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MULTIPOLAR MAPPING IN THE MANAGEMENT OF DIFFERENT ARRHYTHMIAS

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This article brings together the opinions of leading experts in the field of cardiac arrhythmia interventional treatment using multipolar mapping. The advantages and applicability of the PENTARAY® NAV eco mapping catheter are discussed in detail.

Key words: experts opinion; multipolar mapping; catheter ablation; substrate mapping; atrial fibrillation; atrial tachycardia; ventricular tachycardia; ventricular premature beats; electroanatomic navigation; radiation exposure

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Interventional treatment of arrhythmias is one of the fastest growing areas in cardiology.An increasing number of centers and clinics around the world are installing navigation systems to perform catheter ablations (CA) of arrhythmia substrate, and operator training is underway. In parallel, improvements in 3D navigation systems, mapping electrodes and CA continue. Modern mapping systems recreate a 3D reconstruction of the heart and its individual chambers, allow to determine the location of catheters, form color-coded activation and voltage-coded maps with marking of areas of interest.

Multicontact electrodes were introduced as early as the 1990s for the treatment of supraventricular tachycardia [1], but they became more widely used in the 2000s with the advent of three-dimensional navigation systems and electroanatomical mapping. The most widely used navigation systems are CARTO®3 (Biosense Webster), EnSite NavX and EnSitePrecision® (Abbott), Rhythmia HDx (Boston Scientific). The CARTO®3 system (Biosense Webster) provides multicontact mapping with the 20-pole *PENTARAY® NAV* eco mapping electrode, the EnSite NavX and EnSitePrecision® system (Abbott) with the 16-pole AdvisorTM HD Grid mapping electrode, and the Rhythmia HDx system (Boston Scientific) with the 64-pole INTELLAMAP ORION™ mapping electrode. When compared to point-to-point mapping, multicontact mapping has a number of advantages. Among them: high resolution, which determines the degree of heterogeneity in low-amplitude areas, fast mapping time, more likely stimulation with capture of target myocardial areas.

Fig. 1. PENTARAY® NAV eco multicontact catheter.

Despite the availability of a large number of clinical guidelines and other official documents of professional communities in the field of catheter treatment, constantly updated scientific data and rapid progress of CA technologies dictate the need to formulate certain aspects of treatment in expert opinions. Since it is not possible to conduct randomized controlled trials on absolutely all aspects of interventional treatment, it is important to update and harmonize expert opinions on individual issues.

Currently, in the scientific literature one can encounter the name of the technique of electrophysiological and/or electroanatomical mapping of myocardium and arrhythmias using electrodes equipped with more than four contacts: multipole, multicontact, high-density mapping, etc. Any of these definitions has significant limitations because it does not reflect the full essence of the approach - the use of several or multiple (i.e., more than two) pairs of electrodes for bipolar and/or unipolar recording of myocardial tissue electrical potentials simultaneously over some area of its surface, as well as automatic processing of these signals, their interpretation and automatic color coding.

Manufacturers use different aspects of registration (number and size of contacts, geometry of their location, distance between contacts, vector of potential registration, etc.), moreover, each mapping system uses its own methods of filtering and processing of received signals. Thus, in many respects, multicontact electrodes from different manufacturers are not fully comparable. The frequently used term «high-density» mapping is not clearly defined, as there is no common understanding of the «density» of mapped activity recording points to distinguish between «low-density», «medium-density» and «high-density» types of mapping. Therefore, the authors herein have agreed on the use of the term «multicontact mapping» to describe the process of intracardiac navigation, mapping, and processing of electrical signals obtained from catheters equipped with more than four contacts for electroanatomical mapping. Despite the natural limitations of the term's use, a more appropriate one cannot be suggested at this time.

An expert seminar was held on May 31, 2023 (Moscow) to discuss topical issues of multicontact mapping, its application in the treatment of various tachyarrhythmias. This document reflects the main results of the workshop and the agreed position of the experts regarding the terminology of modern invasive mapping, the advantages of multicontact mapping, and its application in selected atrial and ventricular arrhythmias.

Advantages of multicontact catheters over conventional 4-pole catheters in arrhythmia substrate mapping

The resolution of activation and voltage reconstruction of the heart chamber is affected by the electrode size and the distance between these electrodes. The smaller the electrodes and the distance between them, the more informative will be the area of registered pathologic activation, especially in the scar area. The mechanism of tachyarrhythmias is often related to slowed electrical conduction in preexisting or iatrogenic scar tissue.

Until recently, the main mapping tool for complex tachyarrhythmias was the standard 4-pole linear catheter (most commonly, the distal contact size is 3.5 or 4 mm, the second, third, and fourth contacts are 2 mm each; the standard contact spacing is 2 mm, resulting in a distance between electrode centers of 4.75 mm). A bipolar signal is recorded between two neighboring contacts. Unipolar - between the distal contact and a reference electrode on the body surface (most often conventional ECG electrodes). As the interelectrode distance increases, the average peak-to-peak signal increases and more far field signals are detected by the catheter. This reduces the possibility of distinguishing the local signal (near field) from the electrical signals of distant myocardial regions. Therefore, the ideal electrode is an electrode with a minimum contact size and minimum contact spacing, at which the possibility of registering signals of sufficient amplitude is preserved. The experiments show that at the contact size of 1 mm and contact spacing from 1 to 2 mm, optimal visualization of potentials from myocardial areas with impaired conduction velocity, which is characterized by multicomponent (fragmented) electrograms and late potentials, is observed. In most cases of so-called substrate tachyarrhythmias, operators are interested in areas of myocardium with low amplitude of electrical activity, reflecting a disorder of myocardial architectonics with fibrosis or other changes (fatty replacement, amyloid protein, and others). Often the zones with low-amplitude signals are characterized by the presence of multicomponent potentials (fragmented, double, late), which has been called

