STUDIES IN CEREBRAL CIRCULATION II

By Gwee Ah Leng, Lee Yong Kiat and Yeoh Teow Seng

In addition to the status of the Circle of Willis as an isobaric chamber as we postulated (Gwee & Yeoh, 1965), the stability of the cerebral circulation would seem to be dependent upon at least two further compensatory mechanisms. Firstly, there is the communication between extracranial and intracranial vessels through known sites like the ophthalmic artery, ascending pharyngeal artery, and also between leptomeningeal branches of the anterior, middle and posterior cerebral vessels (Abbie, 1934; Van Der Eecken & Adams, 1953; Brain 1957 and Gillian, 1959). The part played by these communications in the state of health is not well-known, but certainly in diseased states where regional vascular deficiencies occur, considerable revascularisation through alternative routes via one or more of these channels has been seen (Clarke & Harrison, 1956; Potter, 1959). Secondly, there is also the possibility of restreaming of blood at the aortic arch so that the deficiency of one system *e.g.* the left carotid, may be remedied by an increase in the flow in the right carotid, the vertebrals, and the circle of Willis. Certainly in the syndrome of "subclavian steal", it appears clear that stenosis of one of the branches of the aortic arch may be compensated at the expense of the other (Sproul, 1963).

It is also not definite whether some of these compensatory mechanisms are of immediate value in the event of a catastrophic blockage. There is evidence that collateral channels, which become significant after the blockage of a main vessel, may not play a significant part in meeting immediate demands such as in the extremities. However, this may not be applicable to the cerebral cirulation. Certainly, unilateral compression of the carotid is well tolerated in healthy adults, and in fact, in diseased states, compression test has been employed with relative immunity in a proportion of cases (Toole, 1959). Bilateral compression of carotids has been used to produce transient comatose states by Chinese boxers, Burmese traditional physicians, and some daring hypnotists. The position would appear conflicting in that during acute deprivation of blood supply regionally, some findings indicate the presence of efficient immediate compensatory mechanisms, whereas others would suggest a compensatory mechanism which is relatively incompetent to start with, but becoming significant if permitted to develop over a period of time.

It was thought that the variability of findings could not be explained on the anatomic variability of the circle of Willis alone, and observation in some of our cases would seem to indicate that other factors being equal, the position of the head in relation to the neck may have an influence, in that rotation of the head may affect the flow of both the carotid and vertebral arteries. A number of studies were made to elucidate some of these points, and the findings are now reported.

1. **Ligature study:** The carotids were ligated in rats in two sittings, first on the left side, then on the right side after 2 weeks. The rats (Wistar strain) were about 10 to 12 months old and weighed about 180 gms. No paralysis was observed after ligation. After 2 more weeks, angiographic study of the cerebral vessel was made by the injection of a radio-opaque dye into the left ventricle through an open thoracotomy wound under ether anaesthesia.

   The result showed that the vertebral system was able to compensate in toto for the two carotid systems intracranially, and in fact, even the extracranial portions of the internal carotids beyond the ligatures were filled by retrograde filling (Figs. 1a & 1b).

2. **Human cadaver study:** The vertebral arteries of cadavers were exposed in the neck at their origin and cannulated. 20% Sodium Iodide solution was injected under pressure, and angiographs were taken with the neck in extension and the head rotated first to left, then to right. The result seems to show that when the head was rotated towards one side, on the side towards which the head was rotated the vertebral artery was straighter and the lumen of the artery bigger compared to itself when the head was rotated towards the opposite side (Figs. 2a, 2b, 3a & 3b).

