

Medical Management of Carbon Monoxide Poisoning:

Understanding Current Practice & Developing Consensus



Workshop Report

Event held 27th November 2018
Gas Safety Trust, 4 More London Riverside
London SE1

About the Gas Safety Trust

The Gas Safety Trust, established in 2005 as a registered charitable body, has become the UK's leading gas safety research charity with the key objectives of further improving gas/fossil fuel safety for the public and industry throughout the UK and reducing the incidents of death and serious injury from carbon monoxide (CO) exposure. The Trust does this through the funding of research and data collection relating to carbon monoxide poisoning.

The Gas Safety Trust provides grant funding, advice and support to any organisation seeking to carry out research and evidence gathering relating to gas safety. The Gas Safety Trust is currently funding projects that include health and wellbeing and the built environment.



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Disclaimer

The content outlined in this report does not necessarily reflect the position of individual attendees and/or of government department or agencies.

Published: March 2019.

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Foreword



The Gas Safety Trust has supported research to improve the diagnosis of carbon monoxide (CO) poisoning by healthcare professionals. The difficulty regarding diagnosis of CO poisoning and the subject of misdiagnosis amongst healthcare professionals is one that has been raised within every area of research.

The limitations of using carboxyhaemoglobin as the principal biomarker for identifying CO poisoning in the clinical environment has become clear. But also the symptoms being common to so many other illnesses such as food poisoning, influenza and headache, reduces the suspicion of CO necessarily being the cause. However, if diagnosed, it was noted that the management of poisoning varied amongst healthcare professionals and that follow-up, as assessment of any neurological problems that occurred after poisoning, was not routine.

The Gas Safety Trust responded to the call from many different healthcare disciplines for the need to discuss the medical management of CO poisoning for both acute high-level and chronic low-level poisonings. It was clear that healthcare professionals and industry needed to come together to highlight the gaps in the provision of guidance for these professionals who had a responsibility for those exposed to CO; they needed to explore the variations between the different professions and assess how these variations might help, or hinder, the process of managing those poisoned by CO.

In November 2018, the Gas Safety Trust held a workshop in London attended by experts from a range of healthcare disciplines and experts from the gas industry to enable this discussion to commence and to explore what possibilities there might be to improve diagnosis and treatment of CO poisoning.

This report outlines those discussions; identifies current information sources, outlines the problems being faced, highlights gaps in understanding and practice, identifies research needs, considers the vulnerable and concludes by reiterating a call for the development of a consensus document on the medical management of CO poisoning.

This report in itself will inform the Gas Safety Trust's future funding priorities, but will also provide support for dedicated discussion and development of consensus on the medical management of CO for healthcare professionals that will, undoubtedly, for the first time, involve the support of industry professionals.

We are indebted to everyone who generously gave their time and expertise to contribute to these debates, and to Isabella Myers who facilitated the event and produced this report.

A handwritten signature in blue ink, appearing to read "Chris Bielby".

Chris Bielby
Chair
Gas Safety Trust

Facilitator's Analysis

The management of CO poisoning requires the involvement of many different professionals and links between these professionals need to be strengthened if a meaningful and effective systems- approach is to be developed and implemented.

This workshop offered participants, all of whom had a role in the prevention, identification/ diagnosis, treatment and follow-up of carbon monoxide poisoning, an opportunity to discuss the problems faced by industry and healthcare professionals in providing what they considered, a first-class patient management pathway.

In the past, this issue had been addressed via meetings and a report supported by GST and prepared by a small multidisciplinary healthcare group (COMED)¹. A specialist workshop funded by GST had sought to improve progress in scientific research on a new biomarker for CO². Smaller meetings on specific aspects associated with poisoning supported by GST had also taken place. However, it had become apparent that for system-change to occur, a larger collaborative event was required. This event would seek to raise suggestions for research to improve the diagnosis, management and treatment of patients and to develop optimum patient management pathways that linked the work of health-care and industry professionals involved in the prevention and management of CO poisoning.

The multi-disciplinary nature of the attendees enabled this workshop to include an active and case-based learning element: this facilitated and enhanced discussion within the workshop sessions. The perspectives of the professionals who attended brought different underlying aspects of the problem to the forefront of the workshop sessions. These, which might not have otherwise been raised included: improved research methodologies, the working environment, vulnerable groups, communication, professional practice, client/patient perspectives, mental well-being, socio-economic factors, ethical considerations.

Amongst the attendees, there was no doubt that the establishment of clear, evidence-based management strategies and pathways needed to be developed. However, it was accepted that to start this process, distinct actions implemented at a local level and distinct pieces of research would be required to lay the foundations on which such important developments could be built. This stimulated a number of smaller action points alongside the broader recommendations set out in the report of the workshop.

A post-workshop feedback form was completed by participants. The participants thought the workshop had been useful and informative, had highlighted issues relevant to their work and had provided a structure from which further work could and should be developed. Participants made clear their wish to be involved in further work.



¹ COMED (2017) Carbon monoxide poisoning: saving lives, advancing treatment – a call for action across the healthcare sector. Policy Connect www.policyconnect.org.uk

² GST (2018) Biomarkers Workshop: Carbon monoxide – report. www.coportal.org/data/199/carbon-monoxide-biomarkers-workshop-report/

On the feedback form, participants provided a list of actions that they would take forward within their specialities. Around 30 actions were listed ranging from training to setting up research clinics; reviewing current reporting systems and broadening discussion at a local level. A request for suggestions about how to best follow-up the issues raised during the workshop resulted in around 20 suggestions that ranged from linking with specialist Royal Colleges to working at an EU/global level to improve working practices, sharing training packages to improving Gas Distribution Network awareness and refining their own and the government's 'vulnerabilities/priorities registers'. Additional comments were also provided; these covered the three clear messages that resounded from all the sessions: the need for training and awareness amongst healthcare professionals, the need for research and the need for consensus.

Harnessing the actions from the report and from the feedback form will be important in ensuring that the energy and ambition shown during the workshop is not lost and that the agreed objectives are achieved.

The findings of the workshop indicate that a fairly small workshop attended by professionals from a range of disciplines, all with an interest in CO, is a good way to capture both the practical and research requirements to improve not only the medical management of CO poisoning but to develop good working practices. By involving both healthcare and industry professionals, achievable actions and opportunities for improvement could be suggested on account of the participants' in-depth knowledge on processes, as well as facilitating a holistic improvement in knowledge that could be instantly utilised.

A similar approach is needed to establish the management pathway amongst distinct health-care professionals to ensure that their specialities dovetail into the overall management system needed by the CO poisoned patient. However, a more formal approach and an agreed and recognised process would be required to develop national healthcare guidance and consensus to support the health-care sector in its delivery of optimal care for patients poisoned by CO.

Isabella Myers
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Independent Consultant



Executive Summary

Carbon monoxide can have adverse effects on health. This is clearly shown in the scientific literature; in the form of scientific research, case studies and, experiential reports. When considering the response to CO poisoning events, it is clear that there are many different healthcare professionals involved in the management of the victims of poisoning; there are many services that play an important role in prevention, diagnosis and treatment of those exposed. Acknowledging that poisoning by CO requires different professionals to work in the area of prevention, identification, treatment and follow-up, is important. Government responsibility is also broad and is reflected in the membership of the Cross-Government Group on Gas Safety and CO. The variety of stakeholders that constitute the membership of the All-Party Parliamentary CO Group's Stakeholder Forum draws further attention to the variety and number of professionals with a responsibility regarding CO. In responding to a CO incident, the involvement of a number of diversely skilled professionals is required to ensure that the patient is correctly managed, monitored, and discharged to a safe environment. Successful management of the CO exposed patient therefore requires professionals to work in a joined-up way regardless of workplace location and their currently distinct, reporting responsibilities.

Our understanding of CO poisoning is improving: we know that chronic exposure to lower levels of CO can affect health; studies also suggest that exposure to CO at levels that affect health is more common than previously thought. As the number of studies in the scientific literature are increasing, clear definitions around CO poisoning need to be made in order to enable the production of directly comparable data that will underpin the production of robust protocols.

This workshop was commissioned by the Gas Safety Trust to facilitate discussion of the medical management of CO poisoning. The workshop was intended to facilitate discussion to highlight areas where there is no formal guidance, to review management practices in the light of evolving clinical understanding and technological advances and, improve the working of the wider stakeholder group to ensure a joined- up and agreed patient pathway could eventually be developed. It was agreed that the workshop report should collate key discussion points and be used to develop fundamental items of work that would together facilitate a distinct improvement in the management, treatment and follow-up of the CO exposed patient, and by doing so, support the recommendation made in the All-Party Parliamentary CO Group's report³ that:

"The Healthcare and Academic community should together develop standard definitions for the different levels and durations of CO exposure; and achieve consensus on both the treatment protocols and the description of neurological sequelae. In order to improve the management of CO poisoning and health it's important that the research community produce directly comparable data".

However, without a correct diagnosis, the true prevalence of CO poisoning will not be understood. Diagnosing CO poisoning is notoriously difficult, given that the symptoms of carbon monoxide poisoning mimic those of other more common illnesses. A key requirement is for the healthcare professional to consider CO as a possible cause of ill health and to use a suitable biomarker to confirm the diagnosis. As there are a number of ways to assist the healthcare professional in making a correct diagnosis, these were explored as a series of presentations at the start of the day which also provided a foundation for each of the workshop sessions throughout the rest of the day.

