ARTERIAL NARROWING AND FLOW-PRESSURE CHANGES

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Flow and pressure changes in human arteries have become very complex subjects after the application of hydraulic principles. Thus it has been postulated that there exists a definite relationship amongst factors such as cross-section and length of the tube, the viscosity factor, and the pressure gradient as stated in the Poiseuille equation. In distensible tubes such as the blood vessels, and non-homogeneous fluids such as the blood, the relationship is even more complex (Womersley, 1955) and experimental models as yet do not meet all the possible variations existing in living blood vessels. In the living state, however, the transient and instantaneous changes whilst of great interest to basic scientists are of less significance compared to the final results of flow changes which in fact represent the sum total of all the complicated variations. Hence, knowledge of changes of a grosser kind such as prevaling over an appreciable period of time is more pertinent to the clinician.

Interest in problems of flow and pressure changes in the presence of arterial narrowing has increased only in recent years especially when it was shown that extracranial arterial stenosis or obstruction played a significant part in cerebro-vascular deficiency syndromes, and that hypertension was in a good proportion of instances accompanied by renal arterial stenosis. (A. Libretti and Grazi 1965, Yates and Hutchinson, 1961). Hutchinson and Yates showed that discrete lesions in the brain could occur in the presence of extracranial arterial disease without any intracranial vascular disorder and some postulated that in view of the frequency of renal arterial disorder, hypertensives below the age of 45 should be auscultated for abdominal bruit and studied arteriographically to exclude renal arterial stenosis. (Peart, 1959).

However, the syndrome of brain deficiency is a result of ischaemia, and this may or may not be a state which varies pari pasu with the presence of arterial narrowing. It has still to be shown that there is a change in the flow and pressure of cerebral circulation for the worse under such a circumstance. In vivo studies of this problem is difficult because it involves the study of regional circulation in the brain, and although the use of radioisotiopes has been of some promise, the results obtained so far have not been decisive.

Bryce (1964) investigated this problem with arterial specimen in vitro, and followed it up with verifying blood flow in carotids during operation by indirect determination with a flow meter, and came to the conclusion that carotid narrowing must be at least to the extent of a resulting cross-sectional area of 5 sq. mm. at least before flow could be shown to be adversely affected. This would suggest that arterial narrowing could be of two classes—one resulting in vascular deficiency and the other of no significance dependent on a critical cross-sectional area of the narrowest portion. As this is a question of some importance, we thought that it would be worth verifying and elaboration.

METHODS

Fresh specimens of common carotid arteries were removed after death, and used subsequently. Common iliac arteries were also utilised on one occasion for comparison.

A model was set up powered with a sigma motor pump, and rejected plasma from Blood Transfusion Department was used as the perfusing fluid. Flow and pressure were recorded with a Grass recorder (5D Polygraph) using a flow meter (Rota meter blood flow meter, 2-5%) 1 mm. deflection = 2 mm. Hg. and a pressure transducer, (Statham p. 23) and verified by simultaneous measurement of fluid volume with a measuring cylinder accurate to 5 c.c., and mercury manometers accurate to 2 mm. Hg. Constrictions were produced in the arteries by a calibrated clamp where regulation could be accurate to 1/100 of a mm., and also by placing invaginating stitches through the arterial wall (Fig. 1).

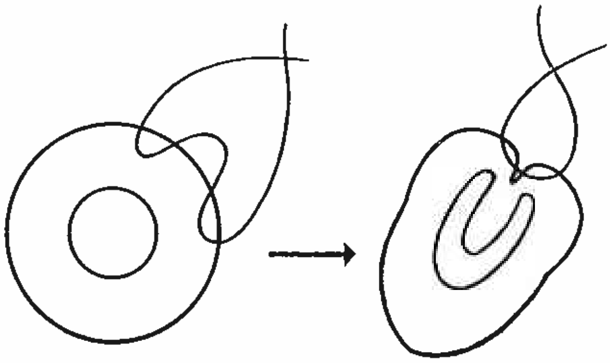


Figure 1.

The area of the constriction was determined by making wax cast of the arteries with the clamp or stitch in place. After setting, the cast was removed and measured. Subsequently, silastic cast was tried instead, and found to be more satisfactory in that there was as in the case of wax no significant shrinkage or cooling, and that the reproduction of the lumen was faithful, and in addition the specimen cast was pliable and less subject to damage.

