INFLUENCE OF AN ARTERIOVENOUS FOREARM FISTULA ON THE
CIRCULATION OF PATIENTS WITH CHRONIC URAEMIA

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Our school medicine has taught us to close any arteriovenous fistula in order to prevent an
impending complication of the cardiac circulation. The treatment of chronic uraemia,
however, requires us to create an arteriovenous fistula by an operation (Brescia et al., 1966)
and thus to learn about its secondary symptoms. The influence of an arteriovenous fistula
on the circulatory system has been demonstrated by different cardiologic parameters and
has often been interpreted in different ways. Naturally we have not been able so far to
consider the special conditions of a uraemic organism. Therefore, the numerous experi-
ences gained by the individual dialysis units will provide a complex picture of the effects
of an arteriovenous shunt on the circulation of the uraemic patient.

METHODS

The circulation of four patients who had been dialysed for at least 5 months by way of an
arteriovenous shunt after a side-to-side anastomosis between the radial artery and a forearm
vein was examined before and 5 months after the fistula was created. The examination was
done by indirect methods as: the indicator dilution and concentration times, the mean
circulation time and the cardiac output after Stuart-Hamilton; the simultaneous registra-
tion of the pulse curves of the external carotid artery and the femoral artery with electro-
cardiogram and phonocardiogram for the calculation of the heart time values after Blum-
berger and Holldack and for the determination of the physical circulation analysis after
Broemser and Ranke (1930) with the calculation of the resistance of the circulation, of the
wind kettle function and the stroke and cardiac outputs. The shunt output was measured after
the puncture of an arterialized vein 4 cm above the shunt with a standardized cannula as an
approximate value. In 3 of these patients the right heart was additionally catheterized 5
months after the fistula had been created along with oximetry and measurement of the
pressures in the basilic vein, brachial vein, subclavian vein, superior vena cava, inferior vena
cava, right auricle, right ventricle, pulmonary artery and in the pulmonary capillaries (p.c.).

The values thus gained enabled us to determine the cardiac output after the method of
Fick. The work of the heart was calculated and an approximate calculation of the shunt
volume was made from the difference between the oxygen saturation of the subclavian vein/
superior vena cava and that of the inferior vena cava. The catheter was inserted in all cases
from the left basilic vein about 20 cm above the arteriovenous fistula. Furthermore oximetric
blood examinations were carried out by means of direct punctures of the forearm veins in
different places.

RESULTS

The information about our findings must be restricted to the essential parameters. The
analysis of all parameters obtained is still incomplete.
### TABLE I

*Measurement taken at catheterization*

<table>
<thead>
<tr>
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<tbody>
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<td></td>
<td>ps/pd</td>
<td>O₂%</td>
<td>O₂Vol.%</td>
<td>ps/pd</td>
<td>O₂%</td>
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<td>13.8</td>
<td>14/11</td>
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<tr>
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<td>18/15</td>
<td>96</td>
<td>13.2</td>
<td>12/10</td>
<td>96</td>
</tr>
<tr>
<td>J.B. 24 ♀</td>
<td>10/6</td>
<td>94</td>
<td>12.2</td>
<td>10/5</td>
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<table>
<thead>
<tr>
<th></th>
<th>r. Atrium</th>
<th>r. Ventricle</th>
<th>Art. pulm.</th>
<th>p.c.</th>
<th>R.R. mm Hg</th>
<th>Shunt output ml/min.</th>
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<td>O₂%</td>
<td>O₂Vol.%</td>
<td>ps/pd</td>
<td>O₂%</td>
<td>O₂Vol.%</td>
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<td>11.5</td>
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<td>10.5</td>
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### TABLE III

*Comparative values of different measuring values*

<table>
<thead>
<tr>
<th></th>
<th>circulation time (msec.)</th>
<th>Indicator dilution technique</th>
<th>Cardiac output (l/min.)</th>
<th>Catheterization shunt volume (l/min.) (%)</th>
<th>Heart work (mkg/min/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a.f.</td>
<td>p.f.</td>
<td>5 mo.</td>
<td>a.f.</td>
<td>p.f.</td>
</tr>
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<td>Dr. H.E. 42 ♂</td>
<td>16.5</td>
<td>15.8</td>
<td>5 mo.</td>
<td>90.2</td>
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<td>B.E. 30 ♂</td>
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<td>11.3</td>
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<td>154</td>
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<td>R.A. 29 ♀</td>
<td>14.7</td>
<td>16.7</td>
<td>12.9</td>
<td>91</td>
<td>134.6</td>
</tr>
</tbody>
</table>

a.f. = ante fistula; p.f. = post fistula; 5 mo. = 5 months post fistula; s.v. = stroke volume; c.o. = cardiac output.
Right heart examination (Table I)

All pressures are above normal in the fistula existing for 5 months. A decreasing pressure can be observed with increasing distance from the fistula. The increased pressures up to the inferior vena cava suggest an influence on the entire venous system. There is a direct relation between the amount of the shunt output and the pressure in the arterialized veins. The oximetry values show an intense oxygen saturation of the venous blood up to the subclavian vein and a distinct increase in the superior vena cava. Here, too, the shunt volume is decisive for the degree of oxygen saturation.

TABLE II
Heart time values calculated from the pulse curves in msec.