³ APPCOG Carbon monoxide poisoning: saving lives, advancing treatment, 2017. www.PolicyConnect.org.uk

The first presentation provided the background to the workshop. This was followed by four scene setting lectures to:

- 1) **Understand the basic science on CO poisoning and bring attendees up to date on the progress made in assisting with a correct diagnosis from the field of toxicology:** the improvement in our understanding of what happens to the normal functioning of the body when exposed to CO; how more advanced techniques used in related fields of science can be applied to CO; how this understanding and use of the advanced techniques can improve diagnosis and treatment
- 2) **Apprise attendees of the equipment that is available for detecting CO in the indoor ambient environment:** the regulations pertaining to sensors; scenarios of their use; investigations into CO exposure situations and changes in guidance based on research evidence
- 3) **Understand how to use a breath analyser to assist in the diagnosis of CO poisoning:** the variations between analysers that are available for different patient groups and their use in different settings and patient scenarios
- 4) **Understand the role of the gas engineer:** to understand how the role of the engineer has developed and the training that they undertake to detect and prevent CO exposure; how gas appliances have been improved to prevent malfunction; how other industry sectors, personal / occupant behaviours and natural events can cause appliance malfunction and / or exposure to CO

Short discussion sessions followed each presentation and the information from these lectures was considered in the workshop sessions throughout the day.

The first workshop session considered the emergency services and the role of others in the response and diagnosis of CO poisoning.

The attendees in this session identified the many different professionals that are involved in the response and immediate diagnosis of CO poisoning; information gathering and sharing; knowledge gaps; and worker safety. In their consideration, they suggested pathways that needed to be developed to facilitate a joined-up approach to the response and identification of CO exposure.

Conclusions arising from the workshop:

- a) *There are a number of professionals that could be involved in identifying CO exposure in the home who are not currently incorporated into a joined-up healthcare reporting pathway*
- b) *There are a number of professionals who could use healthcare equipment and receive training in the identification of CO exposure in the home, who currently do not have access to or training in the use of such equipment*
- c) *There are professionals who are trained to use equipment to identify CO exposure, but who are not routinely equipped or trained at a national level*

General recommendations arising from the workshop:

- a) *E-Learning should be compulsory for all professionals identified*
- b) *Reporting pathways need to be developed across all stakeholder sectors*
- c) *An algorithm to assist different professions is required*
- d) *Alarm sounding or a positive health monitor reading should be regarded as a reliable indicator of exposure*

The second workshop session considered the Emergency Department. A short presentation was delivered to provide attendees with an understanding of the emergency environment and the roles and responsibilities of professionals working in this environment. This highlighted the difficulties in diagnosing CO in this environment. The attendees were then asked to consider diagnosis, treatment and follow-up of the patient from the moment the patient enters ED and to develop chains to confirm current practices and to highlight areas where there could be improvements.

Actions arising from the workshop:

- a) Heads of emergency departments should be contacted regarding the provision of CO awareness sessions to ED staff by the Gas Safe Register
- b) Incorporate CO information into local level triage notes
- c) Information regarding CO to be provided on discharge forms
- d) Develop standard protocols for optimum use of treatment with normobaric oxygen (NBO₂), particularly in light of known reperfusion injury
- e) Develop research regarding the use of HBOT in light of advances in our understanding of CO and improvements in research methods

The third workshop session considered CO exposure during pregnancy. A short presentation

was delivered to provide attendees with an understanding of the actions currently undertaken and the concerns being raised by midwives. The attendees were then asked to consider aspects that had a particular impact on the pregnant woman, their unborn child and their care. This included toxicology, diagnosis, treatment, patient care-pathways and gaps in knowledge and barriers to improvement.

General recommendation arising from this workshop:

- a) Midwives need protocols to work to and simple pathways for referral, and rapid and long-term response

Actions arising from the workshop:

- a) There is a need to establish how figures for CO poisoning in pregnant women can be collated
- b) A study to understand the scale of CO poisoning in pregnant women should be conducted
- c) The Priority Services Register and equivalent services run by gas, and other fuel industry stakeholders, should be scrutinised to establish how pregnant women are protected as a specific vulnerable group
- d) Consider referral methods between midwives and neurologists
- e) Information on CO needs to be provided for pregnant women





The fourth workshop considered the neurobehavioural impacts of CO poisoning.

Two short lectures were delivered: one that considered patients' experiences following CO poisoning and the other that considered how CO affected the brain and its similarities to other brain injuries. There followed discussion on the diagnosis, treatment type and potential pathways to help the patient in terms of neurobehavioural outcome.

General recommendations arising from this workshop:

- a) To develop a specialist referral clinic to treat and improve research into the neurobehavioural problems in CO exposed patients

Actions arising from this workshop:

- a) Make contact with the charity Headway
- b) Links should be made between relevant GST projects on the neurological effects of CO exposure

The day concluded with a discussion session that considered specific aspects of CO poisoning, noting that:

- a) the work to develop a persistent biomarker was of specific importance for healthcare professionals
- b) other fuel industry stakeholders must be involved in the work going forward
- c) consensus and pathway work should be developed within the UK, but taken forward at an EU/global level

More holistic discussion highlighted not only the important role of industry stakeholders and healthcare professionals in the prevention, diagnosis and treatment of CO exposure, but also deeper level enquiry as to the drivers that lead to actions that result in CO exposure:

- Poverty, tight budgets and fear of eviction were listed as primary drivers, that could make it difficult for customers or patients to act on professional advice
- It was suggested that this should be taken into consideration at every stage of a management pathway

Discussion also highlighted that indoor air pollution in the home is not sufficiently recognised as a contributor to ill health and that the actions and studies emanating from this workshop could go some way in helping to raise this broader issue amongst healthcare professionals:

- a) it was suggested that discussions should be held with the NICE Indoor Air Pollution Group and other groups currently working on indoor air pollution and health

Introduction

The scientific literature clearly shows that exposure to CO can have adverse effects on health. It is therefore important for healthcare professionals to be able to correctly diagnose CO poisoning, and to provide the correct treatment to minimise adverse effects on health. It is also important for the healthcare professional to be reassured that the patient will not be returning to an environment where poisoning can re-occur. However, the fact that the symptoms of CO poisoning mimic those of other more common conditions can lead to misdiagnoses. Diagnosis of poisoning from lower levels of CO can be easily missed altogether. Therefore, involving other professionals who would be able to assist in the provision of information regarding possible poisoning incidents and in the protection of the patient, is important.

Studies of CO exposure in dwellings, statistics on faulty appliances and calls to helplines regarding suspected exposures, all suggest that exposures to CO are more common than previously thought, but it is unknown how many exposures go unreported. For the healthcare professional, if CO exposure is suspected and carboxyhaemoglobin (COHb) levels measured, it remains difficult to interpret what the different levels of COHb (and exposure levels and duration of exposure) mean for health. In the scientific literature, comparing data has been difficult as there are no clear and accepted definitions for 'high' or 'low' exposure levels.

Knowing what concentrations and durations of exposure to CO have on health is key to the provision of optimum care for the exposed patient, particularly as the science develops. This is becoming especially pertinent when considering the long-term neurological sequelae associated with CO exposure and also exposure of the pregnant woman and her unborn child. Investigations into these areas are currently considered of importance in light of the impact the effects of CO has on the neurological system and because of the importance of fetal health and its particular vulnerability regarding CO exposure; neonatal health and that of the mother. UK Government policies are highlighting the importance of maternal and child health as part of the drive to improve lifelong health and wellbeing and public health over the long-term, with a particular focus on factors associated with non-communicable diseases and preventable incidents such as accidental CO poisoning.

In recognising the implications of healthcare professionals missing cases of CO poisoning, the role that other professionals could have in improving aspects of the patient pathway to ensure optimum treatment and a return to health, and in the prevention of further exposure, the Gas Safety Trust (GST) have extended their series of workshops to develop work on diagnosis and treatment of CO poisoning. They commissioned a workshop to improve the approach to diagnosing CO poisoning, optimising treatment and providing a foundation on which to build consensus on the diagnosis and management of CO poisoned patients, and identify and prioritise key research gaps. Engaging professionals with expertise within the field of CO, but who were not healthcare professionals, was a key step forward in developing a holistic approach to patient management.

This report is a summary of the workshop that described and then discussed the development of practices around diagnosis and management of CO poisoning, taking into account the diverse but important roles basic scientific research and industry professionals play in assisting healthcare professionals, in improving scientific understanding and thus the improvement of diagnosis, treatment and patient care-pathways.

The day started with presentations that provided a broad overview of the situation. These were referred to throughout the facilitated workshop sessions that focused on four broad areas: roles and responsibilities of professionals; the Emergency Department (ED); CO in pregnancy; and neurological outcome. These workshop sessions were introduced by lectures related to the workshop specialty.



1

The Workshop

1.1. Workshop aim

The main aim of the day was to map the current patient pathway regarding a response to a CO exposure incident, to then raise questions about that response, generate discussion and highlight gaps in the current understanding of the problem, and to identify challenges and clear steps to improve the patient-care pathway.

