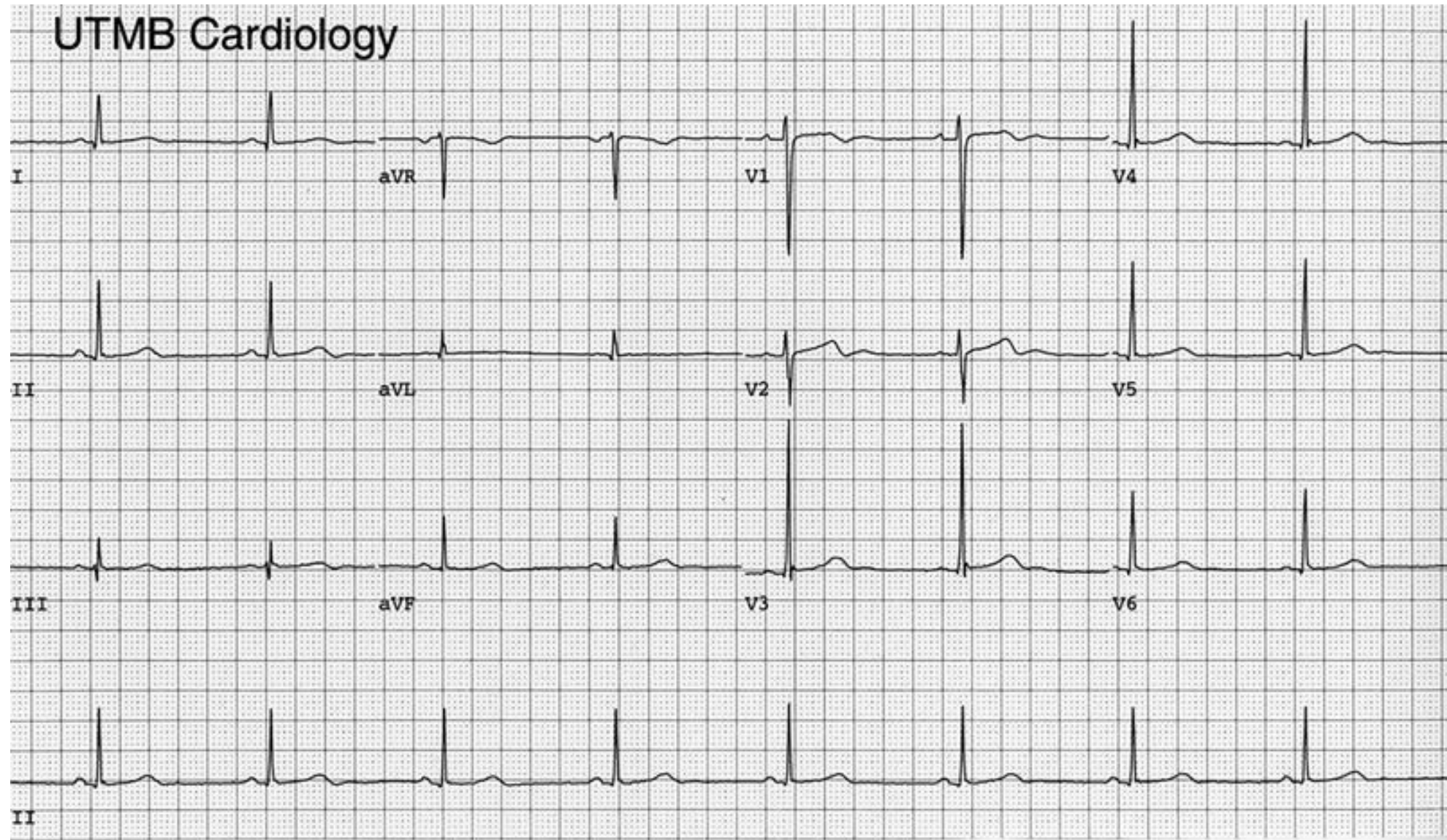


Sinus rhythm, Osborn waves can easily be recognized on almost all derivations (arrows). Right axis shift, wide QRS complexes (200 ms) and the prolonged QTc interval (680 ms). In this case, a 75-year-old woman, after 1 day of continuous hemodialysis, showed a marked hypothermia (28.5°C) and severe hypokalaemia (1.7 mEq/l). Bradycardia was seen on the monitor and J waves were recognized on the ECG recording. After appropriate replacement of potassium and treatment of hypothermia, the J waves disappeared spontaneously.



Clinical diagnosis: parathyroid adenoma with severe hypercalcemia (serum calcium level was 16.3 mg/dL (normal, 8.6 to 10.6 mg/dL)), ionized calcium was 10.29 mg/dL (serum pH, 7.39).

ECG diagnosis: J wave.



After correction of the hypercalcemia, the electrocardiogram was normal.

Classification proposal for ECG J waves (Yan 2004a; Yan 2004b; Li 2015; Lévy 2011; Antzelevitch 2010)

J wave syndromes: represent a spectrum of variable phenotypes, that can be inherited or acquired, characterized by appearance of prominent J wave consequence of amplification of the Ito-mediated J waves that can lead to phase 2 reentry capable of initiating VF. A prominent J wave is encountered in a number of life-threatening cardiac arrhythmia syndromes, including early repolarization syndromes. and the Brugada syndrome differ with respect to the magnitude and lead location of abnormal J waves and are thought to represent a continuous spectrum of phenotypic expression termed J-wave syndromes (Antzelevitch 2015). This involve accentuation of the epicardial AP notch in different regions of heart, leading to the development of prominent J waves that reflect at the body surface the substrate for development of phase 2 reentry and VT/VF.

Inherited

I. Early repolarization syndrome (ERS)

- 1. ERS type 1:** J wave in I, V4-V6 (anterolateral LV). Rare ventricular fibrillation, very prevalent in healthy male athletes and rarely found in VF survivors. The frequency of J-point elevation among young athletes is intermediate (higher than among healthy adults but lower than among patients with idiopathic VF) (Rosso 2008). This variant is considered benign and electrocardiographically is characterized by frequent sinus bradycardia, axes of QRS, ST segment and T wave, oriented in the same direction in the frontal plane, deep and narrow Q waves followed by R wave of great voltage in left precordial leads, notch or slurring of R wave descending branch, transition area in precordial leads of sudden occurrence, J point and ST segment elevation, usually < 2 mm (exceptionally it may be > 5 mm) of superior concavity in middle and/or left precordial leads (I, V4-V6), possible reduction in J point and ST segment elevation by sympathetic action and sympathomimetic drugs, absence of reciprocal or mirror image (exception in VR lead), near symmetrical T waves, with great width and polarity matching QRS. In this variant, there is a voltage gradient, however, no dispersion of duration of action potentials in ventricular wall thickness. For this reason, these patients showed ST segment elevation with no tendency to develop arrhythmias. Gene mutation: CACNA1C, CACNB2B.

ERS type 1 (truly benign ERP)

Notch or slurring in R wave descending branch

T waves of great voltage and polarity matching QRS

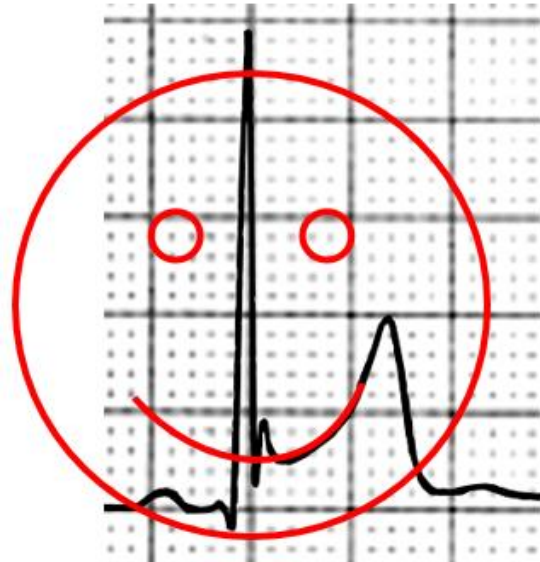
Voltage Gradient

(Riera 2008b)

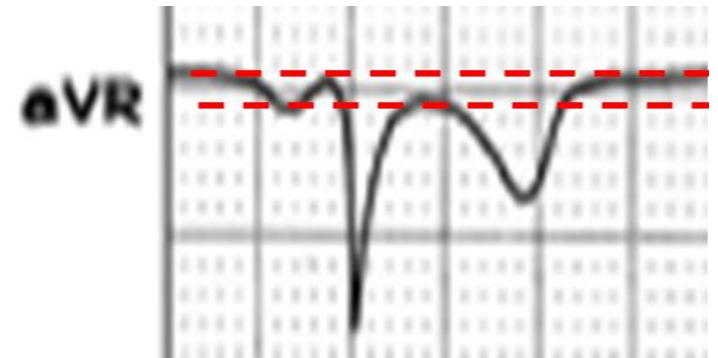
J point and ST Segment elevation (upwardly concave) from 1 to 4 mm from the isoelectric line

