Pregledni rad / Review article

Ablacija ventrikularnih aritmija iznad semilunarnih valvula

Ablation of ventricular arrhythmias above semilunar valves

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SAŽETAK: Aritmije iz izgonskog trakta desne ili lijeve klijetke mogu imati svoje ishodište u supravalvularnim miokardnim ekstenzijama. Medikamentozna terapija je tradicionalno neuspješna pa se kod simpomatskih slučajeva ili onih kod kojih se razvije aritmijom inducirana kardiomiopatija treba odlučiti za interventno rješenje. Za njihovu uspješnu eliminaciju ablacijom mapiranje i primjena radiofrekventne energije mora se učiniti iznad semilunarnih valvula, u regijama koje imaju specifične anatomske osobitosti. U ovom preglednom radu donosimo kratak osvrt na anatomsku podlogu ovih aritmija i intraproceduralne korake koji vode uspješnoj i sigurnoj ablaciji, kao i pregled vlastitog iskustva.

KLJUČNE RIJEČI: ablacija ventrikularnih aritmija, idiopatske ventrikularne tahikardije, ventrikularna tahikardija iz koronarnih kuspisa, preferentna kondukcija, potencijal velikih arterija.

SUMMARY: Arrhythmias from the right and left ventricular outflow tract may stem from supravalvular myocardial extensions. Medical therapy has traditionally been unsuccessful, so in symptomatic cases or those in which arrhythmia-induced cardiomyopathy develop we should opt for an intervention. Mapping and use of radiofrequency energy has to be performed above semilunar valves for their successful elimination by ablation, in the regions that have specific anatomical features. This review article provides a brief overview of the anatomical substrate of these arrhythmias and intraprocedural steps that lead to successful and safe ablation, as well as an overview of our own experience.

KEYWORDS: ablation of ventricular arrhythmias, idiopathic ventricular tachycardias, ventricular tachycardia from coronary cusps, preferential conduction, great arterial potential.

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Idiopatske ventrikularne aritmije čine dobro opisani entitet u elektrofiziologiji. Prvi prikazi serija pacijenata su pokazali predilekcijsku sklonost za izlazni trakt desne klijetke (RVOT). Razvojem elektrofiziologije shvatilo se da značajan dio tih aritmija može dolaziti i iz izlaznog trakta lijeve klijetke (LVOT), a u tim slučajevima je supstrat dominantno smješten supravalvularno[1].

Suvremeni prikazi serija pacijenata s ovim entitetom upućuju da supravalvularne ventrikularne aritmije čine čak oko 16% od ukupnog broja pacijenata s idiopatskim ventrikularnim aritmijama, što daje naslutiti da je ovaj entitet bio u prošlosti nedovoljno shvaćen i u većine pacijenata previđen[2].

Anatomska i patofiziološka podloga supravalvularnim aritmijama

Koncept ekstenzija ventrikularnog ili atrijskog miokarda u velike krvne žile je poznat već dugo. Prošla su puna tri desetljeća od prvog sistematskog opisa ekstenzija atrijskog miokarda u plućne vene do spoznaje da su ti izolirani tračci tkiva električki nestabilni i mogu biti okidač aritmije, u ovom slučaju fibrilacije atrija[3]. Dva razloga su u podlozi, prvo, izoli-

Idiopathic ventricular arrhythmias are a well described entity in electrophysiology. The first presentations of a series of patients showed a predilection for the right ventricular outflow tract (RVOT). With the development of electrophysiology it was found that a significant proportion of these arrhythmias can stem from the left ventricular outflow tract (LVOT), and in these cases the substrate is predominantly located in the supravalvular region[1].

Modern presentations of a series of patients with this entity suggest that supravalvular ventricular arrhythmias even make for 16% of the total number of patients with idiopathic ventricular arrhythmias, which suggests that this entity was not sufficiently understood in the past and it was overlooked in the majority of patients[2].