The perfusion fluid was passed through the arterial segment through the flow meter into the reservoir open to air. The pressure in the system was maintained by a balance between the sigma motor pump rate and the peripherial resistance provided by the clip. At the start, the pump rate was set at 80/min., and the pressure in the system was adjusted to be at about 120 mm. Hg. systolic. The arterial segment was kept moist by an absorbent tissue paper wrapping soaked in plasma throughout the experiments. With this set up, the flow and pressure remained stable over the duration of the experiments under fixed conditions.

1st. experiment

The arterial lumen was gradually reduced by the application of the calibrated clamp until the polygraph tracings of flow or pressure showed changes. It was found that the change in pressure was noticeable before change in the flow—the recording device was sensitive to a change of 10 mm. Hg. pressure, and 10 c.c. flow volume. The amount of the constriction at the time when the first noticeable pressure change occurred was noted, and then further constriction was made till flow change was also noticeable. Then a series of readings in flow and pressure were made with further constrictions (Figs. 3 and 4).

After the experiment, the arterial segment was filled with melted wax, and then subject to the pressure of the calibrated clamp to the known extent and left to set. When fully set, the wax cast was removed for measurements.

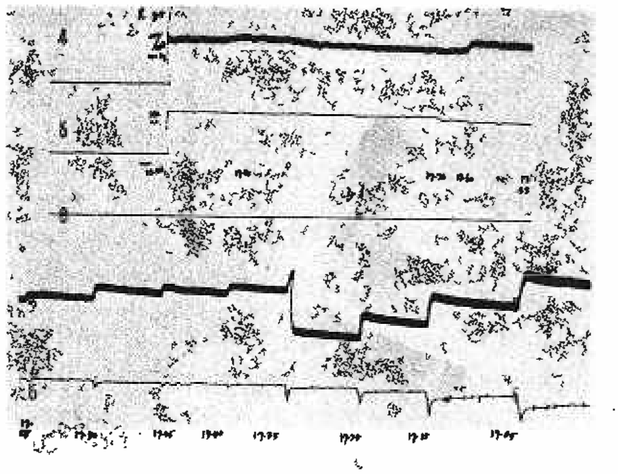


Figure 3.

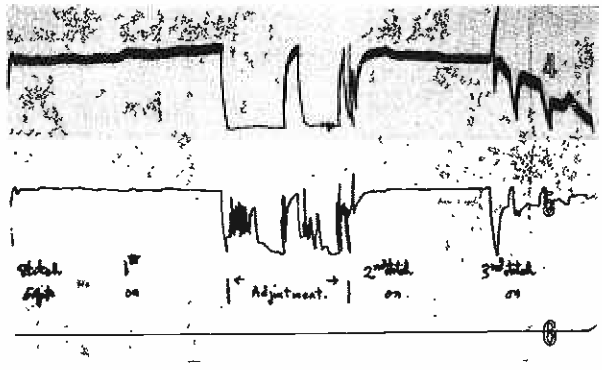


Figure 4.

2nd experiment

With the arterial segment constriction produced as before, the rate of the sigma motor pump was varied from 60-120 mm. Hg. to determine if a change of rate had any modifying effect on the degree of constriction required to produce flow and pressure changes.

The same experiment was repeated but this time the rate was kept constant at 80/min. and the pressure in the system was varied by varying the peripheral resistance to determine if the change in pressure in the system had any modifying effect.

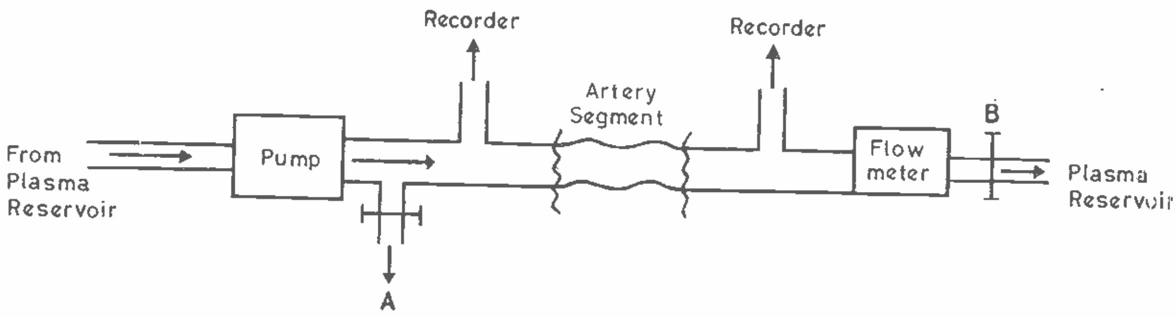
3rd experiment

The experiment was repeated, but this time, the narrowing of the arterial lumen was produced by invaginating stitches to see if the changes brought about by narrowing were modified by the shape of the cross-sectional area of the narrowed segment.

