MORPHOLOGY AND PATHOMORPHOLOGY

Postinfarction Remodeling of the Heart: Types of Pathomorphological Changes in the Right Ventricle

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New geometric characteristics of the right ventricle depended on the localization of macrofocal transmural scars in the left ventricle of postinfarction heart. Most pronounced changes in the right ventricle were observed during dilatational and hypertrophic remodeling of the heart. The increase and decrease in the volume were most frequently occurring and pathognomonic forms of pathomorphological changes in the right ventricle. Dilatational remodeling was accompanied by a decrease in the volume of the right ventricle. The increase in the volume of this ventricle was typical of hypertrophic remodeling. Pathological variability in the right ventricle underlies the development of severe disturbances in intracardiac hemodynamics, *i.e.*, patho- and thanatogenesis of postinfarction heart.

Key Words: *macrofocal cardiosclerosis; types of cardiac remodeling; cardioventriculography; cardiometry; histopathology*

Remodeling of postinfarction heart (PH) is determined by scar changes in the left ventricle and morphofunctional state of marginal and conventionally intact myocardium [2,3]. During studies of this complex process in clinical and pathomorphological practice, particular attention is given to changes in the left ventricle [9]. It should be emphasized that the dynamic process of PH remodeling is related to inadequate hemodynamic parameters and followed by the development of profound changes in the right ventricle, which determines clinical course of myocardial infarction.

The increasing incidence of right ventricle damage in the postinfarction period and the absence of pathomorphological diagnostic criteria formed the basis for a special investigation.

Here we evaluated most reliable criteria for variability of the right ventricle during remodeling of PH, studied their influence on intracardiac hemodynamics, and determined the main stages of patho- and thanatogenesis.

MATERIALS AND METHODS

We examined 260 hearts of patients who died in various stages of the postinfarction period (184 men and 76 women, mean age 56.4±0.6 years). The mean postinfarction period was 8.4±0.2 years. Sixty hearts without pathomorphological signs of myocardial scars were taken from individuals of comparable age after accidental death and served as the control.

The state of cardiac ventricles and type of remodeling were determined by means of postmortem contrast cardioventriculography. Cardiac ventricles were filled with a contrast solution (20-30% barium sulfate in gelatin, the volume of this solution was measured) on a dissection table over the first hours after death. Polypositional X-ray study was performed before filling with the contrast solution and after solidification of gelatin.

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The severity of scar injury in the myocardium was evaluated by the method recommended by the World Health Organization and involving macroscopic examination of transverse serial sections of the heart after cardioventriculography. We analyzed samples with transmural postinfarction scars, whose diameter was equal to or surpassed 2 cm. Functional capacity of PH was determined by weight-volume and planimetric cardiometry and pathohistological assay [3]. Myocardial samples were fixed in 10% neutral formalin and embedded in paraffin. The sections were stained with hematoxylin and eosin, van Gieson's picrofuchsin, and Weigert's picrofuchsin-fuchseline to reveal elastic fibers. Muscle and connective tissues were visualized by staining with hematoxylin, eosin, and light green. We evaluated the dependence of pathomorphological changes in the right ventricle on the main localization of macrofocal transmural scars in the left ventricle. These changes were classified depending on the type of PH remodeling [3]. The results were analyzed by methods of variational statistics (pairwise Student's *t* test).

RESULTS

Configuration of the right ventricle during various types of PH remodeling was evaluated depending on the main localization of macrofocal transmural scars in the left ventricle. Profound changes in geometric characteristics of the right ventricle were revealed in 59.2% samples (Table 1). Changes in the configuration of the right ventricle most often accompanied dilatational remodeling with circular scars in the left ventricle of PH (67% samples). Hypertrophic remodeling with the main localization of scar injury in the interventricular septum and apex of PH ranked second by the incidence of pronounced reconstruction of the right ventricle (56% samples).

Aneurysmal remodeling of PH with the main localization of postinfarction scars in the septal-apical region of the left ventricle ranked third in the incidence of geometric reconstruction of the right ventricle (52% samples). Changes in geometric characteristics of the right ventricle were found in 50% samples with endocardial remodeling. Macrofocal scar injury in the left ventricle was circular. It should be emphasized that geometric characteristics of the right ventricle remained unchanged in 16% samples with various types of remodeling independently on the main localization of scars.

