TCP (tricresyl phosphate): pilot, aircrew and passenger safety and secondary myalgic encephalomyelitis

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Injury to the brain caused by a virus or a toxic chemical may not be obvious and, hence, difficult to diagnose, unless it affects a motor, visual, coördination or sensory brain centre (approximately 70% of the brain is involved with emotional, memory, immune and decision-making areas; injuries to these areas are not immediately visible on external or physical examination). New scanning technologies, especially when combined with tomography algorithms to yield three-dimensional images, have been enormously helpful in directly examining the brain for injury rather than relying on consequential behavioural and other effects. The better known technologies, such as X-ray computed tomography and magnetic resonance imaging can reveal structural (i.e., anatomical) damage but cannot detect functional (i.e., physiological) damage. For the latter, techniques such as single-photon emission computed tomography (SPECT) and positron emission tomography (PET) are very valuable. They have enabled many previously mysterious conditions to be diagnosed as myalgic encephalomyelitis (ME). It would appear that many sufferers from aerotoxic syndrome are actually suffering from ME.

1. INTRODUCTION

I have the honour and responsibility of being the sole full time physician invited to speak here today. It would appear that there are two reasons for this invitation:

1. A few years ago I spoke in London (England), concerning the measurement and diagnosis of diffuse brain damage in patients injured by toxic chemical exposure; and

2. I am one of few physicians worldwide who has spent any major time, in fact the past 27 years, doing detailed total body investigation of both infectious and toxic brain-injured patients.

How does my knowledge interconnect with the main purpose of this Workshop, which is to clarify toxic chemical injury to pilots, flight crew and, may I add, frequent flyers? These individuals are from time to time exposed to toxic chemical leaks into the cabin ventilation system of commercial jet airliners, specifically to TCP (tricresyl phosphate) and its toxic by-products. Many of those here today have good reason to believe that toxic aerosol exposure from the jet turbine TCP (a lubricant additive) represents a significant danger to aircrew and aircraft safety and this danger has to be properly investigated. This toxic TCP air contamination is an implicit problem of all modern jetliners with the exception of the new Boeing 787. Except for the 787, airliners are manufactured with a built-in defect allowing, from time to time, the escape of TCP and its breakdown products into the aircraft pilot and passenger areas. My connexion is simply my experience in examining patients with toxic chemical injury.

A few years ago, in London, I discussed how the brain changes due to toxic chemical injury were indistinguishable from those found following nonlethal viral injury, as seen in a postviral central nervous system (CNS) injury, commonly termed myalgic encephalomyelitis (ME). At that time I referred to the chemically induced brain injury as secondary ME. I have been invited here today to discuss ME and CNS (brain and spinal cord) dysfunction in both virally and chemically induced brain dysfunction as it may affect pilots, aircrew and frequent flyer passengers exposed to jet turbine leakage of TCP into the airliner pilot and passenger compartments.

Any injury of the brain caused by either a virus or a toxic chemical is always one of degree. *Only when an injury kills or significantly affects a motor, visual, auditory, balance, respiratory or coördinating centre of the brain or CNS do these injuries become obvious.* Yet these zones may make up no more than 30% of the brain volume. Injuries to the remaining 70% of the CNS, if not consolidated as in a focal encephalopathy, appear invisible, even to the expert neurologist—but not to the patient. In diffuse, spotty brain injury to the remaining 70%, depending upon the degree, the extent and any consolidation of the injuries, the patient may react in any of several fashions. The injured person may experience:

Phase 1: No more than a few days malaise, as in minor flu or travel exhaustion, until an additional cumulative insult forces the injured person into the 2nd or 3rd phase (as noted below);

Phase 2: Persisting intellectual, cognitive, physical,

Journal of Biological Physics and Chemistry **11** (2011) 172–179
Received 11 October 2011; *accepted* 30 December 2011

doi: 10.4024/29HY11A.jbpc.11.04

spacial and visual dysfunction causing significantly decreased ability and speed in the work place; or

3. Phase 3: The patient may be sufficiently ill to be largely house-bound or even bed-bound.

The major problem with these first three aspects of CNS injury (to 70% of the brain volume) is that they are relatively invisible even to the trained investigator. Even in this 70% seemingly "blind" volume of the CNS, sufficient injury will push the patient into what we might call the 4th phase, particularly if the injuries are to some extent consolidated:

Phase 4: Diffuse injury is sufficient to cause coma or death.