4th experiment

The experiment was repeated with the side shunt open to see if the findings were valid when only a portion of the total flow was passing through the narrowed segment.

The set up was as in Figs. 2a & 2b.



A and B are clamps to cut off flow or raise resistance.

Figure 2a.

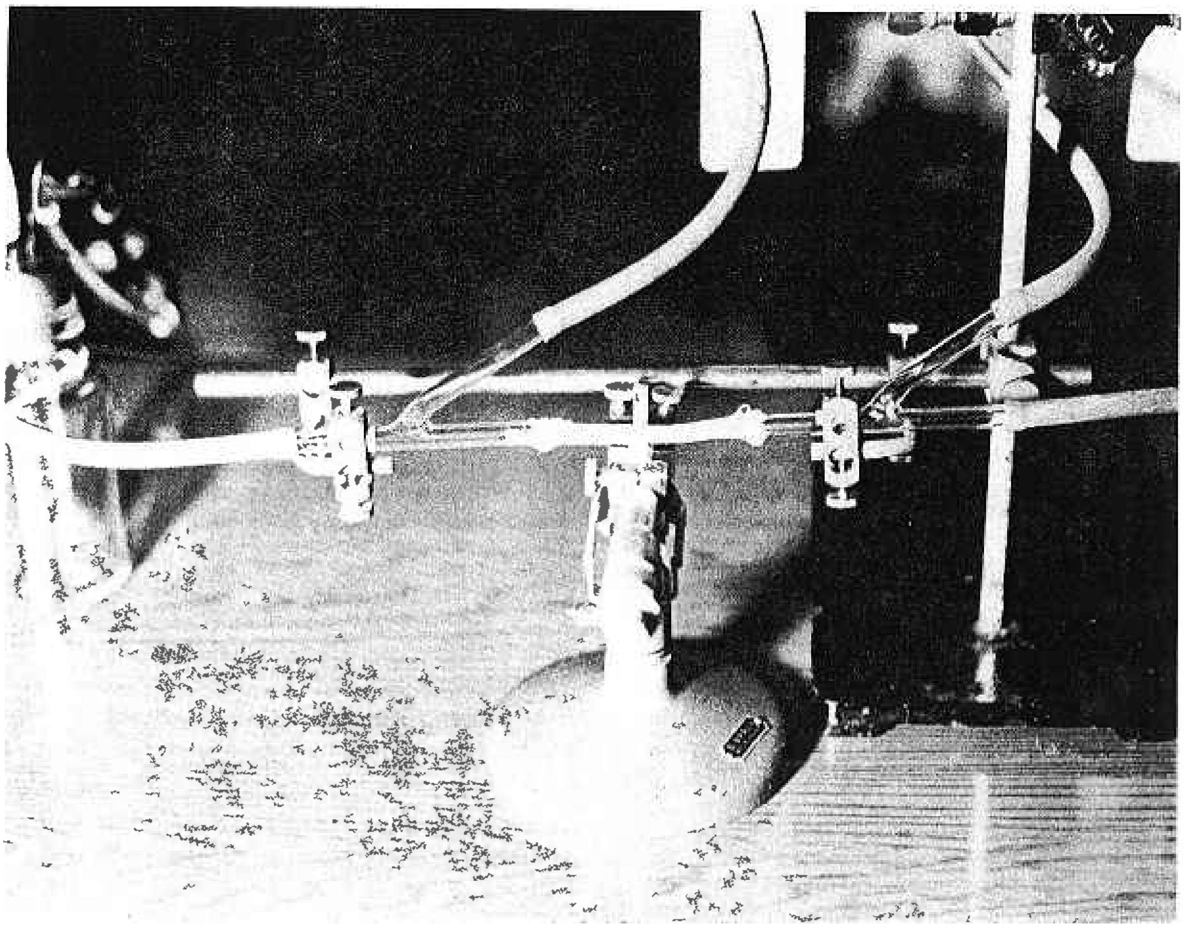


Figure 2b.

All the readings of the experiments were reduplicated, and were found to be reproduceable within a margin of 5% accuracy. The experiments were repeated with common carotid arteries from other cases of different ages and both sexes, and also with the common iliac artery in one instance.

RESULTS

It was found that the findings were the same irrespective of the source of the artery. Hence all the findings were pooled for the purpose of comparison and discussion.