Notch

Slur

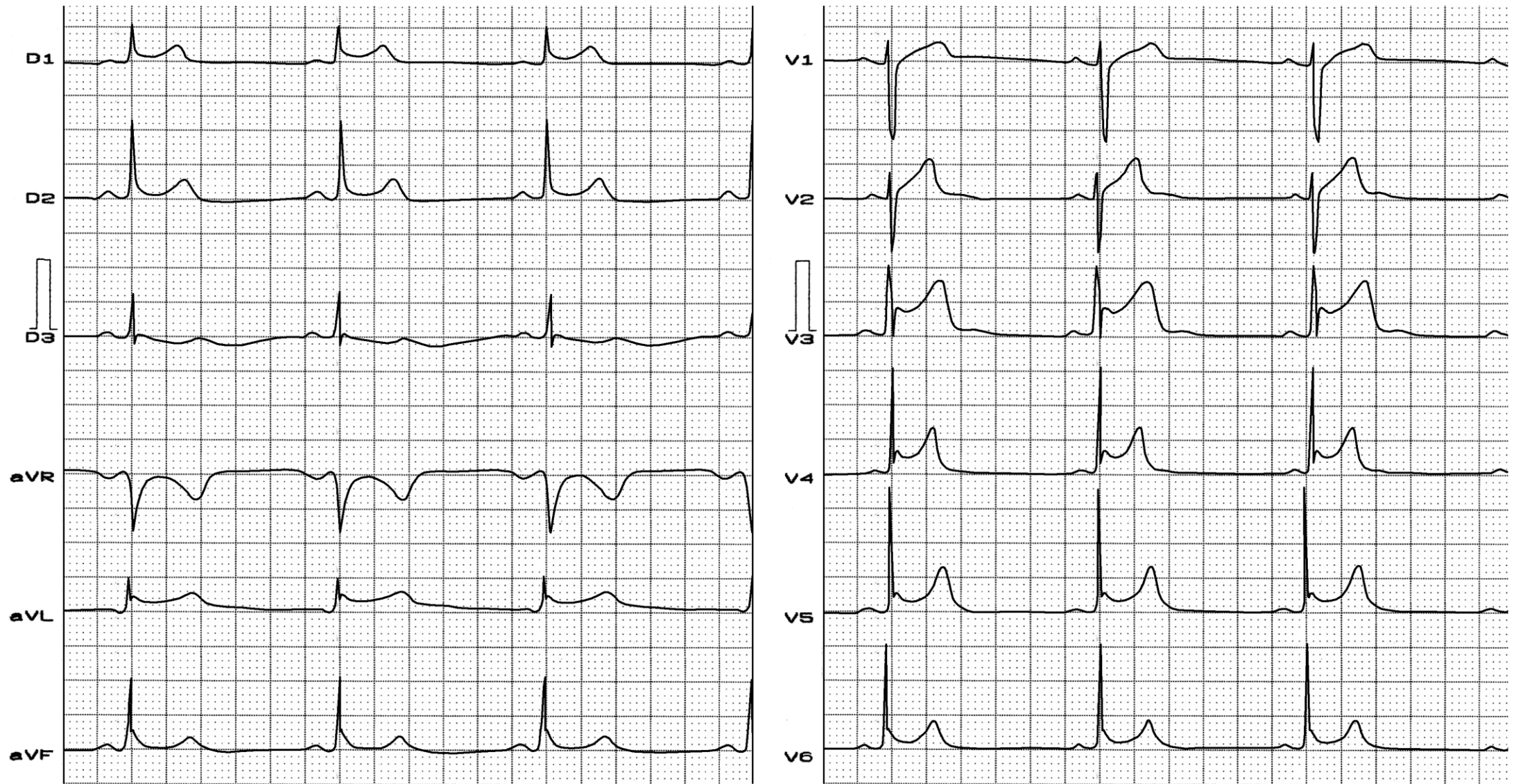


V4 precordial lead with STSE concave to the top followed by large positive T wave that resembles a "smiling face".



Mirror image or reciprocal changes only in aVR lead

ERS type 1 (truly benign ERP)

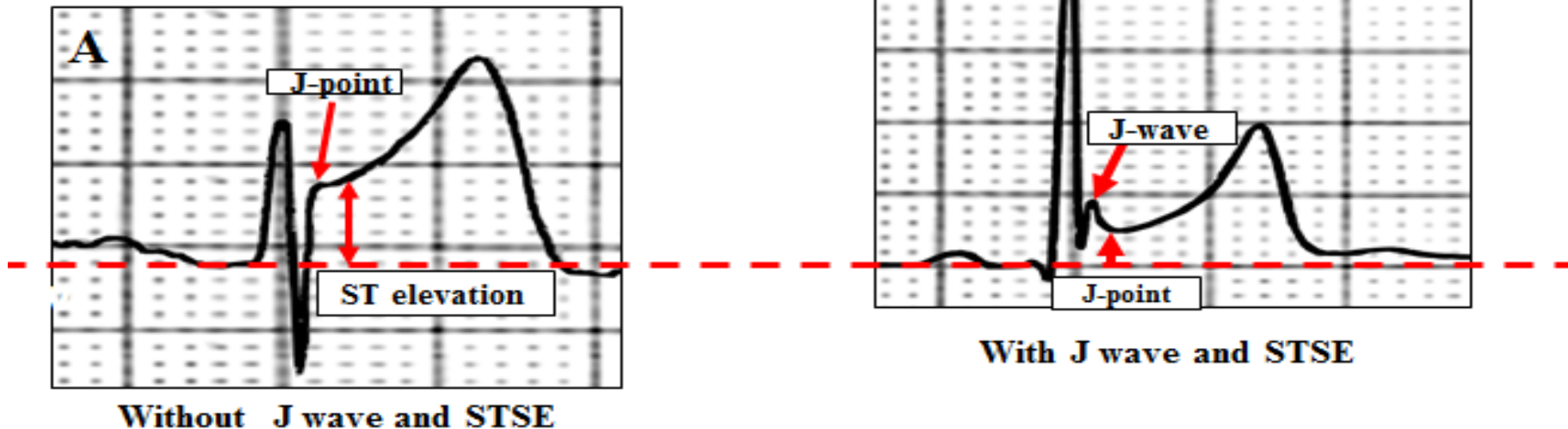


Clinical diagnosis: Young normal black male athlete.

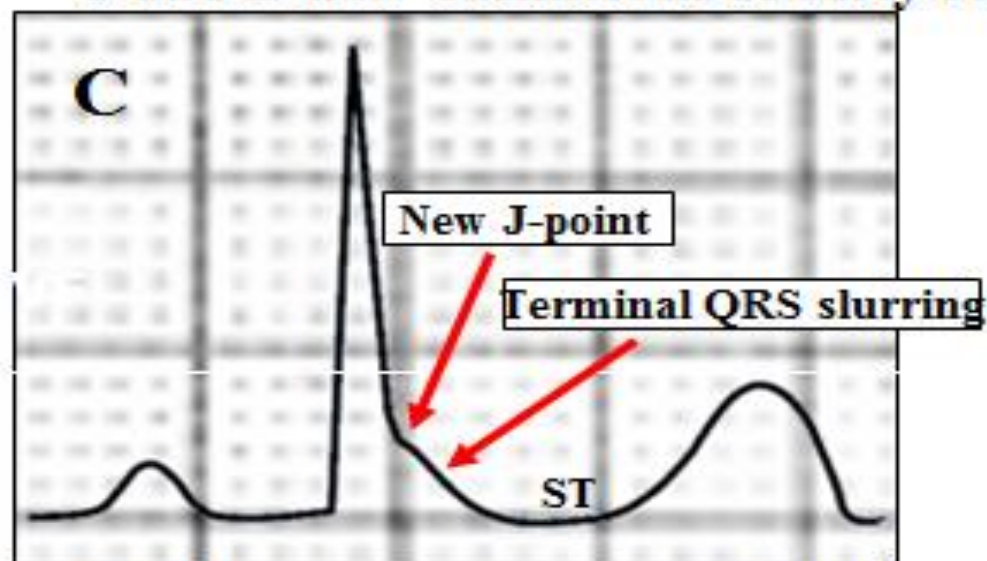
Electrocardiographic diagnosis: typical ECG pattern of benign early repolarization: sinus bradycardia, P, QRS and T directed to the same place, ST segment elevation concave to the top from V2 to V5 followed by tall pseudo symmetrical T waves concordant with precedent polarity of QRS complexes. Absence of mirror image or reciprocal changes (with exception of aVR).

2. **ERS type 2:** J wave in II, III, aVF (inferior wall). Frequent VT/VF. Gene mutation: KCNJ8, CACNA1C, CACNB2B. It shows an ER pattern mainly in the inferior or inferolateral leads, which is similar to previously called IVF in the setting of J wave in the inferior leads, and is related to a higher level of VF risk. An early-repolarization pattern in the inferior leads of a standard electrocardiogram is associated with an increased risk of death from cardiac causes in middle-aged subjects (**Tikkanen 2009**).
3. **ERS type 3:** J wave in left and right ventricles. shows an ER pattern globally in the inferior, lateral and right precordial leads and is associated with the highest level of risk for the development of VF storms. Frequent VT/VF. Careful attention be paid to patients with ER and J-point elevations > 2.0 mm, particularly in patients with otherwise unexplained arrhythmias or a family history of unexplained SCD. Patients with ER were more likely to be male, to have experienced symptoms during sleep, and to have a shorter QTc interval than those without ER. Nowadays it is not necessary the presence of ST segment elevation for the diagnosis of ER (**Pérez 2012**). Nowadays, following these authors, we have ER with only ST segment elevation (A), with notch or slur at the end of descendent ramp of R wave and ST segment elevation (B). Additionally, today is accepted ER without STSE. This variant could have terminal QRS slurring without ST segment elevation (C) and terminal notch without ST segment elevation (D). Gene mutation: CACNA1C.

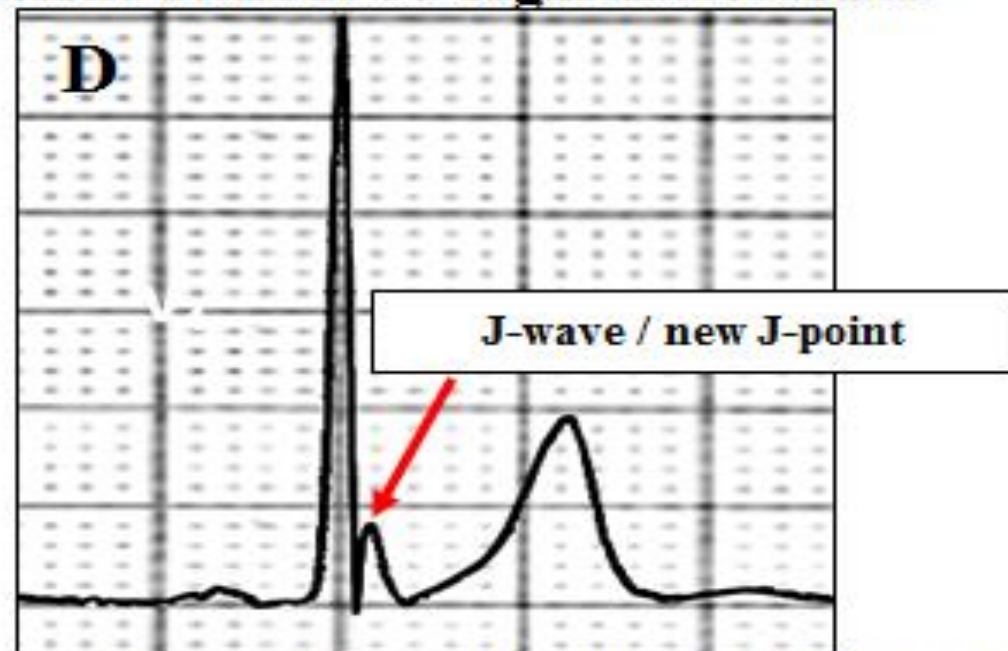
A and B classic definition of early repolarization: with ST segment elevation



