UNIVERSITY OF JAFFNA

Dr. Arunasalam Sivapathasundaram

Memorial Lecture

HYDROCEPHALUS - RECENT ADVANCES

by

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Vice - Chancellor, University of Jaffna. Dean, Faculty of Medicine: Members of the family of Dr. Arunasalam Sivapathasundaram: Ladies and Gentlemen: and my dear students:

Dr. Arunasalam Sivapathasundaram met a tragic death on 22nd October 1987. A loss of indescribable nature that we are gathered here today in commemoration. His courage, compassion and dedication had no parallels: and these qualities come to our mind whenever we think of him. He was adored by his staff and students: for them no doubt, he gave his life: he went on that fateful morning with some money to help his staff. He was adored by the children and mothers of his ward; for them he was not merely just another doctor: he was a good doctor and Paediatrician. We train each of our medical students not to become just another doctor but a good doctor. We have to recollect Dr. Sivapathasundaram to visualize the portrait of a good doctor.

His life in Jaffna was not easy: that he discharged these qualities despite the obstacles make one and all adore him. I have great pleasure in delivering this memorial lecture: the honour, however, I am not worthy of. My acquiantance with him was brief: but we had many times discussed the management of children with hydrocephalus. Thus, I have chosen a subject he himself would have appreciated: Hydrocephalus - Recent Advances.

Hydrocephalus, a condition in which there is excess of cerebrospinal fluid (CSF) in and around the brain, is easily recognised in babies as a large or an enlarging head: in children and adults with modern imaging techniques such as Computerised Tomogram (CT) and Magnetic Resonance Imaging (MRI) scans as dilated ventricles in the brain.

Large head in a child does not always indicate hydrocephalus: there are other masquerading lesions. Young Sivapathasundaram was well known as a drama artist: not only at Hartley College, but also at Jaffna where he delighted us with his acting in the dramas staged by the Jaffna Medical Association for its Annual Sessions. Large head may be due to a mass or space occupying lesion in the brain: megalencephaly or diffuse enlargement of the brain itself: or thickened skull associated with skeletal dysplasia affecting skull. The common mass lesions include brain tumours, arachnoid cysts and large collections of serosanguinous fluid in the subdural space. In megalencephaly the increase in brain substance is due to accumulation of carbohydrate or lipid material within the brain as a result of inherited enzyme deficiencies or diffuse infiltration of brain tissue by cells other than neurones (for e.g. Histiocytes in Histiocytosis X). Skeletal dysplasias include Osteogenesis Imperfecta, Rickets and Osteopetrosis.

Hydrocephalus is due to an abnormality of the dynamics of CSF. Born at Puloly, educated at Hartley, Dr. Sivapathasundaram became more dynamic after his marriage in 1966. He had by then graduated from the Colombo Medical Faculty with his basic medical degree and served his internship at Ratnapura hospital. CSF is formed in the ventricles of brain by the choroid plexus. Some CSF (20–30%) comes from the brain tissue where it is formed as interstitial fluid (ISF) from the cerebral capillaries in which a blood - brain barrier (BBB) is located. CSF shows a bulk flow from the lateral ventricles through the foramen of Monro into the third ventricle and then through the narrow aqueduct into the fourth ventricle, whence it exits into the subarachnoid space (SAS). The bulk flow of CSF in the subarachnoid space is complex, but finally it is absorbed into the venous system through special structures formed from the arachnoid membrane- the arachnoid villi. The CSF in the ventricular system

forms an internal component whereas that in the SAS an external component. Like the CSF flow Dr. Sivapathasundaram accompanied by his wife had travelled and served in many parts of the island: he was at Wattipola, Balangoda, Ragama, Kuliyapitiya and Anurhadapura hospitals.

Abnormal dynamics of the CSF that leads to hydrocephalus may associate with; a) choroid plexus lesions, b) obstructions to the bulk flow pathways of CSF or c) CSF absorption defects.

What is the role of the choroid plexus in hydrocephalus? Choroid plexus is a villous structure which projects into the ventricle from the ependyma. the epithelial lining of the ventricle. It elaborates CSF by an active process from blood. Increased secretion of CSF as a cause of hydrocephalus is seen in choroid plexus papilloma, a rare benign tumour of the choroid plexus. Removal of the papilloma, however, may not relieve the hydrocephalus as there may be also an obstruction to the bulk flow pathway of CSF, possibly by some tumour products, which perpetuates the hydrocephalus. Choroid plexus carcinoma and metastatic tumour may mimic each other and may cause obstructive hydrocephalus. Ablation of choroid plexus is not an etfective treatment for hydrocephalus as CSF is also produced by the brain tissue as ISF.

