TABLE VI

Annual Incidence of Congestive Heart Failure (CHF) According to Sex and Diabetic Status at Each Biennial Examination Excluding Subjects with Coronary (or Rheumatic) Heart Disease Before the Development of Failure: 18 Year Follow-Up Study

Diabetic Status	Person Years At Risk	New CHF Cases	Annual Incidence: Crude per 10,000	Annual Incidence: Age-Adjusted* per 10,000	Relative Risk
Men aged 45 to 74 Years					
Nondiabetic	23,844	32	13.42	13.53	3.79†
Diabetic	970	6	61.86	51.41	
Total	24,814	38			
Women Aged 45 to 74 Years					
Nondiabetic	32,892	30	9.12	9.23	5.48†
Diabetic	980	7	71.43	50.54	
Total	33,872	37			

* Indirect method.

† Significant at $P < 0.01$ level (chi square = 8.15 and 17.27 for men and women, respectively).

TABLE VII

Annual Incidence of Congestive Heart Failure (CHF) According to Sex and Diabetic Status at Each Biennial Examination in Subjects with Coronary (or Rheumatic) Heart Disease Before the Development of Failure: 18 Year Follow-Up Study

Diabetic Status	Person Years At Risk	New CHF Cases	Incidence: Crude per 10,000	Incidence: Age-Adjusted* per 10,000	Relative Risk
Men Aged 45 to 74 Years					
Nondiabetic	3,144	54	171.76	172.07	1.11
Diabetic	256	5	195.31	190.99	
Total	3,390	59	...	...	...
Women Aged 45 to 74 Years					
Nondiabetic	2,436	39	160.10	147.39	3.16†
Diabetic	210	10	476.19	465.17	
Total	2,646	49	...	...	...

* Indirect method.

† Significant at $P < 0.01$ level (chi square = 8.51).

count in this tabulation. This hypothesis is confirmed by the finding that even when patients with prior coronary or rheumatic heart disease were excluded, patients with diabetes still had a four- to fivefold increased risk of congestive heart failure (Table VI). Also, among persons with prior coronary or rheumatic heart disease, diabetic women had an excess rate of congestive heart failure. This excess could not be demonstrated for men in the small number of cases available (Table VII).

Furthermore, a comparison of the regression coefficients in the bivariate (taking only age into account) and multivariate case (taking into account blood pressure, cholesterol and relative weight as well) indicates that the effect of diabetes is not mediated through these atherogenic traits (Table VIII). An examination of the regression of the incidence of congestive failure on diabetic status in men with and without coronary heart disease also reveals substantial and significant coefficients only for patients without coronary heart disease. The regression coefficients in the multivariate case are only slightly reduced compared with those in the univariate case (Table VIII).

Taking all these facts into consideration it appears unlikely that diabetes promotes congestive failure by accelerating coronary atherogenesis. Nor does it appear that hypertension accounts for the increased risk. In women, significant regressions are noted in both those with and those without prior coronary heart disease although the coefficients are somewhat larger in the latter group. Also, the coefficients are substantially larger in women than in men.

Role of insulin: Further examination of the group of patients with diabetes who had congestive heart failure revealed that more than half were taking insulin. Treatment of diabetes was therefore subjected to analysis, revealing that the only subgroup of diabetic subjects that sustained a substantial and statistically significant increased risk of congestive failure was the group treated with insulin. This was demonstrated by a bivariate regression analysis accounting for age (Table IX).

Discussion

The finding of an increased risk of congestive heart failure in diabetic subjects is not unexpected in view of the frequent association of diabetes with hypertension, hyperlipidemia, obesity and coronary heart disease. The strength of the relation, particularly in women, and the demonstration that the excess risk of myocardial decompensation in the diabetic subject is independent of all these atherogenic traits are unexpected and indicate some other mechanism. It has been suggested that some form of cardiomyopathy is associated with diabetes.[6] The findings reported herein lend some substance to this claim.

Metabolic causes of diabetic cardiomyopathy: Such diabetic cardiomyopathy could result from diabetic microangiopathy or an abnormal myocardial metabolism. The heart normally derives most of its energy for contraction from free fatty acids, although glucose, lactate and pyruvate are also used.[7-11] Any reduction in oxygen tension immediately produces changes in the electrical and contractile performance of the heart. Efficient metabolism of fatty acid and pyruvate is hampered by hypoxia, leaving only the glycolytic pathway to generate the high energy phos-