Intracoronary ECG guided PCI in the contemporary catheterization laboratory. Part 2

ABSTRACT

Intracoronary ECG, which was created with unipolar guide introduced into coronary artery to analyze ischemia, was invented in 1974, and firstly performed in human body in 1985, Intracoronary ECG still remains rarely used technique for percutaneous coronary interventions (PCI). The article sums up studies dating from 1974 to 2016 which show that intracoronary ECG is useful for discovering the zones of ischemia, predicting myocardial necrosis, exploring vital myocardium, predicting myocardial recovery during primary PCI and finding new possibilities for the development of PCI. Intracoronary ECG is still very cheap and easily performed, even though it requires additional time and deserves much more interest among the staff incatheterization laboratories.

Key words: intracoronary ECG

Kardiol. Inwazyjna 2016; 11 (6): 38–41

STRESZCZENIE

Wewnątrzwieńcowe EKG zarejestrowane za pomocą jednobiegunowego prowadnika wprowadzonego do tętnicy wieńcowej w celu oceny niedokrwienia zostało wynalezione w 1974 roku, a po raz pierwszy zostało wykonane u człowieka w 1985 roku. Wewnątrzwieńcowe EKG wciąż jest bardzo rzadko stosowaną techniką diagnostyczną podczas przezskórnej interwencji wieńcowej (PCI). Artykuł ten podsumowuje badania z lat 1974–2016, pokazując, że wewnątrzwieńcowe EKG może być przydatne w znalezieniu strefy niedokrwienia, przewidywaniu martwicy mięśnia sercowego, detekcji żywotnego miokardium, prognozowaniu zdrowienia mięśnia sercowego po pierwotnej PCI, jak również w poszukiwaniu nowych strategii podczas PCI. Nadal bardzo tanie i łatwe do wykonania, mimo że wymaga dodatkowego czasu, to zasługuje na większe zainteresowanie pracujących w pracowniach hemodynamiki.

Słowa kluczowe: EKG wewnątrzwieńcowe

Kardiol. Inwazyjna 2016; 11 (6): 38–41

Liubomir Dosev[1], Dobrin Vassilev[1], Kiril Karamfiloff[1], Jacek Bil[2], Robert J. Gil[2, 3]

[1]"Alexandrovska" University Hospital, Medical University, Sofia, Bulgaria,

[2]Department of Invasive Cardiology, Central Clinical Hospital of the Ministry of Interior, Warsaw, Poland

[3]Institute of Experimental and Clinical Medicine. Polish Academy of Science, Warsaw, Poland

Intracoronary ECG in treating bifurcational lesions

Coronary bifurcation lesions remain a major therapeutic challenge with high early and late complication rates. It has been shown that angiographically high grade ostial side branch (SB) stenosis is not flow limiting and may not cause ischemia. Previous studies [1] with delayed gadolinium enhancement magnetic resonance imaging (DGE-MRI) before and after bifurcation PCI demonstrated that the occurrence of angiographic stenosis which is more than 70% in diameter is associated with periprocedural myonecrosis in the region of SB. Moreover, the post-procedural myocardial injury after uncomplicated percutaneous coronary intervention (PCI) is not uncommon [2–4] with the frequency of 5% to 30%. Although this is thought to have no clinical significance, clinical trials demonstrated the incre-

asing risk of adverse cardiac events among patients with periprocedural myonecrosis [5].

In the study the authors [6] performed intracoronary ECG (icECG) guided PCI of bifurcation lesion. True bifurcations (001) were 55% and provisional stenting was the default strategy. A wire in the main branch and second wire in the side branch monitored intracoronary ECG. An icECG map of the main artery and its side branches was created before, during and after the procedure. Troponin I was measured before and after the intervention. Final and residual intracoronary ST elevation was found in only 14% of the main branch (MB) and in 19% of the side branch, intracoronary ST elevation occurred in 17% of the both branches. In total, ST elevation is present in 36% of the main branch and 31% of the side branch. There was significant difference between groups and the linear increase of the postprocedural troponin concentration with icECG STE (troponin I concentrations: SB vs. MB vs. SB+MB STE — 0.61 ± 1.76 ng/ml vs. 1.73 ± 6.16 ng/ml vs. 2.99 ± 7.88 ng/ml, overall $P < 0.001$) in SB, though MB in both branches.