Major causes for hydrocephalus are obstructions to the bulk flow pathway of CSF. Many lesions obstruct the narrow parts of the ventricular system. These include congenital lesions such as aqueduct stenosis and Dandy Walker syndrome in which the outlets of the fourth ventricle are malformed and tumours such as colloid cyst of the third ventricle and medulloblastoma or ependymoma of the fourth ventricle which obstruct the outlets of the fourth ventricle. The hydrocephalus in these

cases is described as obstructive (as these causes obstruct the flow of CSF in the ventricles), noncommunicating (as there is no direct communication between the ventricular and SAS CSF) and internal (as the ventricles only show dilatation due to the excess of CSF.)

Obstructive lesions may also occur in the cranial SAS at stratergic points where the space becomes narrow. These include congenital lesions such as Arnold Chiari malformation in which a small poster or fossa associated with adhesions obstruct the flow of CSF at the craniovertebral junction and meningitis in which inflammatory adhesions occur in the SAS. The hydrocehalus in these cases is communicating type (as there is direct communication between the ventricular and SAS CSF).

That defective absorption associated with venous sinuses obstruction and abnormalities of arachnoid villi might cause hydrocephalus was only surmised for a long time. Recent research has advanced our knowledge about absorption defects and many other aspects of hydrocephalus and CSF dynamics in this condition. Dr. Sivapathasundaram advanced his knowledge by obtaining DCH in Colombo in 1970 and DCH and MRCP in London in 1975 Venous sinus obstruction/ abnormalities at arachnoid villi may lead three pathological states: hydrocephalus is one of them. Benign intracranial hypertension (BIH) and cortical vein thrombosis (CVT) are the other two. Raised intracranial pressure (ICP) is a common feature in all three. In hydrocephalus the ventricles are dilated along with the SAS. This is communicating hydrocephalus. In BIH the CSF spaces are minimally dilated; but there is increased fluid (ISF) in the brain tissue causing raised ICP and papilloedema. In CVT cerebral oedema of venous origin is seen with raised ICP; the CSF spaces are minimally dilated. It is not known why some patients develop hydrocephalus while others develop either BIH or CVT: suffice to say that CSF and ISF drainage is not straight forward and the two fluids have alternate pathways of flow.

The clinical features of hydrocephalus differ depending on the age group and rapidity of evolution of hydrocephalus (Table I). The pathogenic basis of these symptoms was thought to be raised ICP and ability to compensate for the raised ICP by accommodating some of the excess volume by architectural rearrangements such as bulging and stretching or shifting certain volume of some of the intracranial contents out of the cranial cavital. These volume compensation mechanisms for raised I C P include ventricular dilatation (earliest mechanism which leads to a uniform sign in hydrocephalus - dilated ventricles), bulging fontanelle, suture diastasia, engorged scalp veins due to displacement of venous blood and thinning of brain tissue.

Earlier special investigations demonstrated the dilated ventricles only (for e.g. ultrasound and ventriculography). Modern imaging studies. CT and MRI scans clearly demonstrate the bulk flow pathways of the CSF and their abnormalities in hydrocephalus. Neuroendocrine assessment is important in children lest they suffer from chronic pressure effects.

Regarding the treatment of hydrocephalus, when the cause of hydrocephalus cannot be rectified symptomatic treatment is indicated. Based on the simple pathogenic mechanism of volume - pressure effect, the symptomatic treatment of hydrocephalus is expected to be simple. Dr. Sivapathasundaram also settled for a simple life as Paediatrician after completing the postgraduate studies. A shunt tubing or catheter system which works on a differential pressure gradient between the ventricle and tip of the catheter will drain the excess volume of CSF from the ventricle and thus work satisfactorily. Innumerable shunt systems that have been marketted recently, however, suggest that a satisfactory shunt is yet and probably not possible to be designed All shunt systems are beset with complications of the order of 30% (Table II)[3]