Proposals for different types of investigative research and the involvement of non-healthcare professionals were considered throughout the day with the aim of discussion being to:

- Contribute ideas and actions to facilitate the development of a document that improves the patient care-pathway
- Contribute ideas and actions to facilitate the development of a document that improves multi-disciplinary and joined -up working practices
- Improve the management of CO poisoned patients both in the short term and long term
- Highlight gaps in research and professional knowledge
- Facilitate an improvement in knowledge amongst different professionals involved in the prevention and treatment of CO exposure
- Understand the drivers and pressures that challenge patients

and

- Seek to identify and develop actions to overcome barriers to an improved system.

In doing so, attendees:

- Considered methods from translational research
- Discussed technological advances that have improved and could further improve an understanding of the effects of CO
- Investigated the use such technological advances to improve qualitative and where possible quantitative approaches to measure the effects of CO
- Highlighted the importance of new biomarkers
- Explored the neurological effects of CO
- Explored the implications of fetal exposure on lifelong health and wellbeing and on the health of the mother

1.2. Event attendance and programme

The workshop was held on the 27th November in London 2018 with 28 attendees on the day.

Isabella Myers opened the workshop, welcoming attendees and providing some opening words.

Dr Oliver Sykes then gave an introductory presentation.

The day consisted of four short presentations that provided a broad understanding of CO, technology, and appliances, each of which were followed by a short question and answer session. There then followed four workshop sessions. Each presentation was preceded by a scene setting, experiential and evidence-based presentation. The workshop sessions focussed on: the roles and responsibilities of different professionals in the response, diagnosis, treatment, follow-up and fatalities associated with CO poisoning events; the emergency department pathway; CO in pregnancy; and neurological outcome. The day concluded with a discussion of research gaps and actions that could be taken. Attendees provided further feedback and suggestions via a feedback form (Appendix 3).



2

Welcome and Introduction to the Workshop

The workshop was opened, attendees were welcomed and the funders, GST, thanked for their support of such an important event. It was noted that their support recognised an understanding of the problems being faced by

the healthcare and basic science community in improving the diagnosis and treatment of people exposed to CO. Attendees were informed that the discussion throughout the day would be conducted under Chatham House Rules.



3

Setting the Scene: Background to the workshop

Dr Oliver Sykes (University College Hospital): gave an address that highlighted how the work that he and colleagues had been involved with regarding CO poisoning had developed over the years. However, he revealed that they were increasingly coming across barriers: problems that made progression in specific directions unsatisfactory or impossible, or that raised currently unanswerable questions. In trying to overcome some of these problems he had become aware of some important considerations:

- *Accidental poisoning by CO is considered rare in that the field of CO touches many different professions*
- *That it plays only a small part within many different jobs*
- *That collectively, CO poisoning is a large problem*

and stressed that these factors meant that a co-ordinated effort is urgently required.

Oliver also highlighted another significant issue: definitions of CO poisoning have, historically, included fatal, near fatal or clearly symptomatic poisoning events, with a focus on higher levels of exposure. However, with the scientific literature now showing evidence of effects on health at lower levels than previously considered, definitions relating to poisoning, diagnosis, survival and the long-term consequences of exposure needed to be revised and clear endpoints determined. This would enable comparable scientific research to progress and provide the evidence for continued funding to enable the problem to be tackled. In turn, this would assist healthcare professionals in their diagnosis and treatment of the CO poisoned patient.

In considering treatment, this too had changed. Treatment of CO poisoning is now no longer purely about ensuring survival of the patient: it is about optimising long-term health and wellbeing. The list of health problems associated with exposure to CO is large and varied and, in some cases, poorly defined or understood making the management of patients difficult.

Oliver apprised attendees of the change in treatment options in the UK: hyperbaric oxygen therapy (HBOT) is being removed as a treatment for CO poisoning. Conversely, in other countries, it is a first line of treatment for those exposed to high levels of CO. This has reignited questions, debate and scientific interest relating to the proven efficacy of HBOT and has in parallel, raised questions about the evidence behind the provision of normobaric oxygen (oxygen at atmospheric pressure): for which we have no standard guidelines.

It was noted that the issues raised regarding our understanding of CO are not specific to the UK and, in light of this, an international CO research network (ICORN) had been developed to tackle the issue of CO poisoning at a global level. Oliver noted the need for a review of the literature, to collate answers, raise the importance of areas where there is little, or inconclusive, research to provide the evidence that will clearly show how the problems he and his colleagues are experiencing are preventing an improvement in the health of those exposed to CO.

Oliver concluded by making a call for the need to start the process to develop consensus on CO. He indicated that discussion from this event would improve our understanding of the scope of such work. He hoped that by trying to define the unanswered questions and by highlighting areas where changes could be made to assist healthcare professionals in their diagnosis, treatment and follow-up of patients, the UK would be able to lead a global effort in the improvement in both research, and in the medical management of CO poisoning.



Overview

4.1. Toxicology

Robert Dickinson (Imperial College): gave a presentation which ensured that attendees had a basic understanding of CO, how it is produced, sources, known mechanisms of action and figures on deaths and recorded non-fatal exposures.

He emphasised the need for basic and clinical research. Such research would provide the scientific evidence-base that would support healthcare professionals in diagnosing and treating cases of CO exposure. Without such evidence, diagnosis and treatment would not improve. He highlighted some aspects of CO that remained unanswered or poorly understood and which required more immediate attention:

- *We need to know and understand what are the health effects of repeated low-level exposure to CO*
- *In the setting of guidelines, we need to be able to move away from extrapolating from high- level effects in an attempt to improve understanding of low-level effects*
- *As CO poisoning affects the brain, the heart, other organs and the gut, the effect of CO poisoning on these distinct areas of the body must be specifically addressed*
- *Normobaric oxygen and HBOT are currently the only treatments available⁴ for CO poisoning and research is required to define the role that each plays as a treatment option*

Robert described various methods of both qualitative and quantitative assessment that were routinely used in the scientific assessment of behavioural outcomes. Whilst these were more usually associated with other illnesses, he showed how he had successfully applied these methods to his pre-clinical work on CO and also traumatic brain injury.

The application of these methods highlighted the value of pre-clinical basic research and illustrated how CO had been a neglected area of study, given the recognised methodologies that could now be easily applied to the investigation of the toxicological effects of this gas. Robert demonstrated how his work assisted in the interpretation of findings that could be directly attributed to the effects of exposure to CO.

He noted two important aspects that highlighted the value of pre-clinical basic research studies in this field: the precision attained in every aspect associated with such work, including defined concentrations of CO. This meant that the translation of results to a more holistic understanding of behavioural outcomes that could also be supported by histological evidence, was now achievable.

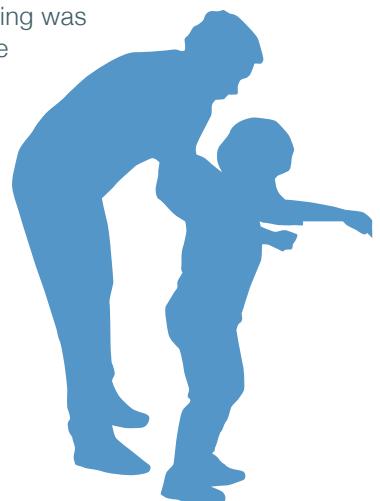
He described the functional evaluation processes that could be used in similar work on CO and described a method used in the detection and evaluation of memory loss associated with the hippocampus. He showed examples of gait analysis to highlight locomotor deficits (e.g. locomotion speed) and motor co-ordination (e.g. placing of limbs); the use of imaging analysis to reveal brain cell injury and the effects that brain injury can have on long-term survival. Examples were shown in the presentation of published and unpublished work.

Robert highlighted the need for making a mechanistic connection between low-level exposure and neurological impairment and in making the work translational to humans.

Robert concluded that it was currently possible to:

- Evaluate novel treatments for CO
- Find biomarkers relevant to humans
- Establish an optimum paradigm for treatments
- Simulate real life scenarios (e.g. exposure scenarios based on activities)
- Quantify the effects

but recognised that funding was required to undertake the work. Robert finished by acknowledging GST in the support of the work he is currently undertaking on CO.



⁴ Note: NHS England is withdrawing HBOT as a treatment for CO poisoning in England.

4.2. Diagnostic equipment

Leigh Greenham (CoGDEM): gave a synopsis of the different sensing equipment available to detect the presence of CO in patients, indoor air and in emissions from fuel burning appliances. He explained the role of the Council of Gas Detection and Environmental Monitors (CoGDEM) in writing standards for monitoring equipment in environments ranging from domestic boats to large offshore industrial gas and oil refineries and platforms.

Information was provided on three devices used in the healthcare setting. He highlighted how the breath analyser worked making it a useful, non-invasive form of testing in healthcare and non-healthcare settings and for screening purposes. From a standards perspective, it was noted that the makers of the Bedfont® device had applied for USA FDA 510(k) approval (see talk below for further detail on this device) to show that their device now being marketed in the USA is at least as safe and effective as a substantially equivalent legally marketed device.