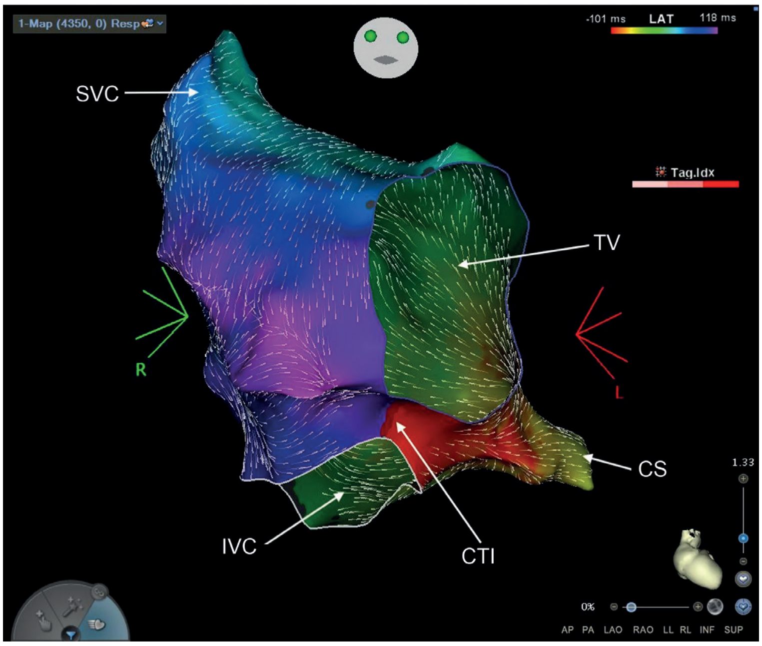

Fig. 2. Three-dimensional electroanatomical map of the right atrium (CARTO®3 system, Biosense Webster, Johnson and Johnson, USA). Anterior projection with caudal angulation of 20°. Visualization of electrical activation of typical cavotricuspid atrial flutter using the Coherent (coherent mapping) software module. Hereinafter: SVC - superior vena cava, IVC - inferior vena cava, TV - tricuspid valve, CTI - cava-tricuspid isthmus, CS - coronary sinus.

local anomalous activity. The advantage of multicontact catheters in diagnosing such zones of electrical activity is obvious, because due to the design features of a standard 4-pole catheter, the resolution of the voltagecard is reduced and low-amplitude signals important for analysis may be missed.

Studies have shown that the use of a multicontact catheter is a more effective tool for mapping the low-amplitude region with a higher density of recorded endograms [2]. The present paper focuses on one commonly used variant of multicontact mapping electrodes, the PENTARAY (*PENTARAY® NAV eco*, Biosense Webster, Inc, USA); the electrode has five beams (splines) with a diameter of 3Fr, each fitted with 4 1mm electrodes, inter-electrode spacing of 2-6-2mm. Electrograms are recorded at one time over 7 cm² of myocardial surface area (Fig. 1). In animal studies [3], the benefit of low-amplitude mapping in postinfarction reciprocal ventricular tachycardia (VT) [4] and reduced mapping time in VT [5] compared to standard catheterization have been demonstrated. Mapping with *PENTARAY® NAV eco* provides higher mapping density and better (optimal) substrate detection, higher detection of low-amplitude altered signals and electrical conduction channels within scar areas, by reducing the probability of detecting far-field signals and enhancing local signals.

Radiofrequency (RFA)/cryoballoon CA is an established treatment modality for patients with symptomatic paroxysmal/persistent forms of atrial fibrillation (AF). One frequent variant of recurrence after RFA of AF is recurrent AF associated with recovery of electrical conduction from pulmonary veins (PV), and/or concomitant atrial tachycardia (AT). According to various studies, the incidence of AT development after AF ablation ranges from 3 to 29% [6]. AT may present with more severe symptoms than primary AF and in most cases requires repeat CA. Atrial tachycardia after AF ablation can occur with different mechanisms: macro re-entry or focal (local automatism). Electrophysiologic tools for AT ablation most commonly include mapping of

