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Forearm blood flow and heart rate after haemorrhage

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THE EFFECTS of venesection on the cardiovascular system in man were studied by Barcroft *et al.* (1944). When fainting occurred there was a sudden fall of blood pressure, bradycardia, pallor, sweating and a marked though transient muscle vasodilatation. In these and subsequent studies, observations were not prolonged after recovery from fainting. There have been only a few studies of the effects of venesection, uncomplicated by fainting, on the peripheral circulation in man. De Wardener *et al.* (1953) followed the changes in forearm blood flow in nine subjects under light anaesthesia when they were bled an average of 1175 ml. There was a fall in forearm blood flow from the beginning to the end of venesection, the initial level being 6.6 ml/100 ml forearm/min to 2.1 ml, and this level persisted until retransfusion some 20–80 min later. It was suggested that anaesthesia prevented the reactions observed in vasovagal fainting.

It is of some importance to know what the changes might be in venesection without anaesthesia, and also to follow the effects of venesection for several hours. The observations reported in this paper are confined to changes in forearm blood flow, blood pressure and heart rate, in

subjects who had substantial quantities of blood removed, only some of whom fainted.

Subjects

The majority of the subjects were medically qualified, the others were senior medical students (Table 1).

TABLE 1
Characteristics of subjects

Subject	Age (yr)	Wt (kg)	Ht (cm)	Volume bled (ml)	Faint	Trans-fused	% ven.	Estimated total blood vol. (ml)
A	29	63	177	1000	—	+	20.0	5000
C	24	70	172	1050	—	+	19.0	5600
D	28	81	180	1150	—	+	18.0	6450
H	33	84	187	1000	—	+	15.0	6700
I	30	79	183	1110	—	+	17.5	6300
P	29	81	182	1270	—	+	20.0	6450
S	20	74	171	820	—	+	14.0	5900
T	30	70	172	840	—	+	15.0	5600
W	28	64	170	1000	—	+	20.0	5100
JD	28	77	180	1120	+	+	18.0	6150
DH	24	86	175	300	+	—	4.5	6900
M	24	89	186	1245	+	+	17.5	7100
O	23	69	170	720	+	+	13.0	5500
R	31	62	168	755	+	+	15.0	5000
RT	27	75	177	270	+	—	4.5	6000

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Forearm blood flow

Venous occlusion plethysmography was employed; water temperature was maintained at 34°C. Blood pressure was measured by auscultation. Heart rate was measured continuously using a cardiograph devised by Loucks, Kostashuk & Burton (1948). The interval between each R wave of the ECG is measured and recorded.

Plan of experiment

Experiments started at approximately 09.00 hours. The subject reclined on a couch with the back rest elevated to 45°. Measurement of left forearm blood flow, blood pressure and heart rate began about 30 min later; venesection of the right antecubital vein after approximately 1 hr of recording. Bleeding continued until either the subject fainted or approximately 20% of the estimated blood volume was removed. Recording continued after haemorrhage for approximately 3½ hr. The removed citrated blood was then retransfused, unless the volume bled was less than 600 ml, and recording continued for approximately 30 min after the end of transfusion. The whole experiment lasted, on the average, 7 hr.

Results

Venesection without fainting

There were nine subjects who were bled an average of 1000 ml and who did not faint. The average changes in forearm blood flow and 'mean' blood pressure are shown in Fig. 1. Mean blood pressure was taken as diastolic pressure plus one third of the difference between systolic

FIG. 1. Mean blood pressure (●) and blood flow (○) following venesection in nine subjects who did not faint, plotted as deviation from control values (Time 0 = end of venesection). The average of mean blood pressure during the hour before venesection was 91 mmHg, the corresponding blood flow was 24 ml/100 ml forearm/min.

and diastolic pressure. Mean blood pressure fell slowly for some 75 min, but the average fall was only 8 mmHg. Thereafter blood pressure gradually rose but was still slightly below the pre-venesection level after 3½ hr.

Blood flow followed a similar pattern. The average maximum difference from the pre-venesection level was 0.5 ml/100 ml forearm/min. Part of this fall could be attributed to the concurrent fall of mean blood pressure. By the end of 3½ hr the blood flow was identical with pre-venesection values.

The volume of blood withdrawn in this group did not vary greatly, ranging from 820 to 1270 ml. Within this small range there was no obvious relationship between volume of blood withdrawn and either blood pressure or blood flow alteration. In only one case was there a significant decrease in peripheral blood, with a significant increase in local peripheral resistance. Pulse rate changes were variable, but on the average heart rate was increased during the first hour after venesection but was close to pre-venesection rate for the next 2–2½ hr.