The CO-pulse oximeter was another non-invasive device available to healthcare professionals. It measured blood CO levels via a sensor applied to the finger-tip of the patient. It was noted that this device was indicated as a screening tool and that to confirm a diagnosis it should be used in conjunction with blood gas analysis. The capacity of this device to accurately detect lower levels of CO exposure and thus pick up chronic low-level CO exposure, was noted as having been queried.

Blood gas analysis for confirmation of CO exposure was noted as the standard method used to confirm CO exposure in hospitals in the UK. However, this requires blood to be drawn. Leigh highlighted the use of the Avoximeter®4000, a portable blood gas analyser used in some countries in Europe, a device brought to his attention at a discussion on CO held in the EU Parliament (Nov. 2018). The advantage of this device was that blood could be analysed at the point of care.

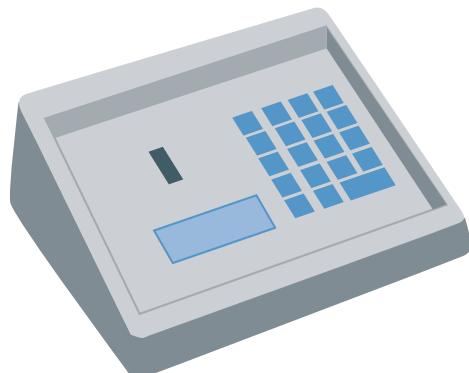
In his presentation on alarms, Leigh explained that CO alarms were designed to alert occupants to an immediate danger that could escalate into a fatal CO exposure situation.

The BS 50291 standards for CO alarm thresholds were given:

CO level ppm	CO test level
<30 ppm – no alarm	(tested with 33 ppm +/- 3 ppm for 120 mins)
50 ppm – must alarm between 60 & 90 mins	(tested with 55 ppm +/- 5 ppm)
100 ppm – must alarm between 10 & 40 mins	(tested with 110 ppm +/- 10 ppm)
300 ppm – must alarm before 3 minutes	(tested with 330 ppm +/- 30 ppm)

Innovations had been made in the design and development of alarms. The features introduced included: low concentration indication—introduced as the evidence on the health effects of longer term exposure to lower levels of CO became clearer; warning displays – to improve occupant awareness of actions to take on alarm sounding; wireless communications and internet record keeping – to improve monitoring; internal data logging – for manufacturers to keep a record of alarm and sensor functioning. Development in alarm design included those used specifically for travel purposes; combined smoke and CO alarms and those designed for monitoring voids in buildings.

Leigh noted how industry had responded to emerging scientific evidence on low-level exposure by developing ‘health’ monitors specifically designed to detect, display and alarm at levels of CO of either 25ppm or 10ppm found in the indoor environment. He noted that there were monitors available in Canada that were able to measure levels of CO down to 5ppm.



CO data loggers were available for use in research. They came in a USB stick format, making the recorded data easily downloadable for analysis. They had a programmable logging period ranging from every 10 seconds to every 5 minutes and ranges of detection from 0-1000ppm or 0-300ppm. The data loggers could store 32,000readings. He noted that, as research instruments, they were fairly low-cost. Leigh demonstrated how these loggers had been used in research into CO exposure in houseboats, work with which he had been involved. He illustrated how unobtrusive the devices were and how the results could be clearly interpreted from graphs produced from the data.

Personal, industrial grade CO detectors were now recognised as an important part of Personal Protective Equipment (PPE) for professionals who might find themselves in situations where CO is present. Leigh noted their use by all Gas Network First Call Operatives, but only some Ambulance response teams and Fire and Rescue Service home

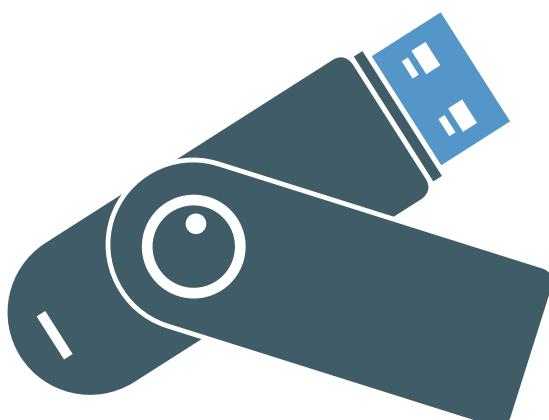
safety check teams. Leigh noted that the importance of such protection being given to workers who enter people's homes was beginning to be acknowledged. These instruments tended to be small, fixed to a lapel and had some datalogging capacity. The devices were battery sealed and had a working life of one or two years. These too were considered inexpensive.

Another example of PPE was the Blackline Safety 'G7', a CO (and other gas) detector that had additional features to ensure not only worker safety, but also monitored the worker's physical and mental status (fall and no-motion checks) and provided two-way voice and text messaging. It also ensured rescue of workers by using multiple location software that utilised GPS and indoor location beacons. It could automatically alert response teams if the worker did not respond or if the no-motion sensor was activated.

Finally, Leigh updated attendees on the developments in European and British Standards regarding the use (including training) and specification of flue gas analysers (FGA). These are shown below:

Standard / Training	Date of implementation / publication (where applicable)
EN 50379	2012 (performance and testing of FGA products, updated)
BS 7967	(for the use of FGAs)
TS 50612	2013 (first EU guidance document, led by UK)
CPA1 mandatory in UK	2012
CMDDA1 option	2013
Mandatory measurement of the combustion performance of new gas boiler installations	2014

CO alarms with accumulative exposure level features were now available making the work presented and future work discussed, important for the improvement of research and the development of policy.



4.3. Breath analysers

Karl Kolodziejcyk (Proact Medical Ltd): apprised attendees of the new generation of breath analysers that Bedfont® produce specifically for the detection of CO exposure in patients. The ToxCO® had a number of features that were considered beneficial for its use as a screening tool, including:

- *Being quick, easy & non-invasive*
- *Face mask testing for children & unconscious patients*
- *Fully interactive colour touchscreen*

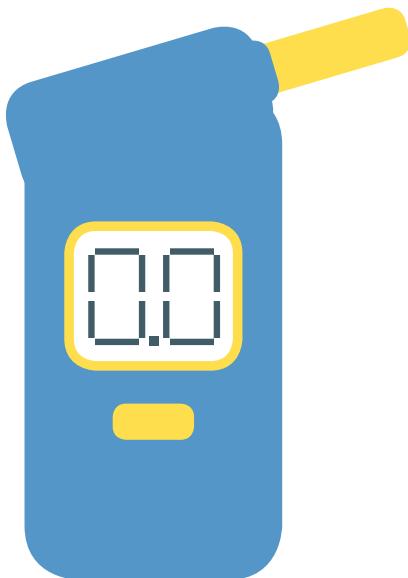
making it ideal for use by emergency services, first responders, GPs and for mass casualty triage.

The different sampling modes were explained to indicate how the analyser could be used in different screening situations: using a mouthpiece for routine or mass screening; using a facemask for unconscious, compromised or child patients and ambient monitoring used for safeguarding during responses to incidents.

It was noted that 1,000 readings could be saved on the device which highlighted the value of the ToxCO® as a triage device during mass casualty situations.

Karl apprised attendees of three studies that had used the ToxCO® in different scenarios: a fire brigade study, an ambulance study and a mass casualty triage study. In all three studies, the advantages of using the ToxCO® were acknowledged.

A video was played that showed attendees how the device was used.



4.4. The Engineer

David Bendle (British Gas): explained the role of the engineer and the responsibilities that the gas supplier has in the investigation of CO incidents reported to the Health and Safety Executive (HSE) in accordance with the Gas Safety (Management) Regulations.

He outlined the four basic tests that have to be performed regarding gas appliances:

- *Flue inspection*
- *Ventilation inspection*
- *Gas pressure and consumption*
- *Confirmation of safe operation*

and explained that the engineer must also undertake an analysis of any risk.

When considering the causes of CO spillage into a room, there are four main causes:

- *An open flued and/or its associated appliance is malfunctioning*
- *Poor installation*
- *Lack of servicing*
- *Inappropriate operator behaviour*

David highlighted how appliance design had developed, noting an inherent design problem in older open flue appliances, that could still be found being used in homes in the UK. Their design takes air for combustion from the room in which the appliance is located before burning it and discharging it safely to the outside atmosphere via the flue. However, any defects with the ventilation, flue or appliance means the combustion products have direct access into the room. Modern appliance design has changed with appliances either becoming:

- *Room sealed (sealing the appliance from the room it which it is located ensuring that air is drawn from outside the property and that the appliance vents to outdoor air)*
- *Or a sensing device is fitted to open flues which turns the appliance off if spillage of combustion products is detected*