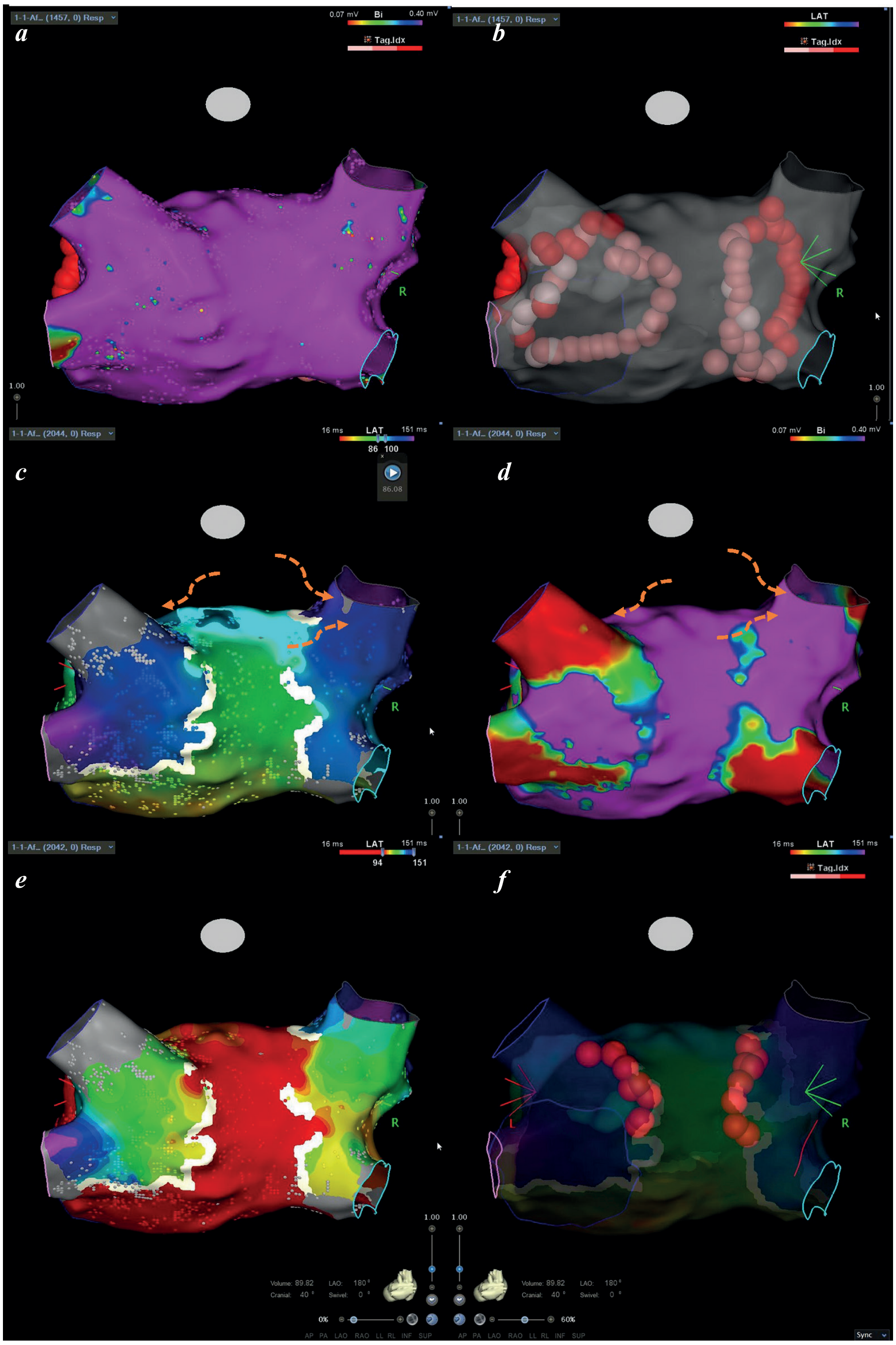

Fig. 3. Left atrium (LA), posterior projection, where a - bipolar map of LA built on atrial stimulation from coronary sinus before application of actions (purple color characterizes normal amplitude of electrical activity); b - anatomical map of LA with applied RF current actions around pulmonary vein mouths (red and pink dots); c - activation map of the LA, built on atrial stimulation from the coronary sinus, after primary ablation around the pulmonary veins (it is obvious that electrical activity in the pulmonary veins is preserved, dotted arrows show probable places of residual electrical conduction from the atrium to the pulmonary veins); d - bipolar map of the PV after primary PV isolation (dotted arrows show probable locations of electrical conduction in the LV); e - isochronous map of the PV constructed on coronary sinus stimulation after primary ablation around the PV auricles (in manual mode, the LAT scale is adjusted to better visualize LV conduction sites); f - activation map of PV built onatrial stimulation from the coronary sinus after additional influences (red dots), conduction blockade in PV.

the circle of re-entry using three-dimensional electroanatomic mapping systems.

The traditional mapping method is based on recording electrograms using a single pair of electrodes, according to a selected intracardiac reference (usually a diagnostic catheter in the coronary sinus). However, this method can be complex and time-consuming due to point-to-point mapping or if there are multiple consecutive circles. Another method is the use of a circular diagnostic electrode equipped with nephluoroscopic navigation capability with signal visualization [7].