TABLE I CLINICAL FEATURES OF HYDROCEPHALUS

	Volume Compensation Features	Raised ICP Features
1) Infants	Open fontanelle Head enlargement Sun-set sign (due to pressure by the dilated IIIrd ventricle on the midbrain upward gaze centre) Increased limb tone (due to stretching of white matter) Engorged scalp veins	Tense fontanelle Poor feeding Febble cry Vomiting Drowsiness
2) Children	Large head Suture diastasia Cracked - pot sign Defective hypothalamic & Pituitary function (due to pressure by dilated IIIrd ventricle on its floor)	Acute Pressure Effects: Headache, vomiting & papilloedema Chronic Pressure Effects: Slowing of mental functions Unsteady gait
3) Adults	Large ventricles on CT scan (with or without dilated SAS)	Acute Pressure Effects: Headache, vomiting & papilloedema Chronic Pressure Effects: Clinical triad Dementia, ataxia & urinary incontinence (due to loss of peri-ventricular architecture with or without ischaemiu)

TABLE II SHUNT COMPLICATIONS
Infection
Obstruction
Overdrainage leading to:
Subdural haematoma
Slit – ventricular syndrome
Craniosynostosis
Seizures

While shunt infections can be minimised by meticulous surgical technique, obstruction and overdrainage are constant recurring problems and difficult to control. Furthermore failure of treatment is common with the adult chronic hydrocephalus, also described as normal pressure hydrocephalus (NPH). Hakim and Adams in 1965 described the NPH, now known to manifest by the clinical triad dementia, ataxia, and urinary incontinence[4]. There have been many investigations (Table III) used since then to select the appropriate patients for shunt treatment; but none of them provided any consistent criteria. To obviate the shunt failure early treatment of hydrocephalus before the onset of chronic pressure effects has been considered essential.

The bitter truth about hydrocephalus treatment is that the pathogenesis of this condition is still ill understood. Dr Sivapathasundaram learned the bitter truth about his twin daughters gradually, but that only made him to persevere more him to persevere more in life; more dedicated and caring to children he became a successful and the only Paediatrician in Jaffna during his time.

Let us examine the pathogenesis of hydrocephalus and the abnormal dynamics of CSF in this condition.

Table III Investigations for NPH
CT & MRI scans
Xenon enhanced CT scan
Cisternography
Single photon emission CT (Spect)
Urodynamic tests
Neurophysiological tests
Continuous CSF pressure monitoring
Lumbar constant flow infusion test
Lumboventricular perfusion test

Fluid systems in our body have three parameters: pressure, volume and flow. Detrimental effects of abnormal fluid dynamics may stem from alterations of any or all of these parameters. Thus, any symptomatic treatment of hydrocephalus should aim to restore these to normality.

Any cause of hydrocephalus, commonly obstructions to the bulk flow pathways of CSF and uncommonly choroid plexus lesions, results in an increased volume of CSF. This increased volume within the cranial cavity necessitates a compensatory response in which extra space may be provided to accommodate the excess by distension of intracranial compartments, for e.g. by ventricular dilatation, enlargement of skull and bulging fontanelle, or by drainage of a volume of any of the other two fluids within the cranial cavity, namely the venous blood and ISF. Architectural damage will occur with time due to distension and early treatment of hydrocephalus will only restore the normal anatomy, for e.g. of sutures that separate to provide extra space. The space provided by the displacement of venous blood and ISF is usually limited unless the cerebral blood flow (CBF) is concurrently maintained. As we shall see later, the abnormal CSF dynamics in hydrocephalus

is associated with an impairment of CBF. When these volume compensation mechanisms (or the volume compliance mechanisms) fail the intracranial and CSF pressure will rise and the raised ICP accounts for many of the symptoms and signs of hydrocephalus.

If hydrocephalus is associated with increased CSF volume with attendant increased pressure, The pressure dependent shunt treatment should be effective in restoring CSF volume and pressure back to normal. But hydrocpehalus is unfortunately not merely a state of increased CSF volume and pressure: there is also a CSF flow. abnormality and thus any treatment should also aim to restore normal CSF flow.s CSF diversion by simple shunting will not restore flow: this failure no doubt accounts for the complications of obstruction and overdrainage associated with shunts.

