ON THE ORIGIN FROM THE SPINAL CORD OF THE VASO-CONSTRICTOR NERVES OF THE PORTAL VEIN.

By W. M. BAYLISS, B.A. (*Oxon.*) and ERNEST H. STARLING, M.D. (*Lond.*), M.R.C.P., *Joint Lecturer in Physiology to Guy's Hospital.* (Plate III.)

(*From the Physiological Laboratory of Guy's Hospital.*)

It has been shown by Mall[1] that the splanchnic nerves contain vaso-constrictor fibres for the portal vein and its branches. In the course of our work on Venous Pressures[2] we had occasion to observe the effect of stimulation of the splanchnics on the pressure in the portal vein, and we have been led to make further observations of a similar kind with the aim of determining the origin from the spinal cord of the fibres in the splanchnics which affect the portal pressure.

Method of Experiment. Medium-sized dogs weighing from 6 to 11 kilos. were used. They were given hypodermically about ½ an hour before the experiment a dose of from 1 to 2 grains of morphia. During the experiment they received in addition a small amount of A.C.E. mixture. Curare was injected into the external jugular vein and artificial respiration kept up in the usual way. The carotid was prepared for taking the arterial pressure and the vagi cut unless otherwise mentioned. All this was done with the animal lying on its back. It was then turned over and the spinal cord exposed at different parts of its length in different experiments for an area including 3 to 5 nerve-roots (from 8th cervical to 3rd lumbar were taken in the various experiments). The dura mater was opened, and silk ligatures tied around the anterior and posterior roots together of each nerve, which were then cut close to the cord. As a rule the piece of cord exposed was cut out entirely to avoid the possibility of reflexes by escape of exciting current. The method of recording the portal pressure was

[1] Mall. *Du Bois Reymond's Archiv*, 1892, S. 409.

[2] Bayliss and Starling. This *Journal*, XVI. p. 159.

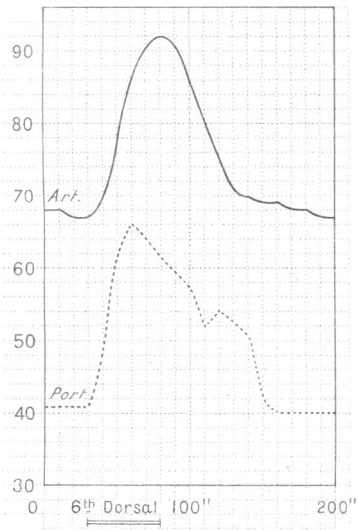

FIG. 1.

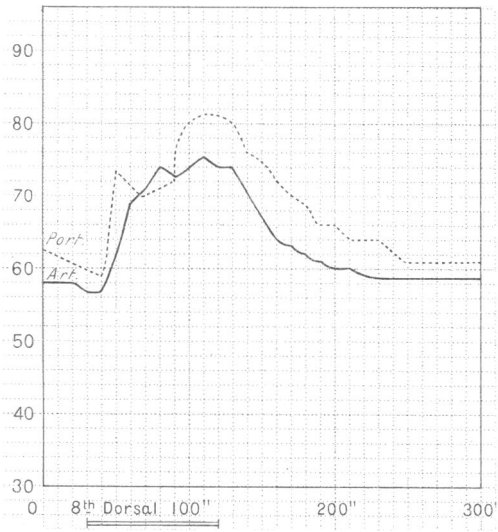

FIG. 2.

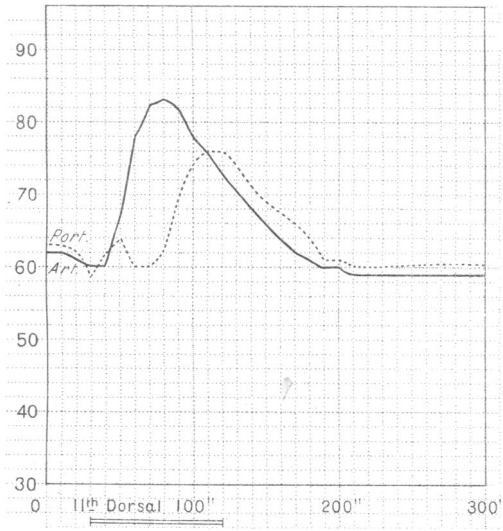

FIG. 3.

