Chronic Lead Exposure in Nuclear Medicine.

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Abstract

INTRODUCTION

Lead has been used as a means of radiation shielding in the Nuclear Medicine since the profession emerged (Christian et al, 2007; Thrall, O'Malley, & Ziessman, 2006). Today, lead is used in products ranging from collimators and structural walls to that of simple lead syringe shields and carry pots (Christian et al, 2007; Holden, 2008). While the less malleable properties of tungsten has seen it replace the use of lead in many products, the lower cost of lead has ensured widespread use remains. Despite a long history of widespread use of lead, there is a paucity of information relating to health implications of such generalised exposure in Nuclear Medicine.

The detrimental health effects of lead have been well documented (Herman & Geraldine, 2007; Khan, 2009; Landrigan et al, 1994). Both chronic and acute forms of lead exposure affect numerous organ systems, producing long term irreversible conditions such as cognitive deterioration, renal failure and sterility (Herman & Geraldine, 2007; Khan, 2009; Marcus, 2007). Although workplace exposure within areas of lead production such as smelting and battery production are well documented, knowledge of the degree of exposure to allied health workers is poor (Cunningham, 2007; Roscoe et al, Dec 2002; Saito et al, 2006). The chronic exposure rate to lead of Nuclear Medicine workers is unknown (Bellinger, 2004; Khan, 2009; Parsons & Chisolm, 1999).

LEAD

It is generally reported that lead has been utilised by humans for over 3 millennia, however, only in relatively recent years has greater understanding of the detrimental health hazards been reached and preventative methods taken to reduce the incidence of occupational lead exposure (Cunningham, 2007; Marcus, 2007). The first lead mine, however, dates back to 6500BC and the detrimental health effects of lead

were reported as early as 200BC (www.lead.org.au). Indeed, lead poisoning was first described in 100BC.

Several studies performed have made reference to a decline in the incidence of lead exposure in recent decades (Cunningham, 2007; Khan, 2009; Staudinger & Roth, 1998). This is predominantly thought to be due to the introduction of national codes of practice for the control and safe use of inorganic lead (Saito et al, 2006). Despite the significant reduction in cases of notifiable lead exposure, inorganic lead toxicity remains one of the leading clinical environmental health issues throughout the world (Cunningham, 2007; Herman & Geraldine, 2007; Marcus, 2007; Staudinger & Roth, 1998). No substantial pathological link has been made between incidence and that of age, ethnicity or gender (Khan, 2009; Marcus, 2007).

LEAD EXPOSURE

The ideal properties of high malleability, resistance to erosion, ductility and a low melting point (328 degrees Celsius) has promoted the use of lead in the manufacturing of numerous industrial products (Khan, 2009; Marcus, 2007; Papanikolaou et al, 2005). The added advantage of lead's ability to absorb radiation has also sealed its' role in the production of Nuclear Medicine and radiographic products (Christian et al, 2007; Khan, 2009). Consequently, the widespread utilisation creates numerous sources of lead exposure (Cunningham, 2007; Khan, 2009; Landrigan et al, 1994).

ROUTES OF EXPOSURE

Lead contaminates the atmosphere through particle emissions that subsequently settle on soil, water supplies and vegetation to later be consumed by both humans and animals (Herman & Geraldine, 2007; Papanikolaou et al, 2005). Lead is neither biodegradable nor quickly excreted from the body, making it's affects long term and cumulative

(Papanikolaou et al, 2005). The two most widely documented and predominantly accepted routes of lead entering the body are those of inhalation and ingestion (Landrigan et al, 1994; Papanikolaou et al, 2005; Roscoe et al, 2002). Some studies suggest that dermal exposure is a mode of access for lead absorption but this may indeed reflect dermal contact leading to ingestion. Another means of uptake not generally considered is that of in-utero transmission across the placenta to the brain of the foetus in women exposed to lead during pregnancy (Khan, 2009; Papanikolaou et al, 2005).

The absorption of lead from the gastrointestinal tract due to ingestion and the degree of lead retention vary widely depending on age and iron stores (Bellinger, 2004; Cunningham, 2007). Up to 20% for adults and 70% for children of an ingested dose of lead can be absorbed, with the primary site of lead absorption being the duodenum (Khan, 2009). Inhalation requires lead particle size to be no larger then one micron with up to forty percent of these particles absorbed in the blood (Cunningham, 2007; Khan, 2009). Lead that is not absorbed is slowly excreted through the kidneys and liver (Khan, 2009; Sedman, 1989).