Anatomical and pathophysiological substrate for supravalvular arrhythmias

The concept of ventricular or atrial myocardium extension in large blood vessels has already been known for a long time. It has been full three decades since the extensions of atrial myocardium in the pulmonary veins were systematically described for the first time until we realized that these isolated tissue fibers are electrically unstable and may trigger arrhy-

rani miokard gubi električnu stabilnost jer nije dio sincicija. Gubi se komunikacija između stanica i stvara podloga autonomnoj električnoj aktivnosti. Kao drugi razlog se opisuje heterogenost u brzini provođenja impulsa (anizotropija) što stvara uvjete za lokalizirani reentry. Za idiopatske ventrikularne aritmije supravalvularnog ishodišta se smatra da je izoliranost tih vlakana od ostalog miokarda osnovna podloga njihovoj autonomnoj aktivnosti.

Bitan koncept za objašnjenje ovog entiteta je i razumijevanje povezanosti ovih vlakana s miokardom. Ako se promotre intimni anatomski odnosi LVOT, RVOT te koronarnih kuspisa postaje jasno zašto naprimjer fokus iz lijevog koronarnog kuspisa može imati višestruke regije izlaza impulsa, najčešće prema LVOT, ali i prema septalnom RVOT što onemogućava korištenje elektrokardiografskih kriterija za lokalizaciju ishodišta aritmije[4] (**Slika 1**). Razumijevanje ovog fenomena, tzv. preferentne kondukcije impulsa, vrlo je važno jer objašnjava zašto u istog pacijenta možemo imati ventrikularne aritmije različitih QRS morfologija, a sve se mogu ablirati u istom fokusu (**Slika 2**). Tradicionalno bi višestruke QRS

thmias, in the case the atrial fibrillation[3]. Two reasons lie in the substrate, first, the isolated myocardium loses electrical stability because it is not a part of the syncytium. The cell to cell coupling is lost, thus creating the foundation for autonomous electrical activity. The second reason is described as heterogeneity of the rate of impulse conduction (anisotropy) providing thus the conditions for localized reentry. For idiopathic ventricular arrhythmias of supravalvular origin it is considered that the isolation of such fibers from the remaining myocardium is the basic foundation of their autonomous activities.

An important concept for the explanation of this entity is the understanding of association of these fibers with myocardium. Looking at the intimate anatomical relations LVOT, RVOT and coronary cusps, it becomes clear why for example, the focus from the left coronary cusp can have multiple exit sites, usually towards the LVOT, but also to the septal RVOT which makes the use of electrocardiographic criteria for the localization of the origin of arrhythmias unreliable[4] (**Figure 1**). Understanding this phenomenon, the so-called

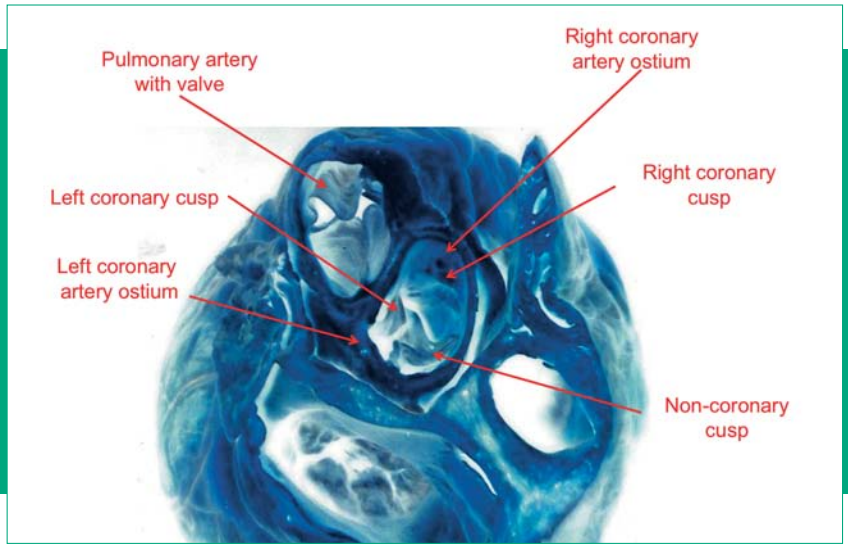

Figure 1. *Cross section through the heart at the level of semilunar valves. Aortic valve is behind and below the pulmonary. Left coronary cusp faces the superoposterior aspect of right ventricular outflow tract and pulmonary artery. Right coronary cusp is in intimate relation to His bundle, while non-coronary cusp is in intimate relation to interatrial septum.*