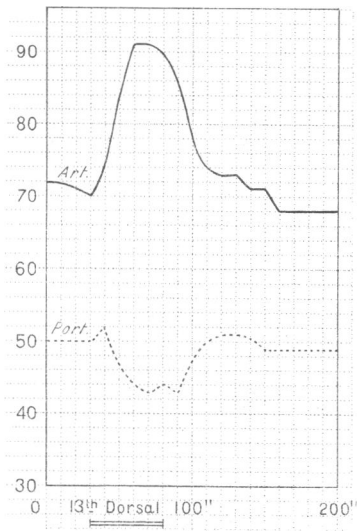

FIG. 4.

CAMBRIDGE ENGRAVING COMPANY.

that described in our previous paper on venous pressures[1]; also the method of plotting out curves from the readings so obtained was similar. All the experiments made were put into the form of curves, and samples of some typical ones are given in Plate III.

It is to be noted that a rise of pressure in the central end of the splenic vein under excitation of the splanchnics indicates increased resistance on the peripheral side of the place where measured, i.e. constriction of the portal branches in the liver; constriction of the mesenteric veins noted by Mall to follow excitation of the splanchnic would cause *fall* of pressure in the central end of the splenic vein by increasing resistance on the cardiac side of the point where the pressure is measured.

Results.

Although in the light of Gaskell's work on the outflow of visceral nerves we did not expect to obtain any effects from the excitation of any nerves above the 2nd dorsal, we thought it well for the sake of completeness to commence at the 8th cervical and take the whole of the nerve-roots below this in order down to the 3rd lumbar. The results of excitation of each we will now proceed to describe.

Eighth Cervical Nerve. This root we excited three times in two different dogs; in the first experiment the cord was left *in situ* and a large rise of both arterial and portal pressure was obtained; this was obviously due to escape of current to posterior columns of the cord, since it was absent in a second excitation after removal of the piece of cord exposed. In the third case we obtained an extremely small rise of portal pressure and a slight fall of arterial pressure; here we had at once removed the piece of cord before proceeding to any excitations. We conclude that this nerve-root contains no fibres for the portal vein. The fall of aortic pressure is of some interest because we have obtained it also sometimes with the 1st, 2nd and 3rd dorsal nerves and shall discuss it more fully under the head of the 2nd dorsal nerve.

First Dorsal Nerve. Five experiments. With cord *in situ* a large rise of arterial pressure followed by a slight fall, the portal pressure being stationary during the rise and rising slightly during the fall; in the same dog with cord removed a slight fall of aortic pressure and a moderate rise of portal pressure. In another dog a slight rise of aortic pressure which could be accounted for by the cardiac acceleration

[1] *Loc. cit.* p. 164.

present in this case, no effect on the portal pressure. The rise of portal pressure sometimes produced by this nerve is not due to portal constriction since it is still present after section of both splanchnics, hence we say that this nerve again contains no portal fibres.

Second Dorsal Nerve. Five experiments. In one we obtained a fall of aortic pressure, this was with cord intact, but could not have been due to escape of current because such reflexes cause a rise of aortic pressure. In all the other experiments there was a slight rise of aortic pressure associated with rise of portal pressure, the latter not being due to excitation of portal constrictors because it was still present after section of the splanchnics. With respect to the fall of arterial pressure obtained occasionally with 8th cervical and 1st four or five dorsal nerve-roots which has also been noticed and discussed by Bradford and Dean[1], we think that it does not always result from the same cause; when produced by exciting the 8th cervical or 1st or 2nd dorsal nerves it is always accompanied by a *rise* of portal pressure and may possibly be due to excitation of the fibres described by Roy and Adami[2] as passing through the stellate ganglion and causing weakening of auricular and ventricular contractions, thus producing heightened pressure in the vena cava and perhaps backwards through the liver to the portal vein; or it may be due to excitation of Cyon's fibres to the hepatic artery. On the other hand the fall of aortic pressure produced by excitation of the 3rd, 4th or 5th nerve-roots is most obvious after section of the splanchnics and is associated with no portal rise, if anything there is a slight fall, and may possibly be due to excitation of vaso-dilators to the fore-limbs, since Bradford and Dean state that it is still present after section of the cervical sympathetics and hence cannot be due to vaso-dilatation in the head and neck; the variability of its appearance may be accounted for by varying degrees of curare poisoning which is very apt to paralyse vaso-dilators. Langley[3] however describes the vaso-dilators of the fore-limb as passing out in the 4th or 5th to the 8th dorsal nerve-roots; and probably the true explanation is that given by Bradford and Dean who find along with this aortic fall a simultaneous rise of pressure in the pulmonary artery and hence consider it to be due to the increased resistance in the lung vessels diminishing the flow of blood to the left heart; the slight portal fall is probably then a passive effect of the aortic fall since the passive changes of portal pressure follow the