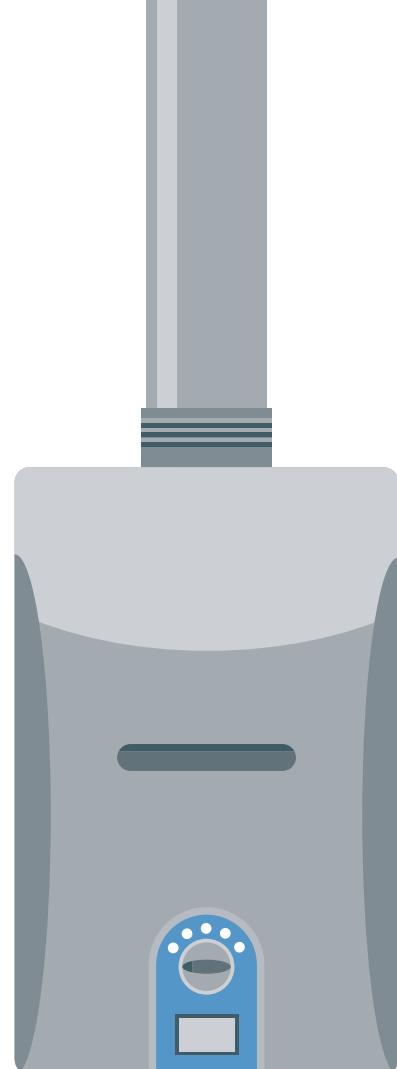
David outlined a number of situations and shared case studies to highlight causes of an appliance or flue malfunction resulting in CO exposure:

- *Wind direction across the top of a flue/ poor flue positioning preventing sufficient venting in non-room sealed appliances*
- *Nesting birds / snow / debris blocking the flue in non-room- sealed appliances*
- *Inappropriate building work leading to poor flue positioning, height or direct venting into the indoor environment*
- *Inappropriate flue work e.g. multiple bends leading to flue failure*

These latter two points highlighted a lack of understanding and awareness of the consequences of engineer / building work in relation to gas.

David noted that occupant behaviour impacted on the normal functioning of an appliance. Attendees were shown how irregular servicing can prevent exhaust gases from escaping safely to the outdoor air and instead, being released indoors. Case studies highlighting improper use of appliances were also shown. Flues should always be considered as a functioning part of the appliance.

David highlighted throughout his presentation that the proper use of gas is safe and should enhance health by providing warmth and a means of cooking food. Problems are more likely to occur when appliances are improperly installed, maintained, used or if inappropriate changes are made to the surrounding area or flue.



5 Workshops

5.1. Roles and responsibilities

This workshop was designed to facilitate discussion on the roles and responsibilities that professionals currently have regarding a pre-hospital response to an incident of CO exposure. The workshop was intended to identify responders and suggest possible pathways for information provision to facilitate a correct diagnosis within a primary or secondary healthcare setting.

By combining the information provided in the recent presentations with points raised by attendees, questions were asked by the facilitator to develop discussion of specific response pathways. These were developed once a professional, who was in a position to suspect or confirm CO exposure in a pre-hospital setting, had been identified. The facilitator then posed further questions to establish how novel pathways could be implemented, by drawing upon the knowledge of attendees as to the requirements that might influence their success or failure.

The home was considered as the environment in which the source of the exposure would be identified. Attendees were asked to identify professionals that were likely to enter that environment and be able to identify signs within the home and/or symptoms in the occupant that could indicate that CO exposure could have been, or was possibly still, occurring:

- *Twelve professionals were identified as having the capacity to identify CO exposure in the home environment. The health of other occupants, for example family members, and the behaviour of household pets were also considered important in the identification of exposures*
- *It was noted that whilst these professionals had access to the home, many were neither equipped with, nor were trained to use, diagnostic equipment. Those with equipment and who had been trained to use it included: London Ambulance Service staff; Midwives; some Fire and Rescue Services staff and Gas Engineers*
- *The development of pathways was discussed. It was quickly realised that each of the professionals identified as being able to raise suspicion or confirm exposure would have to initiate a referral pathway within their own sector, but should in collaboration with other sectors, explore how the pathway would be advanced*

Conclusions arising from the workshop:

- a) There are a number of professionals that could be involved in identifying CO exposure in the home who are not currently incorporated into a joined-up healthcare reporting pathway*
- b) There are a number of professionals who could use healthcare equipment and receive training in the identification of CO exposure in the home, who currently do not have access to, or training in the use of such equipment*
- c) There are professionals who are trained to use equipment to identify CO exposure, but they are not routinely equipped or trained at a national level*

General recommendations arising from the workshop:

- a) E-Learning should be compulsory for all professionals identified*
- b) Reporting pathways need to be developed across all stakeholder sectors*
- c) An algorithm to assist different professions is required*
- d) Alarm sounding or positive health monitor reading should be regarded as a reliable indicator of exposure*



5.2. The emergency department pathway

Mushahid Raza (Frimley Park Hospital NHS Trust):

provided an overview that highlighted the difficulties encountered in the Emergency Department setting when considering a diagnosis of CO poisoning. In particular, he highlighted a number of factors that made the diagnosis of CO difficult:

- *The emergency department is a very busy environment*
- *As the clinical presentation of CO poisoning is non-specific and highly variable, this can lead to misdiagnosis*
- *The time-sensitivity associated with diagnosing CO poisoning: a delay in the triage process increases the risk of obtaining a “false negative” %COHb*
- *A normal %COHb does not rule out CO exposure*
- *An abnormal %COHb doesn't give information of the source of CO, or an indication of the patient's prognosis*

Case studies were provided as examples of how difficult diagnosing CO poisoning could be, based on the different presentations of patients.

The important role of the pre-hospital provider in assisting with a correct diagnosis was reiterated, and the significance of the information made available to emergency department professionals was explained. Questions that should be asked included:

- *Where was the patient found and under what circumstances?*
- *Was there evidence of combustion or abnormal odours/fumes indicating a burning process or presence of toxins?*
- *Was there a clear evidence of CO exposure?*
- *Was there loss of consciousness?*
- *Was a pre-hospital ECG performed?*
- *Was there evidence of attempted self-harm or suicidal intent?*
- *Were there other people in the vicinity?*
- *Was empiric treatment with oxygen given en-route to ED?*

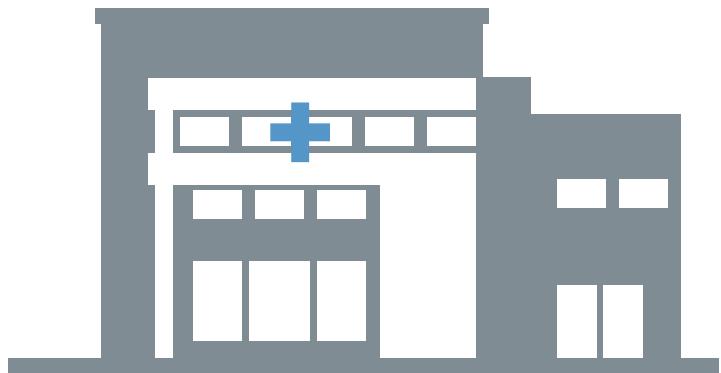
Mushahid mentioned that cherry pink skin is rarely seen in the emergency department as it is indicated only in patients who are very severely poisoned or are deceased. He also stressed that cherry pink skin is not always present even in these extreme cases.

The seriousness of missing a diagnosis of CO poisoning was made clear, and included:

- *Returning patients to an unsafe environment can be lethal*
- *Patients are at risk of Delayed Neuropsychological Sequelae (DNS)*
 - ◆ *Patients can develop disorientation; cognitive difficulties including effects on judgement, on memory and on concentration*

Mushahid suggested that we need to:

- *Accurately explore the extent of the problem*
- *Raise awareness and increase training of both medical and paramedical staff*
- *Improve and make history taking more specific (e.g. PHE - COMA acronym) to patients presenting with non-specific complaints*
- *Explore the use of non-invasive CO monitors as they are better tolerated and quicker/easier to use on patients*
- *Develop robust clinical algorithms for the management of CO exposure*
- *Develop the role of public health investigators in order to reduce the risk to other members of the public*



5.3. Emergency department workshop

Attendees were guided through aspects of the presentation to develop discussion and ways forward in the diagnosis and treatment of CO poisoned patients. Discussion started with how to improve CO awareness in a busy ED. It was noted that there are a number of initiatives that could be implemented that would assist in improving awareness amongst ED professionals. There was discussion regarding the development of e-learning initiatives, seminars, as well as the development of protocols on the management of CO exposure and discharge information that improved patient follow-up. It was noted that many of these suggestions would need to be taken forward at a local level and some initiatives would require collaboration with other healthcare professionals, particularly in light of reporting mechanisms. It was highlighted that the Gas Safe Register held a Gas Awareness Week that would play a part in informing healthcare professionals about gas safety and CO awareness as part of their reach to the general population. However, a targeted approach had not been previously considered. There was appetite amongst attendees for the Gas Safe Register to target healthcare professionals in the ED by providing awareness sessions within the hospital environment. It was suggested that by starting with one of the hospitals involved in the EDCO study, this would facilitate feedback based on current ED professionals' experiences. ***This idea will be taken forward.***

It was agreed that to facilitate an improvement in the diagnosis of CO poisoning in the ED environment, there had to be an increase in suspicion amongst all staff. Whilst improving awareness was important, triage nurses were considered to play a key part in this process due to their role in initial patient management and in the light of information they received during the handover of patients from paramedics to hospital staff. It was suggested that this process could be facilitated by including CO in local level triage notes.