C and D new definitions of early repolarization: without ST segment elevation

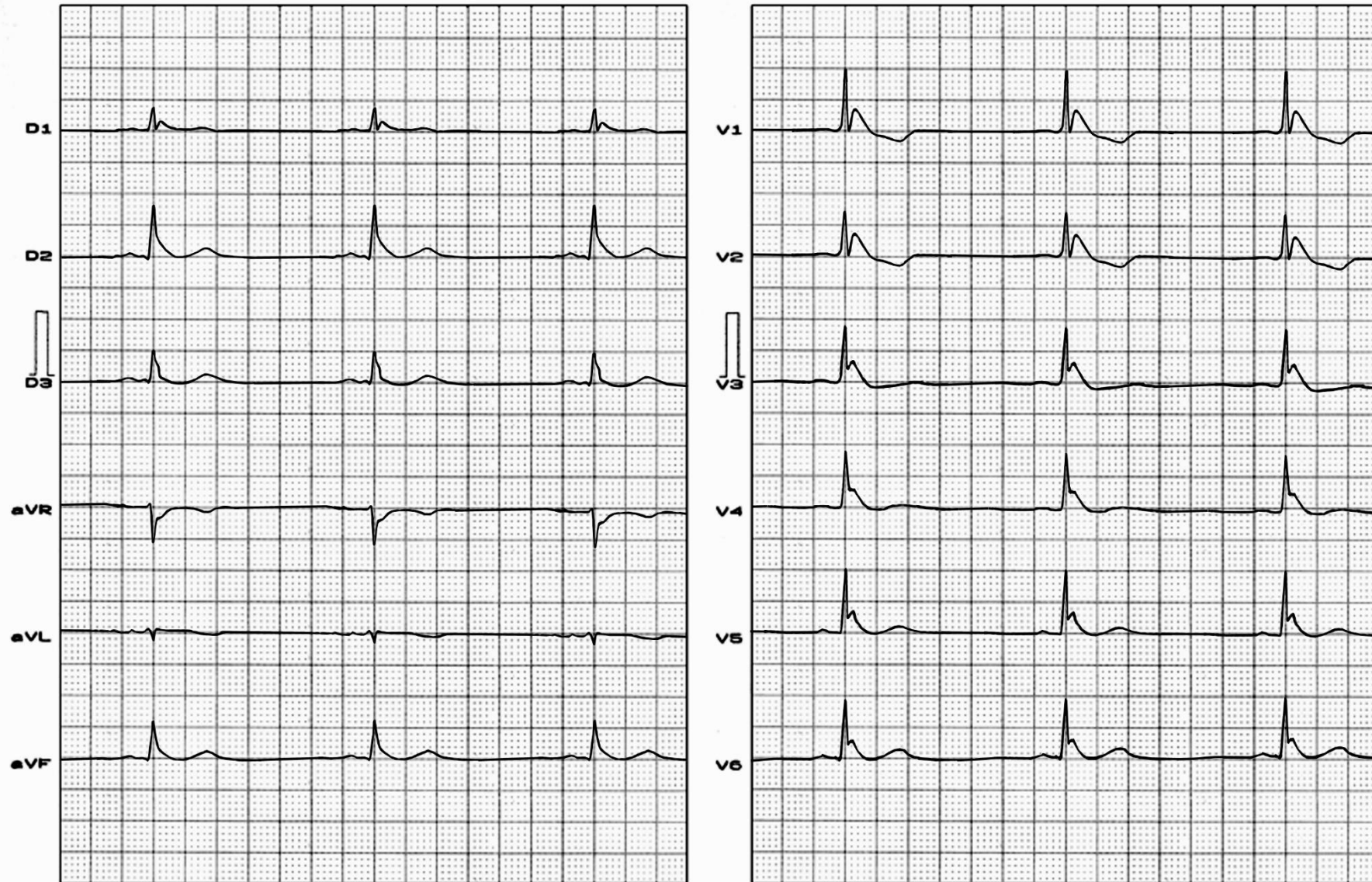


Slurred QRS downstroke without STSE



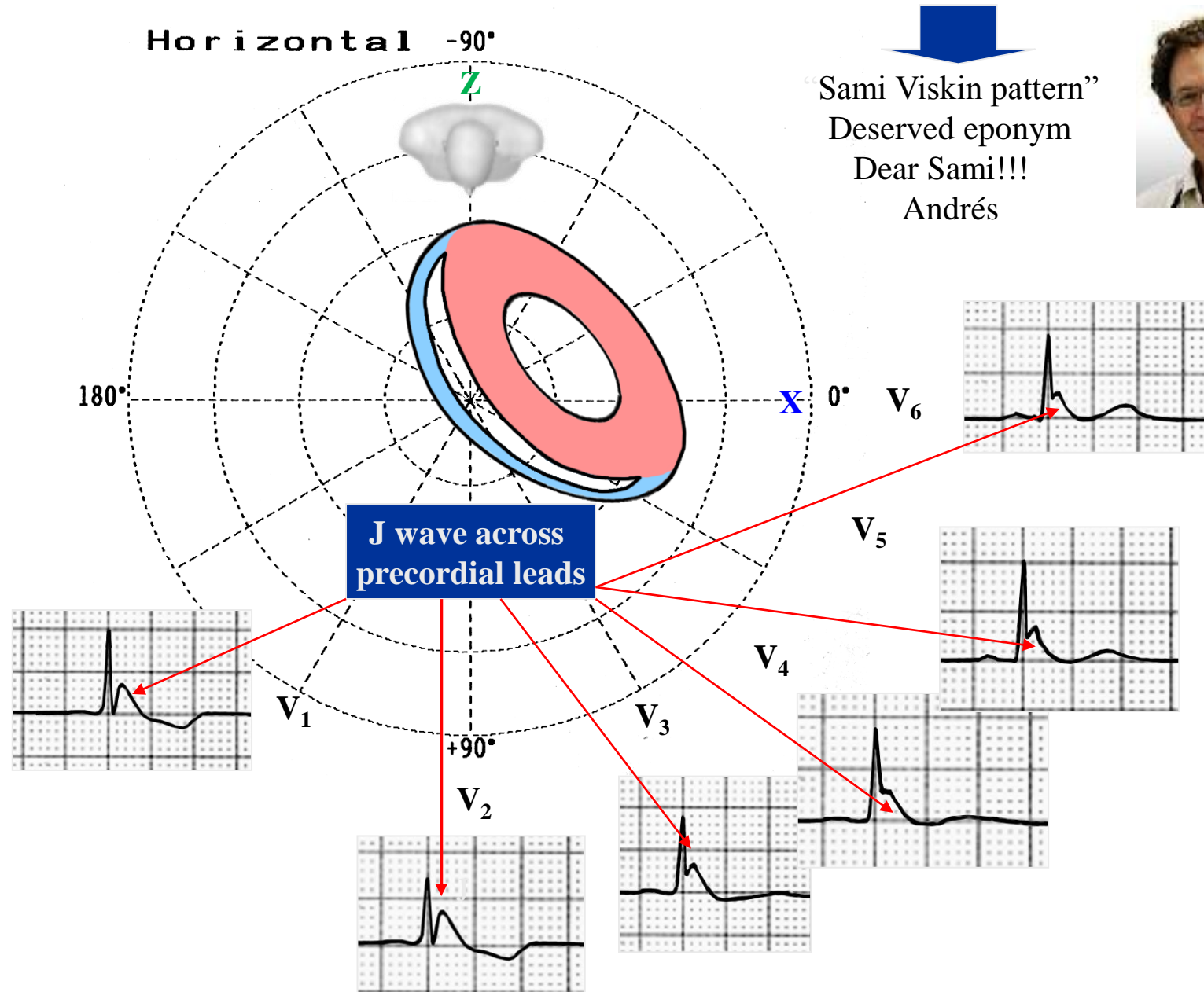
J-wave or the new J-point elevation without STSE

Typical example of ERS type 3 ER pattern globally in the inferior, lateral and right precordial leads

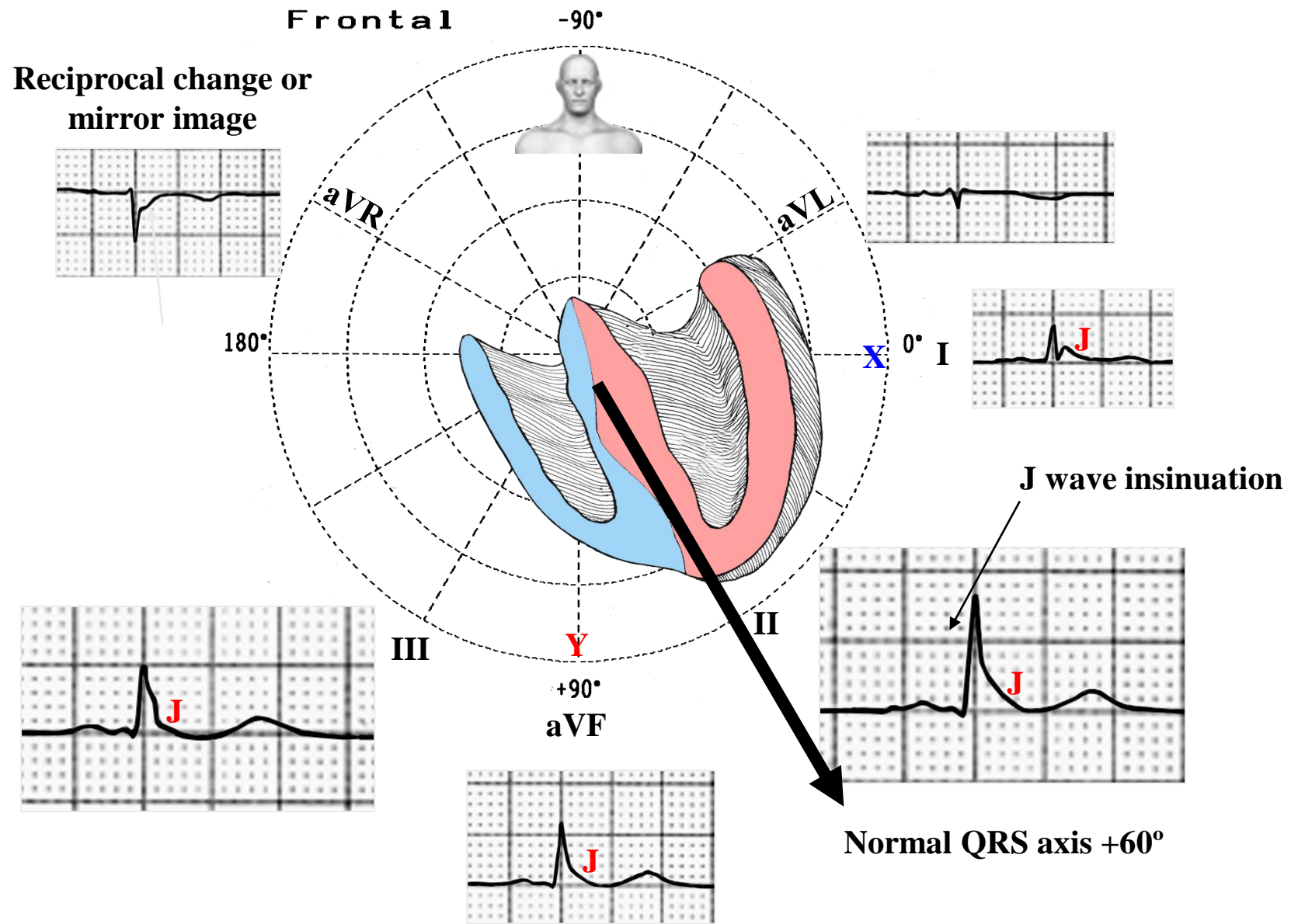


Malignant Early Repolarization Pathological global or diffuse J or malignant waves. Idiopathic ventricular fibrillation associated with global early repolarization pattern (ERP): the “Haïssaguerre pattern” (“Le Syndrome d’Haïssaguerre”) (**Viskin 2009**), also denominated by this author as MER (see the meaning in the next slide).