Our results indicate that pathomorphological changes in the right ventricle are most pronounced during dilatational and hypertrophic remodeling of PH. Macrofocal transmural scars localized circularly or in the septal and apical region of the left ventricle play a

TABLE 1. Incidence and Main Localization of Macrofocal Transmural Scars in the Left Ventricle of the Heart and Degree of Geometric Reconstruction of the Right Ventricle during Various Types of Postinfarction Remodeling

Type of remodeling	Main localization of macrofocal transmural scars in the left ventricle of the heart				Geometric changes in the right ventricle of the heart		
	anterior wall	posterior wall	interventricular septum and apex	circular scars	severe	moderate	not observed
Dilatational (*n*=108)	12	14	30	52	72 (67)	26 (24)	10 (9.8)
Hypertrophic (*n*=78)	10	6	42	20	44 (56)	18 (23)	16 (21)
Aneurysmal (*n*=46)	4	6	20	16	24 (52)	12 (26)	10 (22)
Endocardial (*n*=28)	2	10	4	12	14 (50)	8 (28)	6 (21)
Total (*n*=260)	28	36	96	100	154 (59)	64 (25)	42 (16)

Note. *n*, number of samples. Percentage is shown in brackets.

special role in geometric reconstruction of the right ventricle in PH. Scar injury in the anterior and posterior walls of the left ventricle produces little effect on postinfarction reconstruction of the right ventricle during various types of PH remodeling.

Polypositional cardioventriculography showed that the increase and decrease in the volume were most frequently occuring and pathognomonic forms of pathomorphological changes in the right ventricle. Dilatational remodeling was accompanied by a decrease in the volume of the right ventricle. The hypertrophic and shifted interventricular septum in dilated PH displaced the right ventricle in a proximal-lateral direction. This ventricle gained a triangular shape with sharply reduced cavity. The volume of the right ventricle was 4-12 times lower than that of the dilated left ventricle in PH (Fig. 1, *a*).

Pronounced dilation, increased volume of the left ventricle, and reduced volume of the right ventricle promote a significant increase in end-diastolic pressure in the remodeled right ventricle and contribute to the development of pulmonary hypertension [6]. The reduction of systolic function in the right ventricle of PH is associated with abnormal contractile activity of the myocardium and increase in afterload. It results from the inadequacy of myocardial hypertrophy and dilation of the left ventricle to a sharp decrease in the volume of the right ventricle [4]. These changes are the major cause of insufficiency of dilated PH after reduced-volume remodeling of the right ventricle.

The decrease in the volume of the right ventricle was also observed during hypertrophic remodeling of PH. The hypertrophic interventricular septum displaced free cavity of the right ventricle. This ventricle gained a triangular shape and the cavity volume decreased, but was only 2-4 times lower than that of the left ventricle in PH (Fig. 1, *b*).

It should be emphasized that the decrease in ventricle cavities in PH was primarily related to pronounced non-proportional hypertrophy of the interventricular septum and marginal myocardium. These changes decrease right ventricle compliance and decelerate its relaxation. Impaired myocardial relaxation in the remodeled right ventricle of PH correlates with the decrease in contractile activity [4,7,10]. Profound changes in isovolumic relaxation of the myocardium and filling of ventricles lead to the development of chronic cardiac insufficiency, which is a major cause of death in these patients [5].

Volume-increasing reconstruction of the right ventricle is typical of hypertrophic PH remodeling. Pronounced hypertrophy of left ventricular walls and interventricular septum reduced its cavity. However, the volume of the right ventricle sharply increased and 6-fold surpassed that of the left ventricle in PH. It should be emphasized that the volume of the right ventricle increased in some samples after combined remodeling of PH (hypertrophic and aneurysmal, Fig. 2).