It was agreed that the National Poisons Information Service and TOXBASE® provided an essential service to healthcare professionals regarding the treatment of CO poisoning once poisoning had been suspected / identified. However, this prompted discussion on treatment with normobaric oxygen in light of HBOT being removed as a treatment for CO poisoning in England. A number of questions were raised that could not be answered regarding the provision of 100% oxygen – for how long should oxygen be provided? Should treatment be repeated? For how long should 100% oxygen be given to a pregnant woman? It was concluded that a standard protocol for oxygen provision, underpinned by sound scientific evidence, was required.

Discussion of treatment was extended to HBOT. It was noted whilst there was very clear guidance and protocols attached to the use of HBOT as a treatment for CO poisoning, it was the lack of scientific evidence that it was of greater efficacy than normobaric oxygen therapy that was contentious. Whilst it was agreed that the workshop was not the place to debate treatment options there were some important points raised. It was agreed that HBOT despite also a lack of randomised controlled trials, would seem to accelerate the excretion of CO (as does normobaric oxygen, but several times more quickly) and that tissue hypoxia can be quickly reversed using HBOT. However, with regards to the effect of HBOT on long-term neurological outcome, where such trials have been attempted, the scientific evidence is weak in showing an effect. It was proposed that the HBOT community should consider developing studies to answer the questions now being raised regarding the usefulness of HBOT and when and where it might be best indicated for use in those with CO poisoning, with particular focus on those who were vulnerable such as the pregnant woman, neurological deficit or cardiac ischaemia. It was agreed that this was an area where the use of animal models could again prove very useful in advancing our knowledge.

Referral pathways were discussed. Being able to grade the level of poisoning would be useful and it was here that the importance of a new, persistent, biomarker was again raised.

It was noted that there was information from the USA and the EU in the form of case studies, information from poisons centres and from country specific polices that should be incorporated into the discussion of the treatment and management of CO poisoning.

Actions arising from the workshop:

- a) Heads of emergency departments should be contacted regarding the provision of CO awareness session to ED staff by Gas Safe Register
- b) Incorporate CO information into local level triage notes
- c) Information regarding CO to be provided on discharge forms
- d) Develop standard protocols for optimum use of treatment with normobaric oxygen (NBO₂), particularly in light of known reperfusion injury
- e) Develop research regarding the use of HBOT in light of advances in our understanding of CO and improvements in research methods

5.4. CO in pregnancy

Hilary Wareing (IPIP): stressed the importance of a healthy pregnancy for both the unborn child and the mother and explained how pregnancy heavily influenced the health and safety of the mother and child in the neonatal stage and beyond.

Hilary emphasised the importance of babies being born alive and healthy, both of which could be compromised by exposure to CO in the womb. The scientific evidence clearly showed that CO poisoning could cause:

- *Fetal and neonatal death*
- *Congenital malformations*
- *Neurological problems*

Hilary informed attendees that every pregnant woman is screened for exposure to CO: this identifies smokers and those exposed to higher than expected levels of CO in the environment.

Whilst the risks to the unborn child of exposure to high levels of CO are well documented, less is understood regarding the effects of chronic low-level exposures. She raised the concern being expressed by midwives that these lower levels of exposure were being identified in pregnant women during their CO screening session. This has raised questions amongst midwifery teams regarding:

- *What the levels mean for the health of the woman and the unborn baby*
- *What action should be taken and by whom*

Raising such questions had highlighted gaps in understanding, advice and referral pathways. Whilst local protocols and information disseminated during training had helped, appropriate and properly tested interventions that could be rolled out at a national level have not been developed. It was emphasised that midwives required clear guidance on the management of CO poisoning during pregnancy.

Hilary expressed concern that the results from routine testing were only able to highlight that pregnant women are exposed to environmental CO. She stated that discussion was urgently required on how to better protect women and their unborn child from CO exposure.

However, information for pregnant women had been developed and the ‘Test your breath’ information card, developed by the Smoking in Pregnancy Challenge Group was now available in maternity packs for women. This discussed the dangers of exposure to CO during pregnancy from different sources.

In noting the different sources of CO, Hilary highlighted how important it was that women should, after this screening and eventually with their babies, return to a fuel-safe home. Whilst this was not the responsibility of the midwife, it supported the need for the development of a referral pathway. This would have to be developed in collaboration with different stakeholders. Hilary noted that there were schemes to ensure fuel safety for those considered vulnerable, but here she raised another issue: that pregnant women are not considered vulnerable under these schemes, despite pregnancy being considered to be a vulnerable state by toxicologists and clinicians. She also emphasised that there are many pregnant women who are particularly vulnerable based on socioeconomic factors and many who could not afford CO alarms.

Hilary concluded that there was overriding concern in maternity professionals that we are not being cautious enough when it comes to pregnant women and CO poisoning. As yet, there were no official recordings being made to understand the scale of environmental CO poisoning in pregnancy and in addition to this, there were barriers to the identification of CO despite a healthcare sector commitment to routine testing. Addressing these issues was urgently required.



5.5 CO and pregnancy workshop

Attendees were surprised that there were no statistics available that could provide an indication of the prevalence of CO exposure in pregnant women. It was suggested that this needed to be discussed with the hospital trusts.

It was suggested that information collected on CO by midwives at the first booking could feed into national health information, such as the Health Survey for England.

A call was made for a study of pregnant women that would provide data, similar to that provided by the screening study being undertaken by St. George's Hospital, London. Initially, this would provide important regional information and an indication of the size of the problem. The potential to extrapolate the prevalence of exposure to a national level, to stimulate dedicated action and awareness across healthcare, social, housing and government sectors as well as industry was noted.

It was acknowledged that there were a number of schemes available to assist those who might be considered at risk from both fuel poverty and CO poisoning, but that these schemes did not consider pregnancy as a vulnerable state and therefore was not regarded as an inclusion factor for the schemes available. It was noted that part of the problem with pregnancy being considered as a vulnerable state was that pregnancy was only considered a 'transient vulnerability' and therefore schemes needed to establish how to manage this. Following discussion on how to improve the protection of pregnant women, it was agreed that these 'vulnerable persons' schemes:

- 1) *Needed to be more deeply investigated to establish how schemes such as the Priority Services Register and others, could truly help pregnant women*
- 2) *Did not address the real need to protect all pregnant women as a vulnerable group and that a comprehensive solution was required*

It was highlighted that service engineers and the fire and rescue services could refer 'vulnerable' customers and that this should be taken into consideration when developing management pathways.

Attendees were concerned that there was an absence of evidence relating to the treatment of pregnant women with normobaric oxygen. Given that this would soon be the only treatment option available, it was considered imperative that standards addressing pregnant women were developed. This would require consensus on concentrations and durations of treatment, based on

scientific evidence, given the greater affinity of fetal blood for CO than that of the mother.

There followed discussion on the mental health of pregnant women who have been exposed to CO. Concern for the mental wellbeing of the pregnant woman was considered in light of two scenarios: a confirmed exposure that had results in neurobehavioural changes in the pregnant woman; and/or mental wellbeing due to concern for the health of their unborn child. It was agreed that CO exposure in pregnant woman should encourage a working relationship between neurologists and midwives. This highlighted the need for protocols on the testing of women and pathways regarding referral. It was noted that the provision of information on CO poisoning aimed at pregnant women needed to be carefully written and for access to knowledgeable support services to be available.

It was noted that midwives required improved information and support regarding the levels of CO produced in exhaled breath: the implications of concentrations blown and readings from different breath monitoring devices needed to be understood by both midwives and pregnant women. It was mentioned that readings were not standardised across different devices. Variations could be found, for example in graduations or in the number of lights that might be triggered during a test. As an example, women might report "blowing a level 2", the meaning of which would vary depending on the device used and could refer to the number of lights that lit up on the device rather than a standard reading.

General recommendations arising from this workshop:

- a) *Midwives need protocols to work to and simple pathways for referral, and rapid and long-term response*

Actions arising from the workshop:

- a) *There is a need to establish how figures for CO poisoning in pregnant women can be collated*
- b) *A study to understand the scale of CO poisoning in pregnant women should be conducted*
- c) *The Priority Services Register and equivalent services run by gas and other fuel industry stakeholders should be scrutinised to establish how pregnant women are protected as a specific vulnerable group*
- d) *Consider referral methods between midwives and neurologists*
- e) *Information on CO needs to be provided for pregnant women*

5.6. Neurological outcome

Julie Connolly (Liverpool John Moores University):

summarised the work that she had been undertaking, considering and examining experiential case studies of people who had suffered from, and were living with, the effects of CO poisoning. She outlined the variety of symptoms and long-lasting effects that CO poisoning had on her patients; effects that were still present and had in some cases affected wider members of the family.

Examples of symptoms and long-lasting effects:

- Fatigue/exhaustion/weakness
- Vomiting/nausea
- Depression/suicidal thoughts
- Aggression/behaviour changes
- Incontinence
- Hearing acuity
- Changes in cognitive ability
- Headache
- Breathing problems/'chest infection'
- Attention deficit
- Confusion/delusion
- Inability to tolerate bright lights
- Memory deficit
- Anxiety/agitation

Pertinent to the discussion were the descriptions of the interactions that her patients had had with healthcare professionals. Julie described situations where a lack of awareness had contributed to patient suffering.