Figure 2. *12-lead electrocardiogram in patient with idiopathic non-sustained ventricular tachycardia originating in left coronary cups. Both non-sustained ventricular tachycardia episodes demonstrate first QRS complex having different morphology when comparing to the rest of complexes, pointing to a preferential conduction being the operative mechanism. Since pattern is reproducible, it proves the preferential conduction and excludes some other possible explanations for this phemonenon, such as fusion.*

morfologije obeshrabrile pokušaj ablacije te rezultirale ekstenzivnom kardiološkom obradom, neinvazivnom i invazivnom, u smislu traženja organskog supstrata za takav obrazac ventrikularnih aritmija.

Klinička slika i medikamentozno liječenje

Kao i kod drugih tipova idiopatskih ventrikularnih aritmija u pojedinačnog pacijenta se može registrirati cijeli spektar, od izoliranih ventrikularnih ekstrasistola, često u obliku bigeminija ili trigeminija, preko nepostojanih ventrikularnih tahikardija (NSVT) do dugotrajnije VT. Ovisno o opterećenju ektopijskom aktivnošću entitet može predstavljati godinama samo simptomatski fenomen, no nerijetko se razvija i aritmijom inducirana kardiomiopatija.

Tradicionalno se ove aritmije kao lijekom izbora liječe beta-blokatorima, no vlastito i iskustvo drugih centara ukazuje da ove aritmije uglavnom nisu inducirane adrenergičnim tonusom, tj. razlikuju se od klasičnih RVOT tahikardija koje su trigerirane, posredovane intracelularnim cAMP. Dokaz za to je da prilikom testa opterećenja u pravilu dolazi do supresije ektopijske aktivnosti, točnije bi bilo reći ipak da dolazi do dominacije sinusnog ritma zbog dužine ciklusa. Antiaritmici skupine I.c (u Hrvatskoj propafenon) mogu u pojedinačnim slučajevima dovesti do značajne supresije ektopijske aktivnosti, no doista je nužno prije liječenja isključiti strukturnu bolest srca.

Ablacija u supravalvularnim regijama

Zbog neuspjeha medikamentozne terapije, ali i činjenice da se uglavnom radi o mladim, aktivnim pacijentima, ablaciju treba rano ponuditi kao terapijsko rješenje. Bilo da je fokus u plućnoj arteriji ili Valsalvinim aortnim sinusima (u i iznad koronarnih kuspisa) ne radi se o posebno zahtjevnim ablacijskim manevrima. Dapače, mapiranje aorte retrogradnim pristupom je vrlo lako, no primjena radiofrekventne (RF) energije mora biti diskretna zbog blizine koronarnih arterija. Naprimjer, kako je pulmonalna valvula oko 1-2 cm iznad aortne, ablacija fokusa tik iznad pulmonalne valvule može biti udaljena svega 5-6 mm od debla lijeve koronarne arterije, dok je jasna, intrinzična, opasnost za ozljedu ušća koronarnih arterija za ablacije u aorti pa se primjena RF energije obvezno mora kontrolirati nekom od slikovnih metoda prikaza, bilo direktnom koronarnom angiografijom (**Slika 3**)

preferential conduction of impulses, is very important because it explains why the same patient can have ventricular arrhythmias of different QRS morphologies, and all of them can be ablated in the same focus (**Figure 2**). Traditionally, multiple QRS morphologies would discourage the attempts of ablation and result in an extensive diagnostic cardiac work up, both non-invasive and invasive, in terms of seeking an organic substrate for such a form of ventricular arrhythmias.

Clinical manifestations and medical treatment

As in other types of idiopathic ventricular arrhythmias, the entire spectrum can be recorded in an individual patient from isolated ventricular extrasystoles, often in the form of bigeminies or trigeminies through non-sustained ventricular tachycardia (NSVT) to sustained VT. Depending on the ectopic activity burden, the entity can make for only symptomatic phenomenon for years, however, arrhythmia induced cardiomyopathy often develops.