Those in Phase 4, of course, are treated seriously and usually an autopsy is done. Often little is discovered on autopsy but due to the nature of the patient's death, their injury is not connected to those in the first three phases. Although, the symptoms and dysfunctions in the first three phases are very real to the CNS-injured patient, their complaints tend to be interpreted by most physicians as a psychiatric manifestation.

My background is unique in that I have spent the past 27 years as a physician, learning how to examine, measure and scientifically diagnose patients in Canada, the USA and the UK who had acquired chronic CNS dysfunction primarily due to viral, chemical or autoimmune injury. The postviral condition is known as myalgic encephalomyelitis (ME). ME, unlike chronic fatigue syndrome (CFS), is characterized by measurable abnormal changes of the CNS whereas, in my experience, CFS as a definition defines nothing other than chronic illness and can be applied to a large number of pathologies, usually physical in nature and less often psychiatric. In my practice, I assume patients diagnosed with CFS are really missed diagnoses, whereas ME patients have measurable injury to the CNS. *Diagnoses* is in the plural because many ME and CFS patients have multiple missed pathologies, usually to multiple organs and multiple systems.

I started this work in 1984, an epidemic period of viral illness, most frequently diagnosed as the effects of an enterovirus infection. In the first year or two I assumed that all of the patients I was investigating were suffering from postviral illnesses but soon I found out that many of my patients had been exposed to chemical toxins and demonstrated the same changes in their SPECT brain scans as those injured by a viral infection. These CNS injuries in both viral and toxic injury were indistinguishable from ME patient brain injuries observed in SPECT brain scans. I will briefly discuss the toxic chemical-induced brain injuries later.

My lecture today will discuss:

1. Patients with toxic chemical injury in my medical practice
2. Understanding myalgic encephalomyelitis (ME)
3. A small glimpse into the technology of brain analysis.

2. THE QUESTION OF TOXIC CHEMICAL INJURY IN MY PRACTICE

During the period 1988-1990, I assumed all *acute onset, chronically disabled diffuse CNS-injured* patients were suffering from the persisting effects of a viral infection. Brain microvasculature and/or brain cells were both damaged and this damage was testable. However, it became increasingly obvious that a group of my patients with *chronic diffuse brain injury*, although clinically identical to post-infectious patients, had clearly fallen ill following gradual, repeated or massive single exposure to toxic chemicals. The injured included: (i) police officers and firemen; (ii) golf course and indoor swimming pool maintenance persons; (iii) farmers; (iv) a college professor teaching dyeing techniques; (v) an individual working in classified military manufacturing technology; (vi) military personnel and the Canadian ambassador to Sri Lanka, exposed to the smoke of a chemical fire in an adjoining building. Until this Workshop I was not aware that flight crew also could be endangered with toxins escaping from gas turbine lubricant additives, notably TCP.

It is easier to demonstrate rather than explain what I mean by *chronic diffuse brain injury* (see Figure 1).

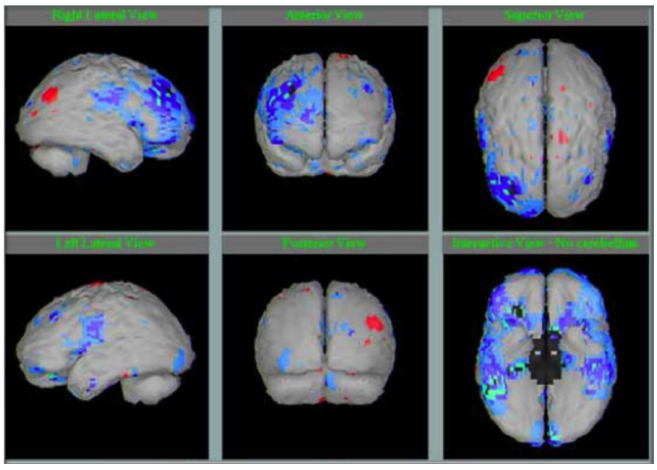

Figure 1. Typical ME brain SPECT demonstrating diffuse brain hypoperfusion injury as seen in either a viral or toxic chemical injury. Where the image is darkest (deep blue online) there is significantly decreased brain function (activity and/or injury). Where it is grey, there is a disturbance of function. Most patients tend to have consistent injuries in the primitive cortex (under the brain mass, lower right). This zone has several purposes, including coördinating abilities and the manufacture of essential enzymes and enabling chemicals, immune factors and hormones, to name just a few. Depending upon the location of the injuries, different intellectual, physical and immune characteristic changes may occur in the injured patient.