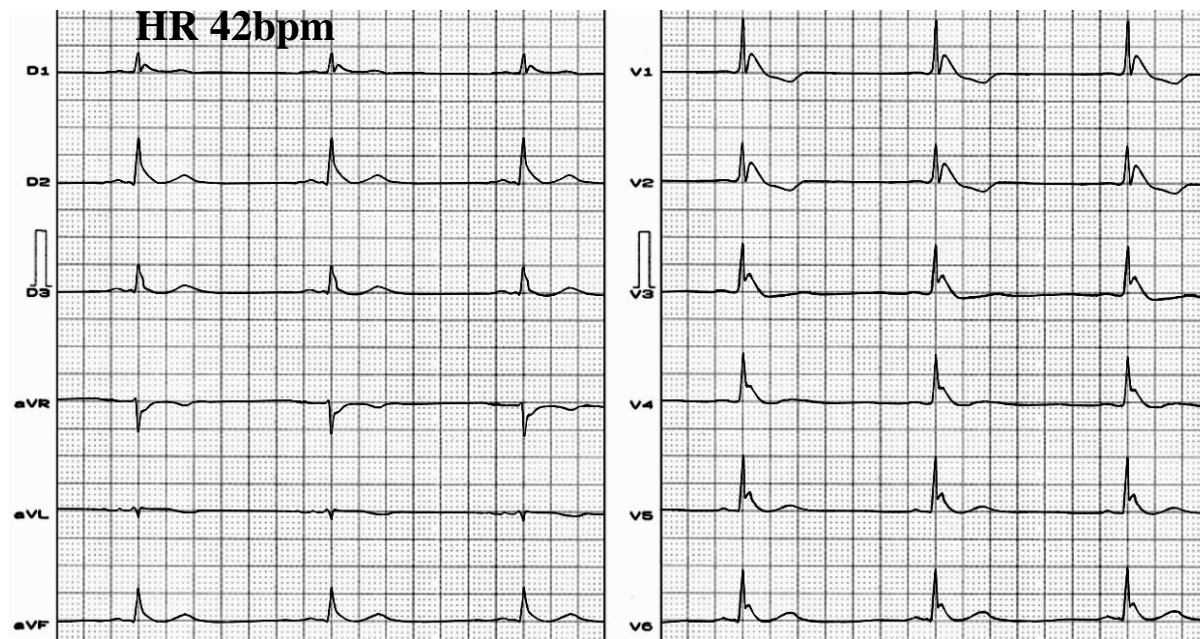
MER “Monstrous Early Repolarization,” or



Classical case of Type 3 Early Repolarization Syndrome (ERS) (**Yan 1996; Antzelevitch 2005**)



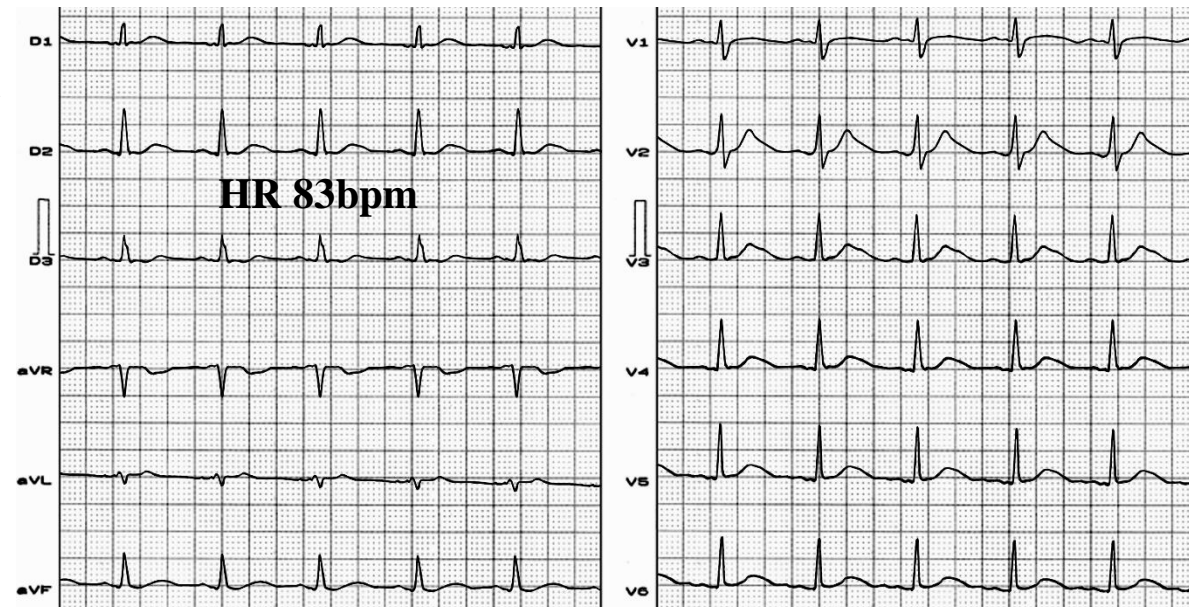
Presence of J wave in inferolateral leads



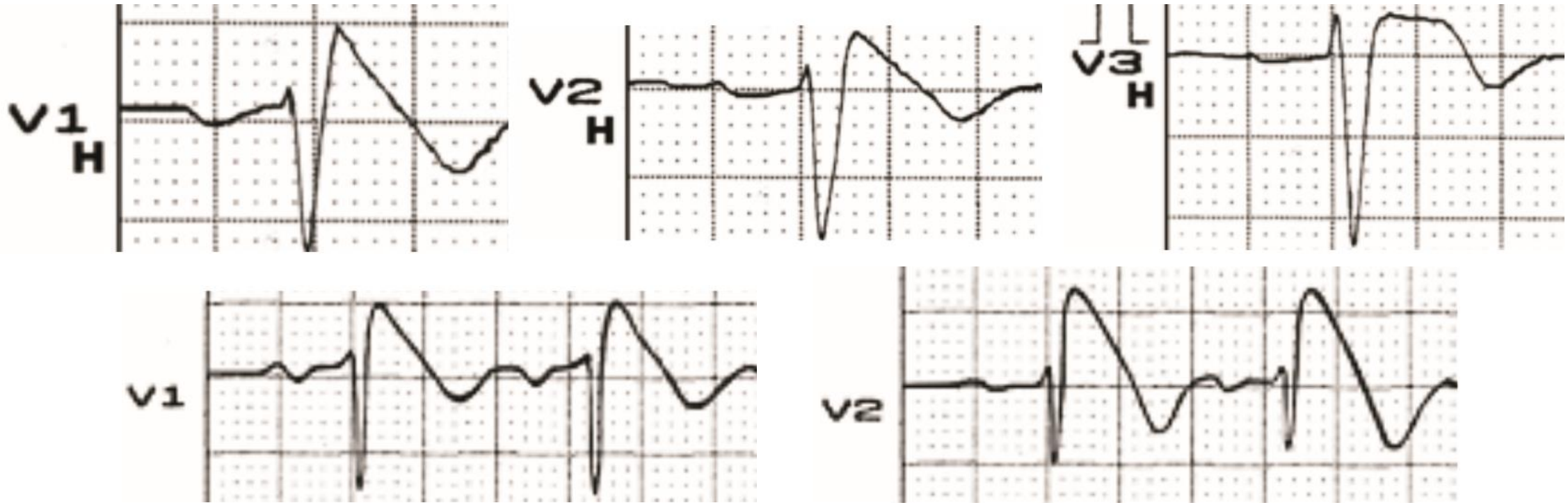
A: Basal tracing. We observe J-wave across all precordial and inferior leads.

B: ECG after two days of oral quinidine 1500 mg/day, J wave disappears

Comments: The drug reduces the magnitude of the Ito channel – mediator of phase 1 and consequently normalize the elevation of the ST segment. Additionally, it could improve repolarization due to its vagolytic effect (M2 muscarinic receptor block) and to the exacerbation of reflex sympathetic tone.

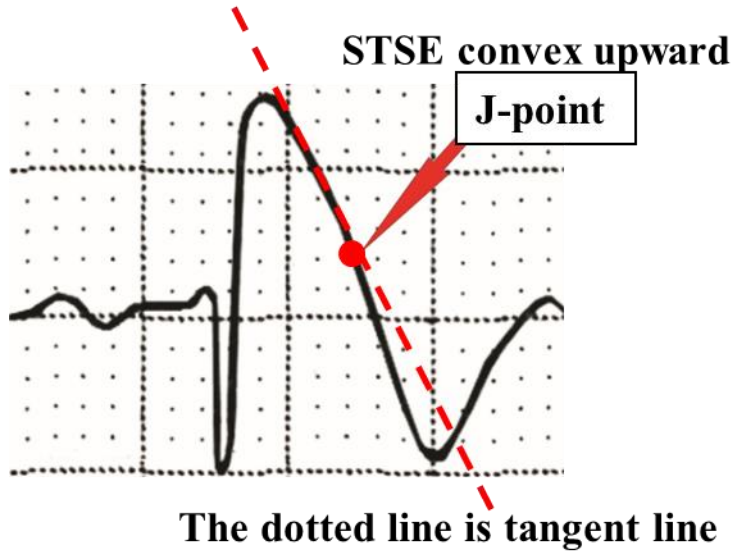


II. Brugada syndrome: Only the type-1 ECG Brugada pattern is diagnosis: It is characterized by J point and ST segment elevation ≥ 2 mm, with upper convexity or descending oblique rectilinear followed by negative T wave on right precordial leads (V_1 - V_2 or from V_1 through V_3) and/or high right precordial leads V_{1H} , V_{2H} and V_{3H} . (figure next slide) also can be observed in some of the limb leads (**Oreto 2010**). Frequent VT/VF. Inferolateral early repolarization is considered an ECG markers in identifying patients at risk in the Brugada syndrome (**Kamakura 2009**). Brugada brothers suggest that in patients with type 1 Brugada ECG no single clinical risk factor nor EPS alone are able to identify subjects at the highest risk. A multiparametric approach (including syncope, family history of sudden death and positive EPS) helps to identify populations at the highest risk **Gene mutation:** *SCN5A*, *SCN1B*, *SCN2B*, *SCN3B*, *GPD1L*, *CACNA1C*, *CACNB2*, *CACNA2D1*, *KCND3*, *KCNE3*, *KCNE1L* (*KCNE5*), *KCNJ8*, *HCN4*, *RANGRF*, *SLMAP*, and *TRPM4*. **Observation:** Vectorcardiogram characteristics differentiate Brugada Syndrome from early repolarization qualitatively and quantitatively (**Pastore 2016**).



