London Ambulance Service NHS
NHS Trust

A feasibility study into pre hospital carbon monoxide monitoring of patients

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Foreword

The threat of carbon monoxide exposure and the risks associated with that exposure are well documented. The Ambulance Services in United Kingdom along with colleagues from the Health and Safety Executive and the Health Protection Agency have dealt with carbon monoxide related incidents for years; however the major issue for all emergency responders remains the early identification of patients who have been exposed where the classic indicators are not present.
Whilst ambulance staff are trained to recognise patients with carbon monoxide exposure, without a high index of suspicion, carbon monoxide exposure is often missed in the pre hospital setting.

Carbon monoxide is the silent killer and all sections of the community, including emergency responders are at risk. The threat comes in many guises and is relevant to both the business and residential sections of the community.

The use of carbon monoxide alarms remains limited in both residential and business premises when compared to the use of smoke alarms. Therefore the early warning systems are not in place and exposures can be prolonged.

The publication of this report is the first step towards increasing awareness of carbon monoxide and the risks associated with that exposure. It will also go some way towards enabling emergency responders to deal safely and effectively with the threat, improving responder safety and ensuring those exposed receive the appropriate treatment.

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Summary
Carbon monoxide (CO) is a colorless and odorless, tasteless, yet highly toxic gas. Produced by the partial oxidation of carbon, sources include malfunctioning gas boilers and vehicle exhausts. CO causes fifty fatal and two hundred non-fatal incidents annually in the UK , and it is estimated that many others go unreported (Corgi 2006).

London Ambulance Service (LAS) crews, called to situations where CO might be implicated are not currently equipped to identify CO as a risk factor. Equipped with such equipment and appropriate protocols and care pathways, crews would be alerted to elevated CO levels and be able to assess patients, pre-hospital, for (CO) poisoning.

The aim of the study was to demonstrate the benefit of pre-hospital monitoring for CO in terms of accurate diagnosis, initiation of early appropriate treatment and facilitating the most suitable referral pathway for patients.

CO Case Review
A review of previous CO incidents attended by LAS was conducted to guide the development of;
· an appropriate service response; and
· diagnosis and patient treatment pathways.
Details of CO incident were obtained from the Health Protection Agency (HPA) and the Health and Safety Executive (HSE) as prior to December 2008 LAS did not specifically identify and record CO-related incidents.

Patient Assessment
Five patient CO monitors (Masimo RAD-57) were made available to selected ambulance crews (three were placed on First Response Units (FRU) and two on vehicles assigned to the Hazardous Area Response Team (HART)). They were used for assessments of patients in known and suspected CO poisoning cases.

Conclusions
Previous incidents demonstrate that on many occasions ambulance personnel had been exposed to un-identified situations of elevated CO concentration, in which crews performed clinical assessment and treatment of patient(s). In the cases reviewed the attending ambulance personnel had neither the equipment nor the protocols to diagnose CO poisoning as the presenting medical condition.

By using the CO monitor for routine patient assessment clinicians have been alerted to raised levels of exhaled CO, enabling appropriate early treatment and rapid extraction of patient and ambulance personnel from the a hazardous environment. Lack of knowledge of the signs indicating CO poisoning by the emergency services have placed blue light responders at risk of CO poisoning.

Following the review of previous incidents, it is clear that many CO poisoning cases had not been reported as such. Also that intelligence of CO risk was not routinely passed between the emergency services. Data on CO poisoning is not collated nationally form the emergency service and therefore prevalence of CO poisoning events remains unknown.

Recommendations
· CO monitors for crew staff safety
· CO monitors to aid patient diagnosis
· Improved training and awareness for all health care providers / professionals
· Direct referral pathway for CO intoxicated patients

· Updated software within Ambulance control call taking system to
· recognise the indicators of CO poisoning
· A greater sharing of information between interested agencies
· A national agency to collate all CO incidents
· Legal requirement for CO incidents to be reported
· Rigid Health surveillance for CO affected staff (all blue light responders)

Acknowledgements
The feasibility study recognises the commitment to the project by the staff of Deptford Ambulance Station and Hazardous Area Response Team (HART), the guidance of the London Ambulance Service Clinical Audit and Research Unit (CARU) and the support given by the HART management team.

Introduction
The London Ambulance Service (LAS) HART lead a feasibility study into pre hospital carbon monoxide (CO) monitoring. The project was originally lead by Team Leaders John Mullin and Martyn Tillett who completed the ground work, project planning, and equipment identification and procurement until they both left HART in July 2007; the project was then handed to Team Leader Andy Humber. John and Martyn must be recognised for the amount of personal time and effort they placed in this study.

CO is known as the silent killer and many people suffer the effects without knowing what has caused the symptoms. It is estimated that there are fifty fatal and two hundred non fatal cases are reported each year attributed to CO poisoning, (Corgi 2006) many go undiagnosed. The aim of this study is to assess patients and staff that have had a known exposure to CO, either through faulty household heating appliances, car exhaust fumes or domestic / commercial fires or other CO producing devices. The ambulance crew staff who respond in Rapid Response Units (RRU) will be using the equipment to assess patients who have displayed symptoms in keeping with CO poisoning or who have collapsed where the cause is unknown and diagnose the undiagnosed CO intoxication and refer the patient to the appropriate treatment centre.

The catalyst to the study was an incident that HART attended on 26th February 2007, a 999 call made to the LAS Emergency Operations Centre (EOC) originally stated that three patients were feeling dizzy and nauseous, the cause of the illness was not identified by the call taking system, the signs and symptoms were recognised by an HART operative whilst screening calls in the EOC. A HART response was sent, once on scene it was apparent that CO had caused the symptoms, at that point the London Fire Brigade (LFB) were activated and Heath Protection Agency (HPA) notified. From this incident it was clear that the CO levels in the building were easily monitored with the detection identification and monitoring equipment (DIME) which is used by HART for staff safety and the Rapid Response Team (RRT) from the LFB for environment monitoring, but patient CO levels were unable to be monitored on scene and so had to be completed at a hospital accident and emergency department, from this, the feasibility study developed.
The feasibility study started on the 1st December 2007 and had an initial end date of 30th May 2008, due to the data collected within the first three months and information retrieved from the LAS archives regarding CO incidents prior to the implementation of the project, it was decided to extend the study for a further six months to complete a full calendar year, therefore capturing any trends that may arise, the finish date of the study, 30th November 2008.

Equipment selection
At the time of the procurement process there were two types of CO monitors in use for monitoring patients, the first of which is an exhaled air monitor similar to an alcohol level breathalyser used by police services and the second being a device that uses the same principles of a pulse oximeter which are widely used within the medical field. Both companies that produced the equipment offered to loan the units they produce (At no cost) for the length of the study. It was decided to use the Masimo RAD-57; the RAD-57 as previously stated works on the same principle as a pulse oximeter which ambulance staff use on a daily basis, it is easy to use, compact and is used extensively in America and France by the Fire Departments and specific ambulance responders. The RAD-57 can be used as a pulse oximeter for reading levels of SpO^2 as well as the SpCO which would be of benefit to the medic using the device. The RAD-57 has a variance of $^+$/- 3%, used in conjunction with the history of the incident, signs and symptoms displayed by the patient would enable the attending ambulance staff to make an accurate diagnosis. The exhaled air monitor made by Toxco and supplied by Bedfont Scientific proved at this time to be labour intensive, the patient was required to hold their breath for fifteen seconds and then breathe in to the device in one sustained breath, this would be adequate for a person who was aware of their surroundings, but for a patient who was confused, unconscious or a elderly patient with pre-existing respiratory illnesses this method would prove difficult in an emergency situation. Since the start of the project Toxco have produced an updated monitor which has resolved these problems.
Masimo provided the study with five RAD-57's and technical support for the duration of the study; they also provided literature which was used in the training of the staff using the devices and also student booklets for all seventy six ambulance stations and training centres in the LAS.