Early on, I demonstrated physiological brain changes and other pathologies in airline pilots and flight attendants and a few frequent airline passengers. I assumed at the time the frequency of CNS injury in this latter group was due to crowding in aircraft and, accordingly, exposure to possible repeated and even exotic microbial and viral infections, some of which might be foreign to the normal North American immune system. In principle, this is still a possibility. The flight crew had the same CNS injuries but I was never able to recover a virus, not an uncommon problem in many post-infection patients.

Patients I had seen following chemical CNS injury include the following persons and/or exposures:

a. Toxic chemical ponds
b. Hospital and golf course maintenance workers
c. Military and police personnel exposed to CS gas (developed by Corson & Stoughton)
d. Chlorine gas (swimming pool workers)
e. Organophosphates used in sheep dips and as other herbicides and pesticides; products based on nerve gases developed in World War II
f. The previously mentioned college professor exposed to aniline dye chemicals
g. The previously mentioned ambassador and firemen exposed to chemical fires.

It was only when asked to speak at this Workshop I was first made aware of the toxicity of TCP and its breakdown products, which may explain the illnesses of my prior patients who were pilots and flight attendants.

Obviously in pilots and aircrew this is a cumulative exposure injury; hence, if proven, it would be a likely cause of injury in very frequent and immune-suppressed flyers. The term used by the commercial pilots is *aerotoxic syndrome*. It is inadvisable to label injured flight crew as having secondary myalgic encephalomyelitis due to the extremely bad press attached to ME, in large part originating from individuals I believe might be employed by the insurance industry.

What is needed is to undertake a serious and unbiased investigation of a good number of pilots and aircrew to, first, find out the cause of their chronic illness. Up until now their illness, although highly likely to be due to TCP and its breakdown products, is cloaked in speculation. It is quite possible some of these patients are experiencing: (a) TCP injuries; (b) missed pathologies due to incomplete or poor investigation on the part of their physicians; or (c) a combination of (a) and (b). It is essential to systematically investigate these pilots and aircrew.

3. UNDERSTANDING MYALGIC ENCEPHALOMYELITIS (ME)

Since 1984 I have worked exclusively with patients diagnosed with ME and others referred to me with a diagnosis of chronic fatigue syndrome.[1] ME is an important and poorly understood condition, even to physicians who work in this area. To my belief, CFS is simply a definition without a specific illness and refers to a large number of diseases and pathologies capable of causing chronic exhaustion and other dysfunctions, conditions invariably missed by their physicians. Let us first look at ME.

3.1 Myalgic encephalomyelitis (ME)

There is debate in the medical community whether:

a. ME is an organic postviral infectious disease, initially affecting the respiratory and gastrointestinal systems, followed a few days later by a permanent diffuse encephalopathy, which effects both the intellectual and physical welfare and abilities of the injured patient; *or*
b. ME is a minor psychiatric disease, a sociological phenomenon of no medical significance, not necessarily eligible for compensation from the insurance industry. This is not a valid proposition but it is important because so many physicians have accepted it. There are reasons for this manufactured misconception.

The evidence, historically, is that ME is a chronic illness that has occurred following over 60 recognized epidemics since the first one struck the Los Angeles County General Hospital in 1934. In this first epidemic, the significantly disabled medical staff never recovered. This epidemic was so severe it threatened to close the hospital. There was a major court case and, five years later, in 1938–9, the insurance industry was obliged to pay out many millions of dollars of compensation to each of the physicians, nurses and hospital staff who had fallen chronically ill as a result of this epidemic infection. Fifty years later, in 1988, I was fortunate to be able to examine two of the original 1934 patients who were still alive. Neither had recovered. According to my host, Dr Alberto Marinacci, who had followed many of these patients, none had ever recovered. In today's terms, the insurance company responsible paid out the equivalent of 2 million dollars to each hospital worker injured; this insurance loss was equivalent to half a billion dollars in today's funds.