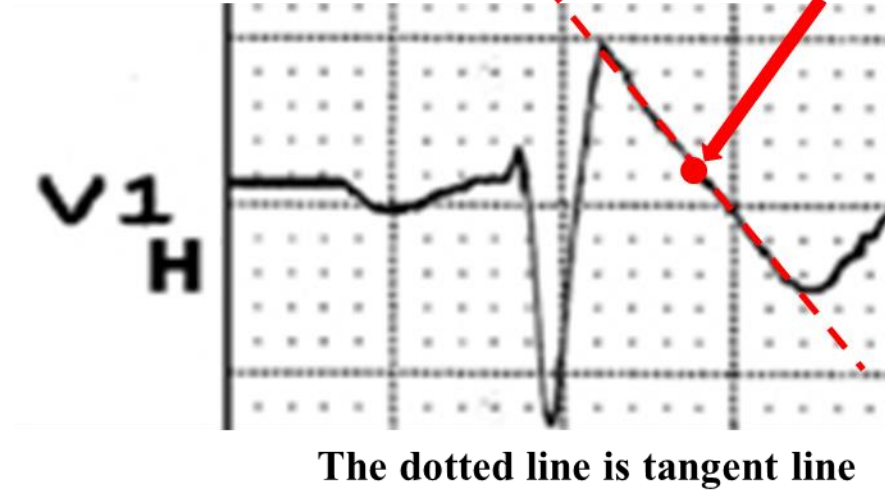
Type-1 electrocardiographic (ECG) Brugada pattern: J point and ST segment elevation ≥ 2 mm, with upper convexity or descending oblique rectilinear followed by negative T wave on right precordial leads (V_1 - V_2 or from V_1 through V_3) and/or high right precordial leads V_{1H} , V_{2H} and V_{3H} . J wave in right precordial leads.

Subtype 1A

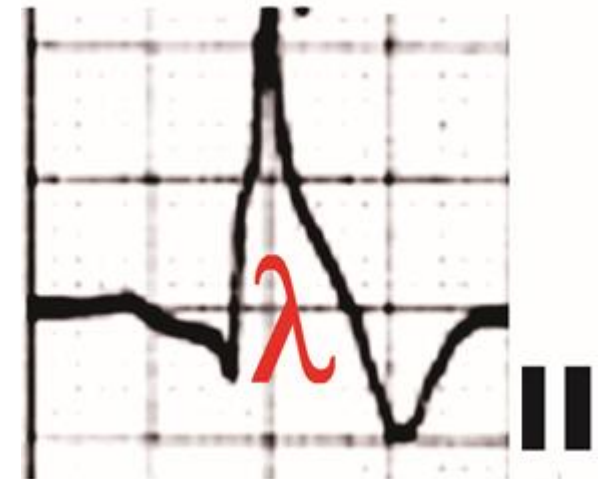


Subtype 1B

STSE rectilinear oblique descend

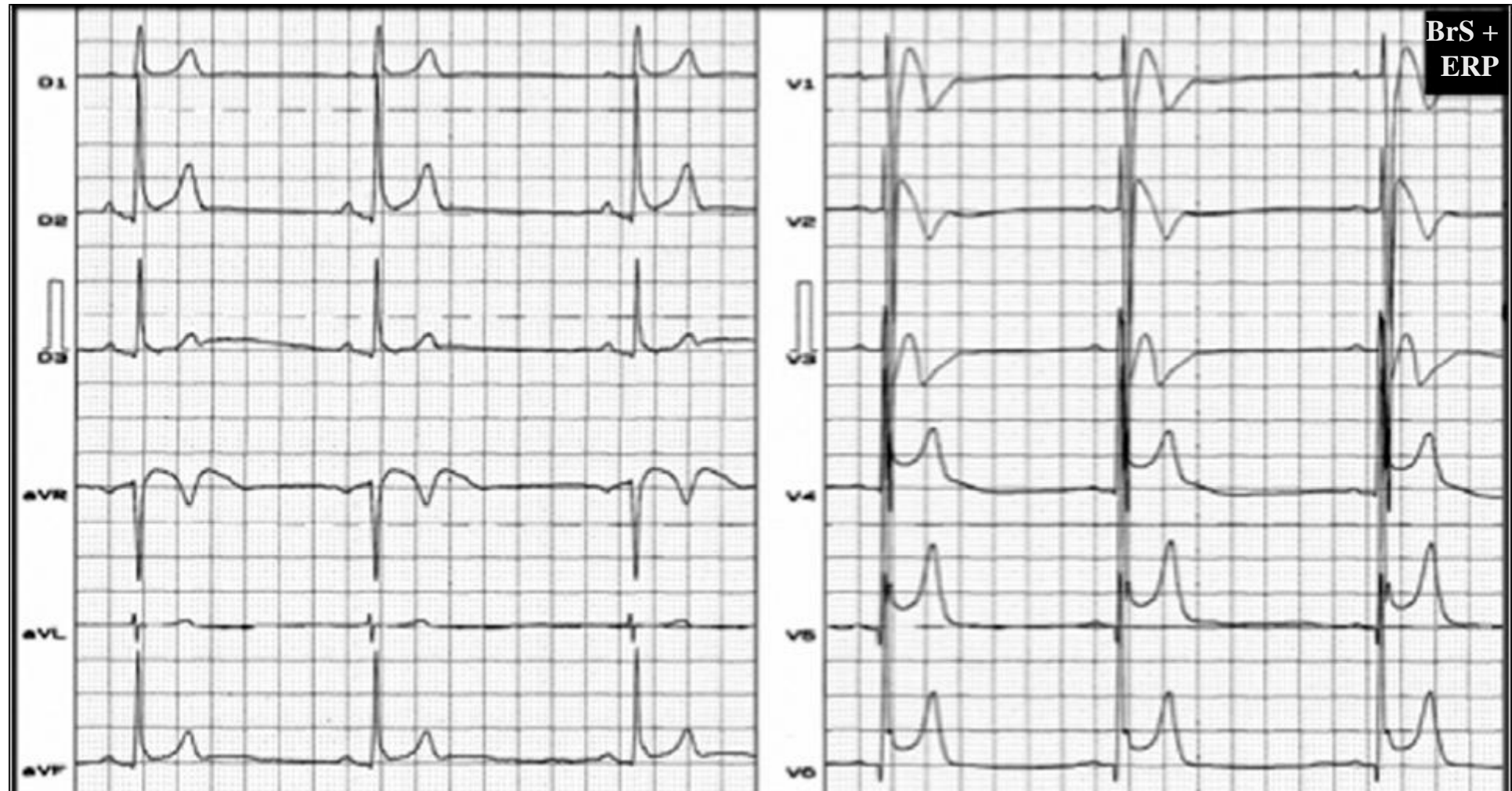


Subtype 1C



J wave in inferior/apical leads
(see next slide)

Coexisting early repolarization pattern and Brugada syndrome: recognition of potentially overlapping entities



Coexistence ECG that shows concomittant early repolarization pattern in inferior lateral leads associated with type 1 Brugada pattern in Young soccer player Caucasian man.

3. Overlapping early repolarization and Brugada syndrome or atypical Brugada syndrome (**Riera 2004; McIntyre 2012; Nademanee 2014; Talib 2014**). See next slide.
4. Idiopathic Ventricular fibrillation (IVF). “Le syndrome d’Haïssaguerre” (**Viskin 2009**). Frequent VT/VF (**Lévy 2011; Haïssaguerre 2008**). IVF patients with fragmented QRS (f-QRS) and J wave suffer the most frequent VF episodes compared to those with only J wave, or without f-QRS and J wave (**Wang 2012**). The combination of J waves with horizontal/descending ST segment improved our ability to distinguish patients with idiopathic VF from controls matched by gender and age (**Rosso 2012**). J waves, particularly of large amplitude and recorded in multiple leads, are more prevalent among patients with idiopathic VF (**Rosso 2011**).
5. In concealed forms of arrhythmogenic right ventricular cardiomyopathy/ dysplasia (**Nava 1988; Corrado 1996**).
6. Overlap of Brugada syndrome and arrhythmogenic right ventricular cardiomyopathy/dysplasia (**Pérez Riera 2005; Forkmann 20015; Kataoka S 2016; Corrado 2016; Peters 2015;; Peters 2016**).
7. Congenital Short QT syndrome (**Watanabe 2010; Adler 2016**)