[1] This *Journal*, XVI. p. 60.
[2] *Phil. Trans.* 1892, pp. 244—247.
[3] Langley. This *Journal*, XII. p. 377.

arterial rather than the venous pressure; for example we have found that the heart failure produced by chloroform causes a fall of arterial and portal pressures and a rise of vena cava pressure.

Third Dorsal Nerve. This is the first nerve that invariably produces a rise of portal pressure and that as a rule with a simultaneous rise of aortic pressure. We have made ten experiments, in one of these there was a fall of aortic pressure with rise of portal and in all the rest a rise of both, although to a varying degree in different cases. Both arterial and portal rise are absent on excitation after section of the splanchnics and there is present instead an aortic fall, along with very slight portal fall, due perhaps to excitation of vaso-dilators. In this nerve we have the first of the series of the portal vaso-constrictors, since the rise of portal pressure is abolished by section of the splanchnic nerves, which convey therefore the portal constrictor fibres in question to the liver.

Fourth Dorsal Nerve. Twelve experiments,—five with cord *in situ.* In all, rise of both arterial and portal pressures, and to a considerably greater height than in the case of the previous nerve. Here again the rise was replaced by fall in both after section of the splanchnics.

Fifth Dorsal Nerve. Ten experiments,—four with cord *in situ.* Same results as with fourth dorsal nerve, except that there is no fall after section of the splanchnics, in fact after that operation excitation of this nerve-root is without effect of any kind either on arterial or portal pressure.

Sixth Dorsal Nerve. Nine experiments,—three with cord *in situ.* Same results as in case of fifth dorsal. (See fig. 1, Plate III.)

Seventh Dorsal Nerve. Six experiments,—two with cord *in situ.* Same results as sixth on excitation. After section of splanchnics slight arterial rise with cord *in situ,* no effect on portal; this arterial rise is probably due to excitation of vaso-constrictors to the fore-limb[1].

Eighth Dorsal Nerve. Four experiments,—one with cord *in situ.* Rise of pressure in both arterial and portal manometers. None after section of splanchnics (with cord removed). In the case of this nerve-root we have the first trace of an effect which becomes more obvious lower down. In one experiment (see fig. 2, Plate III.) the portal pressure after rising for a time begins to fall again, after falling a few millimetres of magnesium sulphate solution it rises again to a height considerably greater than its previous height; this result we will call for shortness the diphasic effect, and we account for it in the following way, our reasons for which will be more obvious later on. The first rise is due to

[1] Bayliss and Bradford. This *Journal,* XVI. p. 15.

contraction of the intestinal arterioles (and perhaps also mesenteric veins [Mall]) driving blood onwards into the portal trunk, these intestinal arterioles being now contracted less blood passes through and the portal pressure falls for a short time until by the active contraction of portal terminations in the liver the pressure is again raised; this effect shows itself more and more as one proceeds downwards as the nerve-roots contain more vaso-constrictor fibres to the intestines.

Ninth Dorsal Nerve. Six experiments,—one with cord *in situ.* In all rise of pressure in both aortic and portal manometers, in those cases where cord removed the portal rise was diphasic. After section of splanchnics no rise either of aortic or portal pressure.

Tenth Dorsal Nerve. Five experiments,—one with cord *in situ.* Rise of both arterial and portal pressures in all, the portal being diphasic, with the notch more marked than in the case of the previous nerves; the curve first rises slightly, then falls to its starting point and later on after the excitation has ceased and the arterial pressure has already fallen considerably it attains its maximum.

Eleventh Dorsal Nerve. Five experiments,—two with cord *in situ.* Rise of arterial pressure in all. In three of them there is a diphasic portal curve like that of the tenth dorsal nerve (fig. 3, Plate III.), in the other two the effect of intestinal arterial constriction is still more marked, the portal pressure rises at first slightly then falls below the level it started from, returning to that level when the arterial pressure falls; in the dog therefore from which these two curves were obtained there were in this nerve-root no fibres for the portal vein and the pressure in it is governed simply by the inflow from the mesenteric veins.

