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Prognostic value of cardiac iodine-123 metaiodobenzylguanidine imaging in patients with indications for cardiac resynchronization therapy

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Background. The aim of our study was to assess the cardiac 123I-MIBG imaging predictive value on the clinical outcome in HF patients with wide QRS complexes and compare its power in different treatment groups.

Materials and methods. We have prospectively investigated 67 heart failure patients with the New York Heart Association (NYHA) functional class II–IV, wide QRS complexes (>120 milliseconds), reduced left ventricular ejection fraction (LV EF) eligible for CRT. 123I-MIBG planar and single photon emission computed tomography (SPECT) scans were performed in a supine position with calculation of early and late heart-to-mediastinum (H/M) ratios, washout ratio (WR), summed defect scores and scores difference from SPECT acquisition. All patients were then divided in two groups according to their clinical status – 36 patients underwent implantation of CRT, and 31 patients were continued with OMT. Initial conventional heart failure markers and NYHA were assessed at the time of 123I-MIBG imaging and 6 months later. Comparisons of two groups were done applying the Student's t-test, and if samples were small, the Fisher's exact test was used. NYHA groups were compared applying the ANOVA single factor analysis. ROC curve analysis was performed to establish cut off values for predictors of response.

Results. Cardiac 123I-MIBG imaging data differed insignificantly, presenting a similar cardiac adrenergic innervation status in both groups. In the CRT group, NYHA and LV EF indicated more pronounced signs of HF. For all patients, NYHA IV patients had significantly larger LV diameter, smaller EF, larger BNP levels, lower late H/M values and larger denervation score difference. Responders to therapy (both groups) had significantly higher early H/M ratio – 2.35 ± 0.41 than non-responders – 2.00 ± 0.44 ($p = 0.004$), and late H/M ratio – 2.11 ± 0.44 for responders and 1.72 ± 0.54 for non-responders ($p = 0.005$). There were no significant differences in regional cardiac 123I-MIBG data for responders and non-responders.

Conclusions. Cardiac 123I-MIBG imaging has valuable prognostic power predicting clinical outcomes of HF patients with wide QRS complexes, despite the chosen type of treatment, with better outcomes for patients with early H/M ratio 2.00 and late H/M ratio above 1.77.

Key words: heart failure, cardiac resynchronisation, nuclear imaging, MIBG

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INTRODUCTION

Despite novel therapeutic strategies for patients with heart failure, limited medical resources and a relatively small amount of heart transplantation donors increase the need to select more effective ways of treating these patients. Cardiac sympathetic activity, which can be assessed by 123I-MIBG scintigraphy, is a good predictor of cardiac death for heart failure patients. Abnormalities of sympathetic cardiac activity for heart failure patients have been expressed in reduced 123I-MIBG uptake, as lower heart to mediastinum (H/M) and increased washout ratio (WR). Abnormal 123I-MIBG uptake predicts cardiac death, arrhythmias and all-cause mortality in patients with heart failure with independent prognostic power added to conventional risk markers, and may identify patients at increasing risk of clinical course (1). Various kinds of heart failure therapeutic modalities showed promising results in treating patients with HF (2). Newer HF treatment modalities, such as cardiac resynchronization therapy, showed clinical benefits for such patients, when response to treatment was determined according to cardiac 123I-MIBG imaging H/M ratio stratifying patients' risk (3).

The objective of our study was to assess the value of cardiac 123I-MIBG imaging in predicting clinical outcomes in HF patients with wide QRS complexes, which were assigned for CRT or optimal medical treatment (OMT).

MATERIALS AND METHODS

We have prospectively investigated 67 stable heart failure patients with the New York Heart Association (NYHA) functional class II–IV, wide QRS complexes (>120 milliseconds), reduced left ventricular ejection fraction (LV EF) eligible for CRT. Part of our patients with mild HF symptoms (NYHA class II) had higher LVEF – 35–45% than recommended in major guidelines and QRS duration ≥120–130 ms.

The investigation conforms to the principles outlined in the Declaration of Helsinki and is approved by the Vilnius Regional Biomedical Research Ethics Committee, Protocol SAIV100, version 2, 7 Feb 2011. Informed consent was obtained from each patient.