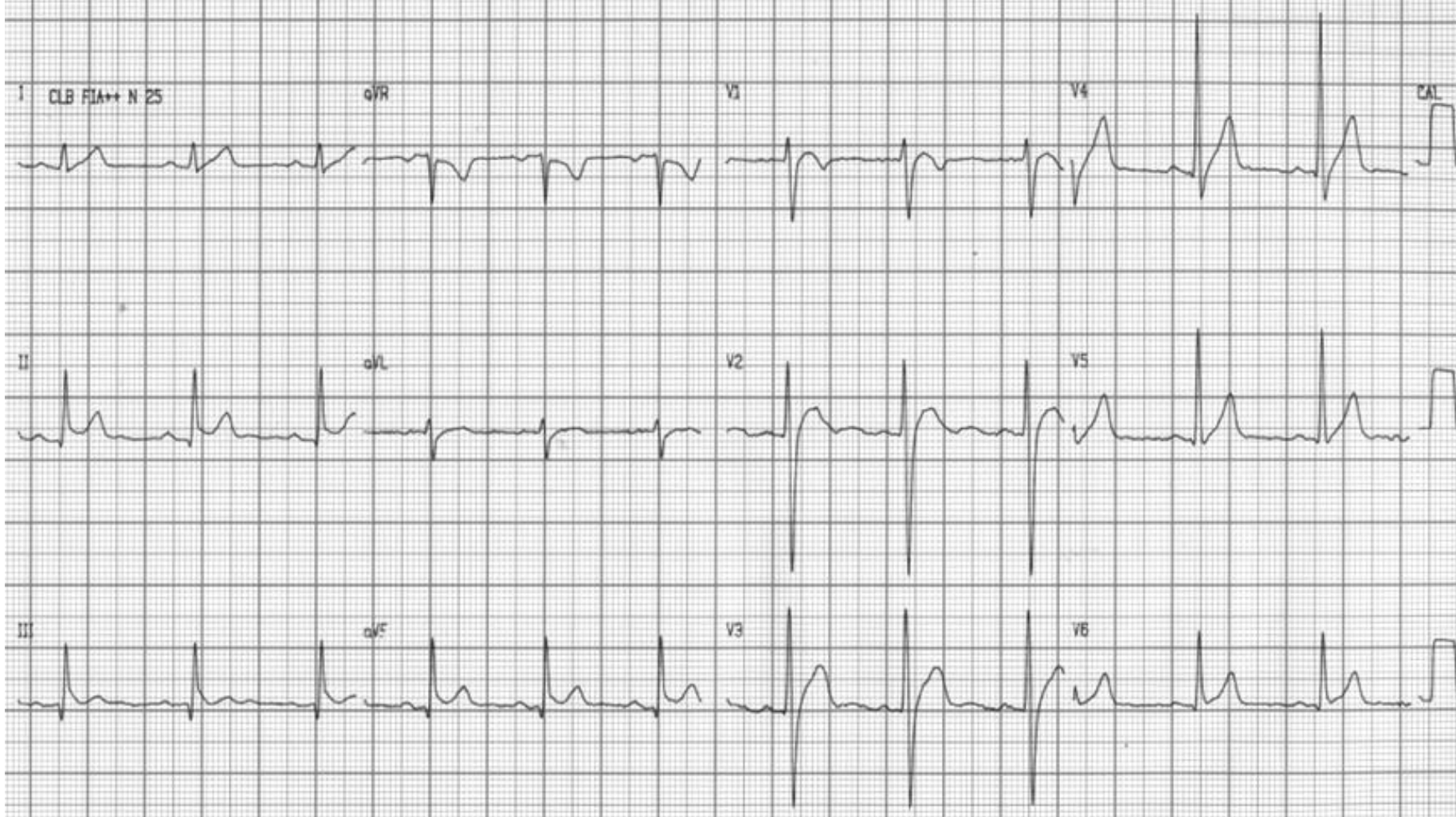
II. Acquired

1. Hypothermia mediated VT/VF (**Pérez-Riera 2013; Omar 2016;)**
2. Ischemia- mediated: Acute STEMI (**Aizawa 2006; Shinde 2007**) and vasospastic angina or variant angina of Prinzmetal’s angina (**Sacha 2012; Zhu 2015**). Clinical observations suggest an association between I_{to} density and risk of primary VF during AMI. Women with CHD have only one fourth the risk for SCD compared with men (**Kannel 1998**) This may be due, in part, to a more prominent I_{to} in males than in females, which is thought to be responsible for the predominance of J-wave syndromes in men. The incidence of primary VF is higher in patients with acute inferior MI who have RV involvement (8.4%) than in those without (2.7%) or in those with an anterior myocardial infarction (5.0%).⁶⁷ This may be due to the fact that I_{to} is much more prominent in right than left ventricular epicardium.^{38,68} Taken together, these observations suggest that the fundamental mechanisms responsible for ST-segment elevation and initiation of VF are similar in the early phases of acute myocardial ischemia and the inherited J-wave syndromes in which phase 2 reentry functions as a trigger and enhanced dispersion of repolarization as substrate for reentry and the development of VF.
3. Hypercalcemia (**Morales 2011; Topsakal 2003; Otero 2000; Jenkins 1987; Sridharan 1984**)
4. Injuries in the central nervous system: subarachnoid hemorrhage (**Katoh 1980**), post-heart arrest (**Jain 1990**) and in cervical sympathetic system dysfunction (**Carrillo-Esper 2004**).
5. Epileptic Hemiplegia: transient postictal hemiplegia (Todd's paralysis) (**O'Connell 2013**)
6. Psychotropic drugs: such as olanzapine, valproate, and flunitrazepam (**Kataoka 2016**)
7. Cocaine use (**Ortega-Carnicer 2001; Talebi 2015**)

SQTS has high prevalence of early repolarization. It is associated with arrhythmic events

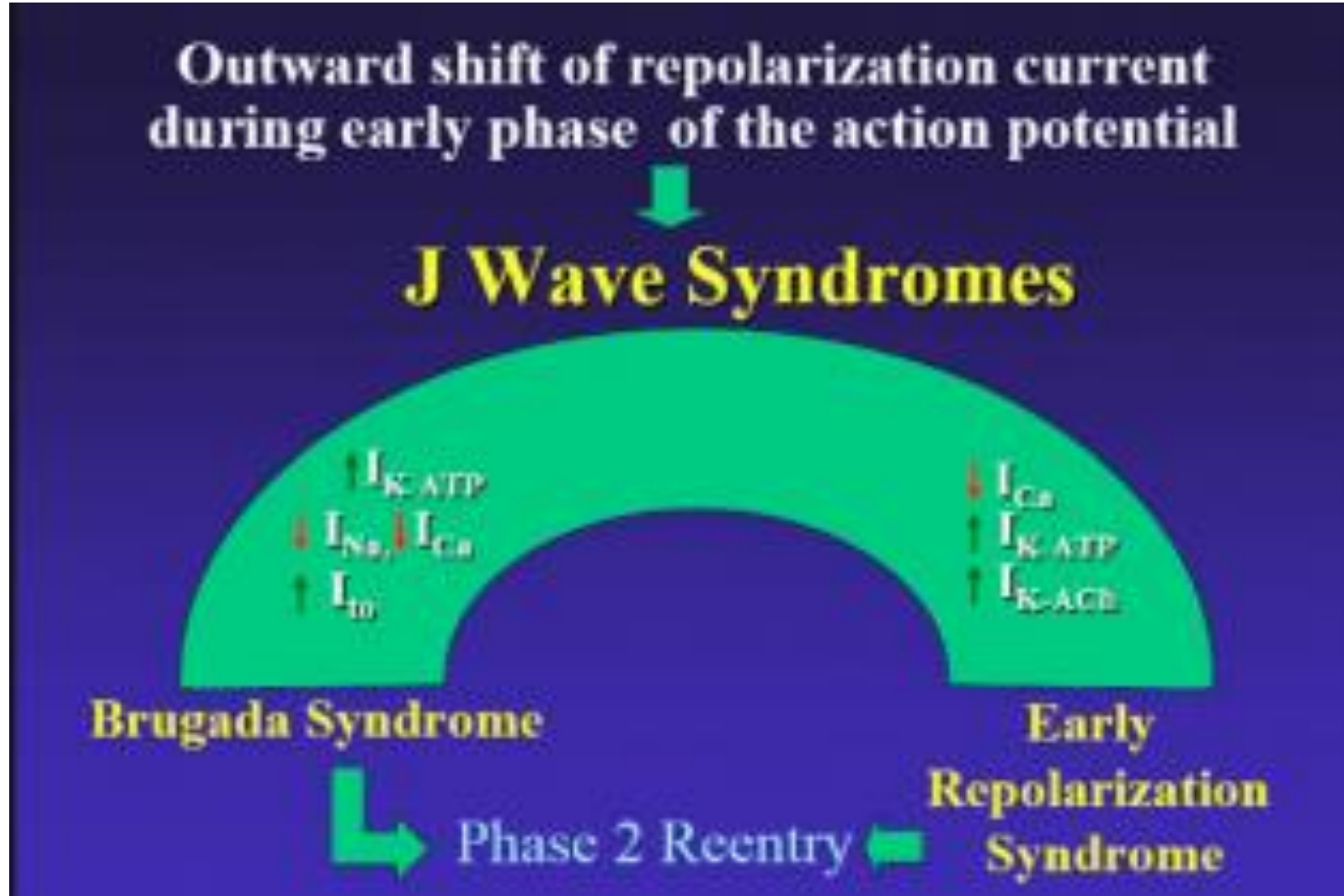
There is a high prevalence of early repolarization in patients with SQTS. Additionally, early repolarization may be useful in identifying risk of cardiac events in SQTS (**Watanabe 2010**).

Example of SQTS associated with early repolarization



HR = 68bpm; QT = 340ms; RR = 880ms; QTc = 362ms

8. Tricyclic antidepressants intoxication (**Bigwood 2005; Bebarta 2007; Brahmi 2007; Meert 2010; (Kataoka H 2016).**),
9. Polytherapy with sodium channel-blocking antiepileptic drugs in patients with epilepsy (**Ishizue 2016**).



This figure was created by the reputed professor Charles Antzelevitch



J-wave syndromes. Schematic depicts our working hypothesis that an outward shift in repolarizing current due to a decrease in Na^+ or Ca^{2+} channel currents or an increase in I_{to} , I_{K-ATP} , or I_{K-ACh} or other outward currents can give rise to accentuated J waves associated with Brugada syndrome, early repolarization syndrome, and some forms of idiopathic ventricular fibrillation. The particular phenotype depends on which part of the heart is principally affected and which ion channels are involved.

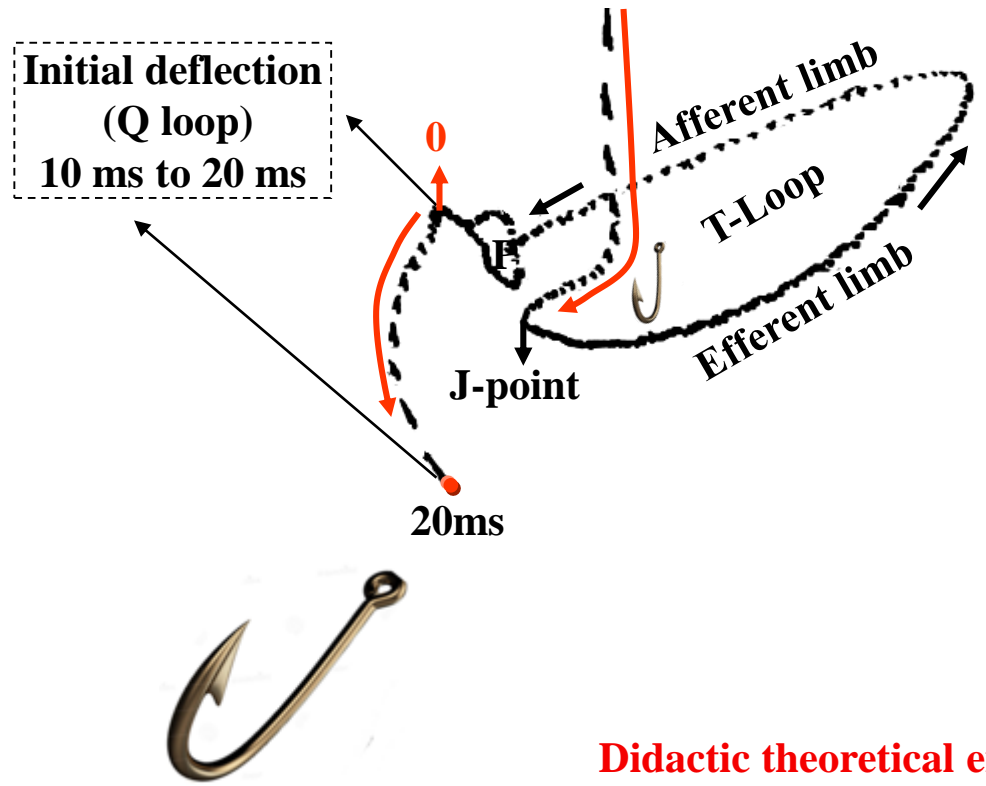
Malignant versus benign early repolarization pattern