Vehicle selection
As the study had five Masimo RAD-57's to use, it was decided to place three onto First Response Units (FRU) (Call signs CS46, IA55, IA56) and two would be placed on HART vehicles (Call signs IA30, IA31). The London Ambulance Service FRU's respond to category A calls which are determined by the illness or injury details given by the caller to the EOC

emergency medical dispatcher. Category A calls are predominantly life threatening incidents, so the use of the CO monitors would be a useful tool both in SpO^2 and SpCO monitoring. As these vehicles' operate twenty four hours a day and experience a heavy call load the monitor would be used on many patients, which proved to be a positive approach, this will be discussed at a later stage. The other two monitors were placed on HART vehicles, as HART are assigned to any potential incident that involves multi patients or any possible inhalation of unknown substances, this again proved to be fruitful in the identification of CO poisoning.

Training and staff education

Before the monitors were issued to the relevant vehicles, all crew staff that would use the monitors were given a training package which included an hour interactive session with supporting literature; the clinical signs and symptoms were discussed in length and also the possible causes. Later in the project, a presentation was given to staff by the team of specialists from the Whipps Cross Hospital Hyperbaric Unit. These lectures were held on five separate dates, these sessions were well attended, not only by crew staff that were taking part in the study but by other ambulance staff that had heard of the project and wanted to increase their personal knowledge of the subject. Further presentations will be planned for the near future and advertised for the attendance of interested personnel.

All of the hospital's with accident and emergency (A&E) departments (thirty five) which the LAS transport patients to were visited and informed of the study and given information about CO poisoning, unfortunately the vast majority of departments visited seemed disinterested, whether this was due to the individual member of senior staff disinterest, or not willing to display the lack of knowledge they have within this subject. On revisiting some of the A&E departments it is clear that the cascading of information from the senior staff to the operational nursing staff was varied. Four hospitals did request further information and literature in relation to the study which was duly delivered. Every ambulance station and Education and Development centre were sent booklets and leaflets describing CO poisoning and information on what to do if a member of staff suspects a patient of being affected, the response to this initiative was yet again, varied. Other information to ambulance staff within the LAS regarding the study and to heighten awareness of CO poisoning was published in the Monthly clinical update which is emailed to all staff members within the service, the LAS news which is a staff magazine also did a feature on the project, although not at length, it put the spotlight on the study and work the team were doing. One case which will be described later, a Team Leader who herself was affected by CO wrote an article for her station news letter about the subject, this generated much interest from staff who read it. (Case study four).

Two of the case studies in this report have been used in the Department of Health document, Recognising Carbon Monoxide Poisoning – 'Think CO' which was released in November 2008.

Previous CO incidents

Prior to the start of the study, information from the Health and Safety Executive (HSE) and Health Protection Agency (HPA) was sought regarding known CO incidents in the London area in the previous twelve months, these agencies were contacted as the LAS patient coding system did not have a code for possible CO poisoning and therefore the management information department were unable to produce the data required. (A code for CO poisoning has since been produced and in use from mid December 2008). At this stage it was clear that the reporting of CO incidents was at best hit and miss, neither agency produced a full year statistics and rarely did the information correspond, (both agencies were guarded in the statistics given to the project, no reason specified). From the data collected from the other agencies, previous Patient Report Forms (PRF) and EOC call logs were obtained for each of the incidents. From the information obtained in these documents and recordings, it was apparent that CO was not being identified by the ambulance crew staff but had been later specified as the cause of death or illness. This also brought to the attention of the study that ambulance crew staff, by not recognising CO related incidents were placing themselves in high level contaminated environments unknowingly.

Case study one.

A call received by LAS EOC to a twenty seven year old female unconscious, reason unknown, after routine questioning by the Emergency Medical Dispatcher (EMD) the life status of the patient was changed to cardiac arrest. Two ambulances and one FRU were sent to scene, the ambulance crew staff actively resuscitated the patient using advance life support techniques, the recognition of life extinct (ROLE) was completed by the lead clinician. From the information gained from the crew staffs PRF's at no time was CO mentioned or indicated, all five of the crew staff had possibly been exposed to high levels of CO whilst treating the patient, (ambient CO levels not monitored at the time) with four of the staff spending in excess of seventy minutes on scene during the treatment and subsequent reporting of the death to the police without knowing the environment CO levels and also the risk they had placed themselves in.

Case study two

A call received by LAS EOC from a male who said that he had found his grandfather on the floor collapsed in cardiac arrest, a secondary remark of the 'stove still on' was reported on the call taking log. An ambulance and FRU were sent to scene, the patient was found to be deceased on arrival, the PRF from the crew stated, the patient was 'in good / reasonable health', it also stated that the 'ring on the cooker was lit', at no time was CO mentioned even though the possible source was recognised by the reporting crew member and the patient had died being in good health. The crew staff spent over seventy minutes on scene with the grandson organising the police and General Practitioner to attend, although it is unclear whether the time was spent inside the property on not.

Unfortunately these incidents are not bespoke to London ; April 2008 an ambulance crew attended a hotel in Newquay, Devon , for a male found in cardiac arrest in his suite. The first attending crew started to feel unwell whilst dealing with the patient, presenting with nausea and feeling flushed, they reported this to the communications centre (Ambulance control) and the alarm was raised, both personnel received hospital treatment for CO poisoning. Later that evening several more crews were dispatched to the hotel to clinically assess the other guests and staff and convey to hospital if required, some of these crew staff later presented with similar symptoms. (Information received from Public Relations department, South Western Ambulance Service NHS Trust. 1st May 2008).

October 2008, six ambulance crew staff from the North West Ambulance Service NHS Trust were treated in hospital after displaying signs and symptoms of CO poisoning whilst dealing with family of four who had been intoxicated by CO over a several day period, this was due to a blocked flu from the central heating system. (www.wirralnews.co.uk/wirral-news/local-wirral-news/2008/10/15/west-wirral-family-and-paramedics-overcome-by-toxic-gas-fumes-80491-22029684)

Research has shown that these are not isolated incidents where members of crew staff have attended 999 calls where CO poisoning has been the cause of death or illness, where attending crews have not diagnosed or thought of CO as the predominant cause, this raises two main issues; firstly, crew safety due to exposure to CO whilst working and secondly, correct patient diagnosis. There ware seven other incidents in London (That the study is aware of) where CO has been the cause of the illness or death which had not been diagnosed through the call taking system or by the attending crew staff which the study has identified.
All staff members who have been identified having been potentially exposed to a CO environment have been contacted through their station management teams and offered Occupational Health referral and also support and information from the feasibility study lead. The departmental head of the LAS Human Resources was notified of the exposure and recorded it accordingly.