ME tends to occur most frequently among health care workers and teachers most exposed to infectious disease in hospitals, schools and their associated residences; they have in common the fact that they are

[1] See [1] and [2]—two books that emerged from this work.

typically heavily insured. ME thus represents a considerable potential insurance loss. In consequence it is in the interest of insurance companies to dispute, with all their means, the existence of such an illness due to the potential enormous financial loss if a large number of individuals in an institution fall ill with it. From the time I first took up the study of ME patients in 1984, the insurance industry has fought against payment of insurance indemnity claims in all cases with only two exceptions.

The two exceptions are of interest. They were a Member of the Canadian Parliament and a young woman working in a factory that manufactured highly sensitive materials for the war industry. The insurance company never once suggested they would not pay for her disability; nor in the 20 plus years during which I have followed her have they ever requested an annual insurance report. In over 26 years of investigating ME patients, these were the only two patients who were not challenged by the insurance industry. This is a very important point in suggesting that pilots and aircrew have a work-associated injury or illness insured by any private insurance company.

Among these over 60 ME epidemics is an interesting subgroup whose investigation was and remains today, classified, since it supposedly involved national security and, hence, was never published. Curiously, in the early days of jet fighter planes (and the Cold War), similar ME-like epidemics involving US Air Force pilots occurred, effectively shutting down the fighter command until the pilots could be replaced. This occurred in US Air Force bases in Augsburg, Reykjavik, Morocco and Texas. It is unlikely these pilots were exposed to an infectious illness epidemic.

3.2 What is myalgic encephalomyelitis (ME)?

After more than 80 years of study we know a lot about ME. The evidence suggests that it is due to a viral infection and the measurable physical and physiological changes in the human brain and body that occur following these infections. We know in its epidemic form the following:

1. Incubation period: ME is an acute onset illness, with an incubation period of approximately 4 days, thus allowing for rapid spread from ill patients and carriers to the healthy population.

2. Enteroviral seasonal peak: ME epidemics tend to peak in late summer and early autumn, typical of enteroviral infections (polio, Coxsackie, ECHO viruses), which also have an incubation period of 4 days. We also know that the enterovirus family is almost impossible to recover in the live patient unless tested at the time of initial infection. Many ME epidemics occurred before the existence of the enterovirus family was known. Subsequently, in only four of the epidemics has the same virus family been recovered. The fact that no virus was recovered in others is not difficult to understand; until very recently it was almost impossible to recover evidence of any enterovirus except from cadavers.

3. Infectious and crowding association: ME is observed most frequently in medical and educational institutions where the patients have most exposure to infectious disease and crowding conditions. It is especially common in those workers with short-term *reduced immunity*, such as health care workers and students who have become significantly exhausted due to their work schedule.

4. A relatively invisible, pathophysiological injury: we know ME can permanently affect the cognitive and physiological abilities of the brain but significant physiological brain changes are *not seen* in X-ray computer tomography (CT) and magnetic resonance imaging (MRI) brain scans, (technologies which measure *anatomical changes*). We know these changes can be seen and measured by brain single-photon emission computed tomography (SPECT), brain positron emission tomography (PET), quantitative (computer-driven) electro-encephalography (QEEG)—also called brain electrical activity mapping (BEAM in the USA) scans (technologies that measure *physiological changes* in the vascular and cellular elements of the brain). Thus ME can be thought of, in computer virus terms, as a permanent serious software injury rather than a hardware injury. It is a good analogy; if you blast a computer with a shotgun, the computer is unlikely to work but the damage is evident to the naked eye. If you seriously injure the software of a computer, the computer looks fine, but it simply does not work or it works in a defective manner. Similarly, ME patients may look normal on the outside, but they are unable to function normally as they did prior to the injury.

5. Chronicity: we know that over time some of these measurable changes may improve to some degree. We also know the disability persists and that few patients over the age of 20 fully recover from this type of encephalitic injury.

