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 cardiodepressing 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 (e.g., 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 function (e.g., 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).

Table 1: Beta-blockers after myocardial infarction

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Relative</th>
<th>Absolute (lives saved/100 treated)</th>
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</thead>
<tbody>
<tr>
<td>CHF (n = 710)</td>
<td>0.69</td>
<td>5</td>
</tr>
<tr>
<td>No CHF (n = 3127)</td>
<td>0.74</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>0.72</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Odds ratio ≥ 95 % confidence interval

Figure 1: Effects of propanolol on mortality after myocardial infarction (BHAT-Trial). Astonishingly the effect of propanolol 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.
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

<table>
<thead>
<tr>
<th>Table 2: Established positive effects of beta-adrenergic blockers</th>
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<tbody>
<tr>
<td>1. Anti-anginal (anti-ischaemic) effects</td>
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<tr>
<td>2. Antihypertensive effects</td>
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<tr>
<td>3. Anti-arrhythmic effects</td>
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<tr>
<td>4. Reduction in infarction mortality rate (by 15–20 %)</td>
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<tr>
<td>5. Symptomatic with hypertrophic obstructive cardiomyopathy</td>
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<tr>
<td>6. Chronic left ventricular failure from dilative cardiomyopathy and after myocardial infarctions</td>
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<td>7. Dissecting aortic aneurism (pressure and heart rate reduction)</td>
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<tr>
<td>8. Symptomatic in mitral valve prolapse syndrome</td>
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<tr>
<td>9. In vasovascular syncope and in QT syndrome</td>
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<tr>
<td>10. Perioperative in coronary heart disease</td>
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</table>

Figure 3: In human myocardium force of contraction increases with the frequency. This is, however, only true for a normal, non-failing myocardium. In heart failure the force of contraction decreases with increasing frequency of contraction. Thus, a high heart rate may lead to deterioration of the patient.
The results of this study should be available in 1998. More than 2500 patients have already been enrolled in the two year study.

383 patients suffering from moderately severe cardiac insufficiency (NYHA II and III) were observed in the MDC study. All patients had an ejection fraction under 40 % as a result of an idiopathic dilative cardiomyopathy and were treated with either a placebo or metoprolol in addition to diuretics, digitalis and ACE inhibitors. 5 mg metoprolol was administered twice daily over two to seven days as a test dose. The target medication was gradually increased to 100–150 mg metoprolol per day. The primary endpoint of the study was seen as death and the necessity of heart transplant, and 34 % fewer patients in the metoprolol group reached this point. This study has been criticized because the necessity of heart transplant was not viewed as a hard criterion. In spite of this, the study shows the favourable result of beta-blocker therapy under the pre-specified criteria for patients suffering from chronic cardiac insufficiency.

Carvedilol was tested in 1094 patients suffering from chronic cardiac insufficiency with an ejection fraction of  \( \leq 35 \% \) [16]. In addition to diuretics, digitalis and ACE inhibitors, 398 patients received placebo and 696 received carvedilol. The total mortality rate among the patients on placebo was 7.8 % and 3.2 % among patients on carvedilol. The study was prematurely ended as a result of the prolonged survival among patients on carvedilol. The carvedilol therapy was much more effective in terms of the frequency of hospitalisation and the incidence of cardiac insufficiency. The fact that 6 patients died during the run-in phase has been widely criticised, but this has been observed in almost all large cardiac insufficiency studies and does not detract from the results of the study.

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 when taken in addition to diuretics, digitalis and ACE inhibitors [26]. Carvedilol appears to improve the prognosis regardless of the cause of the cardiac insufficiency. The results of the CIBIS-II study, in which bisoprolol has been administered to postmyocardial infarction subjects and subjects suffering from dilative cardiomyopathy under controlled circumstances, are convincing. Thus, we now know that bisoprolol improves the prognosis for patients suffering from dilative cardiomyopathy and for all patients with a reduced ejection fraction and cardiac insufficiency symptoms (Table 3, 4).

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**Figure 4:** Survival curves (Kaplan-Meier) of CIBIS-patients with and without history of myocardial infarction.

**Table 3:** Effects of beta-adrenergic blockers on chronic cardiac insufficiency

<table>
<thead>
<tr>
<th>Study</th>
<th>Illness</th>
<th>n</th>
<th>beta-blocker (dose)</th>
<th>Symptomatic improvement</th>
<th>Reduction in mortality rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDC</td>
<td>DCM</td>
<td>194</td>
<td>metoprolol (108 ± 51 mg)</td>
<td>+</td>
<td>18 %</td>
</tr>
<tr>
<td>CIBIS I</td>
<td>CHD/DCM</td>
<td>320</td>
<td>bisoprolol</td>
<td>++</td>
<td>20 % for all</td>
</tr>
<tr>
<td>CIBIS II</td>
<td>CHD/DCM</td>
<td>1300</td>
<td>(1.25–5 mg)</td>
<td>++</td>
<td>53 % for DCM</td>
</tr>
<tr>
<td>US trials</td>
<td>CHD/DCM</td>
<td>623</td>
<td>carvedilol</td>
<td>++</td>
<td>67 %</td>
</tr>
</tbody>
</table>

DCM = dilative cardiomyopathy, CHD = coronary heart disease
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 cardiac insufficiency symptoms when the patient is in a more stable condition 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 tachycardia 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.

Table 4: Discontinuation therapy in beta-adrenergic blocker studies

<table>
<thead>
<tr>
<th>Discontinuation Rates</th>
<th>Placebo</th>
<th>beta-blocker</th>
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<tbody>
<tr>
<td>MDC [2]</td>
<td>16 %</td>
<td>12 %</td>
</tr>
<tr>
<td>CIBIS [24]</td>
<td>26 %</td>
<td>23 %</td>
</tr>
<tr>
<td>US trials [16]</td>
<td>7.8 %</td>
<td>5.7 %</td>
</tr>
</tbody>
</table>

Table 5: Therapeutic recommendations for treating chronic cardiac insufficiency with beta-adrenergic blockers

1. Only with patients who have been stable for longer than two weeks
2. Only in addition to diuretics, digitalis and ACE inhibitors
3. Not when the diuretic dosage had to be increased recently
4. Out-patient therapy for NYHA I–II
5. In-patient therapy for NYHA IV
6. Test dose and starting dose: 1/10 of the target dosage
7. Dosage increase every two weeks
8. Target dosage: 2 mg bisoprolol, 2 x 100 mg metoprolol, 2 x 25 mg carvedilol
9. A full clinical examination of the patient before each dosage increase
10. Improvements should not be expected until 3–6 months after induction

References

5. In-patient therapy for NYHA I–II
6. Test dose and starting dose: 1/10 of the target dosage
7. Dosage increase every two weeks
8. Target dosage: 2 x 5 mg bisoprolol, 2 x 100 mg metoprolol, 2 x 25 mg carvedilol
9. A full clinical examination of the patient before each dosage increase
10. Improvements should not be expected until 3–6 months after induction

Figure 5: The titration of bisoprolol in patients of CIBIS-II-study.

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