Monitoring of patients
The Masimo RAD-57 was placed on the selected vehicles and used extensively by the FRU's, initial feedback from the crew staff using the device said that it was easy to use and useful tool to have, the first indicator that the monitor would be of benefit other than routine diagnostics, not only did the monitor prove a good diagnostic tool for the monitoring of patients, the readings also gave an indication into the safety of the attending crew staff.
Case study three
9th December 2007, vehicle call sign CS46 was sent on a routine 999 call to a female who states she had chest pains and had difficulty breathing. On arrival, the attending crew staff member took the history from the patient and completed a full set of observations, the crew staff then used the RAD-57, this indicted that the patient had 9% SpCO, on seeing this he asked if there were any more persons in the flat, the patient said her mother was in the flat and had also been feeling unwell, the mother was monitored and a reading of 9% SpCO was recorded. The ambulance person evacuated the flat and contacted EOC and asked for the attendance of HART and the LFB. The original address was in a block of six flats, each of the flats was evacuated, and the flat above the original call had two occupiers who had readings of 9%, 12% respectively. It was later established the heating boiler in the above flat was faulty and had leaked CO into the flat below, all of the affected persons received treatment at Kings College Hospital . As the signs and symptoms were detected at an early stage using the patient monitor, this prevented further harm to the patients and possible higher level intoxication and the ramifications of this.

Case study four
February 2008 was the first time where the RAD-57 was used on a member of LAS staff; the original call to LAS EOC was from a female stating her partner who was twenty four years old had collapsed and she thought it was a stroke, during interrogation the caller then became more confused and emotional and then went quiet, the telephone line remaining open. An ambulance and FRU were dispatched, on arrival at the address the crew were unable to gain access and requested police to attend to gain entry to the property. Once inside the property, two unconscious patients were found, one male, one female, the ambulance crew requested via EOC another ambulance to attend, at that point HART were dispatched. On the arrival of IA55 (HART response car) which was forty minutes after the first crew on scene, the patients were placed on a monitor for SpCO, the female had a level of 21% SpCO and the male 20% SpCO, on recognising the cause, a rapid extraction of patients and emergency services personnel took place, the LFB were contacted via EOC for their attendance for the environmental monitoring of the property. Once in safe air, the patients and staff were monitored, patients levels had not changed and were transported to hospital, the two ambulance staff on scene had SpCO levels of 10% and 11% with the police officer who had been assessing the property whilst the patients were being treated had 19% SpCO, all three emergency services staff received hospital treatment for CO poisoning.

For every patient who had been monitored and displayed higher than accepted levels of CO, a data collection form was completed and returned to the study (appendix one), to assist at the receiving hospital and to explain the CO levels, a similar form with explanation sheet was sent with the patient, (appendix two); as stated before these forms and patient SpCO levels were met with some apprehension by receiving doctors and nursing staff as the information which had previously provided,

had not been disseminated, this then in turn delayed the definitive treatment of the patients whilst the hospital reaffirmed the patient SpCO levels. (Case study four)

Table one shows the quantity of data collection forms returned to the study during the twelve month period, the study is aware of incidents where patients have had high levels of CO and the forms have not been completed, unfortunately these incidents could not be used in the feasibility study.

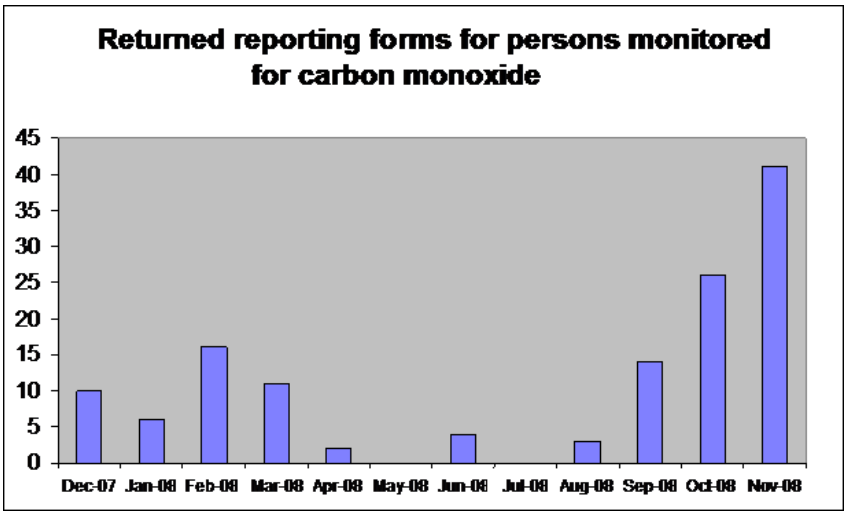


Table 1

Table two shows the patients that had been exposed to CO and had SpCO levels above 5%, if a patient was a known smoker then this was taken into consideration along with the clinical signs and symptoms and the history of the event.

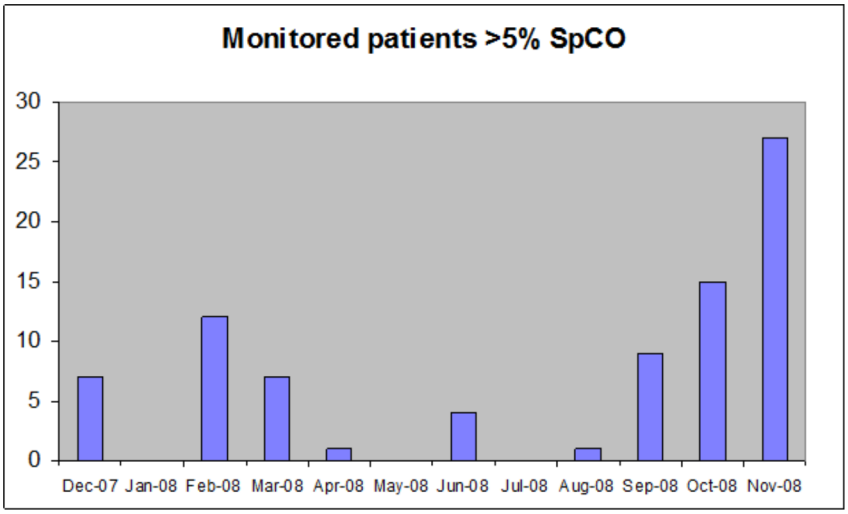


Table 2

From the two tables certain trends can be established in regard to incidents of CO poisoning, it has been noticed that a increase of incidents are during the colder months when central heating systems are in use or other forms of heat are used in domestic premises. There have been two incidents where barbecue coal has been used in premises as a source of heat as there had been a problem with the domestic heating system and this has caused the CO intoxication.

Case study five

The LAS received a call to a 2yr old female collapsed with difficulty in breathing, on arrival of the first responder it was indicated that other members of the family also felt unwell, the child had reduced levels of consciousness and was 'floppy'

when held, on realising there was a problem the ambulance crew staff evacuated the premises taking the family with them, once outside, extra ambulances were requested and duly sent. On the arrival of the CO monitor the patients CO levels were recorded as adult male 20% SpCO, children ages 2yrs, 4yrs and 7yrs had levels of 19%, 13% and 19% respectively, the first responder had a CO level of 5% SpCO. The family had burnt coal in the house for heat as the heating boiler had been condemned. All of those affected received hospital treatment; the family was later referred to Whipps Cross Hyperbaric Unit for further treatment.