6. Access to alternative work: once injured, due to the patient's easy and rapid onset of persistent and uncontrollable periods of significant exhaustion of intellectual or physical ability after normal activity, few ME patients with moderate or major injury can perform any other type of work; hence, they are rarely viable in the economic work force. Perhaps, more than the physical and intellectual dysfunction, ME patients tend to lose something else, and that is their courage.

7. Effect of normal stressors: we also know that the ME-injured patient's ability, whether infectious or

chemically induced, can be further decreased by the following stressors: (I) Physical (normal or modest exercise programmes); (II) Sleep and other deprivations; (III) Intellectual (learning, memory stresses); (IV) Sensory (temperature changes, sound); and (V) Emotional.

Drs Ismael Mena and Jay Goldstein demonstrated a decrease in brain perfusion (circulation), as far back as 1988. It not only worsened following any of the above activities (stressors) but the decreased perfusion continued to worsen for the first three days after they were removed. This laboratory finding is consistent with the typical ME patient's complaint that normal and even minor stressors significantly decrease their abilities, in both duration and degree, far beyond what a normal person would experience.

8. An autoimmune disease: ME is associated with significant autoimmune dysfunction and, as in other autoimmune illnesses such as thyroid disease, multiple sclerosis (MS), lupus and rheumatoid arthritis, approximately 70% of the patients are female. Possibly the most severe of the invisible dysfunctions is dysautonomia, a condition in which the patient looks normal but cannot maintain a normal blood pressure or heart rate. One only has to remember that not long ago, prior to MRI, many female patients were initially diagnosed as suffering from psychotic paralysis when they were actually suffering from MS.

9. Neuropsychological testing: Dr Sheila Bastien has demonstrated that ME patients have typical measurable neuropsychological patterns, which include at least ten testable anomalies affecting energy, intellectual and cognitive abilities.

10. A vascular-mediated disease. Thus, post-infectious ME can be described as an acute onset, biphasic viral illness that provokes a chronic measurable diffuse vascular metabolic encephalopathy. These physiological brain changes are made worse by any stressor, giving rise to unpredictable defects of intellectual, motor, endocrine and autonomic function. As in computer software injuries, the damage is not visible to the naked eye but can be demonstrated by a skilled investigator. You can appreciate the effect of any such brain perfusion injury if it occurs in an airline pilot (Fig. 1). A normal brain would be uniform in colour on SPECT examination.

4. UNDERSTANDING THE TECHNOLOGY OF BRAIN ANALYSIS

Normally, when I am invited to lecture to physicians or patients, these groups are well versed in medical terms and investigational techniques. However, your strengths tend to lie outside of this medical area so let me start with a few basic concepts and analytical techniques.

You have demonstrated today the considerable evidence that, from time to time, tricresyl phosphate (TCP) and its breakdown products enter the fresh air supply of commercial jet aircraft. TCP is a known neurotoxin, meaning it damages the brain and nerve tissue. Since the turbines run at 400 °C, some TCP breaks down to even more toxic components.

The following discussion concerns the problems of brain injury analysis. The brain should not be considered by the audience to be the only site of damage due to chemical injury. The endocrine glands are particularly sensitive, including the thyroid, the pituitary, adrenal and reproductive glands. I will discuss only a small aspect of brain analysis, simply to illustrate the problems in obtaining adequate understanding of a single organ. This will also explain why most physicians do not have access or even understand the power of the available technology. Earlier (§2) I pointed out the four phases of toxic chemical damage to the CNS and explained why it was easier for a physician to dismiss the illness as psychological.

One should not suppose that only pilots and flight crew are affected by these changes. The danger of a toxin like TCP is cumulative. This is why seriously frequent fliers are also at high risk of significant injury and chronic illness to any part of the body. Let us look at why diagnosis of these patients represents a major difficulty.