MIBG scintigraphy protocol

All patients were pretreated with potassium perchlorate 500 mg to block uptake of free 123-iodine by the thyroid gland. Potassium perchlorate was given orally 60–90 min before intravenous administration of 123I-MIBG (4). Each patient received 225 ± 17 MBq of 123I-MIBG.

123I-MIBG planar and SPECT (single photon emission computed tomography) scans were performed in a supine position. The 123I-MIBG planar images of the thorax were acquired 15 min (early image) and 4 h (late image) after injection. The acquisition time was set to 10 min in the anterior view and stored in a 128 × 128 matrix. SPECT images were acquired immediately after planar ones. Images were acquired with a dual detector gamma camera with a detector set in a 90° configuration (GE Infinia, Wisconsin, USA). Rotation of 180° was used (64 projections) starting at the 45° right anterior oblique projection and proceeding to the 45° left posterior oblique projection. The time per projection 35 sec, overall acquisition time 19 min. A 64 × 64 matrix was used for SPECT imaging. Medium-energy (ME), parallel hole collimator was chosen, as the use of an ME collimator provides higher quantitative accuracy and enhances reliability in the evaluation of cardiac sympathetic nerve function (5), 20 percentage energy peak was centered on the 159-KeV energy peak of 123-iodine for planar and for SPECT acquisition.

Cardiac 123I-MIBG scintigraphy data analysis was performed with calculation of early and late heart-to-mediastinum (H/M) ratios, washout ratio (WR), summed defect scores and scores difference from SPECT acquisition. From the planar images average counts per pixel in the myocardium were divided by average counts per pixel in the mediastinum – H/M ratio = H counts / M counts.

Myocardial 123I-MIBG washout ratio (WR) from initial to late images was calculated and expressed in percentage. The decay and background correction was taken in to account WR = [(H early – M early) – ((H late – M late) × 1.21)] / (H early – M early) × 100%.

Cardiac 123I-MIBG SPECT images were processed with iterative reconstruction – the ordered subsets expectation maximization (OSEM). Reorientation of the reconstructed transaxial data into the three standard image planes and polar maps was done using the automated reorientation method – Cedars-Sinai QPS/QGS software algorithm (6).

The cardiac SPECT image set of each patient was divided into 20 segments. The short axis images at the basal, middle, and apical ventricular levels were divided into six segments each. The apical segment of the vertical long axis image was divided into two segments.

Regional 123I-MIBG uptake was scored semi-quantitatively using a four-point scoring system (0, normal uptake; 1, mildly reduced uptake; 2, moderately reduced uptake; 3, severely reduced uptake). The denervation score (defect score) was calculated by the summation of segmental tracer uptake scores. The 123I-MIBG SPECT defect score was calculated for early and late SPECT imaging. Denervation scores were described with respect to denervation severity and extent. The denervation scores difference was determined semi-quantitatively using the arithmetic difference between early and late denervation scores.

Previously published large-scale papers present quantitative data of cardiac 123I-MIBG imaging using low energy collimators (3, 7). We could not find any paper regarding risk stratification using medium energy collimators. For this reason we aimed to calculate the cardiac 123I-MIBG data cut-off values separating patients who will benefit from the chosen type of therapy.

All patients according to their clinical status were then divided in two groups – 36 patients underwent implantation of CRT, and 31 patients were continued with the optimal medical treatment (OMT). A determinant of treatment type was the clinical course of patients. In general, patients assigned to CRT were clinically more severe than to OMT. Initial conventional heart failure markers: left ventricular ejection fraction (LV EF); B-type natriuretic peptide (BNP); left ventricular end-diastolic and end-systolic diameters (LVEDD and LVESD); QRS duration were assessed at the time of 123I-MIBG imaging, before assignment for CRT or OMT, followed by assessment of the same markers after 6 months of therapy. NYHA was assessed at the time of 123I-MIBG imaging and reassessed again after 6 months of treatment.

Global and regional 123I-MIBG scores were calculated, and conventional heart failure parameters were assessed and compared between the patient groups assigned to CRT and OMT.