Traditionally, these arrhythmias are treated by beta-blockers as the drugs of choice, but our own experience and experience of other centers suggests that these arrhythmias are generally not induced by adrenergic tone, that is, they differ from traditional RVOT tachycardias which are triggered, mediated by intracellular cAMP. The proof for this is that the suppression of ectopic activity typically occurs during the exercise stress test, to be more precise, that the dominance of sinus rhythm occurs due to the length of the cycle. Group 1c antiarrhythmics (propafenone in Croatia) can in particular cases lead to significant suppression of ectopic activity, but it is really necessary to exclude structural heart disease before the treatment is initiated.

Ablation in supravalvular regions

Due to the failure of the medical therapy, but also the fact that these are mainly young, active patients, the ablation should be early offered as a therapeutic solution. No matter whether the focus is in the pulmonary artery or aortic sinuses of Valsalva (and above the coronary cusps), no particularly demanding ablation maneuvers are concerned. On contrary, the mapping by applying retrograde aortic approach is straightforward, but the use of radiofrequency (RF) energy has to be discreet because of the proximity of the coronary

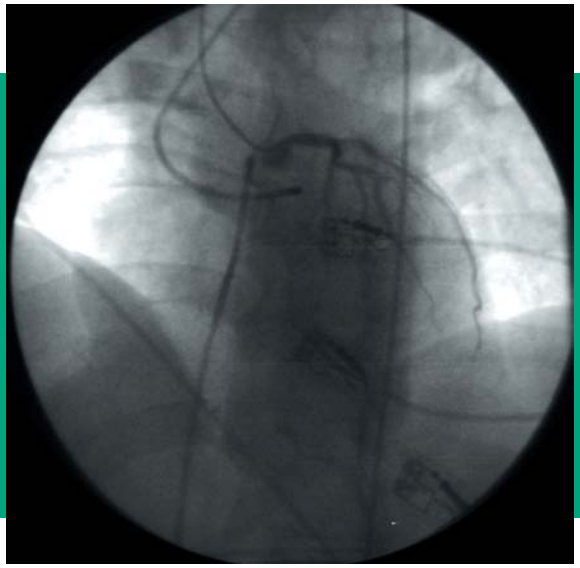

Figure 3. *Left coronary angiography during the ablation in aortic cusps, left anterior oblique 30 view. Ablation catheter is introduced through the right femoral artery and positioned at the left coronary cusp. Catheter for left coronary angiography is introduced via right radial artery. Another ablation catheter is also shown, introduced through right femoral vein for right ventricular outflow tract and pulmonary artery mapping to allow simultaneous right and left sided mapping as per standard institutional protocol. Intimate relation of superoposterior right ventricular outflow tract to left main coronary artery can easily be appreciated.*

ili pod monitoriranjem položaja ablacijskog katetera putem intrakardijalne ehokardiografije (ICE) (**Slika 4**). Za ablacije u desnom koronarnom kuspisu postoji opasnost ozljede Hisovog snopa koja se može izbjeći pažljivim praćenjem signala i stimulacijom s velikom izlaznom energijom koja ne smije postići His stimulaciju.

arteries. For example, since the pulmonary valve is about 1-2 cm above the aorta, the ablation of the focus just above the pulmonary valve may be only 5-6 mm distant from the left main coronary artery, while the danger of an injury to the orifice of the coronary arteries for aortic ablation is clear and intrinsic, so the use of RF energy must necessarily be controlled by some imaging method, either by direct coronary angiography (**Figure 3**) or by monitoring the position of ablation catheter via intracardiac echocardiography (ICE) (**Figure 4**). As for ablations in the right coronary cusp, there is a danger of an injury to the bundle of His that can be avoided by careful monitoring of signals and stimulation with a high power output that can not achieve the stimulation of His.

