Chronic cardiac insufficiency: therapy with beta-adrenergic blockers

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The results of the ISIS-I tests demonstrated that beta-adrenergic blockers have a decidedly positive prognostic effect on secondary prevention of myocardial infarction (Table 1). This applies particularly to patients after major infarctions, and even to patients with cardiac insufficiency symptoms [1] (Fig. 1). In spite of this, the initial reports by Waagstein et al. [2] that therapy with beta-adrenergic blockers leads to an improvement in symptoms and prolongation of life in cardiac insufficiency patients with cardiomyopathy were received rather sceptically. This is not all that surprising, since the treatment of cardiac pump failure with cardiodepressive drugs seems at first glance to contradict traditional therapy which uses substances with a positive inotropic effect or that reduce the pre- and afterload [3, 4].

Current attempts at reorientation are based partly on a better understanding of the pathophysiology of chronic cardiac insufficiency and partly on controlled prospective studies with a large number of cardiac insufficiency patients.

The following text will illustrate the current position on the use of beta-adrenergic blockers in chronic left ventricular failure.

1. Pathophysiological aspects

The human heart is not subject to major sympathoadrenergic stimulation when at rest. Therefore, the administration of beta-adrenergic blockers at the normal levels (eg, bisoprolol 5 mg p.o.) has neither a heart rate-reducing nor a negative inotropic effect. However, heart failure leads to a continual sympathetic stimulation (increase in plasma noradrenaline) first during exercise, then at rest. In cases of reduced left ventricular pump function (eg, ejection fraction < 35 %) this in turn leads to a down regulation of beta-adrenoceptors, an increase in guanine nucleotide binding proteins with an inhibitory effect on adenyl cyclase (Gi) and reduced effectiveness of the intracellular cAMP [5]. The administration of adrenergic blockers to patients with cardiac insufficiency and stimulated neurohumoral system leads to a frequency reduction and a decrease in contractility and velocity contraction [6–9].

In humans, the number of beta-adrenoceptors present in the left ventricular myocardium correlates linearly with the maximum attainable contractility after stimulation with noradrenaline (Fig. 2). A reduction in beta-adrenoceptors results in an equivalent percentile reduction in the maximum stimulatable contractility after administration of noradrenaline or isoprenaline [10]. This means that the human heart has no receptor reserve. The logical conclusion is that patients suffering from chronic cardiac insufficiency (NYHA IV) with beta-adrenoceptors of approximately 30 % of the normal level and a high blood concentration of noradrenaline (symptomatic cardiac insufficiency) can only increase their contractility by a maximum of 30 % above the non-stimulated (rest) condition. Assuming that the patient can only achieve the necessary cardiac output through increased noradrenaline concentration and activation of all remaining beta-adrenoceptors which results from it, it is conceivable that the blockage of an additional 10 % of the beta-adrenoceptors through the administration of beta-blockers could lead to a considerable reduction in contractility (of 10 %) and thus possibly to a critical reduction in cardiac output (pulmonary oedema).

**Key-words:** Heart failure, beta-blocking agents, heart rate, bisoprolol, beta-adrenoceptors

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**Table 1: Beta-blockers after myocardial infarction**

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Relative</th>
<th>Absolute</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHF (n = 710)</td>
<td>0.69</td>
<td>5</td>
</tr>
<tr>
<td>No CHF (n = 3127)</td>
<td>0.71</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>0.72</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Odds ratio $\pm$ 95 % confidence interval

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**Figure 1:** Effects of propranolol on mortality after myocardial infarction (BHAT-Trial). Astonishingly the effect of propranolol in patients with myocardial infarction was especially good in patients with chronic heart failure (CHF). The absolute numbers of lives saved was highest in this cohort.

**Figure 2:** The density of beta-adrenoceptors in human myocardium increases with maximal positive inotropic effect. This means, that the linear relationship is indicative of a missing receptor reserve.