The classical neurologist: Patients, unless they arrive at a hospital emergency unit with a significant and obvious head injury or stroke, tend to be seen by a neurologist on referral from a primary care physician. Either by test, examination but more frequently by patient complaint, the patient is referred to a neurologist. I must also note that the classical neurologist, like the patient, also has an invisible problem; namely, no matter how intensely he might wish to examine the patient, whether he spends 30 minutes or several hours, his efforts are limited by the fact that the insurer will only pay the same amount. In terms of financial survival, this imposes a limit to the time spent on investigating the toxic chemical- or virus-injured patient. Most neurologists proceed by:

a. Noting a short personal and family history, reading the even shorter referral note;
b. Doing a routine physical and neurological examination with needle and hammer;
c. Possibly, ordering a CT or MRI scan;
d. If nothing is found, the patient and referring physician are advised accordingly. Often a diagnosis of stress or anxiety is given to these patients.

This classical neurological approach is simply insufficient to understand viral and chemical brain injury. Let me explain the strengths and weaknesses of CT and MRI, both great tools in their own right, and how the uses of

tools can change a physician's diagnosis. Let me remind you once again that prior to the invention of MRI, many women with early multiple sclerosis (MS) were diagnosed as being ill with hysteria rather than MS. When I became a physician in 1969, this was the case. *In early MS, as in brain malignancy, or toxic chemical injury, there are often no findings on physical examination.*

CT brain scan: computer tomography X-ray; often referred to as a computer-aided tomography (CAT) scan, the use of X-rays being implicit. Cross-sectional X-ray images are produced at different levels of the brain. This is a useful tool for measuring radiologically opaque changes in brain structure, such as a solid malignancy or a bullet. It does not demonstrate changes in brain function. Like many of those present here, the inventor of CT started his career in the air and space industry. CT technology was invented by the English genius and Nobel Prize laureate Sir Godfrey Hounsfield while working at EMI after World War II, then makers of electronic musical instruments. In the late 1940s Hounsfield had become interested in mathematical formulae; using the formula the Germans had invented during WWII to plan carpet bombing, he devised the first primitive CT scan using a gramophone turntable geared to revolve significantly faster and a sheep heart he obtained from the next-door butcher.[2]

MRI brain scan: magnetic resonance imaging. In contrast to a CAT scanner, MRI uses powerful magnetic fields to flip the direction of magnetization of atoms, most usually hydrogen (H). Hence, essentially it is the local concentration of water, the most abundant molecule in any living tissue, that is measured.[3] MRI can reveal soft tissue lesions or injuries missed by X-ray-based CT scans. It also avoids exposure of the patient to the radiation implicit in CT. Both MRI and CAT use the tomographic techniques invented by Hounsfield in order to generate a three-dimensional image. MRI was a by-product of US space agency needs to miniaturize working components. Generally, neither CAT nor MRI are useful in measuring most pathophysiological brain injuries—of process rather than structure—as in chemical or viral injury.

SPECT brain scan: single-photon emission computed tomography. This instrument employs the same image construction techniques as X-ray or MRI computerized tomography, however it employs gamma rays produced by various short-lived radioactive nucleotides to generate the primary data. While CAT and (H-) MRI are structural techniques, SPECT images denote changes in function. Using the metaphor of the computer, CT and MRI demonstrate hardware defects and SPECT and PET demonstrate software malfunctions.

To obtain an adequate understanding of changes in brain physiology, three things are required:

a. A qualified nuclear medicine physician experienced in brain physiology. This is not as self-evident as it would seem. Most nuclear medicine physicians have skills in total body imaging for malignancy. In Canada, cutbacks in health funding have been partly responsible for the loss of many brain physiology nuclear medicine physicians.

b. A brain SPECT scanner: there are essentially two types of SPECT scanners:

(i) Total body SPECT scanner. If a hospital has a scanner, they usually purchase this type since it can image the entire body including the head. The problem of the "one size fits all" is that such a scanner tends not to give a clear view of smaller brain defects, which can be all-important in understanding physiological brain injury.