TOXICOLOGY

After absorption into the blood stream, lead binds to erythrocytes and distributes over a period of weeks to soft tissue and bone (Cunningham, 2007; Herman & Geraldine, 2007; Khan, 2009). Lead's analogous behaviour to calcium results in a high affinity for bone with 94% of the absorbed dose accumulating within the skeletal system (Khan, 2009; Landrigan et al, 1994; Marcus, 2007). Areas of increased growth and calcification also receive larger percentages of the absorbed dose (Herman & Geraldine, 2007; Khan, 2009). Soft tissue organs receiving the majority of the residual concentration of lead are those of the liver, spleen, kidneys and brain (Cunningham, 2007; Herman & Geraldine, 2007; Khan, 2009).

The half life of lead within the body is extremely lengthy allowing fast accumulation of high doses (Herman & Geraldine, 2007; Staudinger & Roth, 1998). Lead absorbed will remain in the body for many years regardless of whether the subject is removed from the initial source of exposure (Herman & Geraldine, 2007; Khan, 2009; Staudinger & Roth, 1998). This is the predominant reason for lead being considered one of the most hazardous environmental toxins (Herman & Geraldine, 2007; Khan, 2009; Staudinger & Roth, 1998).

Lead toxicity can affect all organ systems with a wide, non-pathognomic range of symptoms (Cunningham, 2007; Herman & Geraldine, 2007; Khan, 2009; Landrigan et al, 1994). As can be expected, the mechanism of toxicity for each of these systems varies significantly (Cunningham, 2007; Herman & Geraldine, 2007; Khan, 2009; Landrigan et al, 1994). For simplicity, the most affected systems are summarised below including; the nervous, reproductive, muscular, circulatory, gastrointestinal and urinary systems (Herman & Geraldine, 2007; Khan, 2009; Staudinger & Roth, 1998). A threshold blood concentration of lead at which these symptoms present or do not present does not exist, although generalised exposure level can be utilised to predict when these symptoms will occur (Cunningham, 2007; Stromberg & al, 2003). Low blood concentrations (<10 ug/dL) impair hearing, intelligence and growth while escalating hypertension. Approaching 20 ug/dL sees decreases in nerve conduction velocity and changes in erythrocytes. Impairment of vitamin D metabolism and increased systolic blood pressure is notable at 30 ug/dL. More severe impairment is associated with 40 ug/dL including decreased haemoglobin synthesis, development of peripheral neuropathies, nephropathy and infertility. Above 50 ug/dL sees the evolution of frank anaemia, encephalopathy and decreased life expectancy with death likely when concentrations approach 150 ug/dL.

A more complete list of lead poisoning symptoms includes (www.lead.org.au):

- Altered testicular and ovarian function
- Sterility
- Erectile dysfunction
- Decreased libido
- Nephropathy
- Nephritis
- Renovascular hypertension
- Gout
- Encephalopathy
- Cerbebrovascular disease
- Psychomotor impairment
- Peripheral neural and vascular disease

- Slower reaction time
- Paralysis
- Tremor
- Cardiotoxicity
- Coronary artery disease
- Anaemia
- Clotting disorders
- Red blood cell proliferation
- Depression (including suicide and violence)
- Anxiety
- Memory deficits
- Fatigue
- Insomnia
- Impairment of fine motor skills
- Visual and hearing disturbances
- Nausea
- Bowel irregularity
- Abdominal pain and cramping
- Muscle pain and weakness
- Joint pain
- Headaches

Due to similarities between lead and calcium, lead disrupts nerve impulses through the inappropriate release of neurotransmitters that ultimately interfere with the synaptic transmission of information from the brain to the body (Khan, 2009; Landrigan et al, 1994; Papanikolaou et al, 2005). One hypothesis is that axonal degeneration of the neurons found in the anterior horns of the spinal cord is the cause of lead neuropathy (Khan, 2009). It is thought that lead affects the renin-angiotensin system reflecting hypocalcaemia as lead once again competes with calcium (Cunningham, 2007). This may cause renal disease resulting in hypertension (Cunningham, 2007). Depending on the severity of exposure, pathological changes may be reversible (Cunningham, 2007). Higher renal concentrations of lead

produce interstitial fibrosis and progressive nephropathy (Cunningham, 2007). In the circulatory system, lead inhibits iron uptake ultimately resulting in anaemia as haemoglobin is no longer able to transport adequate levels of oxygen (Damjanov, 2006; Khan, 2009). Electrical disruptions due to ion imbalances also cause cardiomyopathy (Khan, 2009).

Positive results for neoplasia through toxic lead exposure have been confirmed in animal studies (Khan, 2009; United States Department of Labour, 1991). Ethical and moral considerations prevent controlled observations of the carcinogenic affect of lead on humans, inhibiting the elucidation as to whether lead is a human carcinogenic (Khan, 2009; United States Department of Labour, 1991). Nonetheless the International Agency for Research on Cancer considers the animal studies sufficient to assume carcinogenesis in humans (Khan, 2009).