Examples of experiences when in contact with a healthcare professional:

- Not being believed
- Lack of [professional] knowledge
- [Perceived professionals'] Hierarchy of knowledge
- The sick role
- Social services involvement
- Onus on person to provide 'proof' of poisoning
- [Mis] Diagnoses: Fibromyalgia, Chronic Fatigue Syndrome, ME, mental health problems

[] – added by report author

Examples of responses given by healthcare professionals to patients (some paraphrased):

- 'We don't know what to do with you'
- 'There is no such thing as chronic CO poisoning recognised by the NHS'
- 'Shouldn't you be in hospital, if you were really ill?'
- Labelling: 'all in your mind' 'mad and annoying' 'reading too much on the internet' 'there is nothing physically wrong with this woman'
- 'They treated me like dirt'
- 'You can't be ill; you don't have enough CO in your blood'
- 'If you haven't had nausea/vomiting/headache then it can't be CO poisoning'
- 'You're just in no man's land'
- 'This isn't serious enough'
- 'If it is CO, you'll be fine in 60 days'
- 'Do other people get this?'

It was noted that with sometimes such vague symptoms as 'feeling rotten' and 'memory deficits', it was important that these were phrases added to the list of symptoms on the NHS website to help with professional recognition. The absence of such phrases and training had left many of her patients not being believed.

The support given to patients by charities was noted and praised.

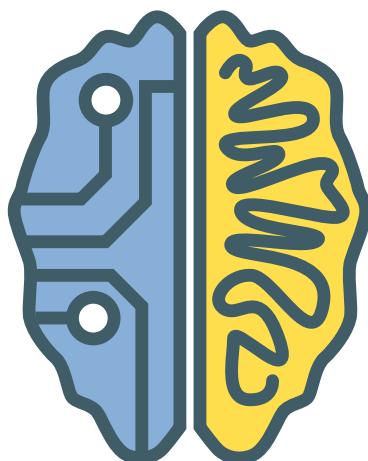


Steve White (Cromwell Hospital): Steve described the 'neurobehavioural sequelae of carbon monoxide exposure' and suggested that it should be considered as an acquired brain injury (ABI). He described the difficulties in assessing long-term neurobehavioural outcomes from exposure and referred to Julie Connolly's presentation regarding the variety of symptoms and clinical outcomes due to CO poisoning.

He highlighted the importance of Robert Dickinson's (Imperial College) work in helping to assist with a mechanistic understanding of CO and the neurological syndrome associated with poisoning. Steve acknowledged that there was a large literature on CO poisoning, but reiterated Oliver Sykes' concerns about the unsystematic nature in approaches to definitions and concentrations etc.

The gravity of the problems associated with neurobehavioural disturbances were emphasised by acknowledging that even the slightest disturbance of executive function or mood, could render someone unemployable. Similarly, close family members of those affected by such neurobehavioural disturbances were often only able to tolerate the consequences for a year or two.

Steve informed attendees that neurobehavioural clinics have been established for patients who have, for example, experienced head injury, or encephalitis. However, there was no such clinic for patients who had experienced CO poisoning. He proposed that a clinic to provide support to CO poisoned patients should be established. Such a clinic would provide support and facilitate an understanding of the neurobehavioural effects of CO. He likened such a clinic to the traumatic brain injury clinic at St Mary's, Paddington which worked well with a multidisciplinary team, charities and researchers. It was suggested that discussion regarding such a clinic should be progressed in the workshop.



5.7. Neurobehavioural workshop

The extent of the effect that different exposure patterns and levels of exposure could have on neurobehavioural sequelae was noted by delegates. The lack of a definitive explanation for the occurrence or persistence of such sequelae was considered as a gap in the evidence base.

The attendees therefore, supported the suggestion of the specialist clinic with enthusiasm. It was agreed that such a clinic should include a research element. This could take many forms, from extending Julie Connolly's work to providing evidence to help develop fundamental scientific research. The use of animal models to augment research undertaken in the clinics was noted and encouraged. The existence of such a clinic would also impact on the teaching and referral pathways for healthcare professionals and increase awareness.

It was questioned whether calculations of the social and economic costs associated with ABI had improved with the introduction of ABI clinics. This was not known, but it was suggested that such information could be gathered from a charity e.g. Headway.

It was suggested that the continued awareness following on from the screening research project (EDCO) at both St. George's Hospital, London and Frimley Park Hospital, Surrey could help with referrals to such a clinic, if a clinic was running by the time the study closed.

It was also noted that such clinics could reduce incorrect prescribing.

General recommendations arising from this workshop:

- To develop a specialist referral clinic to treat and improve research into the neurobehavioural problems in CO exposed patients*

Actions arising from this workshop:

- Make contact with the charity Headway*
- Links should be made between relevant GST projects on the neurological effects of CO exposure*

Discussion

Attendees noted that the discussion throughout the day had highlighted a wide variety of aspects related to CO poisoning that required consideration. Whilst a holistic approach was required to tackle the problem of CO poisoning, it was acknowledged that there were elements that would need to be taken forward within individual healthcare and stakeholder specialisms. It was noted that:

- *To maximise the impact of scientific research, continued collaboration and discussion amongst academics and clinicians was important*

That CO poisoning if not fatal, could have devastating effects on the patient's health and livelihood as well as negative impacts on their wider family, was clearly acknowledged by attendees. Knowing that exposure to lower levels of CO could also affect health, made research in this area even more urgent.

The clearest message emanating from all the presentations and the workshop sessions was that there is a need for consensus on the management and treatment of CO poisoning for healthcare professionals, but that such consensus would be far more influential if there was a clear pathway to improve diagnosis that involved multiple stakeholders. Three clear points were raised and supported in relation to this work going forward:

- *That consensus on the management and treatment of CO should be developed in the UK, but be taken forward at an EU/global level*
- *That other fuel industry stakeholders must be involved in the work*
- *That the science on CO poisoning whilst still developing, should not be a barrier to the production of a consensus document, but:*
 - ◆ *It was recommended that research to provide the evidence needed to underpin protocols on current treatment options should be initiated promptly to enable clear and current guidance to be provided*
 - ◆ *There needed to be clear definitions of high and low-level exposure to help with obtaining comparable data*

Such a document was considered important not only for the research and healthcare community but also across all sectors involved with CO, including industry and government.

The drivers, pressures and states within society that influence a CO exposure event were discussed. It was noted that the three issues listed could themselves

make it difficult for customers, patients or service users to act on professional advice:

- *Poverty, tight budgets and fear of eviction*

In the development of a consensus document, it was recommended that such drivers and pressures, as well as others identified as part of a formal consensus process, must be taken into consideration.

This re-ignited discussion of various sectors' 'vulnerable persons register'. It was agreed that these schemes needed to be re-evaluated. It was suggested that the schemes should be scrutinised in collaboration with holders of other schemes and social and healthcare professionals to establish how they might improve and expand protection and facilitate application to, and functioning of, the schemes themselves.

It was clear that the need for a biomarker that was more persistent than COHb was required to improve diagnosis. It was acknowledged that work in this area was progressing. This developed into a brief but important discussion of the confounding effects of tobacco smoking and exposure to tobacco smoke when considering a diagnosis of environmental exposure to CO. It was noted that this was an area for further investigation and that a key knowledge gap was:

- *The impact of smoking on %COHb results in addition to those levels produced by environmental CO*

This raised the question: what %COHb levels should be the cut off point for smokers when considering environmental exposure?

Following discussion of the need for a whole systems approach to tackle the problem of environmental exposure to CO, it was highlighted that indoor air pollution in the home is not sufficiently recognised as a contributor to ill health. It was agreed that many of the actions highlighted and research required to tackle the problem that had been raised throughout the day could go some way in helping to raise this broader issue amongst healthcare professionals. It was noted that when someone felt ill, they would usually seek medical help. Healthcare professionals therefore needed to be sufficiently supported and resourced to help their patients when indoor air pollution was considered as a cause or contributor to ill health.

It was therefore suggested that:

- *Discussions should be held with the NICE Indoor Air Pollution Group and other groups currently working on indoor air pollution and health*

7

Summary and Close

Isabella thanked all for their involvement in the workshop and for giving their time and thought to the issue of how to improve the management of people exposed to CO. She noted that whilst the day had been full of helpful discussion, experiences and advice on this vast topic, there had been aspects that had perhaps not been discussed in as much detail as others. Isabella accepted that this did not necessarily reflect any lesser importance of those areas compared with areas that were given greater attention. She noted that this workshop was the first event to address the issue of patient management for CO exposure amongst a healthcare and industry stakeholder group and the breadth of discussion had reflected the vast nature of the

topic. Isabella hoped that the discussion and actions raised during the day would help GST enhance their research programme and assist in the development of applications for funding. The collaborative nature of the day had been most evident and this was seen as a positive aspect in terms of the success of the day itself and for future work.

Isabella thanked GST for sponsoring and hosting the event.

Delegates were reminded to complete their feedback forms. A compilation of the responses can be seen in Appendix 3, where many further actions and suggestions made outside of the workshop can be studied.

