- 19 Crutchfield JS, Narayan RK, Robertson CS, et al. Evaluation of a fiberoptic intracranial pressure monitor. *J Neurosurg* 1990;72:482-7.
- 20 Czosnyka M, Harland S, Piechnik S, et al. Systematic overestimation of intracranial pressure measured using a Camino pressure monitor. *J Neurol Neurosurg Psychiatry* 1996;61:427-8.
- 21 Czosnyka M, Czosnyka Z, Pickard JD. Laboratory testing of three intracranial pressure microtransducers: Technical report. *Neurosurgery* 1996;38:219-24.
- 22 Clark WC, Muhlbaier MS, Lowrey R, et al. Complications of intracranial pressure monitoring in trauma patients. *Neurosurgery* 1989;25:20-4.
- 23 North B, Reilly P. Comparison among three methods of intracranial pressure recording. *Neurosurgery* 1986;18:730-2.
- 24 Smith RW, Alksne JF. Infections complicating the use of external ventriculostomy. *J Neurosurg* 1976;44:567-70.
- 25 Winn H, Dacey R, Jane J. Intracranial subarachnoid pressure recording: experience with 650 patients. *Surg Neurol* 1977;8:41-7.
- 26 Keays R, Alexander G, Williams R. The safety and value of extradural intracranial pressure monitors in fulminant hepatic failure. *J Hepatol* 1993;18:205-9.
- 27 Bavetta S, Norris JS, Wyatt M, et al. Prospective study of zero drift in fiberoptic pressure monitors used in clinical practice. *J Neurosurg* 1997;86:927-30.

HISTORICAL NOTE

The circle of Willis (1621-75)

It is easily forgotten that in the century of Shakespeare and Marlowe there was no scientific or rational physiology as we now understand these disciplines. The era was of magic and witchcraft; insubstantial notions of the *spiritus animalis* were rife, and irrational speculation abounded. The genius of Thomas Willis (1621-75) took medicine several stages forward. Willis showed that the cerebral cortex covered many subcortical centres that join the two hemispheres. The cortical grey matter, he thought was responsible for animal spirits, the white matter distributed the spirits to the body, governing movement and sensation. Willis, like Descartes, still believed that man had an immaterial, reasoning soul. Bodily activity was governed by a corporeal soul, in two parts:

"...the animal Spirits flowing from the Medullary substance into the nerves, are as it were rays diffused from the light itself, and the other Spirits everywhere abounding in the Fibres . . . perform the acts both of the sensitive and locomotive Faculty" (Willis, 1681, p126).

The vital soul was the "flame" in the blood, and the sensitive soul was the animal spirit diffused through the brain. His experiments showed that if the blood was prevented from reaching the brain then "nerve function ceased because vital spirits could not reach the ventricles for conversion into the essential animal spirits,"—an early notion of cerebral ischaemia.

He began to employ scientific methods. With Ralph Bathurst, Richard Lower, Thomas Millington, and Sir Christopher Wren, Willis studied neuroanatomy, and comparative and experimental pathology. They all contributed to his *Cerebri Anatome*. He injected dyes to demonstrate the main blood vessels, thus providing new and superior anatomical demonstrations.

The circle of Willis

Amongst his clinical highlights was a man who died of a mesenteric tumour, who in life had no neurological symptoms. He published

a case report in *Cerebri Anatome* in 1664^{2,3}:

"...When his skull was opened we noted amongst the usual intracranial findings, the right carotid artery, in its intracranial part, bony or even hard, its lumen being almost totally occluded; so that the influx of the blood being denied by this route, it seemed remarkable that this person had not died previously of an apoplexy: which indeed he was so far from, that he enjoyed to the last moments of his life, the free exercise of his mental and bodily functions. For indeed, nature had provided a sufficient remedy against the risk of apoplexy in the vertebral artery of the same side in which the carotid was wanting, since the size of this vessel was enlarged, becoming thrice that of the contralateral vessel..."