Twelfth Dorsal Nerve. Four experiments,—three with cord *in situ.* Rise of arterial pressure in all, and in all associated with marked fall of portal pressure; here we are therefore beyond the limits of the portal constrictors.

Thirteenth Dorsal Nerve. Three experiments,—all with cord removed. Rise of arterial pressure and fall of portal pressure in all. (See fig. 4.)

First Lumbar Nerve. This is the lowest nerve-root which gave on excitation any rise of arterial pressure; this was accompanied by a fall of portal pressure as in the case of the nerves immediately preceding.

Second and third Lumbar Nerves. These two nerve-roots gave arterial fall associated with portal fall, probably due to excitation of vaso-dilators to the lower limb[1].

[1] Vide W. M. Bayliss. "On the Physiology of the Depressor Nerve." This *Journal*, Vol. xiv. p. 321.

It remains to meet one or two possible objections.

Bradford and Dean[1] find the nerve-roots in which the pulmonary vaso-constrictors run to be the 3rd to the 7th dorsal inclusive, and it might be said that the portal rise obtained by us with these nerves was due to increased resistance in the pulmonary arterioles and hence increased pressure in the right auricle which might be transmitted backward through the liver; this explanation presupposes the tricuspid valve to be more or less incompetent, an assumption which with the small rise of pulmonary pressure in question is extremely improbable; and a fact which effectually disposes of this objection is that the effects on the portal pressure are abolished by section of the splanchnic nerves whereas the pulmonary effects are unaffected by this operation[2].

A second objection which may be made is that our portal rise is really due to arterial constriction causing a diminution of the total capacity of the vascular system and hence a rise of mean pressure; that the rise of portal pressure is not wholly due to this cause can easily be seen by comparing figs. 1 and 4 of Plate III., where a nearly equal rise of arterial pressure is associated in the case of the sixth dorsal nerve with a large rise of portal pressure and in the case of the 13th dorsal nerve with a considerable fall of portal pressure. Many similar cases can be seen by referring to the table at the end of this paper.

Conclusions.

The constrictors of the portal vein branches in the liver leave the cord in nerve-roots from the 3rd dorsal to the 11th dorsal inclusive, the 5th to 9th contain about an equally large number of fibres, while the 3rd, 4th, 10th and 11th contain few fibres; it is probable that the 3rd and 11th would not contain portal fibres in the same animal, and that in one case (the anterior arrangement of Langley) the nerve-roots would be 3rd to 10th inclusive, and in the other (posterior arrangement of Langley) the roots would be 4th to 11th inclusive. This is a somewhat extensive area and curiously corresponds very closely with that found by one of us in conjunction with Dr Bradford[3] to be the area of vaso-constrictors to the fore-limb; it is not so extensive however as the area of the arterial constrictors to the abdominal viscera, which according to our experiments extends from the 3rd dorsal to the 1st lumbar inclusive, if we take as criterion the large rise of aortic pressure

[1] *Loc. cit.* [2] Bradford and Dean. *Loc. cit.* p. 59.

[3] Bayliss and Bradford. *Loc. cit.* p. 14.

resulting from their excitation; it must be remembered however that in the case of the upper dorsal nerves we cannot be certain how much of the rise of arterial pressure is due to portal constriction alone which may be present without arterial constriction. If we take as our criterion of abdominal arterial constriction the first appearance of the diphasic portal curve the limits of the arterial constrictors in question will be the 8th dorsal to the 1st lumbar roots inclusive, and this agrees with the area of the renal vaso-constrictors according to Bradford[1].

We may mention incidentally that we have noticed cardiac acceleration to result from excitation of the nerve-roots from the 1st to the 5th dorsal inclusive, most marked from the 2nd, 3rd and 4th.

We append a table giving concisely the results of all our experiments. The thin numbers are the aortic pressure, the thick ones the portal pressure corresponding. The numbers in brackets (5) mean a *fall* of so many millimetres of mercury or of magnesium sulphate solution; those without brackets indicate a rise of the amount noted. When several numbers are included together in a large bracket it is intended to point out that they were all obtained from the same dog. When the portal curve was diphasic, the number given is the highest reached.