	Malignant ERP	Benign ERP
Resuscitation from cardiac arrest or documented VF	Yes, very suggestive	Asymptomatic
Positive Family history for SCD in Young relative	Possible	Absent
Sinus bradycardia	No	It is the rule
Axes of QRS, ST segment and T wave	Frequently discordant	Oriented to the same direction
Mirror or reciprocal image	Frequently in several leads	Only aVR
Transient augmentation of J waves	Characteristic	Absent
Short coupled PVCs	Frequently	Absent
Co-existing channelopaties such as BsS, SQTS, idiopathic VF, overlapping syndrome, canceled form of ARVC/D	Frequently	No
ST segment elevation	Frequently > 2 mm	Usually < 2 mm
Widespread J waves in inferior and lateral leads and/or globally across leads	Strong signal	No
J waves convex upward or lambda wave pattern	It is the rule	ST concave upward followed by T waves of great voltage and polarity matching QRS
J waves in the inferior leads	Also present	Possible
J waves in lateral leads, tall R waves, rapidly ascending ST segments	No	Characteristic

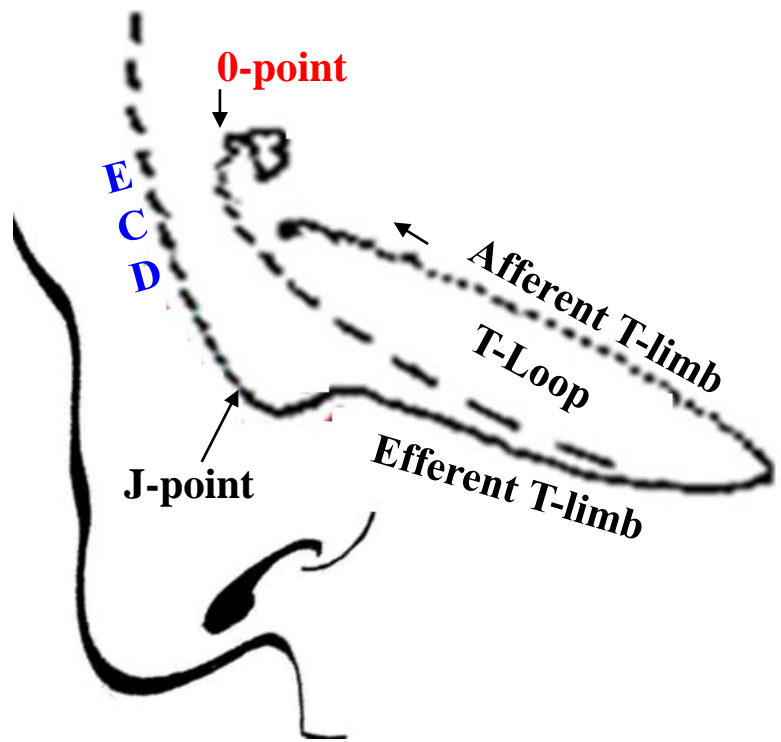
Vectorcardiographic differentiation between early repolarization located on anteroseptal leads and the type 1 Brugada pattern: Pastore's signals: “fish-hook” versus nose signals (**Pastore 2016**)

Partial view of Vectorcardiogram in Horizontal plane or Transversal plane in ER and Brugada type 1

Early repolarization



Brugada type 1

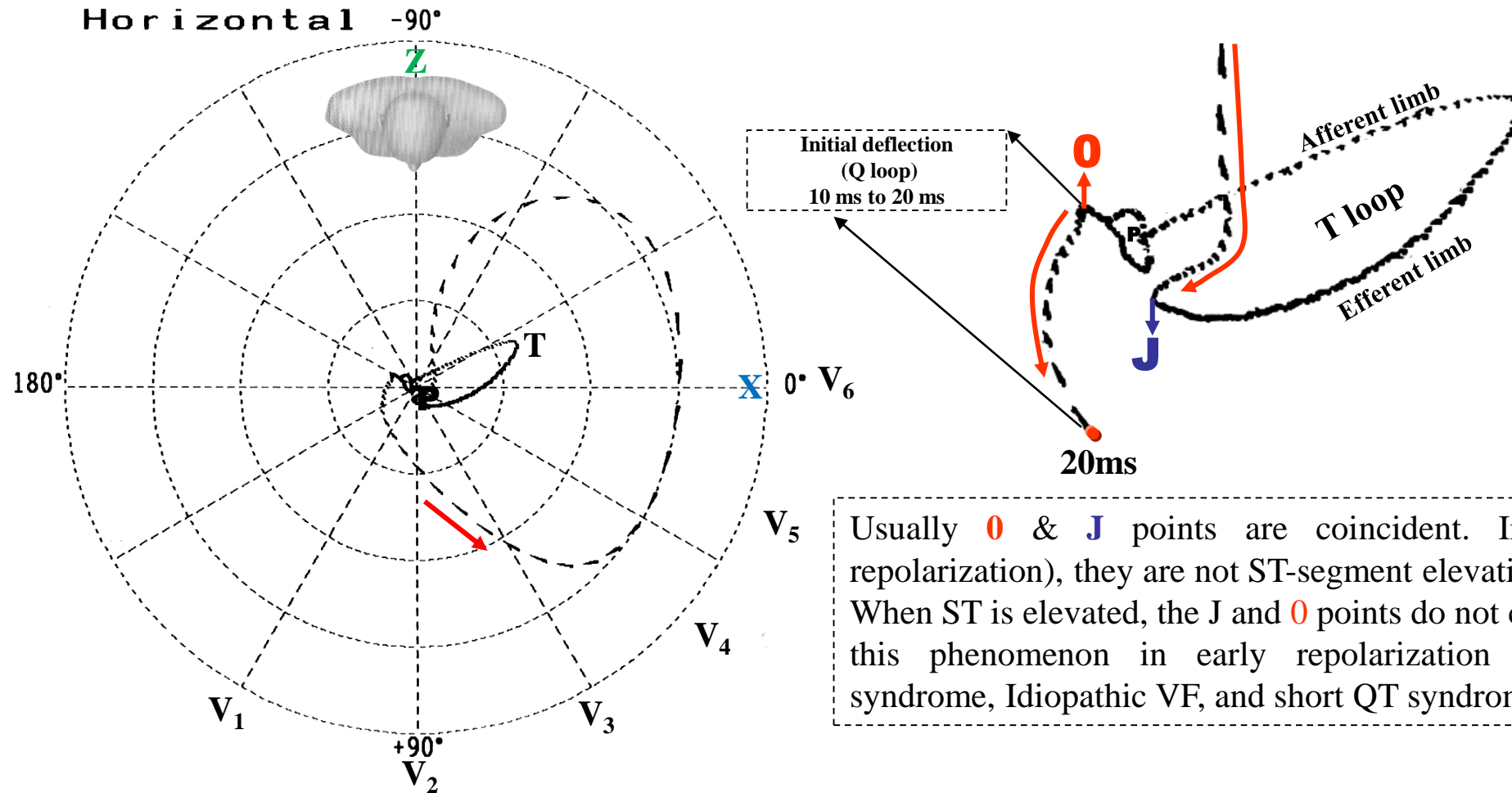


Didactic theoretical explanation in the following slides

The end of QRS loop in the Horizontal plane has “fish-hook” shape (see next slide)

The end of QRS loop in the Horizontal plane has “nose” shape and end conduction delay **ECD**)

VCG horizontal plane correlation



O point: it corresponds to the end of biatrial chamber activation, QRS loop onset (because PR segment does not exist, it is only a point) and the end of ventricular repolarization (T loop).

J point: in vectorcardiography, it corresponds to 3 elements: end of ventricular depolarization (QRS complex); beginning of repolarization (ST segment) when it does not present depression or elevation, and T wave onset.

In vectorcardiography there are 3 basic points:

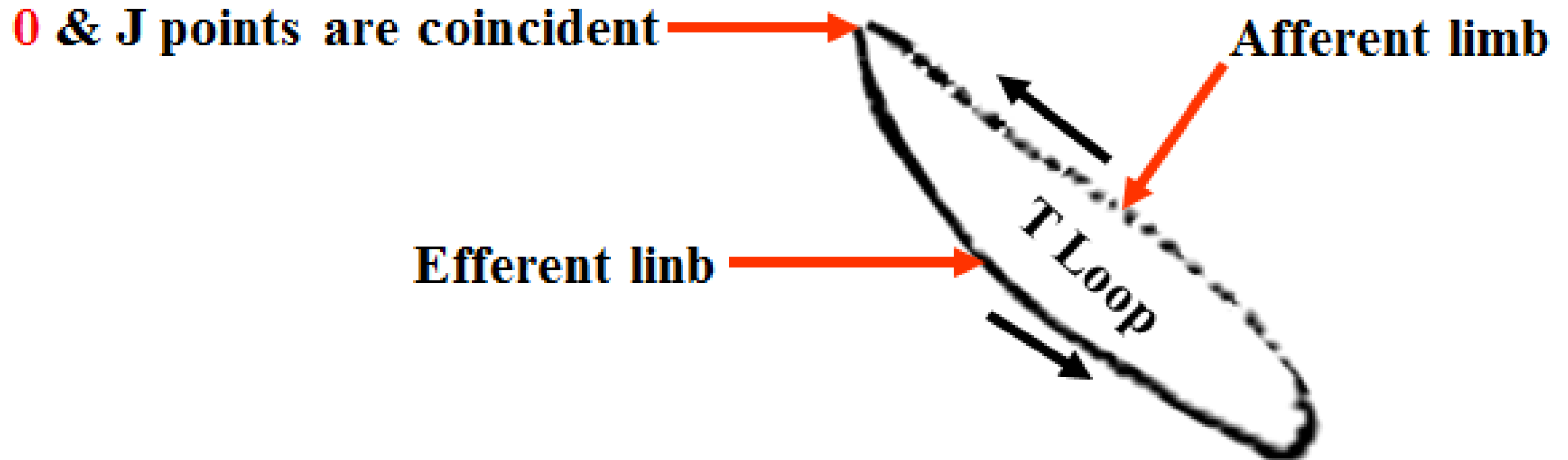
- 1) E point;
- 2) 0-point;
- 3) J-point.

- I. **E point:** it is the point that indicates the onset of heart activation in the superior portion of the right atrium (sinus node). In this point, the intersection of three vectorcardiographic orthogonal leads occurs (X, Z and Y).
- II. **0 point:** it corresponds to the end of biatrial chamber activation, QRS loop onset (because PR segment does not exist, it is only a point) and the end of ventricular repolarization (T loop).
- III. **J-point:** in vectorcardiography, it corresponds to 3 elements: end of ventricular depolarization (QRS complex); beginning of repolarization (ST segment) when it does not present depression or elevation, and T wave onset.