This case shows that Willis was fully aware of both the anatomy and the physiological importance of the circle. Thus he founded his understanding of the vascular circle at the base of the brain'. And, more importantly, he was able to relate the anatomy to the clinical effects of vascular disease.

"...We have already shewn, that these Vessels are variously and very much ingrafted or inoculated among themselves, not only the Arteries with the Veins, but what is more rare and singular, Arteries with Arteries; to wit, the Carotidick Arteries of one side, in many, are united with the Carotides of the other side; besides the Vertebrals of either side among themselves, and are also inoculated into the posterior branches of the Carotides before united. The joinings together of the Carotides, in most living Creatures, are made about the Basis of the Skull under the Dura Mater..."

Willis was not the first to demonstrate the anatomy of the circle. Gabrielle Fallopio (1523-62), Guilio Casserio in 1627, and Johann Vesling from Padua gave descriptions or illustrations of the circle, and Johann Jakob Wepfer has priority for the description but not the illustration of the Circle in his book on apoplexy⁶ of 1658. Willis, however, published the first complete description, illustration, and understanding of the function of the circle. The illustration was probably the work of Wren.

Born on 27 January 1621 at Great Bedwin in Wiltshire, Willis qualified BM Oxford in 1646. He took a house opposite Merton college. Willis married the sister of John Fell, a local priest, and was active in the Church

of England. He became Sedleian Professor of Natural Philosophy in 1660 and in the same year was made Doctor of Medicine. He was one of the early Fellows of the Royal Society and was elected honorary Fellow of the College of Physicians in 1664. He moved to St Martin's Lane in 1666 and was immediately successful:

"so infinitely resorted to for his practice, that never any physician before went before him, or got more money yearly than he" (Wood, *Athenae Oxon.* ii,402).⁷

James II consulted him about the health of his children born with ulcers, "originating in the amours of their father". Willis's opinions ("mala stamina vitae") were too candid, and he was not consulted again. He was widely held to be pious and,

"a man of no carriage, little discourse, complaisance, or society . . . yet for his deep insight, happy researches in natural and experimental philosophy, anatomy, and chemistry . . . pure elegance, delightful unaffected neatness of Latin style, none scarce have equalled . . ." (Wood).

His contemporaries neglected his extensive writings. They are well described by Hughes³, Isler,¹ and in Munk's roll.⁷ He died at St Martin's lane and was buried in Westminster Abbey.

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- 1 Isler H. *Thomas Willis 1652-1675, Doctor and Scientist*. New York: Hafner Publishing Company, 1968.
- 2 Willis T (cited by Hughes). *Cerebri Anatome: Cui accessit Nervorum Descriptio et Usus*. Londini 1664, types Jac Flesher, Impensis Jo Martyn and Jac Allestry. Oxoniae, e theatro Sheldoniano, 1672: pp.95-6.
- 3 Hughes JT. *Thomas Willis (1621-1675). His life and work. (Eponymists in Medicine)*. London: Royal Society of Medicine, 1991:68-9.
- 4 Willis T. *Two Discourses concerning the Soul of Brutes, which is that of the Vital and Sensitive of Man*. English trans: S Pordage, Student in Physick. London: Thomas Dring, Charles Harper, and John Leigh, 1783. Gainesville, Florida: Scholar's Facsimiles and Reprints, 1971:46.
- 5 Willis T. *The anatomy of the brain and the nerves*. Feindel W, ed. Facsimile of the English edition by Samuel Pordage (1681), Vol.II, Figura 1a, Montreal: McGill University Press, 1965:82.
- 6 Pearce JMS. Johann Jakob Wepfer (1620-1695) and cerebral haemorrhage. *J Neurol Neurosurg Psychiatry* 1997;62:387-7. Munk's Role, *Lives of the Fellows of the Royal College of Physicians of London*. Compiled by GH Brown. London: Royal College of Physicians. 1955. Vol 1 Pp338-42.