Management of Cardiovascular Diseases During Pregnancy

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I. The two-step exercise test as a method for evaluating cardiac performance during pregnancy.

Remarkable changes take place in the maternal circulation during pregnancy. The plasma volume increases by an average of approximately 50% during the last trimester of pregnancy (1), and a positive relationship has been revealed between the magnitude of this increase in plasma volume and the birth weight of the infant in primigravidas (2). Therefore, the heart of pregnant women presumably must work harder than that of the non-gravid in order to accommodate the vascular expansion which occurs during pregnancy.

These cardiovascular changes during gestation can be investigated by the ultrasonic cardioechogram method. The stroke-volume of the heart can be calculated by using the cardioechogram to determine the difference between the longest and the shortest diameters of the left ventricle as it changes during the cardiac cycle. This method shows that the stroke-volume as measured in supine position increases by about 20% during the last trimester of pregnancy as compared to non-gravid women (Fig. 1). This increase in stroke-volume, combined with an increase in heart rate, results in a net increase in cardiac output of about 45% during pregnancy (Fig. 1).

![Fig. 1. Changes in stroke-volume and cardiac output during pregnancy as measured by cardioechogram. (From the data of our coworker I. Shintani.)](image-url)
This excessive cardiac load sometimes imposes an untolerable strain that can potentiate heart disease. For example, 15.2% of the cases of rheumatic heart disease and 1.9% of the cases of congenital heart disease culminate in acute congestive heart failure during pregnancy and early puerperium (Fig. 2). Thus, the patient with rheumatic heart disease is especially more liable to congestive heart failure, and the incidence of failure correlates with the increase in cardiac output during pregnancy.

In order to reduce the incidence of cardiac failure, a thorough assessment of the cardiac status of a patient should be made during the first half of pregnancy. A system of grading that has been introduced by the New York Heart Association (NYHA) to classify the cardiac performance of non-pregnant cardiac patients can also be applied (with limitations) to the pregnant woman with heart disease. In women with a cardiac performance comparable to NYHA class I before pregnancy, heart failure rarely occurred (rate=1.2%) during pregnancy. However, patients of NYHA class II, who showed symptoms following ordinary physical activity, experienced heart failure at a rate of 18% in our department during the last 15 years. And, the pregnant patients who fit in NYHA class III (i.e., those who manifested symptoms after less than ordinary physical activity) suffered heart failure in 67% of the cases. Because this latter percentage is based on a small number (n=3) of patients than the NYHA class II group (n=34), the class II group is substantially of clinical importance. However, since the NYHA grading system does not allow us to distinguish which patients in the NYHA class II group are destined to experience heart failure from those patients who will not, the NYHA method of grading cardiac performance is deficient and potentially dangerous; and therefore, in my opinion, it should be abandoned.

In order to distinguish those patients in class II who have poorer cardiac performance,
I have attempted to measure the venous pressure response during exercise.

1) **Preliminary evaluation of venous pressure response after the bicycle ergometer exercise test.**

Since the gestational increase in blood volume has already distended the venous system, the central venous pressure would be expected to rise excessively after only moderate exercise in a patient with poor cardiac performance. In order to confirm this hypothesis, changes in central venous pressure and cubital venous pressure were determined simultaneously in women in their second trimester of pregnancy during and after a 40 watt exercise (i.e., a period of exercise that requires 40 watts/min of energy) on a bicycle ergometer for 3 minutes. The central and cubital venous pressure in normal pregnant women increased moderately (98% and 51%, respectively) immediately after the exercise, and returned to the control levels within 3 minutes after the exercise (Table 1). However, in patients who had valvular heart disease with slight complaint, there was a marked increase in both central and cubital venous pressure (141% and 92%, respectively) immediately after exercise, and the pressure had not quite returned to the original level 3 minutes later. Therefore, on the basis of these observations, it was conceivable that the venous pressure might respond in a similar manner following the two-step test.

