

BMJ Open Cross-sectional study of carbon monoxide alarm use in patients attending the emergency department: a multicentre survey protocol

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ABSTRACT

Introduction The most common place for unintentional, non-fire-related carbon monoxide (CO) exposure to occur is in the home, but this is preventable if CO producing sources are properly maintained and CO alarms/detectors are in use. It is estimated that less than half of all homes have a CO alarm, but there is variation across countries, housing types and different demographic and socioeconomic groups. The purpose of this study is to provide up-to-date data on the use of CO alarms by surveying attendees to emergency departments using an online anonymous questionnaire.

Methods and analysis A multicentre prospective, cross-sectional survey of 4000 patients or carers in three emergency departments will be used. A questionnaire comprising of a maximum of 14 items will be administered following completion of an informed consent process. Data collected include participant demographics, household information and CO alarm use. Statistical analyses will comprise descriptive techniques to present respondents' use of CO alarms and examine associations between alarm use and participant characteristics. The proportion of homes with CO alarms installed will be calculated for all subjects and for selected subgroups.

Ethics and dissemination The study obtained ethical approval from the Westminster Research Ethics Committee (REC number 1/PR/1657). Informed consent will be obtained prior to the participant undergoing any activities that are specifically for the purposes of the study. Findings will be published in scientific journals, presented to national and international conferences and disseminated to CO safety groups.

Trial registration number ISRCTN registry 12562718.

INTRODUCTION

Carbon monoxide (CO) is a colourless, odourless and tasteless gas that results from the incomplete combustion of carbon-containing fuels such as gasoline, coal, wood, propane and natural gas.¹ Typical symptoms of CO exposure include headache, flu-like symptoms and dizziness which can occur following exposure of 100 ppm for 1 hour or 50 ppm for 8 hours.² The most common location for accidental, non-fire-related CO

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ Findings from this study will represent the largest health-based questionnaire in the UK on carbon monoxide alarm use.
- ⇒ This study will be an important source of data for public health clinicians, policy makers, carbon monoxide safety groups and for future research.
- ⇒ The use of non-probability sampling, while methodologically justified, will increase the risk of selection and response bias.

exposure is the home where sources include incorrectly installed, maintained or used fuel burning appliances such as cookers, boilers and wood burning stoves.³

Around 4000 visits to UK emergency departments (EDs) were recorded because of CO exposure in 2019, with 23 deaths.^{4,5} Comparable levels are reported in other countries with higher incidence in lower socioeconomic groups.^{6–8} Reported rates of hospital admission in the UK for those with accidental exposure were 2463 in the period from 2001 to 2010.⁹ It is recognised that these numbers are likely to be an underestimation as, unless there is a clear history of CO exposure, the non-specific symptoms are often attributed to other causes by clinicians leading to under-reporting. Because CO is colourless and odourless, most patients are unaware that they may have been exposed and therefore do not report this as a potential cause of their symptoms. This lack of detection leads to ongoing exposure to the harmful effects of CO, with children, older people and pregnant women most susceptible to detrimental health effects. There is evidence that ongoing exposure to CO can result in adverse cardiovascular effects,¹⁰ and in neurocognitive deficits and delayed neurological sequelae.¹¹ There are also indicators that certain vulnerable populations are disproportionately



affected, with disparity driven by fuel poverty and lower literacy levels.^{12 13}

The home is the most common place for CO poisoning to occur but is preventable if CO producing sources such as gas boilers, cookers and heaters are properly maintained and correctly used and by not using charcoal or wood stoves indoors.¹⁴⁻¹⁶ Additional protection from exposure is given when CO alarms or detectors are in use.¹³ The use of CO alarms can reduce the risk of exposure to CO from faulty or poorly maintained appliances by alerting household occupants to the presence of harmful levels of CO through an audible or visual alert. There is widespread variation in their use internationally, with legislative requirements for installation that vary across countries, individual regions and by housing type. In the USA, many states require CO alarms to be installed in homes but there is lack of uniformity on how this applies to different housing types or the location of the alarm.^{17 18}

In England, CO alarms are not mandated for installation unless under specific circumstances where a 'new or replacement fixed solid fuel appliance (eg, wood and coal burning, not gas) is installed in a dwelling',¹⁹ or under updated 2022 legislation where residential landlords are required to fit CO alarms in rooms with a fixed combustion appliance (except gas cookers).²⁰ Additionally, while not a legal requirement, in 2012, the UK Health and Safety Executive strongly recommended the use of CO alarms to give advance warning of CO in a property, but without regarding alarms as the replacement for regular maintenance and safety checks.²¹