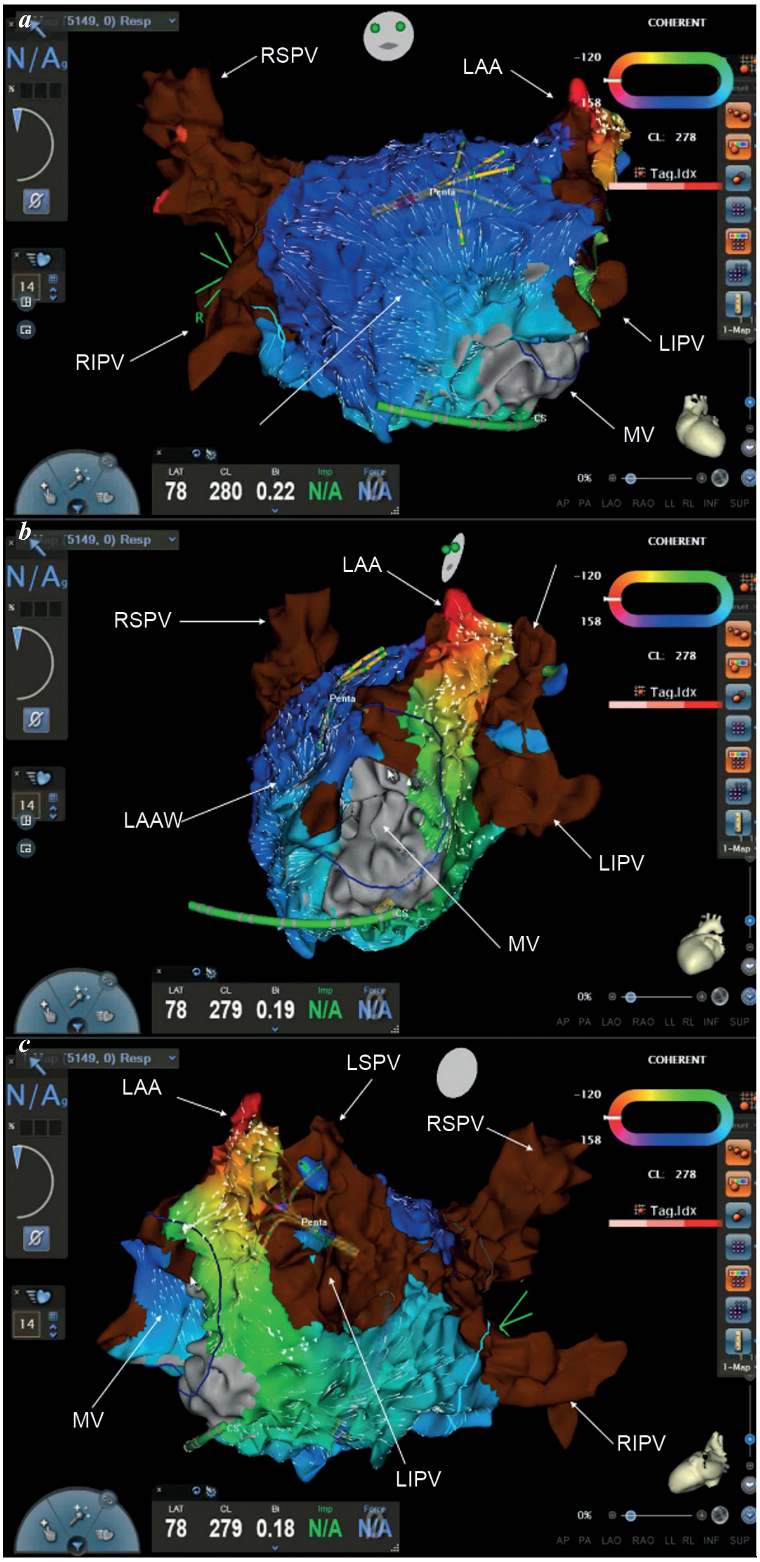

Fig. 4. Electroanatomical map of the left atrium (LA) in Coherent mode against the background of atypical atrial flutter involving the LA appendage and the anterior wall of the LA (CARTO® 3 system), where the critical zone of the re-entry cycle is at the mitral valve annulus in the area of failed previous linear ablation (brown line connecting the LA roof and mitral valve annulus): a - anterior projection, b - left lateral projection, c - posterior projection.

Multicontact mapping of complex A'T, including in patients with corrected congenital heart disease, when compared with point-to-point mapping, has been associated with decreased procedure time in general and fluoroscopy time in particular [8]. Shorter CA procedures require less anesthetic agent, which is also of value in comorbid patients, and in patients with low left ventricular (LV) ejection fraction.

Multicontact catheters in reducing procedure time

In 1999, using a 4-pole electrode and the CARTO® system on porcine heart, Callans et al. demonstrated the relationship between electrophysiological and anatomical changes in the scar after myocardial infarction, which became the basis for the development of «anatomically»-oriented approaches to ablation of VT substrate [9]. In these early experiments, between 77 and 100 endogram points were labeled. In 2008. Patel et al. first demonstrated the use of a five-spline catheter for rapid mapping of left atrial flutter (AFt) [10]. In 2011, Koruth et al. showed that a map of the left atrium (LA) and LV constructed with a multicontact catheter is reasonably accurate and provides similar size and geometry information to that obtained with CT [11]. In 2014, multicontact mapping was incorporated into the CARTO® magnetic-based system. The ability to register more than 8000 points in multicontact mapping was further demonstrated [12]. This increased both anatomic and electrophysiologic resolution and resulted in a decrease in the time required to find the substrate of arrhythmias.

A comparison of multicontact mapping using the special mapping catheter *PENTARAY® NAV eco* and conventional mapping techniques in the context of AFt ablation and AT occurring after AF ablation was among the first to be performed by Bun et al [6]. In their work, the mean value of recorded points with the multicontact catheter was 449±520 over 14±6 min compared to 42±18 points ($p<0.0001$) over 33±25 min ($p=0.04$) in the control group. In the multicontact catheter group, areas of electrical deceleration were easily identified and eliminated with tachycardia management compared to 20/23 (87%) in the control group ($p=0.056$). Mean CA time was shorter in the *PENTARAY® NAV eco* group (760±540 vs. 1347±962 s; $p=0.037$). Recurrence occurred in significantly fewer patients in the *PENTARAY® NAV eco* group (0 vs. 23.5%; p=0.033) during the one-year follow-up. These results led to the conclusions that multicontact catheter mapping was faster in patients with AT than with conventional techniques, with shorter radiofrequency exposure time and better mid-term outcome.

However, it was noted that the duration of the procedure and fluoroscopy was not significantly different between the two groups: 253±77 in the *PENTARAY® NAV eco* group vs. 267±73 min in the control group (p=0.80) and 13.1±8.0 min vs. 15.1±10.0 min (p=0.98), respectively. Possible reasons for this result could be: lack of randomization and selective inclusion of patients (significant proportion of individuals with PV re-entry in the multicontact mapping group [7 vs. 4 in the control group]), as well as a large number of variants of re-entry tachycardia in the same patient.

Some of the authors of this paper started to master the functions of multicontact mapping using the *PENTARAY® NAV* eco catheter with isthmus-dependent right atrial flutter, when the mechanism and anatomical localization of the tachycardia cycle - around the tricuspid valve annulus - are known in advance. This allowed to practice the skill of building activation maps, to make sure that the proposed places of influence coincide with those displayed on the three-dimensional map. These skills were subsequently transferred to left atrial flutter. Fig. 2 shows an example of right atrial flutter mapping (4350 mapping points obtained in 2 minutes).

