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TREATMENT OF CARBON MONOXIDE POISONING

Chris Lourey

Introduction.

The subject of carbon monoxide poisoning really has a rich history and its toxic affects were actually first noted by one of the founding fathers of modern medicine, Claude Bernard, in 1857.[1,2] Most of what I say this morning is really a compilation of evidence and recommendations that have been progressively made over the last sixty years which probably indicates that medicos are pretty slow learners.

My personal interest in carbon monoxide was enhanced when the Victorian section of the South Pacific Underwater Medicine Society gathered all the necessary data to make the ministerial submission to get the hyperbaric facilities for the State of Victoria established at the Alfred Hospital. This required an assessment of projected case load, clinical efficacy and cost effectiveness of hyperbaric oxygen (HBO) therapy pertinent to the State of Victoria. The clinical indications were category 1 indications as recognized by most authorities.[1]

The analysis of the data revealed a significant disparity in the incidence of carbon monoxide poisoning in Victoria when compared with other demographic centres, and unless Victoria is very different (which it is, if you listen to New South Welshmen) at best carbon monoxide poisoning in the State of Victoria was being inadequately treated. But what I think was that it was not even being recognized. A conservative estimate depending on the literature source and areas is a case load of somewhere between 20-50 cases per million people per year. In 1985 in Victoria there were 3 reported cases. In addition accruing clinical evidence challenges the clinical efficacy of treatment with normobaric oxygen as is recommended in standard texts. So in this context I will present a brief overview.

The disease

Carbon monoxide is a colourless, odourless, non irritating gas produced by the incomplete combustion of carbonaceous materials. The commonest sources are fire, automobile exhaust, petrol or propane engines, especially when operating in confined spaces, and generally, the colder the climate the greater the danger of carbon monoxide poisoning when operating engines in confined spaces, charcoal burners and faulty furnaces. Natural gas does not contain carbon monoxide, however if combustion is incomplete because of a bird's nest or a dead possum or accrued rubbish in the flue, carbon monoxide production will occur. Most of the commercial paint strippers contain methylene chloride which is readily absorbed through the skin and mucus membranes and metabolised into carbon monoxide.

The classical text book description of carbon monoxide poisoning, cherry red mucus membranes and skin, is not commonly seen and therefore is a most unreliable clinical aid. Because the initial symptoms of toxicity mimic other disorders such as influenza, acute confusional states and coma, a very high index of suspicion is necessary for diagnosis.

The strong possibility of dual pathology such as cardiac disease also must be considered. What is very interesting is that the highest percentage of deaths in fires (which the general population think is due to burns) is in fact due to carbon monoxide poisoning, and carbon monoxide poisoning in combination with coronary artery disease and burns. I ask the question rhetorically "In how many patients when admitted to a hospital for burns is a carboxyhaemoglobin level done ?"

Pathology

The primary toxic effects of carbon monoxide are those of tissue hypoxia. The biochemical lesion involves a preferential binding of carbon monoxide with haemoglobin, myoglobin and cytochrome oxidase A3, all are pyrole iron complexes.

Evidence also suggests that, in the brain, altered mitochondrial activity is not immediately reversible with re-perfusion and re-oxygenation.[3] This explains some of the symptoma-

tology one sees. In addition the oxygen dissociation curve is pushed to the left, further exacerbating the physiology of hypoxia.

The organ systems most affected are those with a high metabolic rate and oxygen utilisation, especially the myocardium and central nervous tissue. The affinity of carbon monoxide for haemoglobin is approximately 200 times that of oxygen. The severity of the symptoms will depend upon the concentration of the carbon monoxide, the duration of the exposure, the haemoglobin level and the level of metabolic and physical activity. For example, in a given time frame, one expects a greater concentration in the fire fighter exposed, or the worker exposed, than one would in the individual who has taken a combined overdose of barbiturates and then placed himself in the car. The metabolic rate of the latter is lower.

The previous health or accompanying disease of the affected individual also affects the outcome. Generally, and again I stress generally, such is the disease, no symptoms will develop if the concentration of carboxyhaemoglobin is 10% or less with acute exposure. I stress acute exposure as chronic exposures have been shown to impair mental function.

Exposure to 0.05% carbon monoxide for 1 hour with light physical activity will produce carboxyhaemoglobin levels of up to 20%. This will produce "flu like" symptoms, malaise, headache, loss of concentration, which are all very vague. Greater physical activity or longer exposures to that concentration will produce saturations of between 30-50% of carboxyhaemoglobin. Symptoms at these levels will vary between weakness and headache, to that of acute confusional states. Exposure to 0.1% for 1 hour will produce 50-80% carboxyhaemoglobin levels which left untreated will result in coma, respiratory failure and death.