There were several major findings in this study. Firstly, a modified method for icECG recording of epicardial electric potentials was introduced for ischemic zone detection at conclusion of PCI for coronary bifurcation lesions. This method provides a unique opportunity for determining areas of residual ischemia, which may be probable sources of postprocedural increase in troponin I concentration. Secondly, this is the first study which demonstrates that about one third of patients have ischemia in ,at least, one distal location (MB, SB or both) after stenting of coronary bifurcation lesions as detected by means of icECG. This residual ischemia was found to be a sensitive and specific marker for postprocedural increase of troponin and for prediction of troponin defined postprocedural myocardial infarction according to the third definition of myocardial infarction. Thirdly, it was found that the increase of ischemic territory in bifurcation region (SB region — MB region — both distal regions) is linearly related with postprocedural troponin I concentration. The icECG recording provides a possible mechanism for postprocedural increase of the rate of enzyme in patients with icECG STE in distal MB only may be distal embolization from plaque components, while spasm or local thrombosis of microcirculation appeared to be possible reason for those with icECG changes in both zones (below the stent and distal MB). This is in the agreement with magnetic resonance studies which demonstrated late gadolinium enhancement zones in adjacent areas around the stent. One third of patients had ischemia in SB region at the end of coronary bifurcation interventional procedure, unrelated to extent of SB final stenosis. The SB ostial stenosis, after stenting, correlated significantly with maximum icECG STE in SB region immediately after stenting, but not with final icECG STE in SB region. Although this parameter, as well as final SB ostial stenosis, did not correlate with either final icECG STE or postprocedural troponin elevation, almost 60% of patients had icECG STE after stenting in SB region (nearly half of this ischemia could be eliminated by balloon inflation at SB ostium). When attempted, balloon inflation at SB ostium was successful to eliminate ischemia and to prevent from further myonecrosis in almost 70% of cases. In cases where SB ostium ballooning is ineffective to alleviate SB ischemia (even after larger balloon dilatation), application of IIB/IIIA inhibitors and vasodialtors may be effective but the hypothesis remains to be validated. In cases where there was no icECG STE after stenting in SB region, no further treatment of SBes was needed regardless of the angiographic appearance of the lesion.

By using the icECG mapping technique, it was able to predict almost 80% of cases with any troponin I rise after intervention for coronary bifurcation stenosis and 90% of troponin I rise more than 5 times the upper normal limit, with 95% negative predictive value (i.e., the lack of icECG STE casuses 95% probability of negative troponin I after intervention).

As a posthoc analysis occured, the residual ischemia in MB (ST segment change) was also significantly related with TLR (ST segment change (+) 14.2% vs. ST segment change (–) 3.6%, $P = 0.031$) but not in SB region [7]. Final residual ST elevation in the main branch is independent predictor for TLR for the following 12 months (OR = 5.3.19, CI = 1.197–23.809, $P = 0.028$) [8].

Another important conclusion is that the final residual ST elevation in side branch is not depended on the final side branch stenosis > 50% as well as side branch stenosis > 50% which does not mean indicate that the stenosis is hemodynamically significant when measured with FFR.

This statement is used in another study, comparing FFR result and intracoronary ECG in side branch after stenting the main branch. After stenting the main branch, there is often > 50% stenosis in the side branch, but it is rarely hemodynamically significant (FFR < 0.8), as well as there is rarely residual ST elevation in this side branch. If there is ST elevation on intracoronary ECG this could be hemodynamically significant stenosis acutely compromising SB ostium and this should be treated or distal embolization — SB may not have > 50% stenosis and usually FFR result is > 0.8.

Myocardial preconditioning and postconditioning

It is believed that recurrent ischemic episodes fail to deplete ATP in vitro [9, 10]. Recurrent angina is found to have benefit in infarct size [11]. This concept of ischemic preconditioning was tested through angioplasty using chest pain and measuring surface ECG, lactate levels as ischemic detectors [12]. Since intracoronary ECG is proven to be more sensitive than surface ECG in detecting ischemia it is better to be used in this setting. A study using consecutive balloon inflations showed that intracoronary ECG could show preconditioning [13]. Many studies [14–19] have used intracoronary ECG to search for substances that change preconditioning. The substances which attenuate preconditioning are found to be endothelin, phentolamine, bamiphylline, aminophylline, enaprilat, dipyridamole and naloxone. Other substances as nitrates, adenosine, diltiazem, nifedipine and bradykinin showed to have preconditioning effects [20–25]. Some conditions like diabetes and increased age were proven to be not deleterious in preconditioning [26, 27].