There were one hundred and thirty four returned research forms, of which, eighty four of the persons monitored had levels of 5% or move above normal expected levels of SpCO. To put this into perspective, in the CORGI second report (www.trustcorgi.com/carbonmonoxidekills/corgicarbonmonoxidereport.htmx) it states that in the United Kingdom there had been between April 2007 and March 2008, 21 fatalities and 125 injuries due to carbon monoxide. These were gas related incidents as CORGI only reports on this subject. In this feasibility study using only five patient monitors in London , eighty three patients have received treatment for CO poisoning, (1st December 2007 to 30th November 2008). The CORGI report also states, 'lack of an official, centralised incident reporting system and many cases going undiagnosed, means the overall figures in this report could be much higher'
There have been a number of times where vehicles carrying the RAD-57 have been targeted to domestic CO alarm activations, along with the LFB RRT, with the equipment in place the ambulance crew staff have been able to reassure patients that they have not been exposed to CO and with the ambient monitoring by the RRT which has supported this, a vast majority of these calls were due to the low battery alarm activation and not a CO activation, being able to monitor on scene has reduced the number of persons being transported to hospital for assessment after such an alarm activation, therefore reducing the number of patients entering the A&E system and also allowing ambulances to return to core duties earlier.

As part of their core duties HART attend a large number of fire calls, whether it be domestic or commercial, the main duties are to medically support the fire service and treat the patients of the incident. Being able to monitor patients for CO post fire incident has had an effect on how many persons attend the A&E department. Previous to the monitoring many patients would not seek medical aid as they didn't believe they had had sufficient smoke inhalation to cause a clinical issue, leading to attendance at a later date, this was exacerbated by ambulance staff assessing for smoke inhalation using soot staining around the nasal passages and mouth as an indicator and a taking of SpO^2 reading which would give false positive if the presence of CO was in the body, if the patient didn't show any signs or symptoms even though there was a history which suggested smoke inhalation the patient tended to remain on scene. Using the monitor, patients with any elevated SpCO levels or strong evidence to support smoke inhalation were transported to hospital for further assessment. This reduces the long term effects of untreated smoke inhalation and also reduces the clinical risk to the ambulance service. Unfortunately the majority of fire calls received by the LAS are not attended by ambulance crew staff with the ability to monitor for CO, this is due to a number of reasons, i.e. vehicles already deployed on other incidents, the vehicles not being activated by EOC or the vehicles being cancelled before their arrival by other resources on scene.
It was also noted on several occasions, fire-fighters were placing themselves in areas of smoke logging without the wearing breathing apparatus and therefore breathing in the smoke from the fire, it has been suggested at the scene of these incidents to the fire incident commander that these personnel should be monitored for their CO levels, this was declined. A meeting between the study lead and an officer of the LFB was held to discuss these issues, at this time, no further progress has been made in fire-fighter monitoring at the scene of a fire.
As part of the research behind this study, other agencies that use the RAD-57 were contacted to see how the monitor was used and to what effect; it was discovered that the New York State Fire Department, Saratoga County Fire department and the fire departments in Paris and Marseille in France predominantly use the RAD-57 to monitor fire-fighters post incident to maintain a comprehensive health surveillance record on each of the personnel in their charge. The fire departments are aware of the long term neurological effects of CO and put procedures in place to reduce the risk to the fire-fighters and also the possible financial implications to the departments. (Information, Professor M McEvoy, PhD, REMT-P, RN, CCRN) (www.saratogaems.org/mike.htm)

Recommendations

1. Personal CO monitor for crew staff safety

The safety of all ambulance personnel must be paramount, this study has highlighted and described several incidents where ambulance crew staff and other blue light responders have unknowingly been exposed to a CO contaminated environment, as shown previously, this is not just a London problem, ambulance staff across the country also face the same potential hazard when responding to emergency calls. There are several products currently produced on the open market which could be issued to each ambulance person such as the Electronic Personal Dosimeter (EPD) which was issued to detect sources of Beta and Gamma radiation for staff safety. Personal safety devices are used by ambulance services in Holland and France for the protection of the ambulance staff (France for the past five years) and have highlighted CO environments when CO had not been indicted during the call taking system. Each of the services have strict procedures for when crew staff recognise the potential hazard facing them. The CO detectors are small and robust and can be as complicated or as simple to use as the individual ambulance service specification demands. Companies

such as Dräger, Rae Systems and Industrial Scientific supply products that have proven to be effective in personal environmental CO monitoring, and have the necessary support mechanisms in place. Nationally, ambulance service personnel go into thousands of homes every day, with a personal CO monitor assigned to them could prevent numerous CO injuries or deaths by early detection of the problem. Since the placement of personal monitors on ambulances in France (2001) there has been a dramatic increase, with over four thousand detected CO incidents in 2007.

2. Patient CO monitors on all front line ambulance resources

The feasibility study has shown that with five patient monitors and with three in constant use the patients recording higher than expected SpCO is greater than first anticipated. Over a third of the national average for CO poisoning has been highlighted in London , how many patients are the health services missing through not having the relevant equipment? Patient CO monitoring has been undertaken extensively in France for the past five years, mainly in the highly populated areas of Paris and Marseille. Originally using the expired air devices and more recently using the pulse oximetry method (RAD -57). The devices are used mainly on the SAMU ambulances and not the VASU vehicles, only if CO is indicated during the call taking system then the appropriate SAMU vehicle will be sent.

It is recommended that all front line ambulance resources have means of monitoring patients for CO poisoning, there are devices and monitors which already in use within health service that would allow the attending ambulance crew staff to monitor and to make an informed clinical decision and to select the correct treatment and referral pathway.

3. Improved training and awareness for all health care providers / professionals and blue light responders

The education of all emergency personnel into the signs and symptoms and dangers of CO and how to recognise the possible environments must be undertaken as soon as reasonably practicable. As CO is odourless and colourless emergency personnel rule the possibility out, because it can't be seen!

Case Study six

The LAS received a call to a restaurant where four persons felt unwell and a fifth had fainted, first reports from the scene state that the patient that had fainted had been taken outside had felt better and had left the scene, the LAS EOC contacted the LFB for their attendance, HART were also dispatched as there were multiple patients. On the arrival of the HART responder, the LFB were leaving the scene, the Watch Manager on the fire appliance had been into the premises and was unable to detect a problem, although no detection, identification, monitoring equipment was used, the ambulance staff and police officers had accepted the Watch Managers assessment. The patient in the ambulance was monitored with the RAD-57 by the HART responder, the adult male had a level of 27% SpCO, the female accompanying him had recorded levels of 23% SpCO, at that point the restaurant was evacuated and the LFB asked to re-attend. On closer surveillance by the LFB RRT, CO levels of 230 parts per million (PPM) were detected in some parts of the restaurant, with lower but significant levels in other populated areas. Thirteen patients were taken to hospital with SpCO levels ranging from 6% to 27%, six patients were taken directly to the Whipps Cross Hospital A&E where they were assessed by the hyperbaric team.

Dr Andreas K Stehr Hyperbaric Physician (EDTC/ECHM) Hon Consultant Anaesthetist (Receiving Doctor at Whipps Cross Hyperbaric Unit).