Appendix 1: Programme

GST Workshop: **The Medical Management of Carbon Monoxide Poisoning: Understanding Current Practice & Developing Consensus**

GST, 4 More London Riverside, London SE1
Date: 27th November 2018 • Time: 10.30 – 16.30

Morning

Time	Title	Speaker
10.30	Welcome & Introduction	Isabella Myers Independent Consultant
10.35	Background to the Workshop	Oliver Sykes University College Hospital
10.45	Introduction to the Day	Isabella Myers

Overview

10.50	Toxicology	Robert Dickinson Imperial College, London
11.05	Diagnostic Equipment	Leigh Greenham CoGDEM
11.15	Breath Analysers	Karl Kolodziejcyk PROACT Medical Ltd
11.25	The Engineer	David Bendle Centrica

Workshop Chain 1

11.35	Roles and Responsibilities: Response, Diagnosis, Treatment, Follow-Up and Fatalities <ul style="list-style-type: none">• Identification of Stakeholder Roles• Information & Data Gathering /Provision• Developing Patient Pathways• Knowledge Gaps & Barriers to Improvement• Worker Safety/ Awareness /Education	Isabella Myers (Facilitator)
12.30	Lunch	

Appendix 1: Programme

Afternoon

Time	Workshop Chain 2	Speaker
13.15	The ED Physician	Mushahid Raza Frimley Park Hospital
13.25	The Emergency Department Pathway <ul style="list-style-type: none"> • Diagnosis • Treatment Options • Follow-Up • The Deceased • Knowledge Gaps & Barriers To Improvement 	Isabella Myers (Facilitator)
Workshop Chain 3		
14.15	The Midwife	Hilary Wareing IPIP
14.25	CO In Pregnancy <ul style="list-style-type: none"> • Toxicology • Diagnosis • Treatment • Pathways for Care & Protection • Knowledge Gaps & Barriers to Improvement 	Isabella Myers (Facilitator)
15.10	Coffee	
Workshop Chain 4		
15.15	Neurobehavioural Impacts	Julie Connolly/ Steven White LJMU / Cromwell Hospital
15.25	Neurological Outcome <ul style="list-style-type: none"> • Diagnosis • Treatment Type, Availability& Pathway • Other Considerations • Knowledge Gaps & Barriers to Improvement 	Isabella Myers (Facilitator)
16.00	Research Gaps & Actions	Isabella Myers (Facilitator)
16.30	Close	

Appendix 2: Participant List

GST Workshop: The Medical Management of Carbon Monoxide Poisoning: Understanding Current Practice & Developing Consensus

GST, 4 More London Riverside, London SE1
Date: 27th November 2018 • Time: 10.30 – 16.30

Surname	First name	Organisation
Bailey	Georgina	Policy Connect (CO)
Bendle	David	Centrica
Benwell	Mary	Gas Safety Trust
Bothma	Pieter	BHA
Connolly	Julie	LJMU
Crossly	Anna	RCN
Darroch	Scott	GSR
Dickinson	Robert	Imperial College
Doidge	Jennifer	LAS
Edwards	Dan	SGN
Flanagan	Robert	Kings College
Greenham	Leigh	CoGDEM
Harper	Richard	Centrica
Harrison	Paul	IEH-C
Humber	Andy	LAS
Hutt	Adrian	WMFRS
Kolodziejcyk	Karl	PROACT Medical Ltd
Marczylo	Tim	PHE
Matthews	Karen	NIHR
McConnell	Adrian	Gas Safety Trust
Mills	Brin	WMFRS
Myers	Isabella	Consultant
Ong	Ivy	Imperial College
Raza	Mush	FPH
Skene	Imogen	Royal London Hospital
Sykes	Oliver	UCH
Wareing	Hilary	IPIP
White	Steve	Cromwell Hospital

Appendix 3: Summary of feedback and suggestions forms

20 Feedback and Suggestions Forms were received

Thank you for attending the workshop. We would greatly appreciate if you would take a few minutes to complete this form. Using the scale below (1-5), please rate:

1	2	3	4	5
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

	Your rating (1-5)
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The workshop:	
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a) was useful and informative	1 (x14), 2 (x6)
b) highlighted issues that are relevant to my area of work	1 (x13), 2 (x7)
c) provided a structure from which further work should be developed	1 (x12), 2 (x7), 3 (x1)

I would like to be involved in future work emanating from this workshop	1 (x12), 2 (x7), Didn't say 1
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As a result of this workshop, I am considering undertaking the following actions:

(please provide details below)

- Workshop informative and interesting.
- Huge challenge.
- Coherent message is key.
- Need to identify the trigger point for action within different healthcare settings.
- Coherent understanding and agreed pathways good starting point.
- Investigate how medical professionals refer to PSR.
- Consider what work with DHSC needs to happen for more education of medical professionals – national or trust based.
- Liaise with Coroner.
- Multi-centre, multi-national study.
- Interested in taking neurological clinic idea forward (this could be fairly informal?)
- Thinking of ways of extending the psychological study to make it more longitudinal.
- Potential briefing of emergency medical staff at Frimley Park as a pilot for other [communications] activity.
- Increase CO education across pre-hospital / ambulance.
- Collaborators and research.
- Looking at the advice engineers provide to customers suspected to have CO poisoning.
- Pushing for a pan-European medics gathering.
- Acquired brain injury clinics for CO victims' ongoing treatment in London, West Midlands and Merseyside.
- Link up with other authorities and organisations that employ people who enter homes and could be part of a reporting and action chain for CO and other indoor air quality issues. This could, for example, include Housing Officers and EHOs employed by councils and local authorities. NICE PHAC Indoor Air Quality member could be useful contacts to explore this idea.
- Challenging current research projects.
- National roll out of London Ambulance Service projects.
- Follow up with National Ambulance Research project.

(Continued overleaf)

- Investigating our fire and rescue and first response contacts to understand the requirements for CO monitoring as a stand alone
- Expanding current interests in COHb levels in vulnerable populations e.g. pregnancy.
- Better understanding of baseline COHb levels – relationship of location, socioeconomic status etc.
- Susceptibilities to CO poisoning.
- Collaborative working with health partners to collate more information regarding pregnant women.
- Review emergency department pathways and educational materials / opportunities.
- Make contact with speaker re qualitative work in progress.
- Review emergency department reporting information on electronic system.
- Define questions, Literature review, grade evidence, consensus.
- Continuing interest in concept of specialist CO clinic.

Do you have any suggestions about how we might best follow up on the issues that you consider of particular importance or relevance to your profession? (Please provide details below)

- If devices are to be used in primary care, funding and standardisation could be a challenge.
- Would be pleased to discuss this with RCN members to assist with feasibility of plans going forward.
- A defined process is necessary.
- The development of a training package for ambulance services and incorporation into JRCALC practice guidelines would be a good introduction to all MDT healthcare professionals.
- Consider how reporting of CO incidents in the home can feed into medical management – standardisation of reporting.
- Link with ICORN.
- Need to expand to cover ‘air quality’ as gas operatives are not able to cover all sources.
- Whole systems approach.
- Pre-hospital monitoring.
- Pre-hospital pathways for treatment and management.
- More awareness of the Priority Services Register.
- More awareness of the role of the Gas Distribution Network in identifying CO.
- Pre-hospital monitoring and treatment pathways.
- CO monitoring costs are looked at so that a relevant focus area of contacts can be addressed.
- Make CO breath analysis as routine in medical settings as is blood pressure and heart rate etc.
- A national map of CO levels detected by pregnancy monitoring would be very useful. May help to identify population level effects.
- Non-smoking levels in high traffic areas may be as high as some smoking levels in less-polluted areas. Could feed into Health Survey for England etc.
- How to identify vulnerable populations for CO detectors: could use children getting free school meals; could use attending GP for seasonal flu jabs.
- Education: will follow up internally for teaching opportunities.
- Public awareness / incidence of patients presenting to ED that aren’t identified.
- Data collection in ED – collected electronically.
- Further multidisciplinary meetings and networking.

(Continued overleaf)

If you have any further comments about the medical management of CO poisoning and the development of consensus raised at the event, please include them here:

- Do not throw the baby out with the bathwater!
 - Thank you – easily could have many more days like this.
 - There are more questions than answers!
 - I understand that the UK is behind the curve in terms of CO monitoring, are there any routes for the UK to use the data from Europe given that the progress in Europe and success is now a few years old?
 - Training seems key.
 - Better biomarkers would help.
 - How to compensate for confounders – smoking, road traffic pollution etc.
 - Need for more data and greater detail if going to be able to identify CO poisoning because of non-specific symptoms.
 - Difficulty in diagnosis of CO-induced, delayed neurological problems. Perhaps conducting a routine EEG, MEG or MRI after exposure would give a baseline to allow comparison against if symptoms appear.
 - Reinforcing knowledge and awareness amongst junior doctors and frontline staff regarding increasing incidence and prevalence of CO poisoning: via monthly teaching sessions or e-learning during induction will be helpful.
 - Setting up specific CO specialist clinics with incorporation of research facilitator will be helpful.
 - Availability of support staff e.g. specialist nurses – multidisciplinary approach including neurorehabilitation, neuropsychiatrist, neurologist, specialist nurses for long-term support.
 - Need for large scale, well-designed trial on treatment pathways, as well as good data on incidence and outcomes.
-

Thank you for taking the time to complete this questionnaire



Disclaimer

The content outlined in this document does not necessarily reflect the position of individual workshop attendees and/or their government department or agencies.

Date: March 2019.