Rates of CO alarm use in homes are reported to be between 29% and 82.7%, with lowest usage among lower socioeconomic groups and those from ethnic minority backgrounds.^{18 22 23} Levels of ownership are higher in areas where their use is mandated by legislation. In the UK, despite public messaging campaigns by CO safety groups, it is estimated that only 44% of households have a CO alarm fitted.²⁴ Even when households have CO alarms installed, high rates of misuse including incorrect placement and poor maintenance reduce their effectiveness.^{22 25}

This aim of this study is to enhance current understanding of CO alarm use in the UK population and will fill a gap in the research by collecting up-to-date information on key indicators of CO safety in the home. This study will be an important source of data for public health clinicians and policy makers, CO safety groups and for future research. The study objectives are:

1. To establish the proportion of homes with CO alarms of patients attending the ED.
2. To assess household characteristics (ethnicity, socioeconomic status and housing type) of participants and correlate these to alarm use.
3. To establish the type, location and frequency of CO alarm testing in participants' homes to ascertain correct installation and usage.

METHODS AND ANALYSIS

A multicentre prospective, cross-sectional design will be used. The methodology is being reported using the Checklist for Reporting Results of Internet E-surveys.²⁶ The study will collect data from patients (or carers) attending the ED with any condition as this provides access to a diverse study population. The reason for attendance to the ED is not a factor in participation as the study aims to capture data on CO alarm use not the participants clinical presentation.