Reverse LV remodeling was assessed by measuring the changes of LVEDD/LVESD and LV EF from the baseline to 6 months later. Improvement in functional capacity was evaluated comparing the change in the NYHA functional class from initial to 6 months later. The clinical course was estimated 6 months after including into the study. Patients depending on their response to treatment were divided into responders as ones with decreasing or stabile NYHA functional class, and non-responders as ones with increase of NYHA functional class or all-cause mortality. The cause of death was determined from the electronic health record of the hospital by the clinical investigator and confirmed by the referring physician.

Statistical analysis

All continuous data are presented as mean ± SD and discrete data are presented as numbers and percentage. Comparisons of two groups were done applying the Student's t-test, and if samples were small, the Fisher's exact test was used. NYHA groups were compared applying the ANOVA single factor analysis and differences between the groups were analyzed with the least significant difference post hoc test. ROC curve analysis was performed to establish cut off values for the predictors of response to therapy. P value less than 0.05 was considered statistically significant.

RESULTS

Baseline clinical and cardiac 123I-MIBG characteristics of the patients assigned to the CRT or OMT, and the differences are presented in Table 1. In the CRT group, NYHA and LV EF indicated more pronounced signs of HF. There was also less sinus rhythm in the OMT group. However, cardiac 123I-MIBG imaging data differed insignificantly, presenting a similar cardiac adrenergic innervation status in both clinical groups.

In both groups NYHA IV functional class patients had significantly larger LVESD, smaller EF, larger BNP levels, lower late H/M values and larger denervation score difference (Table 2).

Cardiac 123I-MIBG data did not differ significantly for the patients who had AF or sinus rhythm at the time of initial investigation, for the patients who had previous permanent cardiac pacing and who did not, for the patients with various causes

Table 1. Baseline clinical and cardiac 123I-MIBG characteristics of the patients assigned to the CRT or OMT

	CRT patients		OMT patients		p-value
Patient's age	62.2 years ± 10.80		57.7 years ± 11.15		0.102
Gender					
Male	25	52.1%	23	47.9%	0.667
Female	11	57.9%	8	42.1%	
NYHA functional class					
II	1	14.3%	6	85.7%	0.026
III	29	54.7%	24	45.3%	
IV	6	85.7%	1	14.3%	
QRS width, ms	180.7 ± 38.9		169.0 ± 19.8		0.132
Rhythm					
Sinus	10	35.7%	18	64.3%	0.012
AF	26	66.7%	13	33.3%	
LVEDD, mm	6.7 ± 1.1		6.6 ± 0.9		0.595
LVESD, mm	5.6 ± 1.1		5.3 ± 0.9		0.330
LV EF, %	27.3 ± 6.9%		30.9 ± 7.1%		0.042
BNP, pg/ml	713.2 ± 826.4		402.6 ± 439.2		0.069
Early H/M ratio	2.21 ± 0.43		2.32 ± 0.45		0.307
Late H/M ratio	1.95 ± 0.43		2.10 ± 0.55		0.228
WR, %	43.8 ± 14.5		44.5 ± 28.3		0.898
Early extent, %	19.76 ± 17.04%		19.71 ± 13.00%		0.991
Late extent, %	35.90 ± 19.80%		32.25 ± 14.58%		0.481
Extent difference, %	16.14 ± 10.29%		12.54 ± 6.18%		0.156
Early denervation score	14.4 ± 11.83		16.00 ± 10.62		0.641
Late denervation score	28.67 ± 16.00		25.75 ± 11.67		0.485
Scores difference	14.24 ± 10.86		9.75 ± 4.55		0.071

CRT – cardiac resynchronization therapy; OMT – optimal medical treatment; AF – atrial fibrillation; LVEDD – left ventricular end-diastolic diameter; LVESD – left ventricular end-systolic diameter; LVEF – left ventricular ejection fraction; BNP – brain natriuretic peptide; H/M – heart to mediastinum ratio; WR – washout ratio.