The CSF flow in hydrocephalus follows complex alternate pathways when the normal pathways are obstructed and establishment of these abnormal pathways of flow will prevent the volume and pressure changes We have already looked at the dynamics of the normal bulk flow pathway of the CSF. In hydrocephalus, with an excess of CSF in the ventricles and / or SAS, the ventricular CSF can readily cross the ependyma, while the SAS CSF the pia mater to enter the brain tissue and mix with the ISF, the fluid formed from blood across the B B B (located in the cerebral capillaries). The ISF has been shown recently to have a bulk flow along the perivascular pathways and other channels in the white matter, into CSF in the SAS[5]. Even though the ISF is formed at the cerebral capillaries, it does not re-enter the venous blood at the venous end of the capillaries or venules. Normally, after its formation, it will drain into C S F along the pathways mentioned earlier. My research has shown that when there is a raised brain tissue pressure (B T P) or ICP, ISF will cross the venular B B B and re-enter the blood[6], It is possible that in the raised BTP states there is obstruction to the physiological path-

ways of ISF flow, namely the perivascular and white matter pathways. thus, with raised pressure in hydrocephalus CSF may flow into the ISF compartment (from the ventricle or SAS) and thence flow along with ISF into the SAS or though the venules into venous blood. Theoretically this compensatory flow should be effective if volume compensation mechanisms fail to contain the ICP. There is, however, consistently raised pressure in hydrocephalus suggesting that this compensatory flow also has its limitations. Stagnant CSF and ISF in the brain tissue has been shown by electron microscopy along with destruction of the white matter[7]. It appears that the stagnant fluid in the white matter leads to demyelination which probably forms the basis tor the chronic pressure effects of adult hydrocephalus. What is the nature of this limitation of flow?

Since the advent of MRI scan, the CSF has been shown to exhibit a pulsatile flow in addition to the bulk flow. This pulsatile flow is related to the CBF which amounts to about one-fifth of the cardiac output. This volume of blood which enters the cranial cavity with each heart beat has to be accommodated within it to prevent a rise in ICP. The CSF in the cranial SAS and ventricles thus, moves down into the spinal SAS. The exit of venous blood from the cranial cavity in turn is accompanied by upward movement of the CSF from the spinal SAS into the cranial SAS and ventricles. This alternate movement of CSF between the cranial SAS/ ventricles and the spinal SAS with each cardiac cycle constitutes the pulsatile flow of CSF[8,9]. It is obvious that this pulsatile flow of CSF is important for the maintenance of normal CBF.

At this juncture, it is important to understand that a normal CBF is a pre-requisite for the venular flow of ISF (during raised ICP), for the perivascular and other white matter pathways of ISF flow and for effective volume compliance mechanism.

In hydrocephalus, obstruction in the ventricles or SAS interferes with the pulsatile flow of CSF. This will in turn impair the CBF, venular flow, perivascular flow and volume compliance. As mentioned earlier, treatment of hydrocephalus which restores only the volume and pressure abnormalities normally fails to restore the pulsatile flow. Thus, there will be a gradual decrease in CBF leading to ischaemia even after the shunt treatment.

The clinical features of hydrocephalus represent a balance between the effects of compensatory mechanisms and the pathogenic mechanisms. Thus, the increased pressure, stagnant CSF and ISF and cerebral ischaemia are the destructive pathologic features seen on one hand. The compensatory features which include volume compliance, preservation of pulsatile flow of CSF and opening of alternate pathways of ISF and CSF flow work on the opposite side. Usually, if there is ineffective venular flow, there is decreased CBF and failure of volume compliance mechanism leading to raised ICP. On the other hand, an effective venular flow associates with the dominance of the compensatory mechanisms.

What is the rational symptomatic treatment of hydrocephalus based on the pathogenesis? In hydrocephalus, there is not only excess of CSF volume but also defective pulsatile flow of CSF with failure of alternate pathways of CSF and ISF flow. Excess CSF has to be diverted into some space, but this latter may be outside the cranial cavity as for e.g., the CSF is diverted into the peritoneal cavity by ventriculo peritoneal shunts. The extra space may also be provided within the cranial cavity. Thus, in noncommunicating hydrocephalus due to obstruction of CSF in the ventricular system, the CSF in the ventricle proximal to the obstruction may be diverted into the adjacent SAS using a simple tubing. This treatment is using internal shunts as opposed to external shunts such as ventriculo atrial or peritoneal shunts. Unfortunately, the simple tubing of internal

shunts will easily get blocked. What is important is tha the internal shunts should actively open up th[e] SAS and create a sac or volume of CSF in the SAS which in turn should show a pulsatile flow. Restoration of the pulsatile flow will only maintain the CBF, pave way for the alternate routes of CSF and ISF flow through the venules and perivascular and white matter pathways to operate, and prevent the rise in ICP by successful volume compliance. Thus, an internal shunt should establish a good communication between the ventricles and cranial SAS.