On the contrary, postconditioning is a state in which induced ischemia provides protection to myocardium against reperfusion damage. This was proved by two studies [28, 29] by measuring cardiac enzymes, cardiac function by echocardiography and measuring infarct size by ^{201}thallium single photon emission computed tomography. They used surface ECG as a detector of ischemia and postconditioning. It would be interesting if intracoronary ECG was used and there would be differences in other endpoints.

Limitations of the intracoronary ECG

There are basically two main limitations: 1) gaining good ECG trace which is operator dependent and 2) time needed to connect the PCI wire with unipolar lead, done with sterile crocodile wire clips.

Sometimes when there is more than one wire, when stented region is long and there is too many "metal" or the connection between the wire and the unipolar lead is poor the ECG trace is not satisfactory. This problem can be tackled with adding an isolator for the guide wire like microcatheter or balloon catheter.

Other important thing is that the wire tip is required to be largely straight, the tip must not be in more than 90° J-configuration and the tip of the wire must move freely. If the tip of the wire is wedged, the lesion current will appear from wire tip, which erroneously will be interpreted as ischemic changes. Hence, the operator must turn the wire clockwise-counterclockwise to be sure that the tip is freely moving.

Conclusion

Intracoronary ECG is easy to be performed once you have the tools which are not expensive. It is performed better in detecting ischemia and it finds its location easier than surface ECG, which is proved in many applications. It is expected that coronary intervention will be fast and exact and that adding a new method will inevitably slow down the intervention. Sometimes the quality of the tracing is not good enough but could be modified at the expense of time and adding isolators that is why sterile connectors are needed. This could help making better decisions about treating the target vessel and adding information in real time about myocardial damage. In bifurcational lesions intracoronary ECG shows the region of ischemia and it helps to decide whether to treat the side branch which could save procedural time and reduce the adverse events.

References

1. Michalek A., Vassilev D., Odyniec M. *et al.* Assessment by means of MRI Late Gadolinium Enhancement of periprocedural myonecrosis after main vessel stenting of coronary bifurcations. J. Cardiovasc. Magn. Reson. 2010; 12 (Suppl. 1): P58.
2. Selvanayagam J.B., Porto I., Channon K. *et al.* Troponin elevation after percutaneous coronary intervention directly represents the extent of irreversible myocardial injury: insights from cardiovascular magnetic resonance imaging. Circulation 2005; 111: 1027–1032.
3. Porto I., Selvanayagam J.B., Van Gaal W.J. *et al.* Plaque volume and occurrence and location of periprocedural myocardial necrosis after percutaneous coronary intervention: insights from delayed-enhancement magnetic resonance imaging, thrombolysis in myocardial infarction myocardial perfusion grade analysis, and intravascular ultrasound. Circulation 2006; 114: 662–669.
4. Locca D., Bucciarelli-Ducci C., Ferrante G. *et al.* New universal definition of myocardial infarction: applicable after complex percutaneous coronary interventions? J. Am. Coll. Cardiol. Intv. 2010; 3: 950–958.
5. Zimarino M., Affinito V. The prognosis of periprocedural myocardial infarction after percutaneous coronary interventions. Cardiovasc. Revasc. Med. 2013; 14: 32–36.
6. Vassilev D., Dosev L., Rigatelli G., Karamfiloff K., Gil R.J. Prediction of troponin elevation by means of intracoronary electrocardiogram during percutaneous coronary intervention of coronary bifurcation lesions (from COronary SIde Branch Residual IschemiA and COllateralization Assessment Study; COSIBRIA & Co Study) DOI: 10.5603/KP.a2016.0057.
7. Vassilev D., Alexandrov A., Gil R.J. *et al.* Prolonged ischemia, detected by intracoronary electrocardiography, after coronary bifurcation stenting predicts adverse events during mid-term follow-up. J. Am. Coll. Cardiol. 2012; 60 (17_S): B196–197.
8. Vassilev D, Alexandrov A, Bankova A *et al.* The ischemia in distal MB region at the end of coronary bifurcation stenting predicts in-stent restenosis at 12 months follow-up From Intracoronary Electrocardiogram (ECG) and Myonecrosis After Bifurcation Stenting (COSIBRIA&CO). J. Am. Coll. Cardiol. 2013; 62 (18_S1): B127–B127.