'*The incident at the Brazilian restaurant was a good example how important at-scene-triage is. And more important: that the HART team is absolutely capable to do that job. Due to the brilliant information provided on the telephone I was able to make a decision whereto bring the patients (local A&E, Whipps Cross University Hospital (WXUH) A&E, Hyperbaric chamber) and it worked out quite nicely. I saw 6 patients in WXUH A&E in less than 45 minutes and one of them was treated in the chamber, the others were kept on oxygen for 12 hours and were discharged home. All of them were really impressed by the efficiency of the system and said they had never experienced such professionalism before'.*

Ambulance service Departments for Education and Development need to take the lead in the expansion of knowledge for the Paramedic students in relation to the physiological and pathological effects and the possible neurological changes due to CO poisoning. Currently, the only reference in the JRCALC ambulance training manual is, 'The essential requirement with carbon monoxide poisoning is to be alert to the possibilities of the diagnosis. Any patient found unconscious or disorientated in an enclosed space, where ventilation is impaired, or a heating boiler may be defective, should be considered a risk. The supposed cherry red skin coloration in carbon monoxide poisoning is in fact rarely seen in practice'. (JRCALC 2006 v 2.2). Unfortunately CO does not have a lecturing session allotted to the subject, it may be used during the accident approach sessions, but this does depend on the training managers who set the scenarios.

There are thousands of ambulance personnel who serve the public with only a very basic knowledge of this subject; this is not their failing but a failing on the part of the national and individual ambulance service training system. CO has never been at the forefront of ambulance teaching, which now needs to change. All ambulance crew staff should be given the opportunity to be taught more about CO and its effects. It would be impossible to recall all of the staff into the training schools, a recommendation of a national education program including mail drops and an internet learning program would increase the awareness and knowledge bass and in turn improve the service given to the communities in which they serve. It not only the front line ambulance staff that need to be aware of the potential dangers and clinical effects of CO, ambulance managers and control room staff also need to be updated, as in the example in Newquay, the first ambulance crew on scene became overcome and received hospital treatment, later on that day more ambulance staff were sent to

scene to assess further patients, some of those in the second response also displayed signs and symptoms of CO poisoning; it has to be questioned, what mechanisms were put in place to prevent this from happening and what advice was sought and from who?

4. A direct referral pathway for CO intoxicated patients

Whilst conducting this study, it has been noticed that once patients have been diagnosed with high levels of CO and transported to the nearest A&E department, there is then a delay in the treatment regime whilst the transfer of the patient to a specialist care centre is arranged. Case study four is an example of this, the receiving hospital knew the patients they were expecting had high levels of SpCO, yet it was over ninety minutes before the patients were transferred to the hyperbaric unit, thus delaying definitive treatment. From this incident, discussions have been held between the specialists at the Whipps Cross Hyperbaric Unit and feasibility study lead on how best to rectify this problem, it is accepted that patients suffering from known cardiac conditions and other medical conditions can be taken to the appropriate treatment centre, therefore bypassing the nearest A&E departments as long as the patient was clinically stable, why couldn't this happen for CO intoxicated patients? An algorithm has been produced in conjunction for ambulance staff by Whipps Cross hyperbaric unit, which illustrates clearly the parameters for direct referrals, (Appendix 3) a similar algorithm is being successfully used with supporting literature in use in France . (Marseille Hyperbaric Unit) (Appendix four)

Case study seven

The LAS received a call to a hotel in Westminster , four patients had collapsed in a room, two of which were said to be unconscious. A FRU from HART was dispatched as well as an ambulance and local FRU. On the arrival of the first ambulance, the attendant went into the room to find two patients collapsed on the floor and two patients collapsed on beds, not knowing the cause the attendant as per protocols (Steps 1,2,3) left the scene and requested further assistance. The LFB RRT attended with HART, both teams entered the room wearing breathing apparatus (BA); HART assessed the patients and the RRT monitoring the ambient CO levels. The patient SpCO levels ranged from 23% SpCO to 36% SpCO, with an environment level of 150ppm, the information was given to the HART supervisor and in partnership with the LAS Silver officer and Emergency Planning Manager, Whipps Cross hyperbaric unit were contacted and agreed to receive all of the patients. The patients were extracted by ambulance and fire personnel in BA from the premises and handed over to the fully briefed awaiting ambulance crews, the patients were then taken directly to Whipps Cross A&E where they were assessed by the hyperbaric specialist and then received hyperbaric treatment within two hours of being diagnosed, this therefore reduced the overall time spent in hospital (discharged the following day) and improved the long term prognosis and recovery of the patients.

It is recommended by the feasibility study that the direct referral for CO poisoning and the algorithm be accepted and used by the LAS; this recommendation can only be successful if patient CO monitoring equipment is purchased.

Dr Elliott Singer MBBS DFFP DRCOG MRCGP (Chair of the British Hyperbaric Association).

'The HART team has improved the referral times of people with CO poisoning. As a result patients are being assessed and treated at an earlier stage. Our understanding of CO poisoning would suggest that this results in a decrease in the neuropsychological deficit that people with severe CO poisoning can suffer. Our audit data at London Hyperbaric Medicine has shown a decrease in time to first treatment since the HART team started assessing CO patients, so that now 72% of patients compared to 17% of patients are treated within 6 hours and 93% of patients compared to 80% of patients are treated within 12 hours.

On site monitoring of COHb levels mean that the paramedics are now able to triage patients at scene and receive expert advice at the scene, so that they take patients to the most appropriate A&E department and those with severe CO poisoning can now be referred directly to appropriate hyperbaric units. It is due to this that there has been a marked improvement in the time to treatment'.

5. Updated software within MPDS and PSIAM to recognise the indicators of CO poisoning

During this study, it has become apparent that the 999 call taking system, Medical Priority Dispatch System, (MPDS version 11.3) which is used by the LAS is unable to collate CO related symptoms and produce a possible cause. Many of the symptoms displayed by an early stage CO intoxicated patient, such as nausea, headache and dizziness without a known cause would be prioritised as a Green one or two, this would then be passed to the Clinical Telephone Advice department (CTA) for further assessment, an ambulance not being assigned at that time. If there is more than one patient, then CO is considered, but is not a prime reason in this system of the patients' presenting condition. It is only when CO is mentioned by the person calling; the appropriate response is dispatched to scene. If the call is transferred to CTA assessment, a trained clinician using the Priority Solution Integrated Access Management (PSIAM) system will then reassess the patient. If the patient has nausea, not one of the forty eight questions mentions CO as a possible cause, if dizziness is a symptom, question eleven is when CO is considered. Unfortunately if the patient presents with a headache, four causes are suggested, none of which is CO. In the Department of Health document previously mentioned, it states that 90% of CO poisoned persons will have a headache and 50% will suffer form nausea and vomiting. The PSIAM software does allow the clinician to override the system and collate the patients' signs and symptoms and make a diagnosis not using the PSIAM question and answer structure, so therefore CO might be detected depending on the experience of the user. It was noted that the education program and user assessment for PSIAM uses a CO incident as a scenario during the training course for CTA operatives.

6. A sharing of information and the need for a national agency to collate all CO incidents

From the outset of this study it has proved difficult to gain information into CO incidents nationally or London based, agencies such as the Health and Safety Executive (HSE), HPA and CORGI collect data on CO incidents which individually they are responsible for, there didn't seem to be a fluid exchange of information between these agencies. There is no one official body that collates all CO related incidents in the UK , which is why all the statistics gained and published by individual bodies, are approximate and not accurate. (CORGI second report) Having visited separate departments that deal with the patients of CO poisoning and the incident sites, it is clear that the professional personnel dealing are unsure of which agency and whom within the agency to report an incident to, this leads to miss reporting or failure to report at all. It is recommended that a national data base is set up for the reporting of all CO incidents, illnesses and fatalities, this is the only way in which an accurate measurement of the problem will be made, as in France where a national database was set up two years ago. One telephone number for the reporting CO incidents, illnesses and fatalities which is publicised to all agencies involved from the ambulance services, A&E departments, Fire / Police Services to the emergency gas board responders, the reporting must be made compulsory and failure to do so should result in sanctions against that agency.