<table>
<thead>
<tr>
<th>Table 1. Simultaneous measurement of central and cubital venous pressure before and after exercise on a bicycle ergometer. (mean±SD)</th>
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2) **Measurement of cubital venous pressure after the two-step test.**

In order to spend precisely 40 watts/min of energy during the two-step exercise, the total number of trips (i.e., movements) were decided on the basis of the woman's body weight (Table 2). After making certain that the patient did not suffer from supine hypotensive syndrome, she was placed in the supine position and the median cubital venous pressure was measured by a tube manometer filled with 3.8% sodium citrate solution. Subsequently, the patient underwent the two-step exercise test for 3 minutes, after which the venous pressure was measured at intervals of 30 seconds, 1 minute, 2 minutes, 3 minutes and 5 minutes. Fifteen normal pregnant women and 74 pregnant women with various valvular lesions each underwent the two-step test 3 times during each trimester of pregnancy.
Table 2. Number of trips (i.e., movements) in the two-step test which correspond to 40 watts of exercise, as based on body weight.

<table>
<thead>
<tr>
<th>body weight (kg)</th>
<th>number of trips (per minute)</th>
</tr>
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<tbody>
<tr>
<td>41 - 45</td>
<td>13</td>
</tr>
<tr>
<td>46 - 50</td>
<td>11</td>
</tr>
<tr>
<td>51 - 55</td>
<td>10</td>
</tr>
<tr>
<td>56 - 60</td>
<td>9</td>
</tr>
<tr>
<td>61 - 65</td>
<td>8</td>
</tr>
<tr>
<td>66 - 70</td>
<td>8</td>
</tr>
</tbody>
</table>

each step has 23 cm height.

There was no conspicuous change in cubital venous pressure in the control group, or in the NYHA class I group, except for a slight increase at 30 seconds after the exercise in pregnant women (Fig. 3). Likewise, there was only a slight increase in venous pressure following exercise in a group of NYHA class II patients that did not experience congestive heart failure during the remaining period of pregnancy and puerperium. On the other
hand, in a group of class II patients who later suffered congestive heart failure, the mean increase in cubital venous pressure at 30 seconds after the exercise was more than 5 cm H$_2$O higher in every trimester of pregnancy, and this elevated pressure did not return to the original level within 5 minutes after the exercise (Fig. 4). Thus, these results indicate the usefulness of this method in the assessment of the cardiac status of the pregnant patient with heart disease (3).

3) Application of the two-step exercise test to the management of heart disease during pregnancy.

On the basis of the above results, patients with heart disease were divided into the following three groups depending on the pattern of increase in cubital venous pressure after exercise during the first half of pregnancy:

Group A: the venous pressure increase was less than 5 cm H$_2$O, and it returned to the original (control) level within 5 minutes.

Group B: the venous pressure increase was 5 cm H$_2$O or more, but it returned to the original level within 5 minutes (suggesting an excessive blood-volume load).

Group C: the venous pressure increase was 5 cm H$_2$O or more, and it did not return
to the original level within 5 minutes (suggesting an impairment in cardiac performance).

Although only 1.8% of group “A” (1/55) eventually experienced congestive heart failure, 20.0% of group “B” (4/20) and 69.2% of group “C” (9/13) experienced heart failure during the latter half of pregnancy, or during puerperium.

As the prognosis for each of these three groups became more obvious during the course of the first 10 years of this 17-year study, I designed the following management plan for each group and subsequently applied this treatment program to 37 pregnant patients with symptoms of rheumatic heart disease in the years from 1971 to 1977:

Group A: supervision at regular intervals.

Group B: supervision at regular intervals, restriction of physical exertion, low salt diet and oral administration of diuretics to control the blood-volume load.

Group C: admission to the hospital, sodium and caloric restrictions, oral or parenteral administration of diuretics, digitalization and intensive care during delivery and early puerperium in order to protect against congestive heart failure.

As a result of these precautions, the incidence of acute congestive heart failure during pregnancy and puerperium in patients with rheumatic heart disease decreased from 39% during the 10 years preceding the application of this program to 16% during the 7 years after its application (Table 3).