Table 2. Cardiac heart failure markers and cardiac 123I-MIBG markers difference between NYHA functional classes

	NYHA functional class			p
	II	III	IV	
LVESD, mm	5.4 ± 1.1	5.3 ± 0.9	6.4 ± 0.99	0.029 (III and IV)
LVEF, %	33.0 ± 7.3	29.4 ± 6.9	21.7 ± 4.9	0.007 (II and IV, III and IV)
BNP, pg/ml	281.8 ± 294.4	509.4 ± 600.2	1 294.8 ± 1121.3	0.008 (II and IV, III and IV)
Late H/M ratio	2.38 ± 0.38	2.01 ± 0.50	1.74 ± 0.26	0.046 (II and IV)
Scores difference	11.00 ± 6.78	11.11 ± 6.89	28.00 ± 24.04	0.016 (II and IV, III and IV)

LVESD – left ventricular end-systolic diameter; LVEF – left ventricular ejection fraction; BNP – brain natriuretic peptide; H/M – heart to mediastinum ratio.

of heart failure: dilative cardiomyopathy, ischemic cardiomyopathy, hypertensive / tachyarrhythmic cardiomyopathy and valvular cardiomyopathy.

Responders to therapy had significantly higher early H/M ratio – 2.35 ± 0.41 than non-responders – 2.00 ± 0.44 (p = 0.004), and late H/M ratio – 2.11 ± 0.44 for responders and 1.72 ± 0.54 for non-responders (p = 0.005). Responders had significantly lower WR – 40.2 ± 13.8 than non-responders – 56.8 ± 35.2 (p = 0.007). There were no significant differences of regional cardiac 123I-MIBG data for responders and non-responders.

Depending on the type of therapy, in the CRT group responders had significantly higher late H/M ratio – 2.00 ± 0.44 than non-responders – 1.63 ± 0.16 (p = 0.041); in the OMT group responders had significantly higher early H/M ratio – 2.47 ± 0.32 than non-responders – 2.02 ± 0.55 (p = 0.006), and late H/M ratio – 2.25 ± 0.41 for responders, and 1.78 ± 0.67 for non-responders (p = 0.023). The WR for responders – 37.53 ± 14.14 was significantly lower than for non-responders – 59.21 ± 43.46 (p = 0.045).

ROC curve analysis for cardiac 123I-MIBG imaging data (Figs. 1, 2) with selected endpoints – response and non-response to therapy (Table 3) was conducted in order to find the cut off values for patients' improvement measurement.