<table>
<thead>
<tr>
<th>Transformation phase</th>
<th>Tension phase-transformation phase</th>
<th>Ejection phase</th>
<th>Ejection phase (corr. by Wood)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. H. E. 42 ♂️</td>
<td>a.f. 55</td>
<td>a.f. 55</td>
<td>a.f. 280</td>
</tr>
<tr>
<td>B. E. 30 ♂️</td>
<td>p.f. 65</td>
<td>p.f. 60</td>
<td>p.f. 185</td>
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<tr>
<td>R. A. 29 ♂️</td>
<td>p.f. 65</td>
<td>p.f. 55</td>
<td>p.f. 185</td>
</tr>
</tbody>
</table>

a.f. = ante fistula; p.f. = 5 months post fistula.

From the recorded pulse curves the following parameters of an indirect method for the determination of the cardiac output are calculated: the transformation period as the standard for the filling pressure of the left ventricle; the difference between the periods of tension and transformation, the so-called period of the rising pressure, as the standard for the strength of contraction of the heart; and the ejection time. In an established cardiac insufficiency the systole is prematurely cut off and consequently the ejection time is shortened. As the ejection time depends on the pulse rate we have also listed the values corrected after the method of Wood (1958). After a 5-month shunt duration there were no significant changes compared with the standards, except for the patient R. A. Her ejection time fell below normal (Table II).

The most reliable indirect method for determining the circulatory parameters is the indicator dilution technique. The dilution and concentration as well as the mean circulation times show no positive pathologic deviations. On the other hand, there is a distinct rise of the cardiac output after the fistula has been created. The values of the indicator curve correlate with the cardiac outputs that have been found after the method of Fick (Table III). The cardiac outputs calculated after the method of Broemser and Ranke (1930) by means of the pulse curves do not yield any comparative values as the shunt volume of the fistula should not be involved in the calculation. The shunt volumes calculated from the difference of the oxygen content between the superior and inferior vena cava as an approximate value are in conformity with the direct measurements of the shunt output, provided we realize the voidableness of the absolute values. The oximetry in different places in the forearm by means of a direct puncture of the veins showed an oxygen saturation of these vessels between 94 and 98%. Typical changes of the electro- or phonocardiograms due to the fistula were observed in one case only after a 5-month observation. The phonocardiogram traced an isolated auricle sound and the S-wave in the electrocardiogram was intensified as a result of the right heart stress.

Discussion of the results

The behaviour of the principal parameters is demonstrated in the example of a patient (Fig. 1).

The arteriovenous fistula causes a leak in the arterial system and a decrease of the peripheral resistance. The normal blood pressure is exclusively maintained at the expense of an extra
Fig. 1. Course of the cardiac output changes and the pressure and oximetry values of a patient. Black column = indicator dilution technique; h.c. = heart catheter value.

Fig. 2. Pressure recording in arterialized basilic vein (second tracing) with simultaneous ECG and phonocardiograph.
performance of the heart which becomes evident in the increase of the cardiac output (Gauer and Linder, 1948). There is an additional increased pressure stress of the venous system which primarily influences the right heart.

The pressure recording (shown in Fig. 2) resembling an arterial pulsation curve was taken from the basilic vein 25 cm above the fistula with a calculated shunt volume of 23% of the cardiac output and an arterial blood pressure of 185/90 mm Hg. The electrocardiogram indicates right heart stress. The strength of this pressure stress depends on the size of the fistula and thus on the shunt volume and the height of the arterial blood pressure. A right heart decompensation is the most dreaded complication of an arteriovenous fistula, the more so as recompensation without closing the fistula may be very difficult. The pressure curves prove the advantage of the circulation of using the smallest possible fistula. In view of the late prognosis the optimum fistula for dialysis therapy guarantees a sufficient blood flow through the dialyser with the smallest possible shunt volume.

In this respect the side-to-side anastomosis which enables the blood to escape through the distal part of the artery is more advantageous than an end-to-end anastomosis in which the entire arterial blood flow is pressed into the venous part of the anastomosis. The ability to compensate for the stress on the circulation of uremic patients caused by the arteriovenous fistula chiefly depends on the original state of the patient, yet it is also determined by the stage of the uraemia and the therapeutic management of hypertension, and the state of hydration. The success of an arteriovenous fistula also depends on optimal dialysis therapy.

The circulatory values we found after a 5-month arteriovenous fistula all show an increased stress on the circulation of the patients, but no certain indications of decompensation. It proved to be of great use to analyze the circulation with indirect measuring methods before the fistula was created in order to learn about the original state of the patient, and to procure comparative values for the observation of the course allowing us to recognize and to treat in due time an impending circulatory insufficiency. The signs of impending cardiac insufficiency are: decrease of the cardiac output, changes of the heart time values calculated from the pulse curves as e.g. lengthening of the period of the pressure rise as an expression of the damage to the contraction strength of the heart, prolonged transformation period with a diminished filling pressure in the left ventricle, as well as shortening of the ejection time, corrected after Wood, as the sign of an ensuing cardiac insufficiency (Wood, 1958; Holldack and Wolf, 1966).

The supervision of the circulation by measurable parameters in patients with an arteriovenous fistula is probably as decisive for the further prognosis and the successful therapy as are the control and correction of the blood chemistry.

REFERENCES