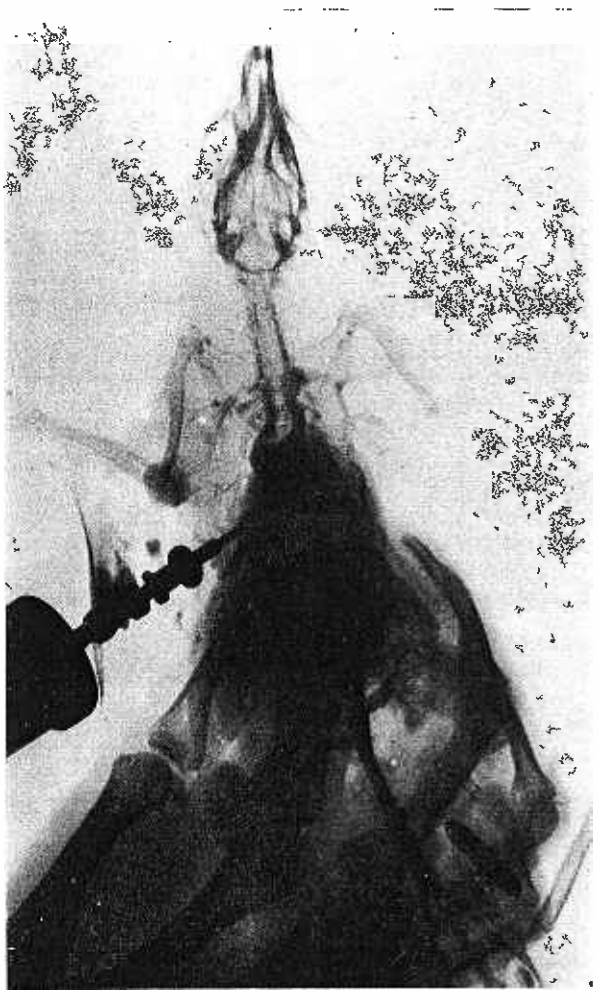

Fig. 1a.

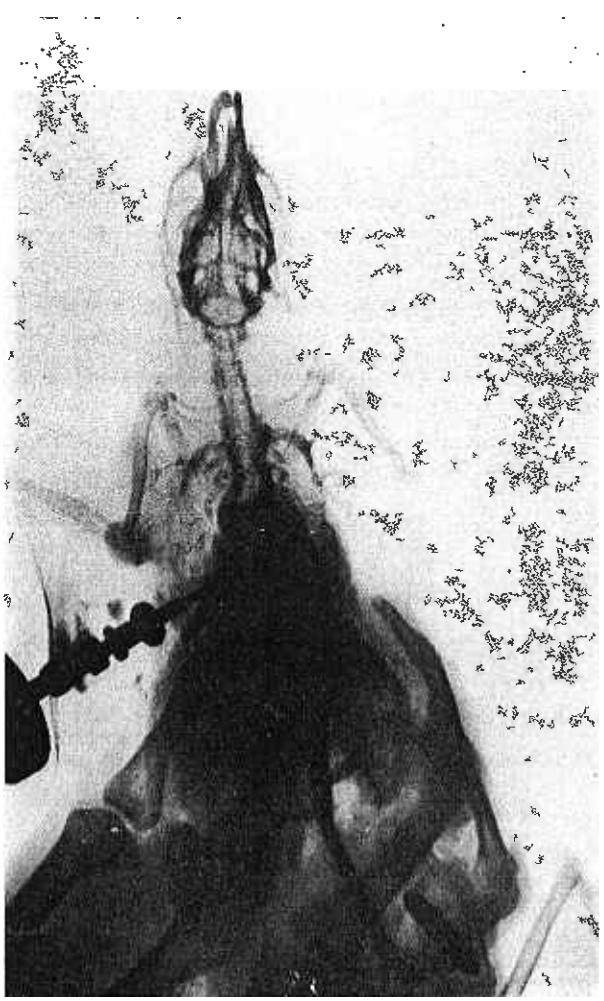

Fig. 1b.

Figs. 1a. & 1b. Showing retrograde filling of syphon after bilateral ligation of common carotids in the neck.

A pliable rubber tubing was inserted into the vertebral foramina of an articulated cervical spine in the position of the vertebral artery. It was found that rotation of the head to one side caused pressure to be exerted on the tubing on the opposite side by the bone rims of the foramina. The tubing on the side towards which the head was rotated was harldy affected as illustrated in the diagram (Fig. 4).