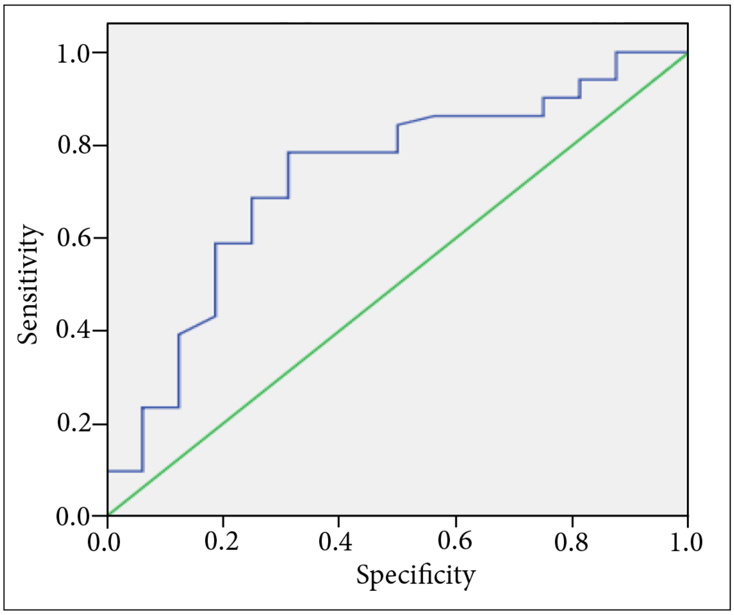

Fig. 1. Early H/M ratio ROC curve

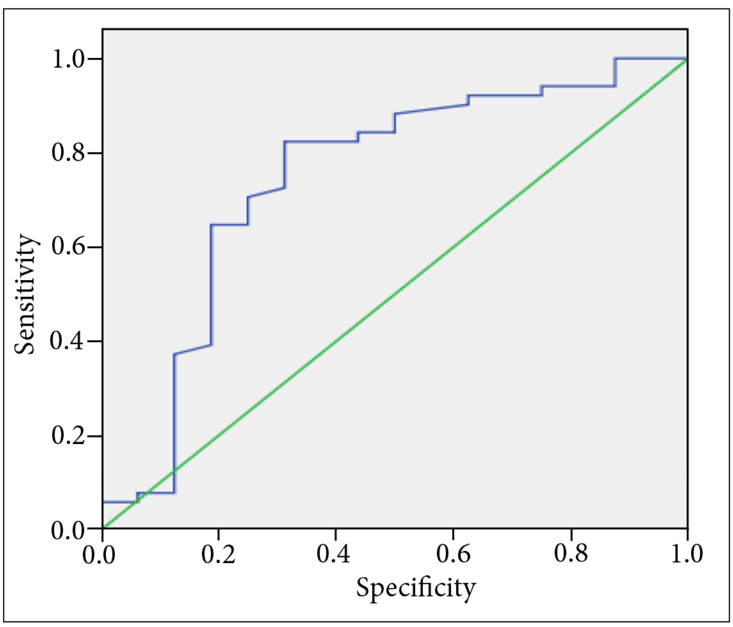

Fig. 2. Late H/M ratio ROC curve

Table 3. ROC analysis of cardiac 123I-MIBG imaging data

	Cut off value	Area under the curve (95% CI)	p	Sensitivity	Specificity
Early H/M ratio	2.00	0.729 (0.583–0.874)	0.006	0.784	0.687
Late H/M ratio	1.77	0.743 (0.586–0.900)	0.004	0.824	0.687

CI – confidence interval; H/M – heart to mediastinum ratio.

DISCUSSION

The neurohormonal system (adrenergic nervous system and renin-angiotensin-aldosterone system) plays a major role in the pathophysiology of heart failure. In chronic heart failure sympathetic hyperactivity is unfavourable and may result in desensitization and down-regulation of myocardial ß-adrenoceptors with further impairment of cardiac performance and poor outcome. 123-iodine metaiodobenzylguanidine is a norepinephrine analogue, which is taken up and stored in the myocardium similarly to norepinephrine but does not undergo further metabolism and is retained in sympathetic nerve endings, providing a strong signal for imaging (7). 123I-MIBG has been in clinical use in Japan and Europe for 2 decades, and a large number of published reports have documented abnormalities of myocardial sympathetic innervation in various cardiovascular diseases. The results of the 123I-MIBG imaging procedure could therefore potentially identify approximately one-third of the HF population studied as either at substantial risk for near-term mortality or to be at low risk on the current level of therapy. Knowledge of the higher risk associated with abnormal cardiac innervation might have facilitated consideration of more aggressive treatment (such as earlier use of resynchronization therapy) in these subjects (8). Results of eighteen studies with a total of 1 755 patients, stratifying survival, and cardiac events in patients with HF indicate that patients with HF and decreased late H/M ratio or increased myocardial 123I-MIBG WR have a worse prognosis compared with those with normal semi-quantitative myocardial 123I-MIBG parameters (9).

In some studies, only 123I-MIBG H/M ratio was a predictor of death or intractable progressive heart failure leading to heart transplantation or unplanned cardiovascular hospitalization for recurrent episodes of acute heart failure. Patients with poor clinical outcome were older and had higher NYHA functional class, impaired left and right ventricular function, and impaired cardiac 123I-MIBG uptake (10). In our study, one of the most powerful prognostic cardiac 123I-MIBG markers – late H/M ratio differed significantly within the assigned NYHA functional class. The data clearly shows a relation between cardiac autonomic function expressed as sympathetic cardiac activity and functional capacity of heart failure patients.

The purpose of this study was not to compare the effectiveness of CRT and OMT but to evaluate the value of MIBG for both therapy options. Therefore, patients were not randomly assigned to OMT or CRT, but CRT was used in clinically more severe HF.