Considerable increase in the volume of the right ventricle leads to relative tricuspid insufficiency ac-

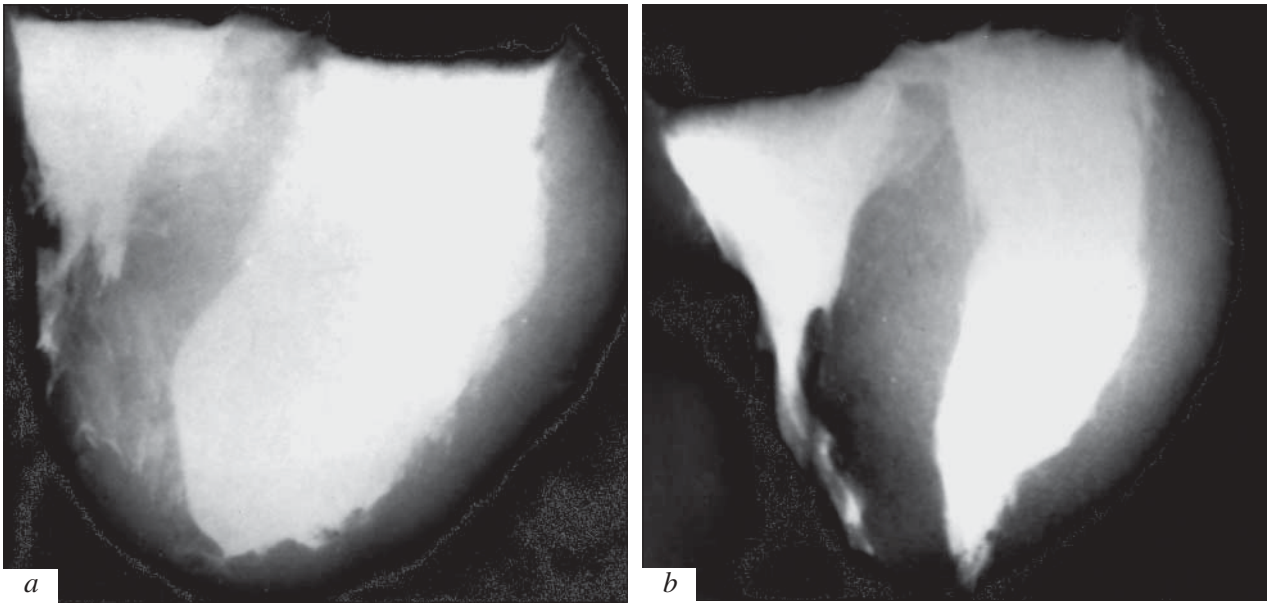

Fig. 1. Reduced-volume reconstruction of the right ventricle during postinfarction remodeling of the heart. Postmortem contrast cardioventriculography. X-ray films, 3-fold demagnification. Fivefold decrease in the size of the cavity and volume of the right ventricle (compared to the left ventricle), which gains a triangular shape during dilatational remodeling (patient G., 54 years, *a*). Sharply hypertrophic interventricular septum displays a free cavity of the right ventricle with a 2-fold reduced volume (compared to the left ventricle) during hypertrophic remodeling (patient V., 56 years, *b*).