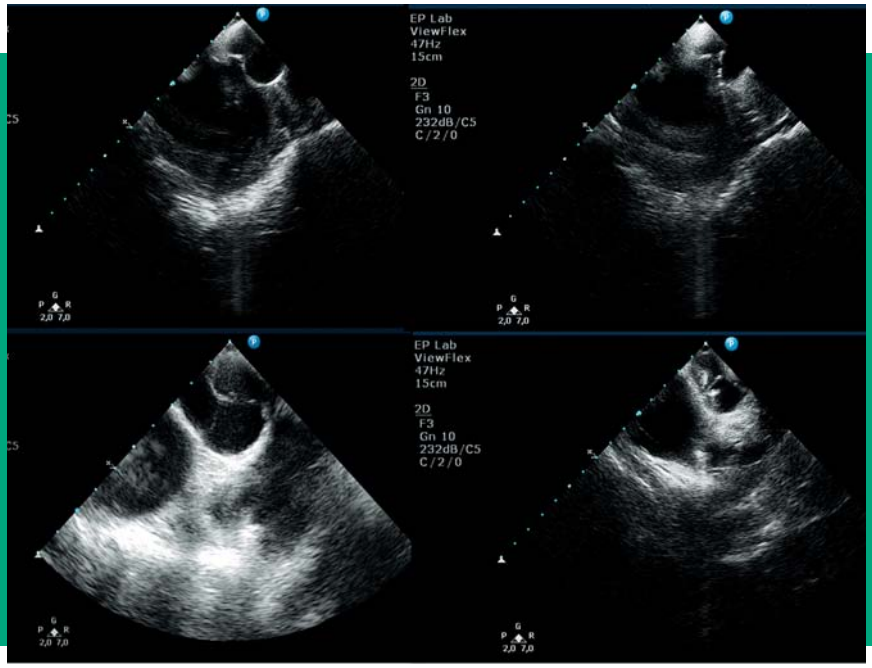

Figure 4. *Intracardiac echocardiography imaging during the ablation in aortic cusps. Left panel shows native images of aortic valve and root before putting in the ablation catheter (longitudinal view-up; cross sectional view-down). Right panel shows ablation catheter positioned in left aortic cups, as imaged by intracardiac echocardiography Using this techique one can perform safe ablation at these sites since it allows clear catheter tip visualization therefore enabling assesment of catheter-tissue contact and its relation to left main coronary artery. Furthermore it helps assesing for complications such as valvular insufficiency.*

Zadnjih godina se naglašava nužnost registracije vrlo tipičnih elektrograma za pronalaženje točnog ishodišta aritmije. Naime izolirani tračci miokarda u aorti ili pulmonalnoj arteriji daju vrlo specifičan potencijal koji je istovjetan onom koji se može snimiti u plućnim venama ili na Hisovom snopu[5]. Taj potencijal, nazvan potencijal velikih arterija, tijekom ektopijske aktivnosti pada vrlo rano ispred QRS kompleksa što dokazuje da je taj miokardni tračak ishodište aritmije i označava primjeren cilj za ablaciju[6]. Ti signali imaju vrlo veliku prediktivnu vrijednost za trajni uspjeh RF ablacije, a ablacija vođena tim signalima tipično rezultira gotovo trenutnim nestankom ventrikularne ektopijske aktivnosti.

Uspjeh i komplikacije radiofrekventne ablacije supravalvularnih aritmija

Uspjeh ablacije supravalvularnih aritmija je bolji nego za klasične intramiokardijalne fokuse, jer je regija iz koje dolazi ventrikularna aktivnost dobro definirana što ne mora biti slučaj kod klasičnih RVOT aritmija gdje je u pravilu nužna primjena višekratnih radiofrekventnih lezija za eliminaciju aritmije. Ablacija vođena potencijalima velikih arterija predstavlja suvremeni standard i nudi 95% vjerojatnost dugotrajne neprisutnosti aritmije.

Od komplikacija su opisane ozljede koronarnih arterija ili kuspisa s posljedičnom valvularnom insuficijencijom. Oboje su

In recent years we highlight the necessity of registering very typical electrograms to find the exact origin of arrhythmia. Specifically isolated myocardial fibers in the aorta or pulmonary artery provide a very specific potential which is identical to that which can be recorded in the pulmonary veins or on the bundle of His[5]. This potential, called the great arterial potential drops during the ectopic activity very early before the QRS complex, which proves that this myocardial fiber of the origin of arrhythmias marks an appropriate target for ablation[6]. These signals have a very high predictive value for the long-term success of RF ablation, and ablation guided by these signals typically results in almost immediate disappearance of ventricular ectopic activity.

Success and complications of radiofrequency ablation of supravalvular arrhythmias

The success of ablation of supravalvular arrhythmias is better than the classical intramyocardial focuses, because the region that the ventricular activity comes from is well defined which needs not be the case in classical RVOT arrhythmias where the application of multiple radiofrequency lesions for the elimination of arrhythmias is required. Ablation guided by great arterial potential is the modern standard and provides a 95% probability of long-term absence of arrhythmias.