Multicontact catheters in improving ablation efficiency

Multicontact catheters are now widely used to improve visualization of the anatomic and electrophysiologic substrate in the interventional treatment of AF. Mapping can be performed both on sinus rhythm and on AF The main advantages of multicontact electrodes over standard electrodes have been shown in several studies [6, 8]. Thus, in Bun et al. [6] demonstrated that in patients with AT and atypical AFt the use of such an electrode shortens the mapping time, reduces the number of exposures and improves long-term results.

In general, the increase in the efficiency of interventional procedures for the treatment of AF using multicontact electrodes was possible due to a number of advantages compared with the standard technique: Rapid construction of the LA anatomy [6], optimization of the construction of the LA voltage map to determine the electrical isolation of the PV auricles and mapping of low-amplitude signal areas [4, 11, 13], mapping of complex fragmented atrial electrograms (CFAE) [14], mapping of areas of spatiotemporal dispersion [15], activation mapping of atypical AFt and AT [16].

In addition to atrial rhythm disturbances, multicontact electrodes are also widely used for the treatment of ventricular arrhythmias (VA). These catheters are widely used in the treatment of both VA in structural heart disease and non-structural heart disease. Increased efficiency of interventional procedures has become possible due to a number of advantages: ablation of VA after high-resolution voltage mapping and with the use of modern software reduces procedure time and complications [17, 18], VA ablation with the use of multicontact electrodes reduces the rate of implantable cardioverter-defibrillator activation, the rate of hospitalizations due to VA and the rate of electrical storm development [19].

It is well established that ablation of the VA substrate is effective in an overwhelming number of cases [18]. However, the detection of localized abnormal electrical activity depends on the hardware and software used, and a limited substrate area cannot always be identified when recording with a 3.5 mm tip catheter [19]. In turn, the use of smaller electrodes used in multicontact systems increases the ability to identify anomalous low-amplitude, fragmented, late signals [20].

Multicontact catheters in reducing radiation exposure

To date, fluoroscopy continues to be used as the primary imaging tool during electrophysiologic studies and catheter ablation of arrhythmia substrate, but there is a significant radiation burden on both patient and staff [21]. The main complications of systematic radiation exposure include cataract, the risk of which is almost 50% (in the absence of special protective glasses), leukopenia, diseases of the reproductive system, thyroid gland; increased risk of cancer [22].

According to previously reported data by H.Heidbuchel et al. (2014), the average radiation exposure during the performance of RFA of AF is 16.6 mSv (from 6.6 mSv to 59.6 mSv) [21]. It should be noted that a dose of 1 mSv is equivalent to 50 X-rays, and 30 mSv is the average radiation dose received by evacuated residents of Chernobyl after the nuclear power plant disaster.

The introduction of electroanatomic nephluoroscopic mapping has significantly reduced the radiation burden on both the patient and the surgical team. In addition, the key point in the use of navigation mapping is to achieve greater ablation efficiency due to more accurate visualization of areas of low-amplitude, inhomogeneous electrical activity, the front of excitation propagation [23-25].

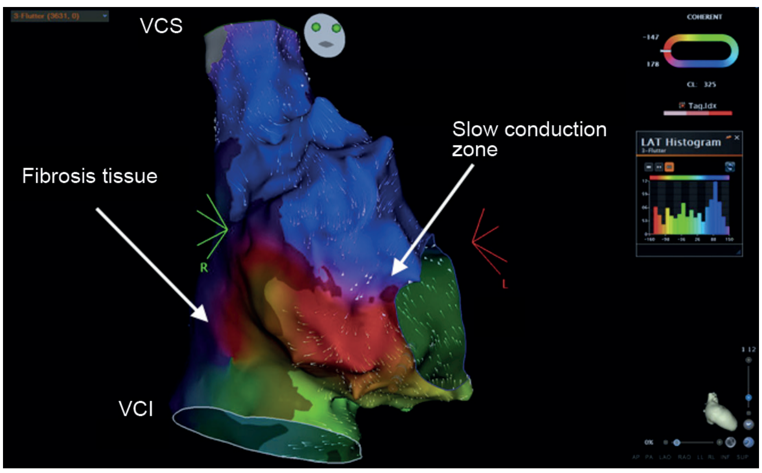

Fig. 5. Electroanatomical map of the right atrium (CARTO® 3 system, Coherent module): atypical right atrial flutter on the free wall in a patient after open heart surgery.

CARDIAC ARRHYTHMIAS

Primary ablation of atrial fibrillation

The use of multicontact mapping during primary procedures has a number of practical advantages: in some cases, it is possible to use only one transseptal introdoser in the LA; faster construction of anatomical and electrophysiological map of the LA (3-7 minutes on average); if it is necessary to visualize the effect of ablation (isolation of PV or separate atrial zones) - rapid re-mapping of target zones. Repeated voltage and activation mapping is performed quite quickly and easily reveals areas of residual electrical conduction (Fig. 3).

In a study of primary radiofrequency PV isolation in 700 patients, the presence of low-amplitude myocardial zones (an indirect sign of fibrosis) in the LA proved to be a significant independent predictor of arrhythmia recurrence, and was also associated with lower left ventricular ejection fraction, larger LA size, and increased levels of circulating inflammatory markers [26].

Repeated atrial fibrillation ablations

Recurrence of AF after CA is not uncommon. The success rate (i.e., no recurrence of arrhythmias) of a single procedure of AF ablation is 55-85%, whereas 20% of symptomatic patients may require repeat ablation. Performing repeat ablation increases the probability of sinus rhythm retention to 90%. The decision to repeat CA is based on an assessment of risk and benefit to the patient. Thus, some patients may be offered drug antiarrhythmic therapy to reduce the severity of symptoms in case of arrhythmia recurrences [27, 28].