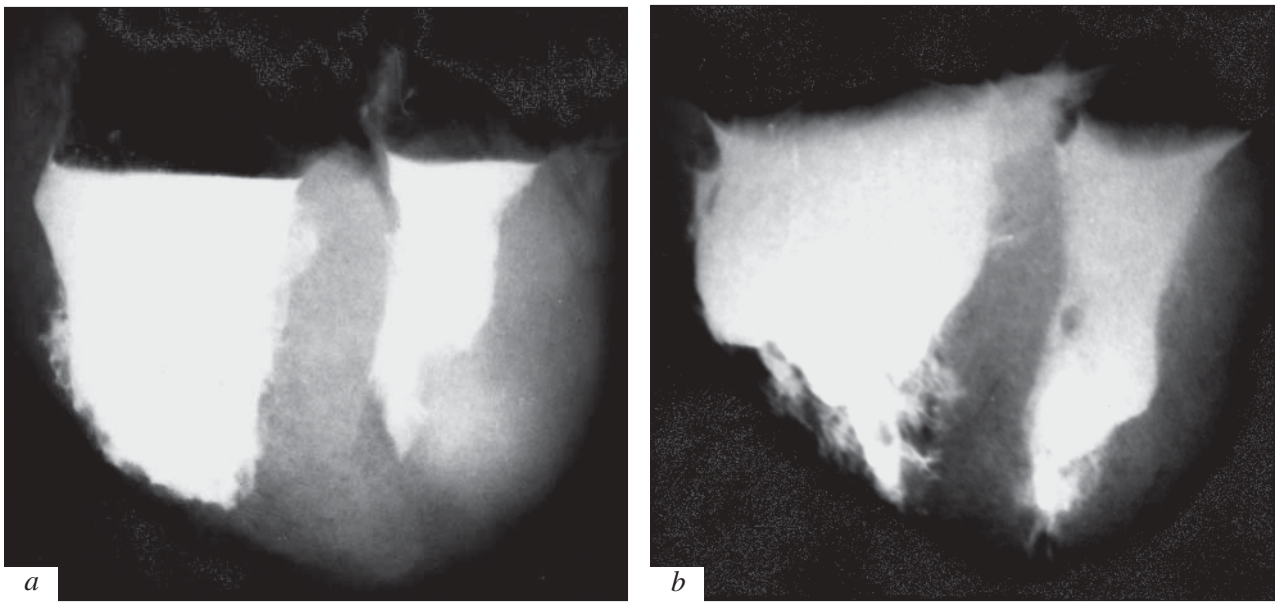

Fig. 2. Volume-increasing reconstruction of the right ventricle during combined remodeling of postinfarction heart. Postmortem contrast cardioventriculography. X-ray films, 3-fold demagnification. Pronounced hypertrophy of left ventricular walls and interventricular septum, decrease in the size of its cavity, and sacculate aneurysm. The volume of the right ventricle 3-fold surpasses that of the left ventricle (patient G., 52 years, *a*; patient N., 58 years, *b*).

companied by a decrease in the efficiency of cardiac output [1]. Pronounced differences in the volume of PH ventricles and predominance of the right ventricle produce a reverse or paradoxical effect [12,13]. These changes affect filling of ventricles and impair the sequence of diastolic events. The presence of aneurysmal structures in reduced left ventricles of PH provides a biophysical basis for low-efficiency diastole and progression of insufficiency [8]. Geometric deformation of the cavity in the left ventricle and complex construction of the dilated cavity in the right ventricle determine asynchronism of PH contractions [11].

Endocardial remodeling of PH was most often accompanied by a decrease in the volume of the right ventricle due to the formation of "scar covering" in the parietal endocardium that diffusely spread from the major zone of cicatrization. These changes violate diastolic function of PH, which is associated with impairmeng of pumping function of the modified right ventricle [13].

Complex pathomorphological study of the hearts from patients dying in various stages of the postinfarction period revealed a correlation between remodeling of the left ventricle and severity of structural changes in the right ventricle of PH. The observed changes in both ventricles determine differences between end diastolic pressure in chambers of PH and lead to serious disturbances in myocardial contractility. They underlie rapid development of cardiac insufficiency, which is manifested in lengthening of isovolumic relaxation and decrease in the ejection period [11]. These changes are most pronounced during moderate hypertrophy of walls in remodeled ventricles [14]. The impairment of myocardial contractility is accompanied by a considerable decrease in the coefficient of myocardial activity, which reflects the formation of scar injury and disturbances in the mechanism of Frank-Starling [15]. The observed changes underlie patho- and thanatogenesis during damage to the right ventricle in PH.

Our findings show that pathomorphological and geometric characteristics during postinfarction remodeling primarily depend on the localization of macrofocal transmural scars in the left ventricle of the heart. Most pronounced changes in the right ventricle are observed during dilatational and hypertrophic remodeling of the heart. The increase and decrease in the volume are most frequently observed and pathognomonic forms of pathomorphological changes in the right ventricle of PH. Dilatational remodeling is accompanied by a decrease in the volume of the right ventricle. An increase in the volume of this ventricle is typical of hypertrophic remodeling of PH. Changes in the geometric characteristics of the right ventricle can be used for differential diagnostics and underlie the development of cardiac insufficiency. This is the major cause of death in patients with damage to the right ventricle during remodeling of PH.

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