The histological findings in cases where death was immediate shows the picture of hypoxia, with petechial hemorrhages in both brain and myocardium and areas of necrosis in the myocardium. In cases where death occurs 24 hours to some days later, one sees necrosis in the globus pallidus and the substantia nigra with generalised oedema. There is cellular disintegration in both nerve and glial cells. In deaths days to weeks post intoxication, one sees substantial brain softening with necrosis. Phagocytosis occurs in extensive areas, again particularly the globus pallidus and substantia nigra. There is accompanying demylination of white matter. All are evident with CT scanning.

The latent or lucid period of the inadequately treated victim is extremely variable, anywhere between 1 to 21 days. Symptoms vary from cloudy thinking, malaise to frank psychosis and a development of a Parkinson-like syndrome. In the absence of hyperbaric oxygen therapy the reported incidence of progressive neurological sequelae is up to 40%.

Treatment

Firstly the treatment is removal of the patient from the toxic environment, establishment of an adequate airway, correction of acidosis and treatment of associated pathology such as arrhythmias, control of fitting and burns etc. The specific therapy is oxygen. The generally held belief that one atmosphere oxygen is satisfactory is no longer tenable in the light of accrued evidence. It stands to reason that if an FIO_2 of 760 mm Hg is preferable to 160 mm Hg for the removal of carbon monoxide and increasing the available oxygen, then 1200 mm or 1800 mm would be better within the limits of oxygen toxicity.[2] This together with the high incidence of neurological sequelae should have laid to rest the normobaric regime, but sadly this is not the case. The latest edition of Harrison[4], the standard text for medical students, concentrates on normobaric therapy, supportive measures such as packed cells and the correction of acidosis. The role of hyperbaric oxygen therapy is only mentioned as being useful in seriously poisoned cases. How does one define useful or serious? As I said this is the standard text for medical students. Ignorance has become an art form!

Hyperbaric treatment

In 1985 Roy Myers[5] from Baltimore did a prospective study of carbon monoxide poisoning. This demonstrated both the subtle and the sinister nature of this disease and the high incidence of relapse in the normobarically treated group. In his group, 131 patients were treated with hyperbaric oxygen therapy. His criteria for HBO was a carboxyhaemoglobin level of 30% or greater and/or neurological signs or symptoms and/or abnormalities on psychometric testing. There were no relapses in this group. The criteria for treatment with normobaric oxygen was carboxyhaemoglobin of less than 30% and no neurological signs and no demonstrated psychometric abnormalities. There was a 12.1% relapse in this particular group. The relapses occurred in 1 to 21 days, the average was 5. They were then treated with hyperbaric oxygen therapy. There were no further sequelae subsequent to this.

Norkool and Kilpatrick[6] from the Virginia Mason Institute in Seattle reviewed their cases between 1978 and 1984. There was a mortality of 9.6% and a major morbidity of 1.9%. Of this 1.9% all were comatose on arrival. The major morbidity and mortality occurred in those who were found 48 hours after exposure or who had a delay of 48 hours before hyperbaric oxygen therapy was initiated. Full recovery occurred in 88.5% of cases.

Mathieu[7] and his colleagues in Lille, Northern France, reported 230 patients in 9 months with carbon monoxide poisoning. When one drives to the area where Mathieu works it is surprising the whole population is not suffering from carbon monoxide poisoning. The air is very polluted. 203 cases were treated with hyperbaric oxygen therapy and there were no chronic sequelae. The mortality was 1.9% and again

the mortality was in the group where there was a long delay before presentation to a hyperbaric unit.

Timchuk[8], from Moscow, reported 33 patients with carbon monoxide poisoning, all were treated with hyperbaric oxygen therapy. Recovery was 100% with no chronic sequelae.

Recommended treatment

Carboxyhaemoglobin levels of 15% and greater and/or neurological abnormalities and/or cardiac irregularities as demonstrated on the ECG and/or a general feeling of being unwell. all require HBO therapy. Wide indications but untreated it is a very nasty disease.

Australia is fortunate in that it possesses an emergency hyperbaric retrieval service nationwide and a level of cooperation and coordination between hyperbaric units not experienced in other parts of the world. The deleterious implication of impaired CNS mitochondrial function in carbon monoxide poisoning, I think offers sound reasons for providing clinically affected individuals with hyperbaric oxygen therapy regardless of their presenting carboxyhaemoglobin level.[3] In the absence of hyperbaric oxygen therapy there is a significant incidence of chronic progressive encephalopathy of up to 40%.

The cost to both the individual and to the community of a progressive encephalopathy is very expensive indeed. Legal settlements in excess of $2,000,000 have been awarded by the courts in the USA against hospitals and individual practitioners who have failed to consult and/or refer cases of carbon monoxide poisoning to a hyperbaric unit.[2] Will it take a similar impetus in Australia for this treatable disease to be recognize and adequately treated ?