The following findings were made:-

1. Pressure change was noted first, and flow change occurred after further narrowing.
2. The narrowing must produce a constant minimum cross-sectional area of 3-5 sq. mm. before changes in flow and pressure were seen. This minimum area was not affected by the change of rate of 60-120/min., and pressure in the system of 80-200 mm. Hg. It was also observed that the variations of size and age of the artery resulting from the donor being of different age and sex did not affect the minimum area. All the donors were adults with ages varying from 20 to 70 years. Arteries which were grossly diseased as to produce very severe obstruction were not used, but in other aspects, the amount of atherosclerosis, thickening of the wall, the size of lumen, the length, and the torturosity varied from case to case sometimes to a marked degree. The lumens of common iliac and common carotid arteries were about the same. It is not determined whether this critical cross-sectional area of constriction would apply in cases where the arterial lumen is much bigger, such as the aorta or much smaller such as cerebral arteries. It seems however reasonably certain that the finding cannot apply to small size vessels where a different flow pressure relationship and change most probably exist.

DISCUSSION AND SUMMARY

Arterial narrowing of a segmental nature is a common finding especially in the older age group. In recent years there has been a lot of interest in narrowing of this type as it is suggested that such reduction of lumen may have haemodynamic significance. However, removal of a kidney with a stenosed renal artery does not invariably lead to reversal of hypertension, and random examination in cadavers has shown that symptomless renal arterial stenosis is not uncommon (Schwartz and White 1964). In the extracranial arteries, findings of extensive narrowing with no apparent neurological deficit in life or death have also been encountered. These would suggest that the finding of a stenosis either during angiographic studies or at operation need not be regarded as being of serious haemodynamic importance except under certain circumstances.

Our study would suggest that for the medium size arteries at least, the stenosis must be of an extent as to reduce the cross-sectional area of the lumen to below a critical level of about 3-5 sq. mm. before it can be of significance.

The finding of a gradient in catheterisation in many instances when the narrowing would appear to have not reached the critical level may be explained by the presence of the catheter in the narrowed portion resulting in a further narrowing of the lumen. Direct measurement at operation with in-dwelling needles is well known to be liable to many errors, and would be an unreliable technique to resolve problems of this natuie.

On the whole, it would seem that the finding of a stenosis must be evaluated with care from the part of pathogenesis, and that greater attention should be paid to the degree of narrowing in relation to a critical area. Radical approaches like nephrectomy, and arterial resection or intimal stripping should best not be undertaken indiscriminately.

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APPENDIX

Rate	Pressure Proximal to Artery	Pressure Distal to Artery	Systolic Grad.	Reading of Constricting Clamp	Flow as measured in cc/min.
I. Common Iliac Artery					
84	120/100	135/85	— 15	17·37	205
84	120/108	105/89	— 5	12·01	187
84	150/124	90/86	+ 45	11·45	190
84	180/152	77/75	+103	11·35	182
84	180/154	85/79	+ 95	11·30	172
84	180/152	67/65	+113	11·25	162
84	204/178	45/43	+159	11·20	142
84	234/216	28/27	+216	11·15	115
II. Carotid Artery					
84	80/65	112/70	— 32	15·30	160
84	80/60	80/75	0	11·65	147
84	158/136	45/42	+113	11·55	102
84	230/215	28/26	+202	11·45	85
84	245/230	20/20	+225	11·41	77
III. Carotid Artery					
84	170/134	160/140	+ 10	19·48	115
84	180/138	130/123	+ 50	19·41	110
84	194/150	94/92	+100	19·39	95
84	230/190	50/48	+180	19·38	70
84	240/200	30/30	+210	19·37	60
84	244/204	20/18	+224	19·36	57
84	284/240	-6/-6	+290	19·34	42
IV. Carotid Artery (Varying rate)					
106	210/170	190/180	+ 30	19·38	140
98	214/188	170/160	+ 44	19·38	135
84	214/160	160/146	+ 54	19·38	127
68	214/114	106/104	+108	19·38	107
56	204/162	90/90	+116	19·38	102
140	352/340	321/320	+ 31	19·38	200
V. Carotid Artery (Varying pressure)					
84	230/178	150/146	+ 80	19·38	138
84	280/224	-64/-64	+344	19·38	125
84	270/210	2/0	+272	19·38	125
84	350/310	310/290	+ 40	19·38	102

Note: Arterial lumen				
cross-section Area:	26 sq. mm.	12·56 sq. mm.	19·6 sq. mm.	19·7 sq. mm.
Area of Constricted Portion:	5 sq. mm.	3·00 sq. mm.	4·25 sq. mm.	5·1 sq. mm.