DIAGNOSIS

Diagnosing lead poisoning is extremely difficult due to the non-pathognomic and irregular nature of symptoms (Herman & Geraldine, 2007; Khan, 2009; Marcus, 2007). Diagnosis is determined through careful analysis of patient history, physical examination, laboratory testing and diagnostic imaging (Herman & Geraldine, 2007; Staudinger & Roth, 1998).

Blood lead concentration levels (BLCL) are currently considered the most reliable form of measurement in the assessment of lead exposure with 95% of the body's initial absorbed dose residing in erythrocytes (Herman & Geraldine, 2007; Khan, 2009; Marcus, 2007; Papanikolaou et al, 2005; Tadashi, 2000). Graphite Furnace Atomic Absorption Spectrometry (GFAAS) is used to determine the concentration of lead in erythrocytes, plasma or urine (Parsons & Chisolm, 1999; Tadashi, 2000). Plasma lead concentrations are generally not performed due to such low concentrations resulting in a complex and time consuming procedure (Tadashi, 2000). The level of lead in urine depends not only on exposure but also on kidney function and is further limited by an inability to differentiate chronic from acute exposure (Tadashi, 2000). Other biological markers such as elevated zinc protoporphyrin (ZPP) enzymes may also be used in the assessment of lead poisoning (Cunningham, 2007; Parsons & Chisolm, 1999; Tadashi, 2000). When used in conjunction with BLCL, differentiation between chronic and acute lead exposure can be made as ZPP elevation occurs only within 2-6 weeks of exposure (Cunningham, 2007; Tadashi, 2000).

Diagnostic imaging is generally reserved for paediatric patients where pathological changes due to normal growth can be visualised (Herman & Geraldine, 2007; Khan, 2009). Visualisation of increased radio-density in the metaphyseal plates of long bones is indicative, but not pathognomic of lead poisoning (Herman & Geraldine, 2007; Khan, 2009). Lead particles may also be seen through ingestion on abdominal images (Herman & Geraldine, 2007; Khan, 2009). Some studies have shown utilisation of both Computer Tomography and Magnetic Resonance Imaging in the diagnosis of lead poisoning through brain imaging, however, findings are once again not specific (Khan, Feb 2009).

TREATMENT

Concentrations obtained determine as to whether chelation therapy is an option (Staudinger & Roth, 1998). Although chelation therapy may be utilised to reduce lead concentrations, it has been used unethically to ensure employee lead levels remain sufficiently low that they can continue working (Papanikolaou et al, 2005; Staudinger & Roth, 1998). Chelation agents have side effects and care should be employed, particularly in acute cases (Papanikolaou & al, 2005; Staudinger & Roth, 1998).

PREVENTION

The primary mode of prevention within the workplace is the education of all workers in lead safety measures (Herman & Geraldine, 2007; Khan, 2009; Saito et al, 2006). These include issues such as prohibition of eating, drinking, smoking and nail biting within the vicinities of the workplace (Cunningham, 2007; Herman & Geraldine, 2007; Khan, 2009). Care should be taken with clothing and general hygiene to prevent the spread of lead dust particles from the workplace to the community (Cunningham, 2007; Khan, 2009). In Nuclear Medicine very little attention is given to lead safety, however, exposure is minimised because similar preventative principles apply to radiation safety. Thus, good radiation handling practices will also minimise lead contamination. Furthermore, many of the commonly used lead products in Nuclear Medicine are sealed within a coating of plastic or stainless steal. This minimises skin contamination from handling but also minimises damage to the malleable lead. Damaged lead may result in small fragments entering the environment in which we work. A number of lead products are not sealed within protective coatings (eg. lead bricks). Handling lead directly should be done so wearing gloves. Double gloving is recommended because of the risk of breaking the glove handling heavy

products. The Nuclear Medicine department should not undertake melting of lead to produce new products.

It is important to remember that although acceptable levels of exposure have been outlined, there is no safe level of exposure to lead (Cunningham, 2007; Khan, 2009; Papanikolaou et al, 2005). Toxic affects can present at levels well below 2.41 umol/L (Cunningham, 2007; Khan, 2009; Papanikolaou et al, 2005). Care must be taken to keep occupational exposure to a minimum (Cunningham, 2007; Khan, 2009; Papanikolaou et al, 2005), especially considering the cumulative effect that lead can have on health.

CONCLUSION

Chronic exposure, of which Nuclear Medicine workers are subjected to, presents potentially serious health concerns. Occupational exposure to lead of Nuclear Medicine workers remains unknown. While education generally provides the key to prevention, it is the education and implementation of radiation safety strategies that has perhaps provided the best safeguard against excessive occupational exposure to lead.

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