According to the ROC curve analysis, early and late H/M ratio had cut-off values for separating patients who are going to respond and who will not respond to therapy. Most of the times mentioned in literature, late H/M ratio had cut-off value 1.77 for separating patients into responders and non-responders with the sensitivity of 0.824 and specificity of 0.687. To our knowledge, this is the first time reporting calculated cut-off values acquiring cardiac 123I-MIBG data using medium energy collimators which are more appropriate for the acquisition of 123-iodine images. An attempt to use state-of-the-art nuclear medicine imaging technologies, acquiring cardiac 123I-MIBG SPECT, and calculating regional cardiac 123I-MIBG imaging data – early and late extent, early and late scores, does not provide any additional valuable information for predicting patient's response to therapy.

Further look at the global and regional cardiac 123I-MIBG imaging data reveals a significant difference between global cardiac adrenergic innervation markers – early and late H/M ratios, and WR, where responders had significantly higher early and late H/M ratios, and lower WR. This supports the need to use the calculated cut-off values for predicting patient's outcome.

These data allow us to state that risk stratification according to cardiac 123I-MIBG imaging clearly divides patients to responders and non-responders, despite the chosen type of the therapy. The same thoughts were made by Tanaka et al. (3), as they concluded that cardiac 123I-MIBG imaging may perform a clinical role in the management of patients undergoing CRT, by looking at H/M ratio as a predictor of response to CRT. At the same time, combining H/M ratio with LV EF or with BNP gave an additional predictive power (11). When combined with plasma BNP concentration or cardiac function, cardiac 123I-MIBG activity is closely related to lethal cardiac events and can be used to identify patients who would benefit most from an implantable cardioverter defibrillator (12). Some studies determined whether LVEF influences the relationship between abnormal myocardial sympathetic innervation imaging by 1231-MIBG and outcomes in patients with heart failure. At all levels of LVEF, the 123I-MIBG heart-to-mediastinum ratio of <1.6 was associated with a higher risk of death or potentially lethal arrhythmic event and of the composite of cardiovascular death, arrhythmic event, and HF progression (13).

Many studies have shown that a one-time 123I-MIBG scintigraphic study during a stable period is useful for determining the prognosis of patients with chronic heart failure. Also the changes of WR obtained by serial 123I-MIBG scintigraphy in patients with CHF can be the only independent predictor of cardiac and sudden death in stabilized patients with CHF (14).

Although the importance of the sympathetic innervation of the heart is unquestioned, and the benefits of therapies that ameliorate the effects of neurohormonal imbalance are well established, doubt lingers about the manner in which quantitative assessment of adrenergic neuronal status should be used. It is unlikely that 123I-MIBG imaging will become a routine clinical procedure for monitoring heart disease status or treatment response. It is in the realm of device therapy that 123I-MIBG imaging is likely to have its greatest impact in the next few years (15).

CONCLUSIONS

Cardiac 123I-MIBG imaging has valuable prognostic power predicting clinical outcomes of HF patients with wide QRS complexes, for both CRT and OMT groups, with better outcomes for patients with early H/M ratio 2.00 and late H/M ratio above 1.77. To our knowledge, this is the first attempt to calculate cut-off values acquiring cardiac 123I-MIBG data using medium energy collimators.

However, cardiac 123I-MIBG SPECT data did not have significant values for predicting clinical outcomes.

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PACIENTŲ, KURIEMS GALI BŪTI TAIKOMAS ŠIRDĮ RESINCHRONIZUOJANTIS GYDYMAS, ŠIRDIES VAIZDINIMO SU 123 JODO METAJODOBENZYLGUANIDINU PROGNOSTINĖ VERTĖ

Santrauka

Mūsų tyrimo tikslas buvo ištirti širdies adrenerginės inervacijos vaizdinimo su 123I-MIBG klinikinių išeičių prognostinę vertę taikant įvairius gydymo algoritmus pacientams, sergantiems širdies nepakankamumu ir turintiems ryškius elektrinio asinchroniškumo požymius (pagal dabartines Europos kardiologų draugijos nuorodas – tinkantiems širdį resinchronizuojančiam gydymui).