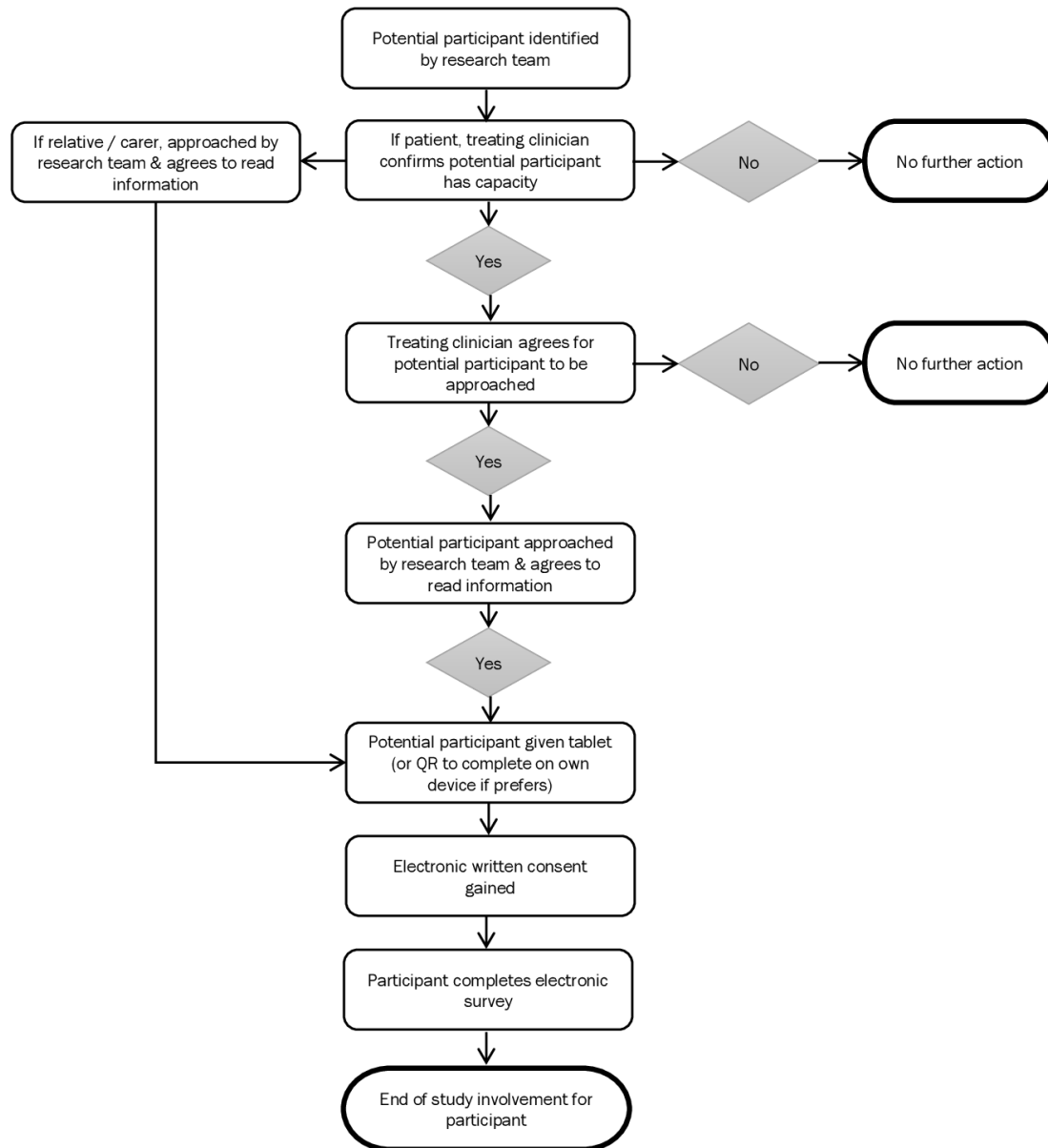
Study settings and participants

Participants will be recruited from three EDs between January 2022 and December 2022. The study sites have been selected based on populations that cover both urban and rural communities. EDs provide access to large populations and can provide a successful recruitment location for survey studies. Patients or carers are often waiting for periods of time to be seen or for the outcome of investigations and are amenable to being approached to participate. This participant group has been used similarly in other studies on CO and fire safety with response rates of up to 78.5%.^{13 18 27}

Reason for attendance to the ED is not a factor when approaching patients to participate as we are interested in collating information from participants from a broad range of backgrounds. Potential participants will be screened using electronic medical records by clinically trained research staff who will apply the eligibility criteria prior to approaching potential participants. Only patients or carers who are being treated for a minor medical complaint or injury will be approached to determine their interest and eligibility. A short verbal introduction to the study will be given by a member of the research or clinical team who is trained in the study. Eligibility criteria are (a) patients or carers of patients over the age of 16, or the carer of a child who is under 16; (b) participants willing to give informed consent; (c) participants are current UK residents.

Participants who are unable to read and understand the study information due to a language barrier, or who lack capacity due to existing cognitive impairment or a clinical diagnosis will be excluded. Participant information, giving more details about the questionnaire, what is expected from the participants and how their information will be used and stored is available in the form of an electronic information sheet. Research staff will be available to answer any questions relating to the completion of the survey. The study schema is shown in [figure 1](#).

We are not able to provide information or the questionnaire in languages other than English. While we accept this as a limitation, our eligibility criteria allow for carers to complete the survey and we anticipate that this will mean that there will be some representation from non-English speakers. The study management team will review participant characteristics weekly during the data collection period to identify any potential biases



EDCO-M study schema
V1.2 26 11 2021

Figure 1 Study schema.

in sampling relating to demographic characteristics (ethnicity and household income) and provide feedback to each site. This approach was supported by the ethics review committee.

Sample size

This study will use non-probability convenience sampling of patients presenting to the ED during the study period. Recruitment of a large sample will allow for subgroup analyses, so a pragmatic approach to recruiting the largest sample within the time constraints of the project was taken. Based on the previous experience of the

researchers, we anticipate the total recruitment across all sites to be around 4000 participants.

Patient and public involvement

Members of a patient and public research expert group have been involved in the design of the study. They have provided specific advice on the participant documents and acceptability of the number and type of questions in the survey.

Data collection

Data capture will be electronic using the REDCap secure web application for surveys and databases (Research

**Table 1** Data points in questionnaire

Demographics	Household characteristics	Carbon monoxide alarm use
1. Role of respondent (Patient, relative or carer of patient age 16 years or over, relative of carer of patient under 16 years old)	1. Type of accommodation	1. Presence of any carbon monoxide alarm(s) in the home
2. Postcode	2. Number of people in household (aged under 18, aged 18–69, aged over 70)	2. Type of carbon monoxide alarm(s)
3. Household income	3. Owner or rental property	3. Testing regime for carbon monoxide alarm(s)
4. Ethnicity	4. Landlord type (if relevant)	4. Location of carbon monoxide alarm(s) and presence of fuel burning appliances
5. Ethnicity (sub-category)		5. Maintenance of fuel burning appliances
		Or Reason for not having an alarm (if relevant)

Electronic Data Capture, Vanderbilt University). Participants can complete the questionnaire on their personal devices, following a linked QR code, or can be provided with a handheld electronic device. The electronic questionnaire contains the invitation to participate letter (participant information sheet), consent form and the questionnaire.