*In situations where there is depression or elevation of ST segment, **the J-point** does not coincide with **the 0-point**, and the greater or lesser distance between both points indicate the greater or lesser ST segment elevation or depression.* This phenomenon is observed in **early repolarization, acute phase of STSE myocardial infarction, variant angina or Prinzmetal angina, acute pericarditis, Brugada syndrome, idiopathic ventricular fibrillation, congenital short QT syndrome, canceled forms of arrhythmogenic right ventricular cardiomyopathy/dysplasia, etc.**

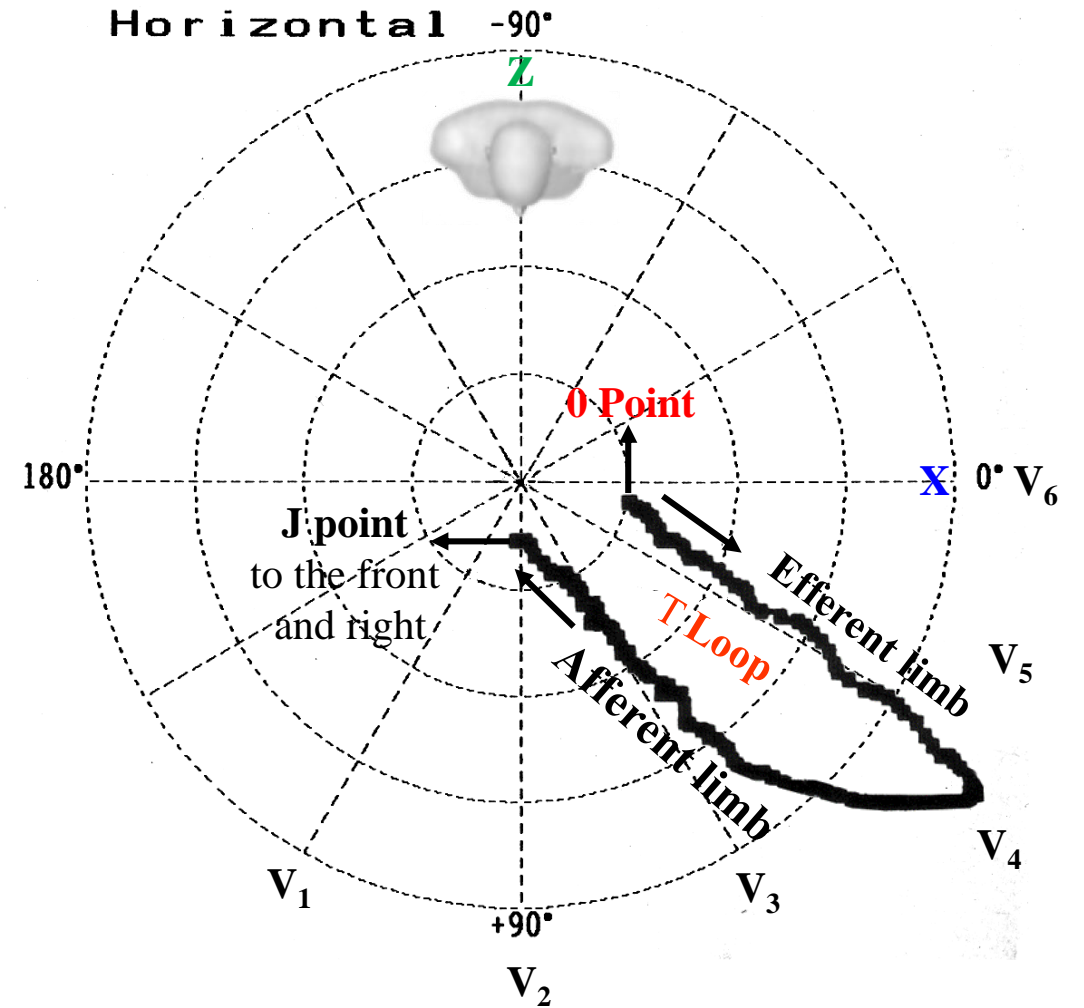
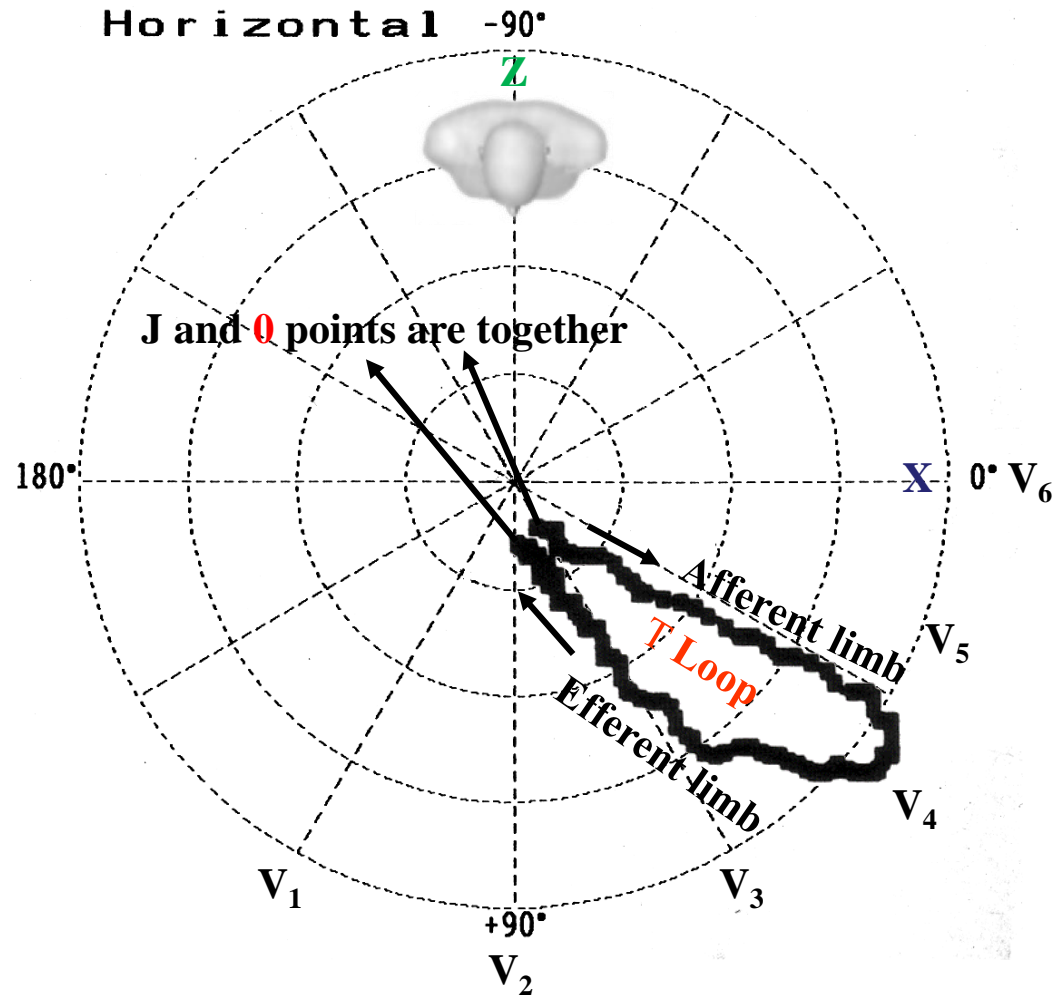
Characteristics of the T loop regarding morphology, magnitude of maximal vector, rotation, recording velocity of efferent and afferent limbs, location and QRS/T angle

- I. **Morphology:** it tends to be elliptic;
- II. **Magnitude of maximal t vector:** this is obtained from the 0 point up to the farthest point of the T loop. The maximal normal magnitudes in the three planes are: FP: 0.75 mV.; HP: 0.75 mV.; RSP: 0.70 mV.
- III. **Rotation: FP: variable:** clockwise or counterclockwise.; HP: counterclockwise exclusively. Clockwise rotation in this plane indicates heart disease.; RSP: clockwise. LSP: counterclockwise
- IV. **Velocity of recording of its efferent and afferent limbs:** the efferent limb is always recorded more slowly than the afferent one;
- V. **Location:** usually, left and inferior, and to the front in adults. **FP:** in left inferior quadrant.; **HP:** in left anterior quadrant.; **RSP:** in anteroinferior quadrant.
- VI. **QRS/T Angle:** $< 75^\circ$. Usually smaller in the FP than in the HP.



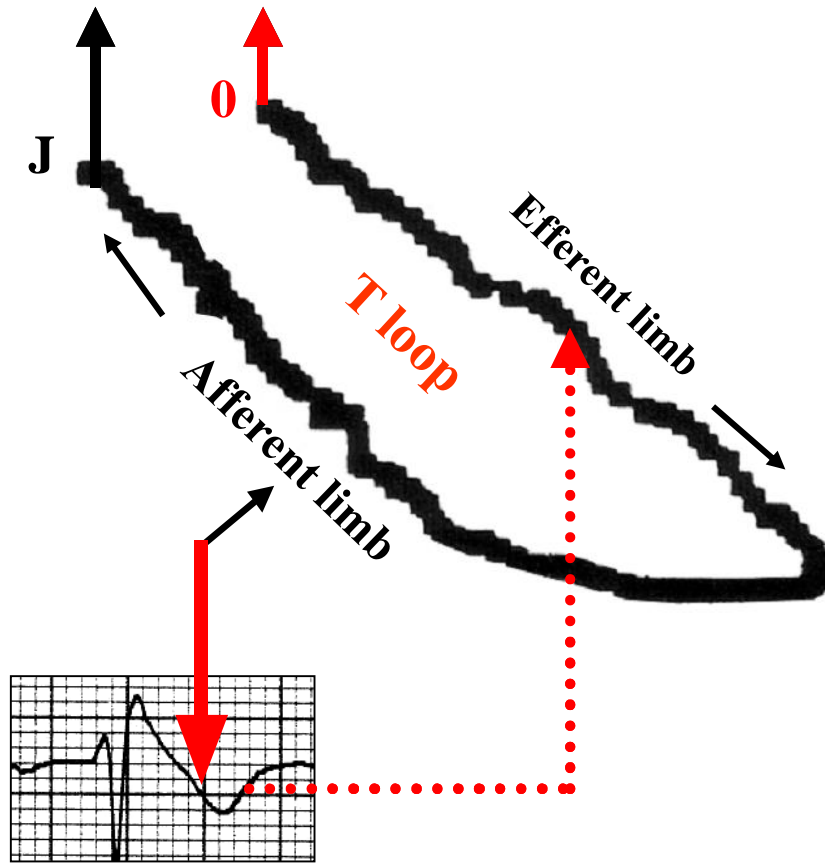
T Loop Characteristics of **0 point** and J point with the ST segment either normal or presenting elevation or depression

When ST is elevated, the J and 0 points do not coincide



Meaning of the distance between the 0 and J points of the T loop

The distance between the 0 and J points is proportional to the degree of ST segment elevation



Conclusion: the greater the distance between the two points, the greater the elevation or depression of the ST segment.

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