3. **Human angiogram scrutiny:** A search was made through the arteriograms done over the last 3 years in Medical Unit II for evidence of compensatory flow, and that of effects ascribable to the rotation of the head. It was found that there were these findings:—

   1. Frequent filling of posterior cerebral artery in carotid angiograms amounting to at least 30%.
   2. Non-filling of anterior cerebral artery when the head was rotated inadvertently in some cases leading to a question of the presence of arterial spasm.
   3. Filling of contralateral anterior and middle cerebral arteries under high pressure unilateral carotid injection; (Fig. 4) and also, when pressure was applied to the contralateral carotids, frequent contralateral filling was noted (Figs. 5a & 5b).

SUMMARY AND CONCLUSION

In ligation experiments on rats and in scrutiny of angiograms done in humans for diagnostic purposes, there is seen a readiness in which one region of the brain blood flow can be readily compensated by the other at the level of the circle of Willis, so much so that the vertebral system can adequately meet the need

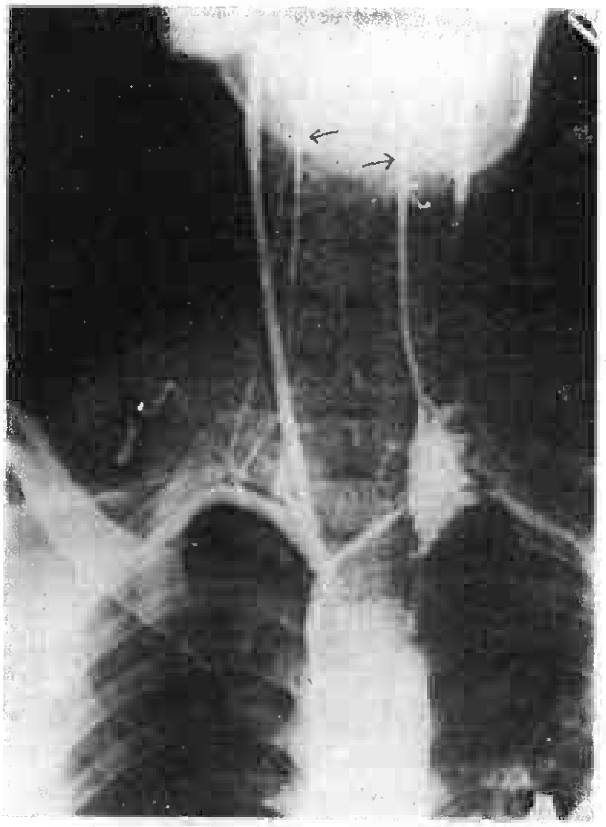

Fig. 2a.

Fig. 2b.

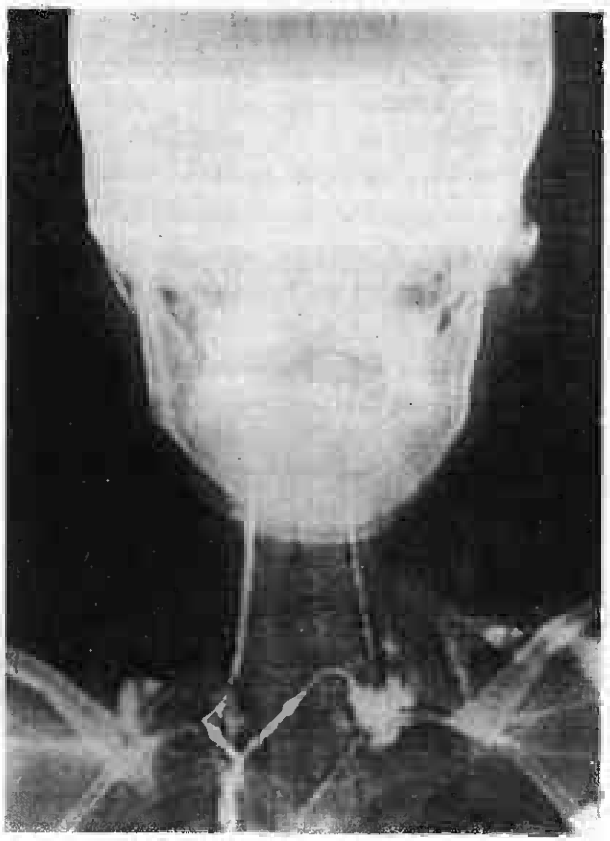

Fig. 3a.