Venesection with fainting

The results in the six subjects who fainted are shown in Fig. 2. After the subject recovered from his faint, the average blood flow was less than in the control period and remained approximately constant throughout the 200 min of recording. Blood pressure recovered within 25 min nearly to 80 mmHg, but then slowly rose throughout the period of observation, never reaching pre-venesection values.

FIG. 2. Mean blood pressure (●) and blood flow (○) following venesection in six subjects who fainted. Control values: mean BP 90, blood flow 2.6 ml. Conventions as in Fig. 1.

The volume of blood removed varied considerably from 270 to 1245 ml. The blood pressure during the recovery period was clearly related to the volume of the venesection. The two subjects who fainted after removal of 270 and 300 ml had reached their pre-venesection level by the end of 170 and 200 min respectively. The other subjects were still 10–15 mmHg below their control values.

Blood flow in the different subjects was more variable than in the subjects who did not faint, and there were periods when the local peripheral resistance was significantly increased. However, the mean local peripheral resistance remained relatively constant at approximately control values.

In this group, heart rate after recovery from fainting remained below control values for periods of 1–3 hr (Fig. 3). Examples of heart rate changes during fainting are shown in Fig. 4. In some cases, owing to involuntary movements, records were distorted but the sudden onset of slowing was obvious in all cases. There appeared to be bursts of slowing in some immediately preceding the onset of the faint.

Effect of transfusion

During transfusion of the removed blood, peripheral blood flow tended to diminish but afterwards, in all cases, blood flow increased markedly. Blood pressure also rose, but seldom exceeded control values.

FIG. 3. Average post-venesection heart rates in fainters (●) and non-fainters (○). Time 0 = end of venesection.

FIG. 4. Cardiometer records, illustrating changes in heart rate during fainting in four subjects. The records read from right to left. A calibration is included in (a) showing size of heart rate intervals of 1.0 sec, 0.8 sec and 0.6 sec. The arrow marks approximate onset of faint, as judged by fall of blood pressure and/or loss of consciousness.

Discussion

The main conclusion to be drawn from these observations is that blood loss of the order of 15–20% of blood volume is not followed by any substantial vasoconstriction in the forearm vessels.

The absence of vasoconstriction in the forearm is in contrast with the results observed by de Wardener *et al.* (1953). In their subjects there was a marked and sustained decline of forearm

blood flow. These subjects were anaesthetized and had a high rate of forearm blood flow. Skin blood flow in the resting forearm is responsible for about one third of the total flow, and muscle blood flow accounts for the greater part of the remainder (Cooper, Edholm & Mottram, 1955). It is possible that the large forearm blood flow in the anaesthetized subjects is due to an increase in skin blood flow, and the decline following haemorrhage may be due to cutaneous vasoconstriction.

In the unanaesthetized subjects a reduction in forearm blood flow due to a fall in skin blood flow might have been predicted. However, no measurements were made to distinguish skin and muscle blood flow, and it is not possible to state if there was any increase in muscle blood flow together with a fall in skin blood flow. It seems more likely that there was no change in either. Price *et al.* (1966) bled volunteers similar amounts to those used in the present study and found no change in the total peripheral resistance. There was also no change in pulse rate or blood pressure, and in that respect their observations differ from those reported in this paper. Price *et al.* (1966) do not describe the posture of their subjects; presumably they were prone; if so, this could account for the difference. Nevertheless, the results reported by Price *et al.* and those in the present paper confirm that blood loss of the order of 17% of the total blood volume can have remarkably little effect on blood pressure or heart rate. Even when a subject faints, once recovery begins forearm blood flow is, on the average, close to prevenesection levels, and the difference can be accounted for by the fall in blood pressure. The main difference following venesection between those who faint and those who do not is in the heart rate (Fig. 3). In the former, heart rate is never increased; on the contrary, it remains slower than control level for a considerable time and only reaches control

level on the average about 2 hr after the end of venesection. The changes in heart rate during fainting have frequently been described (Barcroft *et al.*, 1944). The records of heart rate illustrated in the present paper indicate the sudden onset of bradycardia and its persistence. Similar records were continued throughout the 3½ hr after venesection and show how variable heart rate remained, usually for an hour or more, in those who fainted. In the course of 1 min, heart rate intervals could vary between 0.7 and 1.0 sec, and these changes were not related to respiration. In general, in the subjects who did not faint the heart rate was more stable following venesection than in those who fainted. These heart rate changes are of considerable size and deserve further study.

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