<table>
<thead>
<tr>
<th>Year</th>
<th>Number of cases</th>
<th>Number of congestive heart failure</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961–3</td>
<td>56</td>
<td>22</td>
<td>39.3%</td>
</tr>
<tr>
<td>1970</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1971–3</td>
<td>37</td>
<td>6</td>
<td>16.2%</td>
</tr>
<tr>
<td>1977</td>
<td></td>
<td></td>
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\[ p < 0.01 \]

II. The management of occlusive thromboaortopathy during pregnancy.

Occlusive thromboaortopathy (OTAP) (i.e., Takayasu’s disease, or the so-called pulseless disease) is attributable to thrombo-obliterative lesions of the large arteries as a result of pan-arteritis and fibrosis (4). The majority of patients who have been diagnosed as having this disease are young women; and therefore, the association between OTAP and pregnancy is a matter of concern (5).

1) Types of vascular lesions in patients.

Patients with OTAP can be separated into three categories, i.e., aortic arch type, descending aorta type and extensive type, depending on the location of the vascular lesions
We have treated 23 pregnancies in 20 women with OTAP at our hospital during the last 10 years (Table 4). Eight of these patients had lesions of the great vessels arising from the aortic arch, ten had more extensive lesions which involved the descending aorta, and the remaining two did not have an angiography and therefore could not be classified. Fifteen patients had clinical manifestations before pregnancy — 7 with transient ischemic attacks, 7 with secondary hypertension, and one with an aortic aneurysm that required surgical reinforcement.

The mean age of onset of symptoms in these patients was 19.8 years, and the average interval between marriage and the first delivery was 2.4 years, suggesting that fertility in these patients is not impaired.

2) Events during the course of pregnancy.

Amongst the 23 pregnancies in 20 OTAP patients, we observed 7 that had symptoms of hypertension (including 4 with cardiac symptoms such as angina, left ventricular failure and arrhythmia) and 6 that had transient ischemic attacks. Mild toxemia of pregnancy
complicated 7 (i.e., 35%) of the cases, even though 15 of the 20 cases were primigravida.

To elaborate on the cardiac symptoms, case "11" in Table 4 had been diagnosed by aortography at 19 years of age. Aortography revealed partial occlusion of the right subclavian artery, the aorta and both iliac arteries. Upon examination at the beginning of her pregnancy, this patient was found to be hypertensive, with a systolic blood pressure of 160 mmHg in her left brachial artery, yet the femoral pulse could not be palpated in either leg at that time. After 35 weeks of gestation she was easily fatigued and developed dysnea and chest pains of the angina type upon only slight physical exertion. The chest X-ray showed an increase in pulmonary vascularity and hypertrophy of the left ventricle. She was hospitalized and started on digitalis therapy, after which the symptoms abated within a week. At 41 weeks this patient went into labor. During the second stage of labor she complained of chest pain and dyspnea, which were associated with tachycardia and hypertension. Delivery was by vacuum extraction, and the postpartum stage was uncomplicated.

It is of interest to note that 3 of the patients who had experienced transient ischemic attacks prior to pregnancy became asymptomatic during the last half of pregnancy. For example, in one of the asymptomatic patients (case "1"), the frequency of attacks declined during the course of pregnancy and disappeared completely after 17 weeks of gestation, even though her syncopal attacks had occurred several times a month prior to the onset of pregnancy. The improvement in this case might be explained by an increase in cerebral blood flow concomitant with the increase in blood pressure that occurs during pregnancy (Fig. 5). Whatever the cause, within 10 days following delivery, her syncopal episodes resumed.

3) Events during the course of labor.