The frequency of arrhythmia recurrence is higher in initial persistent AF. In patients with chronic forms of AF (occurrence of AF recurrences after the «blind period»), both tissue remodelling of atria on the background of long-term arrhythmia, i.e. replacement of atrial myocardium by fibrous tissue and fatty infiltration [29], and electrical remodelling consisting in anisotropy of electrical conduction underlie the failure of AF CA. The above leads to the progression of AF and the transition of paroxysmal form of AF to persistent, the «trigger» mechanism of arrhythmia initiation to the «substrate» mechanism of its maintenance.

Because rhythmic atrial tachycardia is not uncommon after CA of AF (either as an initial «concomitant» arrhythmia or as a consequence of the ablation itself with areas of nontrasmural damage), the increase in CA of AF has led to an increased occurrence of AT. The most frequent types of postablation tachycardias include perimitral re-entry, re-entry with conduction in the roof of the LA and in the interatrial septum [30, 31].

On this basis, in some cases PV isolation may be insufficient to preserve sinus rhythm and prevent further recurrences of tachyarrhythmias, modification of the arrhythmic substrate in the LA outside the PV aperture becomes necessary.

Several studies have examined the contribution of additional ablations of arrhythmia substrate outside the PV aperture on the recurrence rate of tachyarrhythmias. For example, in the prospective, multicenter DECAAF II trial, patients with persistent AF were randomized into two groups, where the first group of patients, in addition to PV isolation, also underwent off-PV substrate modification based on magnetic resonance imaging (MRI) with delayed gadolinium contrast. At long-term follow-up, there were no differences between groups in the incidence of AT recurrence (hazard ratio 95%, confidence interval: 0.95 (0.77-1.17), p=0.63). The authors of the study concluded that MRI guided ablation of areas of «fibrosis» in the LA is not appropriate [32]. It is thought that the results may have been influenced by the fact that the decision on the amount and method of ablation was made by the operator and the approach to ablation for the same level of fibrosis was not uniform.

In contrast to the results of this study, other authors have shown that modification of the LA substrate based on isolation of low-amplitude activity zones (voltage-oriented ablation) was associated with a lower risk of arrhythmia recurrence, even without antiarrhythmic drug therapy [33]. Of note, modification of the LA substrate was performed based on the results of electroanatomic mapping, with isolation of low-amplitude zones (signal amplitude <0.5 mV). On the other hand, empirical ablation with isolation of wide zones in the LA of initially normal electrical activity can lead to a significant deterioration of contractility and extensibility (pliability) of the LA, becoming the basis for the development of the syndrome of «rigid LA». This is accompanied by an increase in pressure in the LA as well as in the pulmonary artery, leading to the development of a difficult-to-cure dyspnea syndrome [34]. Another undesirable aspect of extended ablation may be inadvertent isolation of the auricle of the LA, leading to a dramatic slowing of its blood flow velocity and accompanied by an increased risk of thrombosis. In such a case, there is a question of occlusion of the LA auricle with special devices, so it is advisable to refrain from routine electrical isolation of the LA auricle.

Multiple AT are a separate problem in repeated CA in patients with AF. In some cases, such AT are difficult to entrainment- and activation-mapping. In multiple tachycar-

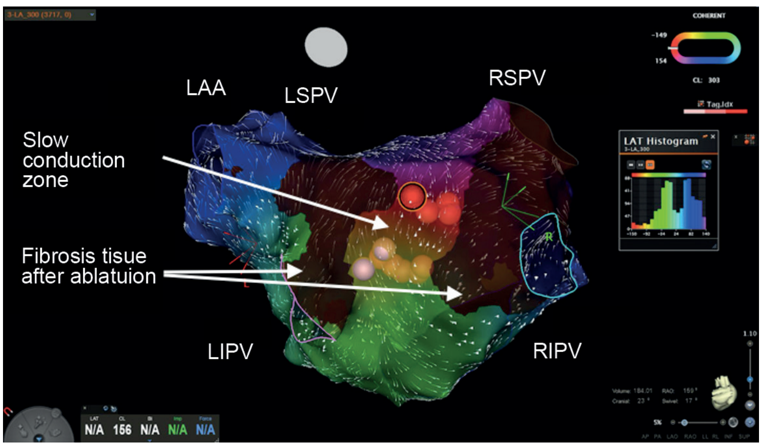

Fig. 6. Electroanatomical map of the left atrium, posterior projection (CARTO 3 system, Coherent module): atypical left atrial flutter after extended antral isolation of the pulmonary vein (brown color indicates areas of no electrical activity).

dias, multicontact mapping can meaningfully speed up the process and provide more reliable information about the mechanisms of each of the tachyarrhythmias present. However, performing additional linear ablations should be approached with caution because it may already lead to iatrogenic arrhythmias. Cases have been described in which ablation of the anterior wall of the LA resulted in the development of complex biatrial tachyarrhythmias [35, 36], the mapping of which is even more challenging. First, 3D reconstruction of both atria is required in this case. Second, it is not always possible to perform mapping of the complete re-entry cycle because part of the cycle is outside the endocardial surface - for example, in the Bachmann bundle [37-39].

Persistent atrial fibrillation

Although electrical isolation of PV orifices is a key stage of AF CA, the recurrence rate of persistent arrhythmia remains quite high despite the improvement of ablation catheters and the emergence of new CA technologies [40-42].

The following have been proposed as approaches to further modify the arrhythmia substrate in persistent AF: ablation of complex fragmented atrial electrograms (CFAE), ablation of ganglionic plexuses, creation of empirical linear influences in the LA, and isolation of the posterior wall of the LA [32, 33, 43, 44]. However, according to randomized trials (STAR-AF II, CHASE-AF, SMAN-PAF), such approaches do not significantly improve ablation efficacy [45].