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1. Anti-anginal (anti-ischaemic) effects
2. Antihypertensive effects
3. Anti-arrhythmic effects
4. Reduction in infarction mortality rate (by 15–20%)
5. Symptomatic with hypertrophic obstructive cardiomyopathy
6. Chronic left ventricular failure from dilative cardiomyopathy and after myocardial infarctions
7. Dissecting aortic aneurysm (pressure and heart rate reduction)
8. Symptomatic in mitral valve prolapse syndrome
9. In vasovascular syncope and in QT syndrome
10. Perioperative in coronary heart disease

This leads to the conclusion that high plasma noradrenaline concentrations lead on the one hand to a reduced physiological stimulation of the diseased heart muscle under the administration of noradrenaline due to the additional down regulation of the beta-adrenoceptors, but on the other hand that they could be necessary to maintain adequate cardiac output in patients with severely reduced pump function. The anti-adrenergic effect of the beta-blockers must have a negative inotropic effect in the presence of higher catecholamine concentrations [5], but protects the heart muscle cells from the negative effect of higher noradrenaline concentrations at the same time (further down regulation of the beta-adrenoceptors, tachycardia, cardiac arrhythmia) (Table 2).

### 1.1. The force-frequency relation of the heart muscle

The sufficient heart muscle increases its contractility as the heart rate increases (Bowditch effect). On the other hand, the insufficient myocardium exhibits a marked decrease in contractility as the heart rate increases (Fig. 3), which leads to the conclusion that higher heart rates (a reduction in the contractility of the individual beats) contributes to an inefficient pump function [11]. In experiments, cardiac insufficiency can actually be caused by continuous tachycardia [12]. The same applies to certain cardiac arrhythmias with permanently increased heart rate [13]. A reduction in the heart rate alone leads to improved pump function. There is apparently no compensatory tachycardia – at least with cardiac insufficiency, rather it must be assumed that the reduction of the increased heart rate is likely to be beneficial for the pump function [14]. There is much evidence which shows that drugs which further increase the heart rate in patients with chronic cardiac insufficiency worsen the patient's prognosis. On the other hand, cardiac glycosides, amiodarone and beta-adrenergic blockers appear to exclusively have a beneficial effect in patients who have previously had an increased heart rate which was reduced through therapy.

### 1.2. Effects of administration of beta-blockers on beta-adrenoceptors

It has been shown in vitro and in cardiac insufficiency patients that the administration of beta-blockers leads to up-regulation of beta-adrenoceptors in the insufficient heart [15]. However, while this is only true of metoprolol and bisoprolol, it is not true of carvedilol, and leads to the assumption that the positive therapeutic effects of the beta-adrenergic blockers on chronic left ventricular failure are not or not only attributable to the increase in beta-adrenoceptors in the myocardium [16]. This also offers a pathophysiological explanation for the beneficial prognostic effect of the beta-adrenergic blockers, namely the reduction in heart rate, the regular increase in the ejection fraction and the anti-adrenergic effect. In any case, it has been proven that the beta-blocker therapy leads to lower plasma noradrenaline concentrations and higher lactate extraction, both of which are positive [8, 12].

### 2. Beta-blockers after myocardial infarction

Beta-adrenergic blockers definitely have a positive effect on the patients' prognosis in the absence of intrinsic sympathomimetic activity (ISA), though the pathophysiological mechanism of this life-prolonging effect is still not understood [17]. It is known that all positive inotropic drugs (eg, digitalis) lead to an increase in the size of the infarct area [18], but all drugs which have been proven to stimulate the neurohumoral system (catecholamines) are unfavourable for the prognosis after a myocardial infarction. This leads to the conclusion that a reduction in heart rate and plasma noradrenaline concentration are beneficial in the post-infarction stage [19, 20]. For this reason, beta-adrenergic blockers would also have to be beneficial for long-term therapy after a myocardial infarction (heart rate reduction, reduction in plasma noradrenaline concentration, increase in lactate consumption) [21], but it is still not clear how long beta-adrenergic blockers should be administered after such an infarction.