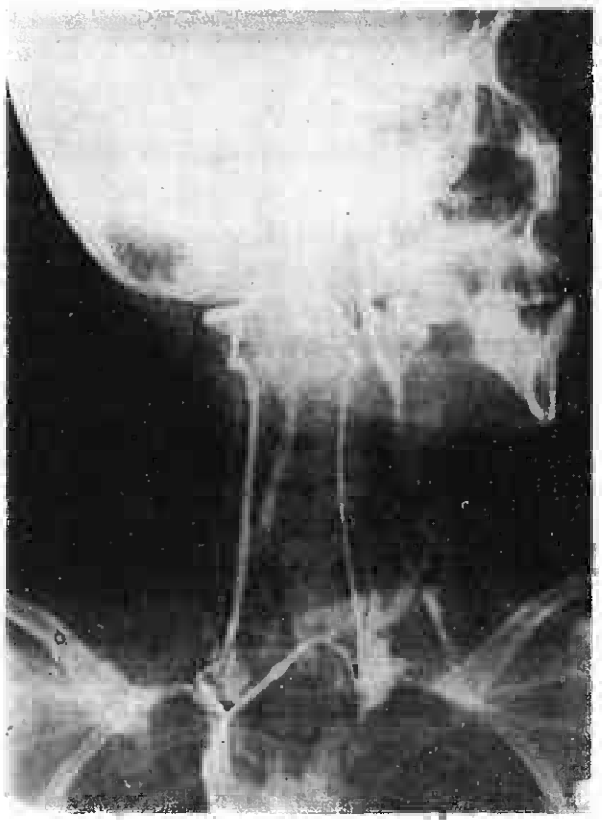

Fig. 3b.

Figs. 2a, 2b, 3a & 3b. Showing variation in the vertebral arteries with positions of the head.

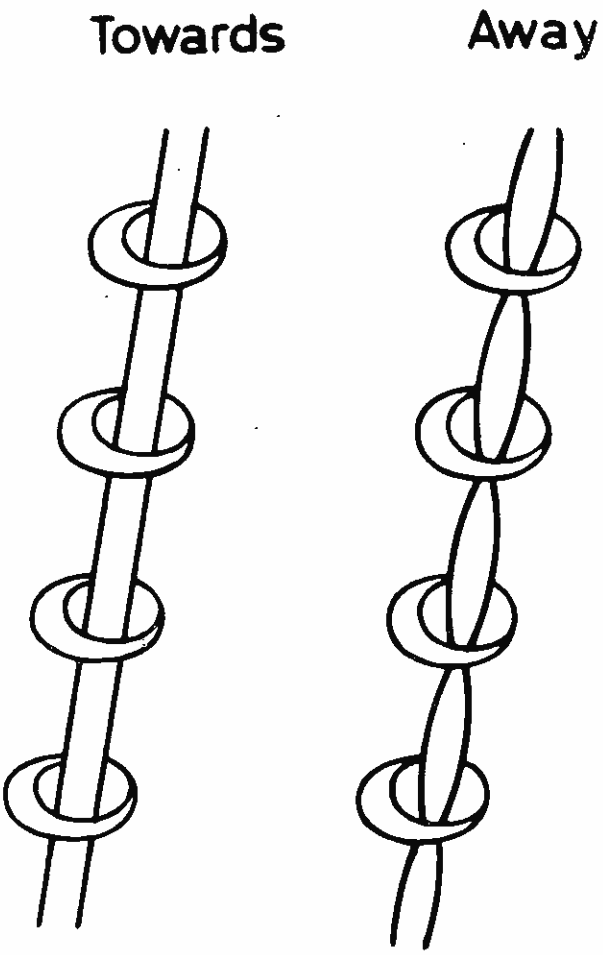

Fig. 4. Line drawing showing sites of pressure on a rubber tube in the vertebral foramina.