Medžiaga ir metodai. Tyrimo metu buvo analizuojami duomenys 67 pacientų, sergančių II–IV NYHA funkcinės klasės širdies nepakankamumu ir tinkančių širdį resinchronizuojančiam gydymui (elektrokardiografiškai nustatyti platūs QRS kompleksai (>120 milisekundžių) ir echokardioskopiškai – sumažėjusi kairiojo skilvelio išstūmimo frakcija (<35 proc)). Širdies adrenerginė inervacija ištirta su 123I-MIBG preparatu dvimatės / plokštuminės scintigrafijos ir vieno fotono emisijos kompiuterinės tomografijos (SPECT) metodais. Iš gautų vaizdų buvo apskaičiuojami kiekybiniai rodikliai: ankstyvas ir vėlyvas širdies ir tarpuplaučio santykio (H/M) rodiklis, išsiplovimo rodiklis (WR), suminiai denervacijos rodikliai ir denervacijos rodiklių skirtumai. Tyrimo eigoje pacientai buvo suskirstyti į dvi grupes: 36 pacientams buvo taikyta širdį resinchronizuojanti terapija (ŠRT), implantuojant biventrikulinius kardiostimuliatorius, 31 pacientui buvo tęsiamas optimalus medikamentis gydymas (OMT). Širdies adrenerginės inervacijos su 123I-MIBG tyrimo metu (dviejų savaičių intervale) buvo atlikti įprastiniai klinikiniai širdies nepakankamumo tyrimai, įvertinta pacientų NYHA funkcinė klasė. Pakartotinai šie rodikliai buvo tiriami praėjus 6 mėnesiams nuo tyrimo pradžios. Abi pacientų grupės buvo lyginamos tarpusavyje taikant Stjudento testą, o esant mažoms imtims – Fišerio testą. NYHA funkcinių klasių dinamika palyginta tarpusavyje pagal ANOVA metodiką. ROC kreivės buvo brėžiamos siekiant nustatyti atsako prognostinių rodiklių slenkstines vertes.

Rezultatai. Širdies adrenerginės inervacijos su 123I-MIBG tyrimo rodikliai tarp vėliau suformuotų pacientų grupių skyrėsi nereikšmingai. Pagal NYHA funkcinės klasės įvertinimą ir kairiojo skilvelio išstūmimo frakcijos duomenis, ŠRT grupę sudarė pacientai, kuriems diagnozuotas labiau pažengęs širdies nepakankamumas. Abiejų grupių sunkiausi – IV NYHA funkcinės klasės – pacientai turėjo didesnį diastolinį kairiojo skilvelio diametrą, mažesnę išstūmimo frakciją, didesnes beta natriuretinio peptido koncentracijas kraujyje, pasižymėjo mažesniais vėlyvais H/M ir didesniais denervacijos rodikliais. Abiejų grupių pacientų, kurių klinikinis atsakas į taikytą gydymą buvo geras, ankstyvi H/M rodikliai buvo reikšmingai didesni (2,35 ± 0,41) nei pacientų, kurių klinikinė eiga blogėjo (2,00 ± 0,44) (p = 0,004). Atitinkamai didesni buvo ir vėlyvi H / M rodikliai pacientų su geru atsaku į gydymą (2,11 ± 0,44) nei pacientų su blogėjančia klinikine eiga (1,72 ± 0,54) (p = 0,005). Regioniniai širdies adrenerginės inervacijos su 123I-MIBG rodikliai pagal klinikines išeitis reikšmingai nesiskyrė.

Išvados. Širdies adrenerginės inervacijos su 123I-MIBG vaizdinimas pateikia vertingą prognostinę informaciją, padedančią numatyti pacientų, sergančių širdies nepakankamumu, klinikinę eigą. Nepaisant pasirinktos gydymo taktikos, geresnis klinikinis atsakas buvo tų pacientų, kurių ankstyvas ir vėlyvas H/M rodikliai atitinkamai buvo didesni nei 2,00 ir 1,77.

Raktažodžiai: širdies nepakankamumas, širdį resinchronizuojantis gydymas, branduolinės medicinos vaizdinimas, MIBG