7. A rigid health surveillance structure for CO affected staff

With the possible advent of CO monitoring equipment, both for patient and crew staff safety, there will need to be a support structure put in place as the possibility of an increase of CO related incidents is apparent. The need for a rigid health surveillance policy for all staff that have been exposed to CO and a structure to support the staff member if the need arises, also the need to reassure staff members who have been exposed to low levels of CO where their health would not be affected but are considered as the 'worried well', managers would need to be confident in their knowledge of the exposure limits and treatment regimes. The call rate for dedicated units and resources such as the LFB RRT, HART and the emergency gas service would increase; the resilience of these sections would be stretched during the peak months when CO incidents are most prevalent

To reiterate the recommendations made in this study;

- CO monitors for crew staff safety
- CO monitors to aid patient diagnosis
- Improved training and awareness for all health care providers / professionals
- Direct referral pathway for CO intoxicated patients
- Updated software within MPDS and PSIAM to recognise the indicators of CO poisoning
- A greater sharing of information between interested agencies
- A national agency to collate all CO incidents
- Legal requirement for CO incidents to be reported
- Rigid Health surveillance for CO affected staff (all blue light responders)

This study did not set out to influence the overall practices in regard to CO poisoning, the remit was to ascertain whether the monitoring of CO in The London Ambulance Service NHS Trust would be beneficial to the diagnosis, treatment and clinical outcome of CO intoxicated patient. From the collated data, information gained during and prior to the feasibility study and correspondence with other interested agencies it is clear that there are gaping holes in the way that CO poisoning is recognised, monitored, treated, recorded and publicised in the United Kingdom. It is from these concerns that the recommendations have arisen, a reasoning for each and supporting case studies, it is realised that there are agencies with personnel who are more eminently qualified than those who have been involved in this study, but it is felt that if these recommendations were not recorded then the study would have failed the ambulance crew staff and patients who would suffer from CO poisoning in the future.

Andrew A Humber
Team Leader
Team Supervisor (Blue Team)
Hazardous Area Response Team
London Ambulance Service NHS Trust
andrew.humber@lond-amb.nhs.uk

Appendix One

Carbon Monoxide Monitoring Patient Report Form (study copy)

Date ___/___/_____ CAD _____ Call Sign _____ Activation Time_____

Call Sign _____

Call Sign _____

Patient Name _____ Age_____

D.O.B ___/___/_____

Does the Patient Smoke? **Yes** / **No**

Brief description of incident

SpO^2 _____ Time_____ BP____/____ Pulse Rate_____bpm

SpCO _____ Time_____ Respiration Rate_____rpm

Treatment Given

O^2 _____% ____Lpm

IV cannulation **Yes** / **No** IV Fluids **Yes / No**

12 Lead ECG **Yes** / **No** ECG Changes **Yes** / **No** If Yes please state

Other Treatment Given

ECG Changes

Other Information

Fire Incident **Y / N**
Heating Boiler **Y / N**
Cause Unknown **Y / N**

	Engine Exhaust Fumes **Y / N** Self Harm **Y / N** CO Alarm Activation **Y / N** Other. Please State

Patient Destination_____

Crew Details Attendant_____ Driver_____

Person Completing Form_____

Would you be willing to be interviewed in relation to this incident by the research team **Yes** / **No**

Please return the completed form to Andy Humber, CBRN office Deptford Ambulance Station.

Appendix Two

Carbon Monoxide Monitoring Patient Report Form (A&E copy)

Date ___/___/_____ CAD _____ Call Sign _____ Activation Time_____

Patient Name _____ Age_____

Does the Patient Smoke? **Yes** / **No**

Brief description of incident

SpO^2 _____ Time_____ BP____/____ Pulse Rate_____bpm

SpCO _____ Time_____ Respiration Rate_____rpm

Treatment Given

O^2 _____% ____Lpm

IV cannulation **Yes** / **No**

12 Lead ECG **Yes** / **No** ECG Changes **Yes** / **No** If Yes please state

Other Treatment Given

ECG Changes

Other Information

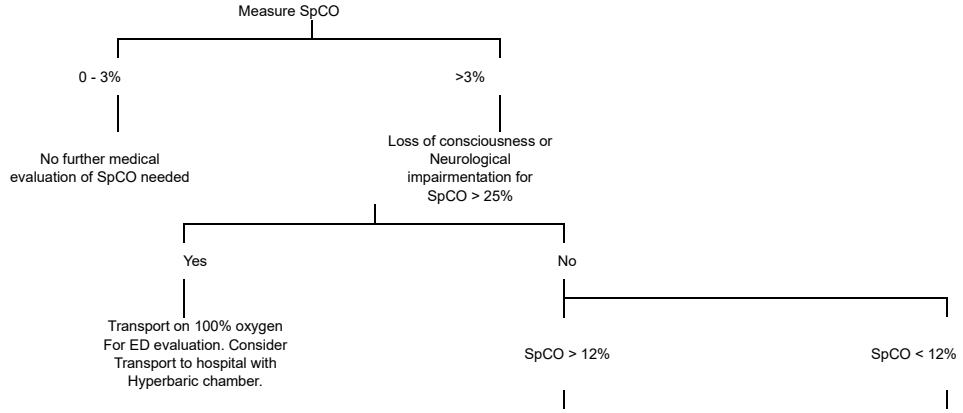
Patient Destination_____

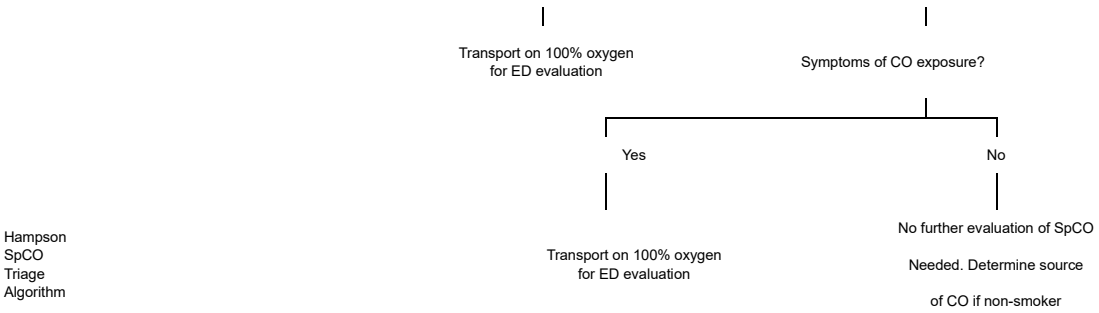
The research team would welcome feedback from hospital A&E staff regarding this project and Specific CO related incidents.