Another approach to modifying the arrhythmic substrate in persistent AF is to isolate areas of low-amplitude electrical activity. Again, detection of such areas becomes more accurate with the use of multicontact mapping catheters [46, 47].

In 2022, the results of a meta-analysis [46] combining the results of CA in 539 patients with persistent AF (269 with standard PV isolation, 270 with LV isolation with additional substrate isolation in the LA) were demonstrated. Extended ablation reduced the risk of arrhythmia recurrence (odds ratio 1.30; 95% confidence interval 1.03-1.64, $p<0.04$]. In another study, the authors performed multicontact mapping of atrial myocardium and confirmed the advantage of low-amplitude ablation combined with PV isolation over PV isolation alone [48].

Atypical atrial flutter

Atypical AFt include atrial re-entry tachycardias with an atrial cycle of 170-260 ms that differ on surface ECG from typical AFt (isthmus-dependent, counterclockwise circulation around the tricuspidal isthmus ring).

Atypical AFt occurs predominantly in patients with structural heart pathology, especially in those who have previously undergone thoracoscopic ablation or «open heart» surgery to treat AF and create linear influences - up to 13-15% [49-51]. Intensive development of RFA AF, the purpose of which is to create a scar in certain areas of the LA and sometimes the right atrium has caused the emergence of a significant number of patients with atypical AFt, the incidence is currently ranked from 3 to 30% [52, 53]. These arrhythmias are most often based on a macro re-entry mechanism. However, there may occasionally be cases of simultaneous coexistence of focal and macro re-entry mechanisms, greatly complicating the interpretation of surface ECG. In such cases, the mechanism of atypical AFt formation and the front of atrial myocardial activation can be established only by means of a detailed electrophysiologic study, including endo- and sometimes epicardial electroanatomic mapping, including stimulation tests.

The purpose of this is to identify the critical isthmus in the re-entry loop for subsequent radiofrequency application in this area and arrhythmia management. However, even with the use of a 3D navigation system and standard diagnostic catheters, it is not always possible to determine the mechanism of AFt. Sometimes the cycle of tachycardia can be erratic, or there may be two or even more. In some cases, part of the loop may be localized epicardially [54]. The advent of navigation multicontact catheters with short interelectrode distances (e.g., *PENTARAY® NAV eco*) makes it possible to record significantly more endograms per unit time, speeding up and facilitating the construction of the electroanatomical map. However, the key advantage is more accurate target identification for subsequent CA: areas of heterogeneous scar, areas of slow pulse conduction (low-amplitude fragmented potentials). Such signals could not always be detected with routine diagnostic, much less ablation catheters.

The design feature of the new diagnostic tools contributed to a decrease in the number of «unmapped» atypical AFt compared to the use of «standard» catheters [55]. This, in turn, led to an increase in the effectiveness of CA of atypical AFt in the acute period on the one hand, and a decrease in the number of arrhythmia recurrences in the distant postoperative period on the other hand. When performing linear atrial interventions, the single-stage use of multicontact catheters to verify the reliability of radiofrequency interventions can reduce the number of so-called «pseudo-blocks» of pulse conduction up to 30%, which are the cause of arrhythmia recurrence [56].

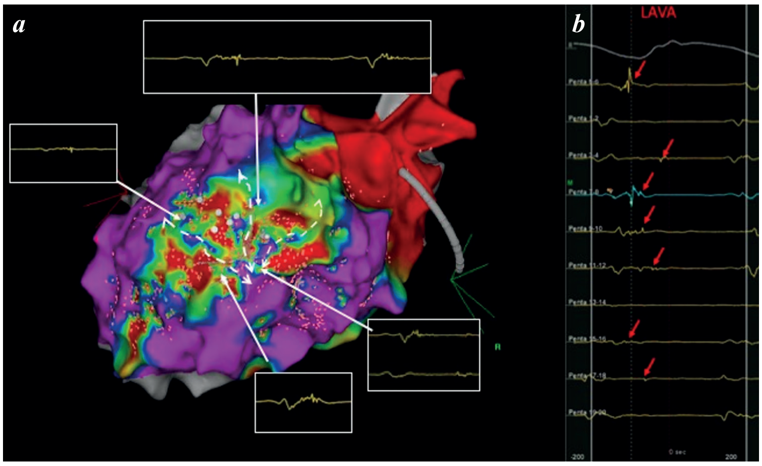

Fig. 7. Voltage mapping in ventricular tachycardia: a - voltage reconstruction of the left ventricle (low-voltage area (postinfarction scar) identified on the lower wall, white lines indicate channels of delayed conduction propagation; b - abnormal ventricular signals (LAVA) in scar tissue.

Electroanatomic mapping using multicontact catheters is another qualitative step toward understanding the mechanisms of complex supraventricular tachyarrhythmias, including atypical AFt. In conjunction with the Coherent mapping algorithm (Fig. 4-6), a precision map of atrial myocardial activation can be obtained with clear visualization of the area of slowed activation where radiofrequency is to be applied to control the arrhythmia. The use of multicontact catheters makes it possible to significantly reduce the operative treatment time, avoid excessive impact on the atrial myocardium, and increase the efficiency of RFA of atypical AFt due to visualization of low-amplitude fragmented potentials, which previously could not be detected when using «routine» diagnostic catheters.

The advantages of multicontact mapping in the treatment of incisional arrhythmias and in macro re-entry AT are higher resolution mapping, which can identify heterogeneity of low amplitude areas by localizing channels with preserved signals; a catheter with closer electrode spacing is subjected to less signal averaging and compensation effects and thus can record a higher amplitude bipolar signal with a shorter electrogram duration.