(ii) Head-dedicated SPECT scanner: these include the triple-headed scanners that can approach the head closer than the total body SPECT scanner. Hospitals in Canada have increasingly sold off these scanners since they cannot scan the whole body for malignancy. Also, on the fee-for-service basis, double scanning the brain takes longer and is more expensive than looking for body malignancies; consequently, the hospital is paid much less money by the government for doing brain scans than looking for malignancies. This has had an injurious effect on understanding brain physiology. Fortunately, some hospitals still have this technology in place.

c. Nucleotides used: hexamethylpropyleneamine oxime (HMPAO; trade name: Ceretec). There are many radiopharmaceuticals used in SPECT but to my knowledge HMPAO is the only one for which there is software and normal age-matched databases to adequately evaluate changes visible on the screen or

[2] Reputedly, Sir Godfrey was an autodidact. He had never completed his primary education and was hired by scientists working on a secret radar facility in the UK in the late 1930s as a floor sweeper. He was hired along with others having limited intellectual abilities for menial tasks since it was believed they were too ignorant to be spies or to inform the Germans. He came to prominence by pointing out to the scientists that the reason their radar did not work was that there were errors in their conceptual designs; he suggested changes, which initially they ignored. The scientists continued to fail to make their radar functional and out of sheer frustration finally turned to the changes Hounsfield suggested. He was correct; the radar worked and Hounsfield was immediately hired to work on its further development. In effect, he can also be credited with the partial invention of radar.

[3] Another popular choice of atom is phosphorus, in which case the concentration of ATP, indicative of local energy consumption, is measured.

printout of the brain. HMPAO may cost more than radiopharmaceuticals for which there is no such database, so for a while HMPAO was replaced in Canada with less expensive radiopharmaceuticals.

The advantage of brain SPECT imaging over MRI and CT scans: infectious, autoimmune and chemical (toxic) insults to the CNS all act in a similar fashion. Some viruses and toxic chemicals injure areas of brain vasculature or brain cells, either slowing them down or destroying them. Unlike CT and MRI, SPECT can demonstrate both activity of the brain microvascularization and metabolic product removal ability**.** If the microvascularization or regional clumps of neurons are injured or destroyed in sufficient quantity this can be imaged with SPECT technology. Brain cells react as all active body cells do; they do their job and produce metabolic breakdown products. The microcirculation in a healthy brain clears away these metabolic breakdown products rapidly, usually while sleeping. If their removal is delayed due to injury, the cognitive and restorative ability of the brain is injured. Since the laying down of new memories occurs largely during sleep, if the metabolic products are not removed satisfactorily, short-term memory may be injured. If removal of metabolic products cannot occur at all, the injured area of brain cells may be destroyed. This gives rise to many dysfunctions as was first illustrated by neuropsychologist Dr Sheila Bastien, nuclear medicine expert Dr Ismael Mena and investigator Dr Jay Goldstein in the late 1980s. The neuropsychological changes may include numerous dysfunctions or deficits including:

a. Short term memory deficits, (quick learning and remembering information once known)
b. Spacial deficits, (difficulty in adequately and quickly determining distances)
c. Manual dexterity
d. Night and colour vision deficits
e. Quick and rational decision making
f. Exhaustion due to failure to recover in a reasonable time period from physical, intellectual and other stressors causing normal fatigue
g. Perception dysfunctions.

It is obvious that such injuries, which would be cumulative, would be of major concern to those here today and to pilots, flight crew and frequent passengers.

There are several other techniques useful in understanding brain physiology and these include, but are not limited to, QEEG (BEAM) and PET brain scanners. Even simple technology such as transcranial Doppler is useful in examining major brain blood supply inexpensively.

Unfortunately, as I have explained, it is rare for most neurologists to access or even understand these technologies and so major physiological brain injury is frequently not diagnosed until it is too late. Failure to diagnose adequately a teacher or hospital care worker, though extremely serious to the patient and his or her family, does not have the implications of a similar injury in someone in charge of flying and navigating a jet airliner. This failure to diagnose is not so much the fault of neurologists; there are already too few neurologists. Also, neurologists are not neurophysiologists, a very rare breed who tend to work in the nonhuman domain. In Canada, for all practical purposes, this profession does not exist in the field of human medicine outside of research. In Canada, I am not aware of a single accessible QEEG instrument outside of Alberta or of a single PET scanner with adequate brain software accessible to the general medical profession.

In both Canada and the United Kingdom, we are in desperate need of funding for neurophysiological physicians and major neurophysiological centres. The technology is available and there are some physicians who understand these technologies. Difficult as it may seem, it is still possible to access them if the investigator understands their sources and how to employ them.