A questionnaire consisting of a maximum of 14 items has been developed for online administration (table 1). It has been designed to meet the study objectives, drawing on previous literature in this area and the categorisation of housing type from the UK National Census 2021 to allow for comparison of the data. Data collected include participant demographics (maximum of 5 items) and household information (maximum of 4 items). CO alarm use will be determined by survey questions (maximum of 5 items) on number, type, location(s) and maintenance of alarm(s) and the maintenance of fuel burning appliances in the home. For patients who indicate they do not have any CO alarms, they will be asked a single further question on the reason an alarm is not installed. Participant postcodes will be collected and linked to Lower Super Output Areas and the Index of Multiple Deprivation using data from the Open Geography Portal to identify differences in alarm use across geographical regions.²⁸ A link to health promotion materials on CO alarms and exposure prevention is available through a link at the end of the survey if participants wish to have further information.

The questionnaire should take no longer than 5–10 min for each participant to complete, and participants will be notified of this at the start. Questions were piloted by the study management group and representatives from the public engagement group. Modifications following piloting were integrated into the survey questionnaire.

Data analysis

Qualitative data will be described using frequency tables/descriptive statistics. The proportion of homes with CO alarms installed will be calculated for all subjects and for selected subgroups. Univariate statistical tests for associations between alarm use and participant characteristics will be conducted using χ^2 /Fishers Exact tests with logistic

regression used to calculate adjusted ORs. Statistical analysis will be performed using Stata (StataCorp. 2021. Stata Statistical Software: Release 17, StataCorp LLC).

ETHICS AND DISSEMINATION

The study obtained UK NHS ethical approval by the Westminster Research Ethics Committee (REC number 21/PR/1657). Informed consent will be obtained prior to the participant undergoing any activities that are specifically for the purposes of the study. Consent is ‘self-completed’ online and requires no input from clinical or research staff. Research staff will not be aware of who has taken part and will not be able to identify any participants. There is no follow-up or other direct contact by research staff. Once logged onto the questionnaire and having read the participant information sheet, informed consent will be obtained by a series explicit consent statements with a tickbox that the participant completes if they are in agreement. In line with Health Research Authority guidance in England and Wales, a handwritten signature is not required.²⁹

These include confirmation/understanding on:

- ▶ How participants may withdraw at any time and what happens to any data given if they do.
- ▶ That participants will not be identified from the answers given.
- ▶ Whom to contact for questions or problems.
- ▶ That they consent to take part in the survey.
- ▶ That the data will be used for analysis and publication/presentation.
- ▶ Only after all boxes have been ticked will the participant be able to commence the study.

DISCUSSION

This purpose of this study is to provide up-to-date data on the use of CO alarms by surveying attendees to EDs using an online anonymous questionnaire. The extent to which the sample is representative of the patients or carers attending the emergency department will not be known, and the use of non-probability sampling, while

methodologically justified, will increase the risk of selection and response bias.

Findings from this study will represent the largest health-based questionnaire in the UK on CO alarm use and be an important source of data for public health clinicians, CO safety groups and for future research.

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Contributors HJ conceived the study, designed the final study protocol, provided the domain knowledge expertise and is the chief investigator of the grant. RWA contributed to the technical design and provided biostatistical and epidemiological support. AB and PM helped in the design of the final study protocol, contributed to the technical design and revised the initial manuscript draft. All authors read and approved the final manuscript.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