A = arterial pressure in millimetres of mercury.

P = portal pressure in millimetres of 25 per cent. magnesium sulphate solution.

PLATE III.

The divisions along the ordinates represent each 2 millimetres, the arterial pressures are in millimetres of mercury, the portal in millimetres of 25 % magnesium sulphate solution in water.

The continuous line is the pressure in the carotid artery.

The broken line is the pressure in the central end of the splenic vein.

The divisions along the abscissa correspond to 10 second intervals.

The absolute values of the portal pressure are probably not quite correct because of some amount of uncertainty as to the exact zero of the manometer.

Fig. 1. Excitation of the peripheral end of the sixth dorsal nerve. Piece of cord removed.

Fig. 2. Excitation of the peripheral end of the eighth dorsal nerve. To show first appearance of the diphasic effect in the portal pressure.

[1] *Loc. cit.*

Nerve-roots	Cord *in situ*										Mean		Splanchnics cut		Cord removed								Mean		Splanchnics cut	
	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P
Cerv. 8	42	14[a]									42	14			(1)	1	(2)	0					(1½)	½		
Dorsal 1	25(5)[b]	3									20	3	8	3	2[o]	1	(2)	5					0	3	2	0
Dorsal 2	3(6)	13									(3)	13	6	3	7[o]	6	1	11					4	8	5	4
Dorsal 3	(9)	25	(2)6	10[c]	6	6[d]	60	40	12	(3)6	14	17	(4)	(2)	8	6	3	5	6	5	6	6	6	12	3	1
Dorsal 4	50	35	6	36[f]	8	31[g]			3	10	17	28	(2)	0	12	11	5	10	9	26	4	8	8	14	(5)	(½)
Dorsal 5	12	26	3	16[h]	18	40[k]			12	18	11	25	1	0			10	18	15	50	6	24	12	28	(1)	(½)
Dorsal 6	13	30	6	24					18	18	12	24	0	0	8	25	14	20			11	28	15	24	0	1
Dorsal 7	15	32	11	23							13	27	4	1	9	16					11	23	18	22	0	0
Dorsal 8			24	26							24	26	3	4	21	33	18	19[r]					20	26	0	0
Dorsal 9			48	31							48	31	2	2	22	30[r]	28	28[r]					25	29	0	0
Dorsal 10													2	2	21	8	22	15[r]					22	12		
Dorsal 11	42	16[l]	50	18[m]							46	17			23	(6)[p]	23	16[r]					23	5		
Dorsal 12	34	(9)[n]	26	(16)[n]	23	(18)[n]					28	(14)			22	(6)[p]							22	(6)		
Dorsal 13															21	(8)[q]	13	(8)					17	(8)		
Lumbar 1																	10	(5)					10	(5)		
Lumbar 2																	(5)	(4)					(5)	(4)		
Lumbar 3																	(9)	(4)					(9)	(4)		

[a] ? Reflex. [b] Rise of 25, followed by fall of 5. [c] Vagi uncut. Cord covered with tinfoil to prevent escape of current. [d] Same dog, vagi cut, tinfoil on cord. [e] ? Reflex. [f] Vagi uncut, tinfoil on cord. [g] Vagi cut, tinfoil on cord. [h] Vagi uncut, tinfoil on cord. [k] Vagi cut, tinfoil on cord. [l] Preceded by slight portal fall. Excitation, coil 13. [m] Same dog, coil 8 (stronger). [n] These three of 12th D. taken one after the other. [o] Cardiac acceleration. [p] Preceded by slight portal rise. [q] Preceded by very slight portal rise. [r] Portal diphasic.

Fig. 3. Excitation of the peripheral end of the eleventh dorsal nerve in the same dog to show further development of the diphasic effect.

Fig. 4. Excitation of the peripheral end of the thirteenth dorsal nerve in same dog as fig. 1. To show passive change in portal pressure in consequence of intestinal arterial constriction, viz. slight initial rise due to driving on of blood into mesenteric veins and then marked fall due to deficient supply of blood through the narrowed intestinal arterioles.

Note. In fig. 1, there is an indication of the second rise of the portal pressure after the arterial pressure has fallen, described by us previously [1] as the effect of excitation of the splanchnic trunk, this second rise is not often seen on excitation of a single nerve-root.

[1] This *Journal*, xvi. p. 171.