9. Reimer K.A., Murry C.E., Yamasawa I. *et al.* Four brief periods of myocardial ischemia cause no cumulative ATP loss or necrosis. Am. J. Physiol. 1986; 251: H1306–H1315.
10. Murry C.E., Jennings R.B., Reimer K.A. Preconditioning with ischemia: A delay of lethal cell injury in ischemic myocardium. Circulation 1986; 74: 1124–1136.
11. Ottani F., Galvani M., Ferrini D. *et al.* Prodromal angina limits infarct size. A role for ischemic preconditioning. Circulation 1995; 91: 291–297
12. Deutsch E., Berger M., Kussmaul W.G. *et al.* Adaptation to ischemia during percutaneous transluminal coronary angioplasty. Clinical, hemodynamic, and metabolic features. Circulation 1990; 82: 2044–2051.
13. Bhargava B., Chandra S., Kaul U. *et al.* Ischaemic preconditioning: An intracoronary electrocardiographic study. Indian Heart J 1996; 48: 129–132.
14. Tomai F., Crea F., Gaspardone A. *et al.* Phentolamine prevents adaptation to ischemia during coronary angioplasty. Circulation 1997; 96: 2171–2177.
15. Kyriakides Z.S., Kremastinos D.T., Kolettis T.M. *et al.* Acute endothelin-A receptor antagonism prevents normal reduction of myocardial ischemia on repeated balloon inflations during angioplasty. Circulation 2000; 102: 1937–1943.
16. Tomai F., Crea F., Gaspardone A. *et al.* Effects of A1 adenosine receptor blockade by bamiphylline on ischaemic preconditioning during coronary angioplasty. Eur. Heart J. 1996; 17: 846–853.
17. Claeys M.J., Vrints C.J., Bosmans J.M., *et al.* Aminophylline inhibits adaptation to ischaemia during angioplasty. Role of adenosine in ischaemic preconditioning. Eur. Heart. J. 1996; 17: 539–544.
18. Klein A.L., Marquis J.F., Higginson L.A. *et al.* Intravenous dipyridamole-induced myocardial ischemia during percutaneous transluminal coronary angioplasty in humans. Am. J. Cardiol. 1989; 63: 419–422.
19. Tomai F., Crea F., Gaspardone A. *et al.* Effects of naloxone on myocardial ischemic preconditioning in humans. J. Am. Coll. Cardiol. 1999; 33: 1863–1869.
20. Leesar M.A., Stoddard M.F., Dawn B. *et al.* Delayed preconditioning-mimetic action of nitroglycerin in patients undergoing coronary angioplasty. Circulation 2001; 103: 2935–2941.
21. Kerensky R.A., Kutcher M.A., Braden G.A. *et al.* The effects of intracoronary adenosine on preconditioning during coronary angioplasty. Clin. Cardiol. 1995; 18: 91–96.
22. Leesar M.A., Jneid H., Tang X.L. *et al.* Pretreatment with intracoronary enalaprilat protects human myocardium during percutaneous coronary angioplasty. J. Am. Coll. Cardiol. 2007; 49: 1607–1610.
23. Saito K., Nonogi H., Goto Y. *et al.* Antiischemic effect of intracoronary diltiazem on myocardial ischemia during PTCA. Heart Vessels 1996; 11: 92–99.
24. Leesar M.A., Stoddard M.F., Manchikalapudi S. *et al.* Bradykininduced preconditioning in patients undergoing coronary angioplasty. J. Am. Coll. Cardiol. 1999; 34: 639–650.
25. Amende I., Herrmann G., Simon R. *et al.* Protective effects of pretreatment with intracoronary nifedipine on myocardial ischemia and dysfunction. Cardiovasc. Drugs Ther. 1990; 4 (Suppl. 5): 887–891.
26. Kyriakides Z.S., Psychari S., Chrysomallis N. *et al.* Type II diabetes does not prevent the recruitment of collateral vessels and the normal reduction of myocardial ischaemia on repeated balloon inflations during angioplasty. Heart 2002; 87: 61–66.
27. Tomai F., Crea F., Ghini A.S. *et al.* Ischemic preconditioning during coronary angioplasty is preserved in elderly patients. Ital. Heart J. 2000; 1: 562–568.
28. Staat P., Rioufol G., Piot C. *et al.* Postconditioning the human heart. Circulation 2005; 112: 2143–2148.
29. Thibault H., Piot C., Staat P. *et al.* Long-term benefit of postconditioning. Circulation 2008; 117: 1037–1044.

Address for correspondence:

Liubomir Dosev, MD
"Alexandrovska" University Hospital, Medical University, Sofia, Bulgaria
e-mail: liubodosev@gmail.com