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REFERENCES

- Ran T, Nurmagambetov T, Sircar K. Economic implications of unintentional carbon monoxide poisoning in the United States and the cost and benefit of CO detectors. *Am J Emerg Med* 2018;36:414–9.
- Goldberg R, McKelvey W, Lane K, *et al*. Evaluation of data sources for carbon monoxide poisoning surveillance in New York City. *J Public Health Manag Pract* 2022;28:E560–5.
- Public Health England. Carbon monoxide: general information, 2016. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/561063/carbon_monoxide_general_information.pdf [Accessed Aug 2022].
- HSE Health and Safety Executive. The cross-government group on gas safety and carbon monoxide awareness. health and safety executive, 2020. Available: <https://www.hse.gov.uk/gas/domestic/cross-government-group-1920.pdf> [Accessed Aug 2022].
- APPCOG All-Party Parliamentary Carbon Monoxide Group. Carbon monoxide poisoning: saving lives, advancing treatment. policy connect, 2017. Available: <https://www.policyconnect.org.uk/research/carbon-monoxide-poisoning-saving-lives-advancing-treatment> [Accessed Aug 2022].
- Tejada-Vera B. QuickStats: Number of Deaths Resulting from Unintentional Carbon Monoxide Poisoning,* by Month and Year - National Vital Statistics System, United States, 2010–2015. *MMWR Morb Mortal Wkly Rep* 2017;66:234.
- Can G, Sayılı U, Aksu Sayman Özden, *et al*. Mapping of carbon monoxide related death risk in turkey: a ten-year analysis based on news agency records. *BMC Public Health* 2019;19:9.
- Roca-Barceló A, Crabbe H, Ghosh R, *et al*. Temporal trends and demographic risk factors for hospital admissions due to carbon monoxide poisoning in England. *Prev Med* 2020;136:106104.
- Ghosh RE, Close R, McCann LJ, *et al*. Analysis of hospital admissions due to accidental non-fire-related carbon monoxide poisoning in England, between 2001 and 2010. *J Public Health* 2016;38:76–83.
- Lee F-Y, Chen W-K, Lin C-L, *et al*. Carbon monoxide poisoning and subsequent cardiovascular disease risk: a nationwide population-based cohort study. *Medicine* 2015;94:e624.
- Rose JJ, Wang L, Xu Q, *et al*. Carbon monoxide poisoning: pathogenesis, management, and future directions of therapy. *Am J Respir Crit Care Med* 2017;195:596–606.
- Landrigan P, Etzel R. *Textbook of children's environmental health*. Oxford University Press, 2014.
- McKenzie LB, Roberts KJ, Kaercher RM, *et al*. Paediatric emergency department-based carbon monoxide detector intervention: a randomised trial. *Inj Prev* 2017;23:314–20.
- Iqbal S, Clower JH, Saha S, *et al*. Residential carbon monoxide alarm prevalence and ordinance awareness. *J Public Health Manag Pract* 2012;18:272–8.
- Rupert DJ, Poehlman JA, Damon SA, *et al*. Risk and protective behaviours for residential carbon monoxide poisoning. *Inj Prev* 2013;19:119–23.
- Iqbal S, Law H-Z, Clower JH, *et al*. Hospital burden of unintentional carbon monoxide poisoning in the United States, 2007. *Am J Emerg Med* 2012;30:657–64.
- National Conference of State Legislatures. Carbon monoxide detector requirement, laws and regulations. 2018 carbon monoxide detector requirements, laws and regulations. Available: [ncsl.org](https://www.ncsl.org) [Accessed Aug 2022].
- Johnson-Arbor K, Liebman DL, Carter EM. A survey of residential carbon monoxide detector utilization among Connecticut emergency department patients. *Clin Toxicol* 2012;50:384–9.
- HM Government. The building regulations 2010: combustion appliance and fuel storage systems, 2010. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/468872/ADJ_LOCKED.pdf [Accessed Aug 2022].
- Ministry of Housing, Communities & Local Government. The smoke and carbon monoxide alarm (Amendment) regulations 2022. Available: <https://www.legislation.gov.uk/uksi/2022/707/contents/made> (legislation.gov.uk) [Accessed Aug 2022].
- Naylor S, Walsh PT, Dowker KP. Survey of the reliability of carbon monoxide alarms deployed in domestic homes and efficacy of use by consumers. *Indoor Air* 2013;23:325–31.
- Roberts KJ, Fowler E, Comstock RD, *et al*. Carbon monoxide alarm and smoke alarm use among parents recruited from a pediatric emergency department. *J Prim Prev* 2018;39:1–15.
- Hampson NB, Weaver LK. Residential carbon monoxide alarm use: opportunities for poisoning prevention. *J Environ Health* 2011;73:30–3.
- Ministry of Housing, Communities & Local Government. English housing survey, 2019–20, 2020. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945013/2019-20_EHS_Headline_Report.pdf [Accessed Aug 2022].
- McDonald EM, Gielen AC, Shields WC, *et al*. Residential carbon monoxide (CO) poisoning risks: correlates of observed CO alarm use in urban households. *J Environ Health* 2013;76:26.
- Eysenbach G. Improving the quality of web surveys: the checklist for reporting results of Internet E-Surveys (CHERRIES). *J Med Internet Res* 2004;6:e34.
- Wood RL, Teach SJ, Rucker A, *et al*. Home fire safety practices and smoke detector program awareness in an urban pediatric emergency department population. *Pediatr Emerg Care* 2016;32:763–7.
- The open geography portal. Available: <https://geoportal.statistics.gov.uk/> [Accessed Aug 2022].
- NHS Health Research Authority. Applying a proportionate approach to the process of seeking consent, 2019. Available: [Proportionate_approach_to_seeking_consent_HRA_Guidance.pdf](https://www.nhs.uk/health-research-authority/seeking-consent) [Accessed Aug 2022].