Endoscopic surgery and minimal invasive surgery are recent innovations in general surgery. These techniques have been, however, in use in neurosurgery for a long time. Recently, endoscopic surgery has been used in the treatment of hydrocephalus, particularly in obstructive or noncommunicating hydrocephalus such as that due to aqueduct stenosis[10]. The operation of third ventriculostomy creates an opening or communication in the floor of the dilated third ventricle so that the CSF in the third ventricle can exit into the basal cranial subarachnoid space, thus short circiuting the normal bulk flow pathways. This operation is thus an internal CSF diversion procedure. Opening of the basal cranial SAS as a result of this diversion restores the pulsatile flow of CSF and in turn establishes the conjugal advantages mentioned earlier. Dr. Sivapathasundaram always had an inquisitive mind and he satisfied his English colleagues opening the coconut to show its origin.

Theoretically, third ventriculostomy should work even in communicating hydrocephalus, as restoration of the pulsatile flow and CBF would no doubt be of benefit in NPH. It was in fact serendipitous to observe beneficial results after third ventriculostomy in NPH by my neurosurgical colleagues at Hull[11].

Third ventriculostomy is under scrutiny all over the world in neurosurgical centres at present. It remains to

be shown that whether or not third ventriculostomy is an effective treatment for all forms of hydrocephalus, will replace the shunt treatment and prevent its associated complications and will be a rational treatment for hydrocephalus, which restores abnormalities of volume, pressure and flow of CSF.

There is, however, no doubt that early surgery is always beneficial. Early third ventriculostomy can open the cranial SAS obliterated either primarily (being the cause of hydrocephalus) or secondarily (due to the diversion of CSF flow along alternate pathways). Early treatment of hydrocephalus has also prompted operations on the foetus. Foetal surgery is now being considered as a speciality by many paediatricians, Neurosurgeons and obstetricians[12]. No doubt Dr. Sivapathasundaram would have endorsed this view.

In conclusion, the traditional treatment of hydrocephalus by shunt is fraught with many complications and third ventriculostomy may eventually replace shunts. This is in keeping with the importance of the pulsatile flow of CSF which has to be restored in any form of treatment for hydrocephalus. Furthermore, early treatment is essential and foetal surgery is an evolving field in this respect. We have seen Dr. Sivapathasundaram's family and his extended family of very many doctors he had taught carrying the candle he had lit searching for new light in many fields of science as in the treatment of hydrocephalus by many researchers. He no doubt led a life like a candle for others.

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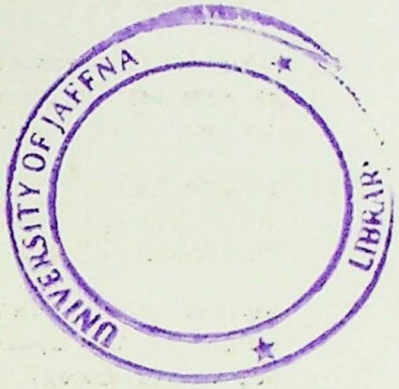
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Prof. Visakasundaram Kunanantham obtained his MBBS Degree in 1970 from the University of Ceylon, Peradeniya. He obtained his professional qualifications FRCS (Edinborough) and FRCS (Surgical Neurology) in 1980 and 1985 respectively. He did his PhD in Medicine at the postgraduate School of Medicine University of Hull in July 1997.

He worked as a Consultant Neuro Surgeon at the General Hospital (Teaching) Jaffna between December 1981 and July 1985. During this period he served as Visiting Neuro Surgeon in the Faculty of Medicine, University of Jaffna. He worked as an Associate Specialist in Neuro Surgery for more than a decade in United Kingdom.

He specialized in Neuro Surgery and published many papers to his credit in the journal of the British Neurological Surgeons.

He has been a Visiting Professor in Surgery in the University of Jaffna since June 1997. Prior to this assignment, he served as an examiner for surgery in the University of Jaffna.

He is dedicated to his work and has been very helpful for continuing the academic progammes in Faculty of Medicine, University of Jaffna during the present difficult time.

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