### 3. The established cardiac insufficiency therapy

It is currently accepted that diuretics, digitalis and ACE inhibitors should be administered for manifest chronic left ventricular failure [3]. Diuretics reduce the pre- and afterload of the heart and therefore the wall tension in the left ventricle. Stimulation of RAAS caused by diuretics is counteracted by ACE inhibitors. Only ACE inhibitors have been proven to lead to prognostic improvement in symptomatic left ventricular failure (NYHA II to NYHA IV). Cardiac glycosides reduce the necessity of inpatient treatment and reduce cardiac insufficiency symptoms by about 20%. It can also be assumed that ACE inhibitors are indicated for reduced pump function (EF of the left ventricle < 35 %) because they reduce the frequency of left ventricular failure. It is not known whether ACE inhibitors should always be used in combination with diuretics or not, but it is certain that diuretics are principally indicated together with ACE inhibitors for hydropic cardiac insufficiency.

The results of the ELITE study indicate that ACE inhibitors can be replaced with losartan, which may reduce the incidence of acute cardiac death and is even more effective than ACE inhibitors.

If we are to continue to strive for an improvement of the rather poor prognosis of chronic left ventricular failure in spite
of diuretics, digitalis and ACE inhibitors, then selected drugs must be applied in addition to the established therapy. This has already been done with beta-adrenergic blockers in large controlled studies. The results correlate closely to a reevaluation of our conventional therapeutic procedure [22, 23].

### 4. Controlled studies of the effect of beta-blockers on chronic cardiac insufficiency

Large controlled studies that combined bisoprolol, metoprolol and carvedilol with diuretics, digitalis and ACE inhibitors yielded positive results in chronic left ventricular failure patients [16, 24, 25] (Table 3).

In a double-blind, placebo-controlled study of chronic cardiac insufficiency (NYHA III to IV) with bisoprolol (CIBIS Study), 641 patients were treated with bisoprolol in addition to basic therapy with diuretics and ACE inhibitors (Fig. 4). The reduction in mortality rate for all groups was not statistically significant. 23 of 115 patients with idiopathic dilative cardiomyopathy yielded positive results in chronic left ventricular failure and carvedilol with diuretics, digitalis and ACE inhibitors, then selected drugs must be applied in addition to the established therapy. This has already been done with beta-adrenergic blockers in large controlled studies. The results correlate closely to a reevaluation of our conventional therapeutic procedure [22, 23].

In March 1998, the safety and scientific committees of the CIBIS-II trial recommended to stop this investigation, because those patients, which had received bisoprolol, experienced a 30 % reduction in mortality. The benefit was irrelevant of the cause of heart failure in NYHA III-IV (CHD/DCM). The final results were reported at the European Congress of Cardiology 1998 but have not been published yet.

### 5. What the beta-blocker studies mean for our therapy

Bisoprolol and metoprolol seem to further improve the prognosis of patients suffering from dilative cardiomyopathy and for all patients with a reduced ejection fraction and cardiac insufficiency symptoms (Table 3, 4).
6. Practical suggestions for therapy with beta-adrenergic blockers

At present beta-adrenergic blockers should only be given to patients with reduced pump function of the left ventricle and cardiac insufficiency symptoms when the patient is in a more or less stable condition under digitalis, diuretic and beta-blocker therapy, i.e., when the diuretic dosage did not have to be acutely increased within the last 14 days. It is vital that the dosage starts at 1/10 of the target dosage and is increased gradually in 14 day increments. It is also advisable that the patients undergo a complete clinical examination before each dosage increase (auscultation of the lungs, checking body weight and checking for malleolar oedema). Experience has shown that too rapid a dosage increase is generally linked with intolerance of beta-adrenergic blockers. Improvement of the cardiac insufficiency symptoms cannot be expected until three to six months after induction, which makes any rapid dosage increase unnecessary and hazardous. The CIBIS study dosage schedule is shown in Figure 5.

The normal contraindications for beta-blocker therapy must of course be followed. Simple cardiac insufficiency does not appear to be a contraindication with proper dosage and when the proper safety measures are followed (Table 5).

The administration of beta-adrenergic blockers to patients suffering from chronic left ventricular failure should never be considered an acute measure, and is therefore superfluous in intensive care or for decompensated cardiac insufficiency – except for the treatment of absolute tachyarrhythmia or other tachycardia. In this case, normal dosing indications for beta-blockers apply.

In our opinion, cardiac insufficiency therapy with beta-adrenergic blockers can be considered to be very safe when carried out properly. Many patients have already benefited from it and the prognosis for this syndrome has improved significantly in recent years.

References

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