Ventricular extrasystole

Ventricular rhythm disorders are one of the most common heart rhythm disorders. Catheter ablation is a highly effective and safe method for the treatment of ventricular extrasystole (VE) [57]. For right ventricular outflow tract VEs, ablation is considered the most effective, whereas the efficacy of treatment of left ventricular outflow tract VEs, papillary muscles, and epicardial VEs is lower, in part because of the anatomic variability and relative instability of the ablation catheter at these sites. Point-to-point VE mapping to identify the target ablation zone can be labor-intensive and operator-dependent.

The use of multicontact mapping, including with the *PENTARAY® NAV eco* catheter, allows for more accurate identification of the earliest zone of tissue activation for RFA. It should also be noted that the *PENTARAY® NAV eco* diagnostic electrode allows the use of modern algorithms for ventricular myocardial mapping [58-60]. By simultaneously recording 20 electrograms, multicontact mapping with the *PENTARAY® NAV eco* catheter can be applied during the procedure in cases of relatively rare VE.

Multicontact VE mapping reduces mapping time and overall procedure time, with equal efficiency to traditional mapping. In a study involving 136 patients randomized into multicontact and conventional mapping groups, the use of the former was associated with a reduction in mapping time (28±19 min vs. 49±32 min, $p<0.01$) and procedure time (110±33 min vs. 134 ± 50 min, $p<0.01$). While acute treatment efficacy (95.6% vs. 90.1%, $p=0.49$) and total adverse events (4% vs. 7%, $p=0.72$) did not differ between groups. Moreover, use of the *PENTARAY® NAV eco* catheter was found to be an independent predictor of long-term efficacy (hazard ratio 6.20 [95% confidence interval 1.08-35.47], $p=0.003$) [61]. Separately, 7 times more electrograms (768±728 vs. 110±79, $p<0.01$) were recorded with the multicontact catheter during the above mapping time, allowing for more precise ablations to be applied to treat arrhythmias.

Multicontact mapping was also highly effective in a series of clinical cases in patients with VE from left ventricular papillary muscles (difficult localization). It has been shown that applying only 6.8±1.9 applications over 6.1±3.0 min in this area was associated with high efficacy and the overall rate of VE among all patients over 8.5±2.0 months of follow-up was 0.7% [62]. It is hypothesized that although the total cost of the VE ablation procedure increases with the use of a multicontact catheter, the reduction in intervention time may allow more procedures to be performed.

Postinfarction ventricular tachycardia

Ablation of VT substrate in structural myocardial pathology is effective even in noninducible and hemodynamically unstable arrhythmia variants. Accurate characterization of the scar (the main arrhythmogenic substrate of VT) can be obtained by bipolar voltagecontrast mapping. Substrate-based ablation depends crucially on the detection of local anamoly ventricular (local abnormal ventricular activity (LAVA) within and at the periphery of the scar; such activity includes bipolar potentials with the following characteristics: multicomponent fragmented activity, low-amplitude activity (typically <0.5 mV), double and late potentials, and diastolic potentials (Fig. 7). Local abnormal activity in the background of sinus rhythm indicates slowing and inhomogeneity of electrical conduction and is often a critical zone of the re-entry cycle in the background of tachycardia.

Localized abnormal ventricular activity exhibits the following features: (1) sharp, high-frequency ventricular potentials distinct from the ventricular electrogram in the far field, (2) occurs during or (most commonly) after the ventricular far field, (3) as double or multiple high-frequency signals separated by very low amplitude signals or isoelectric interval. The key feature to confirm the presence of local abnormal activity and to distinguish them from far field is their relationship with the rest of the myocardium. If local abnormal ventricular activity that merges with distant ventricular field signals appears, stimulation maneuvers are performed to isolate them from the ventricular electrogram. Right ventricular stimulation sometimes reveals areas of abnormal activity that were not obvious against the background of sinus rhythm. Importantly, programmed ventricular stimulation can increase the latency of local abnormal activity from remote ventricular field signals, which is due to the electrophysiologic properties of the zones of local abnormal activity.

Multicontact mapping of scar and border zones is critical to the effectiveness of CA because it more accurately characterizes scar heterogeneity and allows for more precise identification of residual and delayed electrical conduction channels within the scar. The identification of slow conduction channels and local abnormal activity in the scar region depends on the spatial resolution of the electrode and can be «hidden» by the far-field signal during mapping with a standard electrode. Acosta J. et al. (2018) showed that using *PENTARAY® NAV eco* provided the best distinction of late potentials due to lower sensitivity to distant field signals compared to a standard catheter [63]. The use of the *PENTARAY® NAV* *eco* catheter significantly reduced the mapping and ablation time. It should be mentioned that the resolution of the voltage reconstruction also depends on the reliability of the electrode-tissue contact, which must be taken into account when performing the mapping. The CARTO® system uses Tissue Proximity Indication (TPI), a «tissue proximity indication» function, also active when the *PENTARAY® NAV eco* multicontact catheter is connected, to indirectly assess myocardial contact [64].

CONCLUSION

The main advantages of multicontact mapping are rapid and detailed reproduction of cardiac chamber anatomy in the navigation system, detailed characterization of the electrophysiologic substrate of tachycardias, rapid electrophysiologic identification of residual electrical conduction after ablation, and reliable verification of ablation lines.

The authors of this article unanimously agree that current data and clinical experience demonstrate the advantage of multicontact mapping in accurately identifying the substrate of tachyarrhythmias, precision, and shortening the duration of therapeutic applications. This reduces the number of «off-target» ablation applications. Importantly, this applies both to routine procedures for supraventricular and ventricular arrhythmias and to cases where classical diagnostic electrophysiologic maneuvers are not possible, including the coexistence of multiple tachycardia variants.

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