Parturition was complicated by hypertension in 12 cases (i.e., in 52% of the patients)
with systolic pressures of 140 mmHg or higher. This resulted in 7 deliveries by vacuum extraction and 2 by cesarean section. Seven of these 12 hypertension cases had also been hypertensive during pregnancy, and the highest systolic blood pressure (which was measured in case “10” during labor) was 230 mmHg. Despite the hypertension, the deliveries by vacuum extraction or cesarean section were uneventful. In contrast, case “13”, which had stenosis of the left subclavian artery and the thoracic aorta, did not fare as well as the other cases with hypertension. Although her right brachial arterial pressure was normal throughout pregnancy, it began to rise gradually with the onset of spontaneous labor at 38 weeks, reaching a systolic pressure of 160 mmHg by the end of the first stage of labor. At this time she suddenly lost consciousness and had involuntary spasms on the right side of her body and anisocoria. After delivery by vacuum extraction, intracerebral bleeding was confirmed, and the patient underwent a craniotomy with evacuation of a hematoma. She regained consciousness the day after surgery, but the hemiplegia has remained. Thus, it might be inferred that an increase in blood pressure during labor in patients who do not have a history of hypertension may increase the risk of vascular rupture.

4) Events during the postpartum period.

The symptoms in these cases persisted, or even increased, during the early puerperium. Eleven cases were complicated by hypertension during the postpartum period, including 3 patients with cardiac symptoms, and 6 patients with transient ischemic attacks. The ischemic attacks were managed by the avoidance of rapid changes in body position and by the application of elastic bandages on the lower extremities. Case “15” was complicated by septicemia. On the first day after cesarean section, the patient developed a fever which remained at about 38°C for 3 weeks (Fig. 6). Blood cultures grew *Staphylococcus albus*, and her serum C-reactive protein was strongly positive. Eventually, after 2 months with a low-grade fever, her temperature returned to normal as a result of intensive antibiotic treatment.

![Fig. 6. Course of fever during the postpartum period in case “15.”](image)
Finally, I would mention that anticoagulant therapy may be of value during the active phase of OTAP (7). In consideration of this possibility, coumarin was given during the course of gestation in doses that were sufficient to maintain the prothrombin time at about 20 seconds. In the third trimester of pregnancy, it was necessary to increase the average dose of anticoagulant by about 20% in order to obtain the same effect that was observed in early pregnancy. Since there were episodes of transient hematuria and nasal bleeding when the prothrombin time was longer than 20 seconds, the dosage of coumarin had to be reciprocally adjusted to the prothrombin time, which was carefully monitored by repeated measurement. The administration of this anticoagulant was discontinued at the onset of labor. We did not observe any side effects in the infants of the mothers who received anticoagulant.

III. Conclusion.

In order to assess the cardiac performance of pregnant women who are afflicted with heart disease, and to protect them against the manifestation of congestive heart failure, the patterns of change in the cubital venous pressure immediately after the two-step exercise test were classified into 3 groups, according to the prognosis for adequate cardiac function throughout pregnancy and the postpartum period. This classification system was used to plan the therapeutic management of cardiac patients during pregnancy. In the group consisting of pregnant women whose condition was complicated by rheumatic heart disease, and in whom the cubital venous pressure increased by 5 cm H$_2$O or more after the exercise test, a more intense management program was applied. The principles of management were (1) increased supervision (including admission to the hospital), (2) restriction of physical exertion, (3) restriction of sodium and caloric intake, (4) administration of diuretics to control blood volume, and (5) intensive care during delivery and puerperium. As a result, the incidence of acute congestive heart failure during pregnancy and puerperium decreased from 39% to 16%.

Occlusive thromboaortopathy, which is a vascular disease of relatively high frequency in pregnant women, was also discussed in this report. In about 70% of the cases of occlusive thromboaortopathy there was a worsening of symptoms during pregnancy. However, a favorable outcome can be expected if there is cautious management of the patient. The principles of management were (1) prevention of hypertension, (2) control of transient ischemic attacks during the postpartum period, (3) protection against puerperal infection, and (4) avoidance of side effects from drug treatment.

Acknowledgments

The essence of this paper was presented at the Third ICMR Seminar on recent advances in perinatal medicine which was held on the 20th and 21st of November, 1982, at the International Conference Center in Kobe.

To my profound regret, Professor Shimpei Tojo, one of the organizers of the Seminar, passed away on the 8th of November, 1982. I extend my condolences to the departed spirit.
References