It is interesting that the potential benefit of hyperbaric therapy in this disease was first noted by Haldane in 1895.[9] The first reported clinical applications were by Smith and Sharpe in Glasgow in 1960.[10] The number of studies increase and accrue each year, yet traditional thinking and practice still views hyperbaric oxygen therapy with a jaundiced eye. I think what is needed is an educational programme targeted particularly to the emergency services area, police, firemen, ambulance, rescue services, our colleagues in the emergency services area and importantly medical students. I think often the most difficult area is to educate and convince our medical colleagues. In this regard I am reminded of the tortoise, who only advances by sticking his neck out.

Resources are always a problem, but I think it can be demonstrated, certainly in the areas of decompression sickness, carbon monoxide poisoning and anaerobic infection, that HBO is a very cost effective means of treatment. It was really the cost effectiveness of the treatment that convinced the Minister for Health in Victoria. He also raised his eyebrows slightly when it was noted to him that there had been legal settlements of in excess of $2,000,000 awarded against hospitals in the USA. In our health system it would be public hospitals. When the NSCA unit closed down, and the unit has been offered to the State it was a very compelling argument.

Conclusions

The conclusion we can draw is that the outcome does not necessarily correlate with the carboxyhaemoglobin levels and the clinical state on admission. Patients must be observed closely, preferably in a hospital environment. I think that high index of suspicion is probably the most important thing and we will only achieve that when we educate people. But the area which surprised me was the information being given to medical students. That just continues a level of ignorance down the track and it is very difficult to change people's ideas when they have been given the wrong information in their training.

Upon discharge, the relatives must be given clear, firm instructions to report back to the hospital post haste if there is any change in a patient's behaviour or well-being.

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Comments on the two papers

Dr Mike Martyn

We put this subject on the programme was for exactly the reasons that have been explained by Dr Chris Lourey. In the six years that I have been in Hobart we have only treated two cases of carbon monoxide poisoning. At the Royal Hobart Hospital for the whole of 1983 there were only 3 cases admitted with the diagnosis of carbon monoxide poisoning. Firstly people just do not recognise the disease and secondly, they are not providing any active treatment. A lot of the survivors do have major problems afterwards and they are just being referred on to the psychiatrist to sort out the reason they took the carbon monoxide in the first place.

There are cases who have had carboxyhaemoglobin levels in the region of 1 and 2% who have profound neuropsychiatric sequelae. Dr Wood's case had a level of 2% and yet he clearly had carbon monoxide poisoning. The neurologist's comment was that this is the classic finding of carbon monoxide poisoning. The etiology of his disease can not be argued and yet he only had a level of 2%. So one has to be guided by the clinical condition of the patient, the higher quality functions particularly.

About 2 years ago in the Journal of Occupational Health that there was a report on people who had been exposed to chronic low levels of carbon monoxide in the workplace and certainly that there was evidence there that they had impaired cognitive function. Unfdrtunately I cannot remember the reference.

Dr. Chris Lourey

An interesting comment was made by one of the doyens of hyperbaric radiology in Britain when asked about carbon monoxide poisoning in the United Kingdom. He said "We do not see very much of it these days since we got North Sea gas". In fact carbon monoxide poisoning is still probably the commonest cause of poisoning.

Dr Ian Unsworth

The comment about the British scene, which used to have about 2,000 deaths a year from carbon monoxide poisoning, is accurate.

I think a lot of cases are occurring in Australia and they are not being referred for adequate management. I think the way we may have to go is the way of proposed or potential litigation. If we bring to the attention of our medical colleagues the case in the United States where a few million dollars were awarded because of the perhaps inappropriate management, I think our colleagues might sit up and take notice.

We do need to educate our colleagues very much and the areas Dr Lourey picked out were absolutely appropriate, accident and emergency, the police and the ambulance personnel, because the long term sequelae can be averted by appropriate use of hyperbaric oxygen.

Dr Lourey's net was wide but I think it was very very appropriate. At the moment the level of carboxyhaemoglobin that is usually quoted above which hyperbaric oxygen should be given in the perfectly normal patient is usually 25%. You brought it down to 15%. I certainly would not argue with that because of the difficulty of accepting any level of carboxyhaemoglobin is in any way always related to the CNS manifestations. I believe in the future we may in fact have to drop any investigation of carboxyhaemoglobin because it puts people off treating patients. When one can do cytochrome A3 measurements, which may involve taking a brain biopsy we may have better correlation with the clinical presentation. I heartily agree with everything that both speakers have said so eloquently.

Commenting on Dr Wood's case I think that he was probably too late in getting the initial hyperbaric oxygen therapy. After re-perfusion and re-oxygenation cellular activity in the brain does not return to normal straight away, which explains why individuals who are treated hyperbarically and improve significantly or return to normal after their first treatment, may relapse some days later. Often they may need 2, 3, 4 or 5 treatments before full recovery.

Dr Mike Martyn

I do not think one can specifically state that he would have made a 100% improvement and joined his brother in journalism, but what one can say is that there is a chance that he could have been in a better clinical state than he is now.