Regarding the complications, the injuries to coronary arteries and cusps with consequential valvular insufficiency

na razini anegdotalnih opisa i uz današnju dostupnost slikovnih metoda, osobito primjenom ICE se ne bi smjele događati.

Iskustva iz Opće bolnice Zadar

U razdoblju od travnja 2011. do prosinca 2013. godine učinjena ablacija u supravalvularnim regijama u 13 pacijenata (10 u aortnim kuspisima, 3 u plućnoj arteriji) što predstavlja 25% od ukupnog broja pacijenata kod kojih je rađena ablacija idiopatske ventrikularne aritmije. U 8 od 10 pacijenata s uspješnom ablacijom u aortnim kuspisima su registrirani arterijski potencijali te u svih pacijenata s fokusom u plućnoj arteriji (**Slika 5**).

have been described. They are both at the level of anecdotal descriptions, and with today's availability of imaging methods, particularly ICE, they should not occur.

Experience from the Zadar General Hospital

During the period from April 2011 to December 2013, the ablation was performed in supravalvular regions in 13 patients (10 in the aortic cusps, 3 in the pulmonary artery), which accounts for 25% of the total number of patients who underwent the ablation of idiopathic ventricular arrhythmias. Arterial potentials were registered in 8 out of 10 patients with successful ablation in the aortic cusps, and in all patients with the focus in the pulmonary artery (**Figure 5**).

Figure 5. *Signals from the ablation catheter positioned at the left aortic cusp (same patient as at* ***Figure 4****). Upper panel shows 12-lead electrocardiogram, ABLd-bipolar electrogram from the distal part of the tip of the catheter, ABLp-bipolar electrogram from the proximal part of the catheter's tip, ABL U-unipolar electrogram from the ablation catheter. During premature ventricular complex, discreet, sharp potential is reproducibly registered that precedes QRS by 96 ms. This signal represents isolated myocardial fiber potential and stems out of myocardial exstension into aorta thus the designation-great arterial potential. During sinus QRS complexes this signal comes after the local ventricular electrogram, pattern is reversed during premature ventricular complex.*

Za ablaciju je korištena samo konvencionalna oprema za elektrofiziologiju (elektrofiziološke stanice EP Tracer 70, Cardiotek, Netherlands i EP Med 3, SJM, USA), bez pomoći sustava za elektroanatomski mapping. Raspon uranjenosti signala pred QRS-om je bio 50-114 ms za ablacije u koronarnim kuspisima te 30-44 ms za fokuse u plućnoj arteriji. Čak u 4 pacijenta se radilo o ponovljenim procedurama te se u svim tim slučajevima opisivala ranija neuspješna ablacija u subvalvularnom RVOT. Akutni uspjeh u smislu kompletne eliminacije ektopijske aktivnosti je bio zabilježen u svih 13 pacijenata, a postproceduralno je u dosadašnjem praćenju (1-30 mjeseci) zabilježen povrat aritmije u samo jednog. Ablacija u koronarnim kuspisima je u svih pacijenata bila monitorirana direktnom koronarnom angiografijom ili primjenom ICE. Nije zabilježena ikakva komplikacija u smislu ozljede koronarnih arterija ili valvularne insuficijencije.

Only conventional equipment for electrophysiology (electrophysiological stations EP Tracer 70, Cardiotek, Netherlands and EP Med 3, SJM, USA) was used for the ablation, without the help of the electroanatomical mapping system. The early signal range before QRS was 50-114 ms for the ablations in coronary cusps and 30-44 ms for foci in the pulmonary arteries. 4 patients were redo cases and in all these cases the earlier unsuccessful ablation in subvalvular RVOT was described. Acute success in terms of the complete elimination of ectopic activity was observed in all 13 patients, and recurrence of arrhythmia was recorded in only one patient in the postprocedural follow up (at 1-30 months). The ablation in coronary cusps was monitored in all patients by direct coronary angiography or ICE. Not a single complication was observed in terms of an injury to coronary arteries or valvular insufficiency.

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