For further information regarding CO monitoring please contact:
Andy Humber, CBRN Office, Deptford Ambulance Station, 1 New Cross Road, London . SE14 5DS
Tel: 020 7732 5836 Mobile : 07789 867820. fax:020 7636 8145

Dear colleague

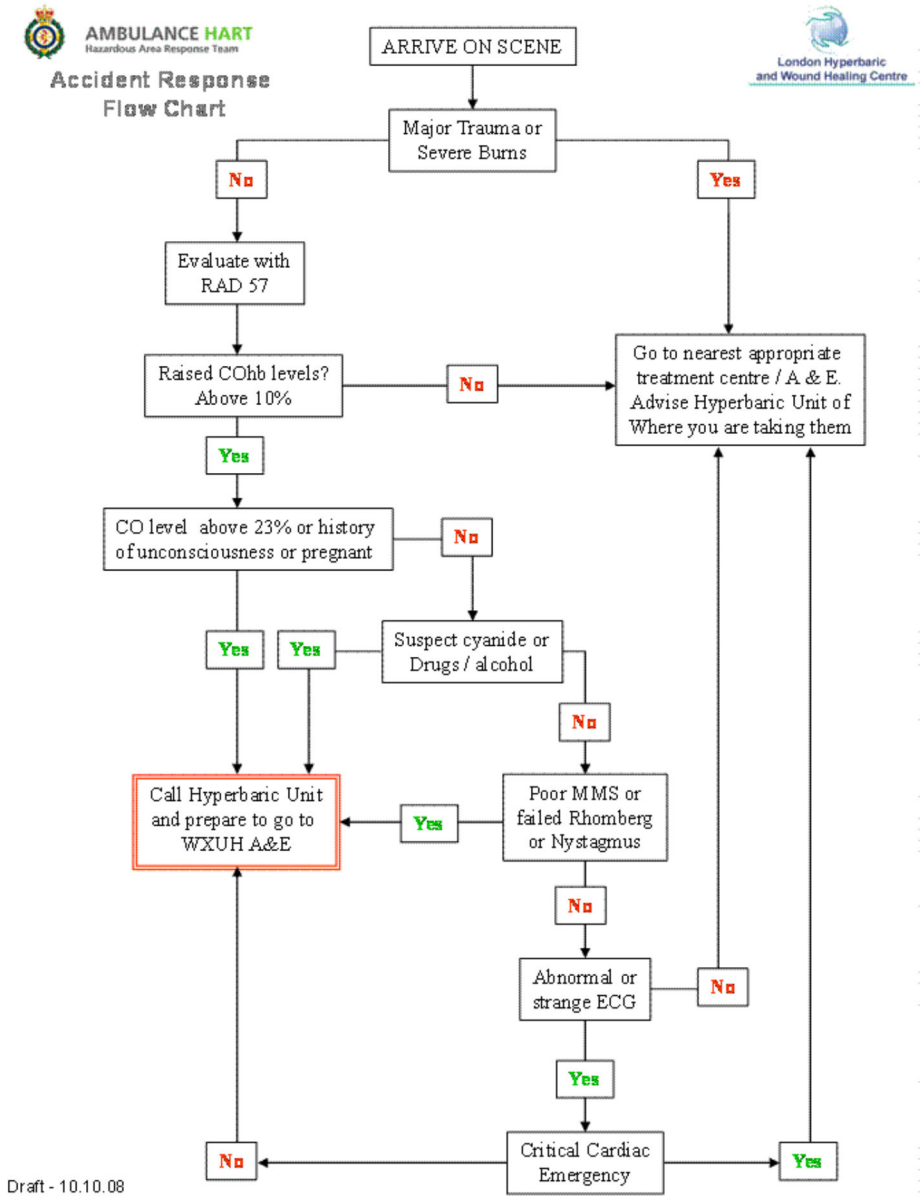
This document records that the patient has been tested for CO exposure and has been shown to be above expected levels. The London Ambulance Service *Hazardous Area Response Team (HART)* and Deptford Ambulance Station FRU are currently trialling the pre-hospital testing of patients and staff potentially exposed to CO environments. To identify raised levels of CO in the body, the Masimo RAD-57 SpCO meter which has similar technology to a pulse oximeter has been used. The RAD-57 displays in CO which correlates to COHb % with +/- 3% error.





Hampson
SpCO
Triage
Algorithm

Appendix Three



Appendix Four

WHAT TO DO IN FRONT OF CO POISONING

Suspect it systematically

When facing any **WINTER COLLECTIVE SYMPTOMATOLOGY** (± domestic animal death)

Usually : **HEADACHE + VERTIGO + NAUSEA**

↓

REMOVE THE VICTIM FROM THE CONTAMINATED ENVIRONMENT

With all required **PRÉCAUTIONS** for the rescue team

CONFIRM CO POISONING

By a non invasive measurement: COHb percutaneous sensor (SpCO) type Rad-57
Or if not available exhaled CO or ambient CO

VITAL DITRESS = Emergency Reanimation + Medicalisation

OTHERWISE SYSTEMATICALLY :

OXIGENOTHERAPY

With high concentration mask (FiO2 : 100%) at 15 l/min

SEARCH FOR SEVERITY CRITERIA

- **Pregnant womem**
- **Neurologic : Prolonged lost of conscious, consciousness troubles, seizure, sign of focalization**
- **Cardiac : collapsus, ischemia, rhythm or conduction abnormalities**
- **SpCO > 25% COHb**

ON SITE EKG

Looking for signs of ischemia, repolarization, rhythm or conduction abnormalities

BLOOD SAMPLE for the adults, as soon as possible

With at least a standard analysis, creatinin, CPK, Troponine, BNP, COHb

PERIPHERAL VENOUS CATHETER

Only if signs of severity or vital distress are present

TRANSFERT PATIENT AS SOON AS POSSIBLE to

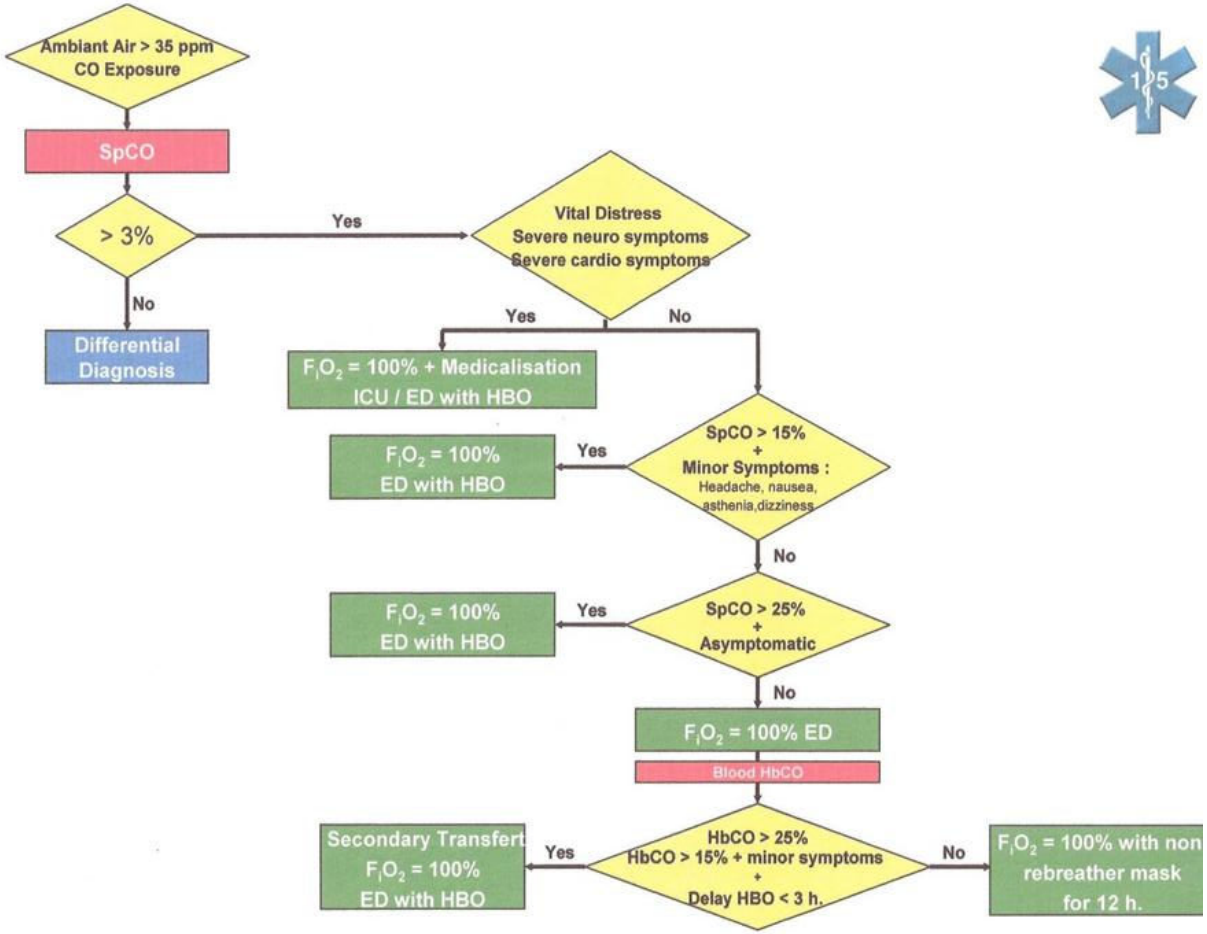
HOPITAL Ste MARGUERITE EMERGENCY DEPARTMENT