of both carotids if called upon. Also the carotids frequently distribute to the posterior cerebral artery, even when under normal conditions when the basilar artery would be the principal source of supply, the reason for which appears to be that during angiographic procedure, the pressure in the lumen of the carotid artery punctured would be enhanced by the pressure of the injection. This enhanced pressure would lead to a shift of flow to the opposite side that is, laterally such as left to right, and anterior-posteriorily such as from in front to behind. The amount of shift must depend on the pressure of the injection if all other factors, such as the existing intra-luminal pressure in the carotids remain constant. This is in fact so, because it can be seen that when the pressure of the injection exceeds the intra-luminal pressure, the dye will not only go up and fill the cerebrals, but will also go down against the blood flow into the proximal end of the carotid to the aortic arch. This enhancement of pressure during carotid angiography would account in part for

Fig. 5a.

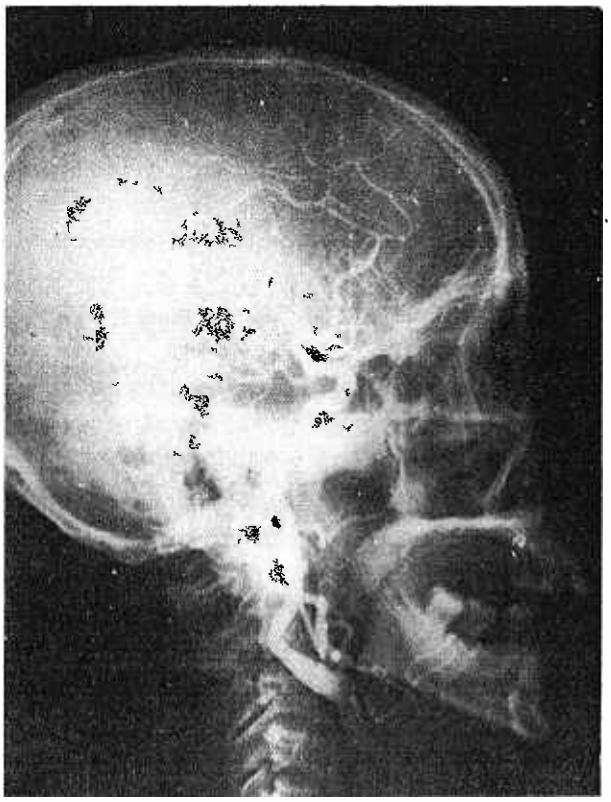

Fig. 5b.

Figs. 5a. & 5b. Showing filling of contralateral middle and anterior cerebral art.

the filling of posterior cerebrals, since a low pressure injection would be less likely to lead to filling of posterior cerebral arteries than a high pressure injection. It is appreciated of course that anomalies in the circle of Willis itself would contribute to the variability in posterior cerebral filling during carotid angiography, but the frequency of posterior cerebral filling compared to the infrequency of normal circle of Willis must mean that other factors such as the varying pressure of injection are also involved.

In the cadaver injections, it is observed that the vertebral lumen is visibly altered by rotation of the neck, being largest during flexion and rotation to the same side, and smallest during extension and rotation to the opposite side. The carotids being not encased, in a manner of speaking, by rigid bony canals, would probably be less liable to this alteration, and angiographic scrutiny does not suggest any such change in our series.

Findings in animals and cadavers must be accepted with reserve, as they need not be applicable in vivo. However, they, like observations in a constructed model, can contribute to a greater understanding of the circulatory state, and in that manner, might be of significance.

It is concluded therefore that there is evidence in these experiments to show that the compensatory mechanism against change of pressure in the cerebral vessels is immediate; and that in the vertebral system, the position of the head and neck is probably of significance in influencing the flow in the vertebral arteries through local effect on the arteries as they course through the vertebral foraminae.

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