This is only one aspect of the difficulties and technologies of examining the pilot and flight crew of commercial airliners.

5. WHERE DO WE GO FROM HERE?

Phase 1A: a central planning committee of pilots and experts should be organized to investigate these pilots and adequate funding be found to carry out the following steps.

Phase 2A: a significant number of pilots and aircrew should be subjected to in-depth total body examination, to be carried out by individuals experienced in this area of medicine. In my experience, major clinics such as Mayo have failed to explore the group of brain dysfunctions outlined in this discussion and brain dysfunction is only one of the problems that might be found on adequate investigation of potentially TCP-injured flight crew. It would be useful if this were done simultaneously in more than one country, employing similar guidelines for investigation.

Phase 2B: a university or private toxicology team should be engaged by the planning committee from the onset.

Phase 3A: once examined, the information should be assessed by experts in the specialty fields of the pathologies found as well as by medical statisticians to explore the frequency of pathologies found compared to non-flight crew populations.

Phase 3B: university-based toxic chemical experts should be then employed to evaluate how to best examine the degree of chemical exposure in this group of flight crew.

Phase 4: based upon the information, obtained a symposium should be held to discuss what was found and

what further specialists should be introduced to the study. Publication in major medical and trade journals should occur at this time.

Caution: for years elements sponsored by the tobacco industry have successfully produced documentation published in major medical journals demonstrating that tobacco products were not injurious to health; for years pharmaceutical companies have successfully paid researchers, hospital and universities to publish positive results in major medical journals showing no patient danger from their own medications; for years the insurance industry has supported physicians, apparently written some of their research papers and fought both against the existence of ME and against any proofs that these patients incurred significant physical injury. Any investigational research into the health and well being of pilots and aircrew should be totally independent of the airline and insurance industry, which would appear to have a vested interest in making sure that there is no TCP-related toxic chemical injury association in these pilots and aircrew.

Investigation: it is obvious there is a great need to seriously investigate pilots and aircrew for chronic injury and illness that could be related to TCP toxicity. The basic work can easily be done in Canada due to our interprovincial universal health system that is available to all Canadian physicians and patients. Such is not the case in the UK, where patients have difficulty in being referred across the district health territories or where primary care physicians do not have access to basic testing procedures. In the USA private insurance companies may pose their own restrictions. I have no significant knowledge of Germany, the Netherlands and other countries' testing procedures. It might be well to institute the investigation of Canadian pilots and flight crew while funding is being found in the other countries represented here today. In Canada we could readily set up the investigational system and learn the pitfalls, which would assist work in other countries. In terms of flight crews, passengers and aircraft safety this needs to be done.

Caution: it should not be a foregone conclusion that TCP is a cause or the sole cause of pilot and aircrew injury, or that the only injury is in the CNS. I have focused on the CNS simply because it is one of the easiest areas to access and investigate when proper technology and experts are involved.

Caution: it might appear self-evident that one can test the human body for the quantitative presence of TCP sufficient to cause any or major injury. Such is not, however, the case. In Canada, although dozens of toxins can be observed under test conditions, they are unable to be quantified as far as I am aware. I have even spoken to members of the Royal Canadian Mounted Police as to whether they can quantify toxins in cases of suspected murder and their laboratory replied they can not. In the United States of America, several private laboratories advertise they can both detect and quantify the existence of toxins but their reliability is open to serious doubt. A few years ago in Glasgow, Professor Peter Behan tested two Scottish farmers who were very ill following a fire in agricultural organophosphate storage areas. He was unable to prove they had been killed by the organophosphates until he had their brains on autopsy. Only then was he able to demonstrate the problem. This is an area that requires more knowledge than I can bring to the discussion.

If the problem of TCP can be proven as a cause of injury to the pilots and aircrew, the airline industry will be obliged to consider one or more measures such as the retrofitting of all commercial and private jetliners with technology as in the new Boeing 787 aircraft. It is unlikely that either the flight or aerospace manufacturing industry will be happy with such a finding and might well raise serious objections to the science as the tobacco industry has done regarding tobacco products. In the B-787, toxic chemicals cannot bleed into the aircraft, thus not exposing flight crew and passengers to potential TCP injury.

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