EXCEPT IF

- **Vital Distress (DESTINATION : ICU Ste Marguerite for adults or PICU Timone for infants)**
- **Symptomatic children without severity signs with SpCO not available or < 15% (DESTINATION : Pediatric ED Timone)**
- **Asymptomatic children with SpCO not available or < 25% (DESTINATION : Pediatric ED Timone)**

Inform as soon as possible

The doctor of the HYPERBARIC UNIT (tel. 04.91.74.49.96)


Ambiant Air > 35 ppm
CO Exposure
SpCO
> 3%
Yes
No
Differential Diagnosis
Vital Distress
Severe neuro symptoms
Severe cardio symptoms
Yes
No
F_iO_2 = 100% + Medicalisation
ICU / ED with HBO
SpCO > 15%
+
Minor Symptoms :
Headache, nausea, asthenia,dizziness
Yes
F_iO_2 = 100%
ED with HBO
No
SpCO > 25%
+
Asymptomatic
Yes
F_iO_2 = 100%
ED with HBO
No
F_iO_2 = 100% ED
Blood HbCO
HbCO > 25%
HbCO > 15% + minor symptoms
+
Delay HBO < 3 h.
Yes
Secondary Transfert
F_iO_2 = 100%
ED with HBO
No
F_iO_2 = 100% with non rebreather mask for 12 h.

ARBRE DECISIONNEL POUR L'ORIENTATION DE L'INTOXICATION AU CO

PATIENT	PRISE EN CHARGE PRE HOSPITALIERE		LOCALISATION DU PATIENT	
	Symptomatologie initiale	Dosage SpCO (mesure capillaire non invasive)	Marseille	Hors Marseille
ADULTE ou ENFANT ≥ 10 ans	**Détresse Vitale** (Intubé Ventilé)		**RDU Ste Marguerite** après accord du réanimateur et du médecin hyperbare A défaut : **UMC Ste Marguerite** après accord du réa, du sénior des urgences et du médecin hyperbare	
	Trouble neurologique grave (perte de connaissance prolongée, trouble conscience, convulsion, signe de focalisation...) **Trouble cardiaque grave** (Ischémie, trouble du rythme ou de la conduction, collapsus...) **Femme enceinte** **Symptôme mineur** (céphalée, nausée, asthénie, sensation vertigineuse) et **SpCO > 15%** **Asymptomatique** et **SpCO > 25%**		**UMC Ste Marguerite** après accord du sénior des urgences et du médecin hyperbare	
	Symptôme mineur (céphalée, nausée, asthénie, sensation vertigineuse) et **SpCO < 15% ou non disponible** **Asymptomatique** et **SpCO < 25% ou non disponible**		**UMC Ste Marguerite** après accord du sénior des urgences et du médecin hyperbare	**UMC secteur** puis transfert secondaire aux UMC Ste Marguerite si délai<3h et HbCO>25% ou >15%+symptôme, après accord du sénior des urgences et du médecin hyperbare
ENFANT < 10 ans	**Détresse Vitale** (Intubé Ventilé) **Trouble neurologique grave** (perte de connaissance prolongée, trouble conscience, convulsion, signe de focalisation...) **Trouble cardiaque grave** (Ischémie, trouble du rythme ou de la conduction, collapsus...)		**RDU Ste Marguerite** après accord du réanimateur et du médecin hyperbare A défaut : **Réa Pédiatrique Timone** puis transfert secondaire au Centre Hyperbare Ste Marguerite accompagné du pédiatre de garde au SMUR pédiatrique	
	Symptôme mineur (céphalée, nausée, asthénie, sensation vertigineuse) et **SpCO > 15%** **Asymptomatique** et **SpCO > 25%**		**UMC Ste Marguerite** après accord du sénior des urgences et du médecin hyperbare	
	Symptôme mineur (céphalée, nausée, asthénie, sensation vertigineuse) et **SpCO < 15% ou non disponible** **Asymptomatique** et **SpCO < 25% ou non disponible**		**UMC Pédiat. Timone**	**UMC Secteur** puis transfert secondaire aux UMC Ste Marguerite si délai < 3h et HbCO > 25% ou >15% avec symptôme, après accord du sénior des urgences et du médecin hyperbare

EN PRE HOSPITALIER

- **Extraction du milieu et oxygénothérapie** normobare au masque à haute concentration 12 à 15 l/min.
- **Prévenir le médecin hyperbare (0491744996)** et le **médecin sénior** des urgences ou de la réanimation
- Mise en place d'une voie **veineuse périphérique uniquement** en cas de signes de gravité ou de détresse.
- Chez l'adulte, prélèvement sanguin (**BS, CPK, troponine, BNP, HbCO**) en préhospitalier le plus précoce possible.
- **Electrocardiogramme**.
- **Rechercher une éventuelle contre indication à l'oxygénothérapie hyperbare** : épilepsie, asthme sévère, emphysème, pneumothorax spontanée ou non drainé... .

AUX URGENCES

- Poursuivre l'**oxygénothérapie** normobare au masque à haute concentration 12 à 15 l/min.
- **Prévenir le médecin hyperbare (0491744996)** au plus vite
- **Radiographie standard du thorax**
- Si non fait en pré hospitalier :
  - Mise en place d'une voie **veineuse périphérique uniquement** en cas de signes de gravité ou de détresse.
  - Chez l'adulte, prélèvement sanguin (**BS, CPK, troponine, BNP, HbCO**) le plus précoce possible.
  - **Electrocardiogramme**.

Rédigé par les Dr V. VIG, P. MICHELET et M. COULANGE

Modifié le : 08/12/2008 par le Dr M. COULANGE