Cost effectiveness of residential carbon monoxide alarms

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ABSTRACT

Background: While residential carbon monoxide (CO) alarms are now required in a majority of states, the cost effectiveness of the devices is unknown. This analysis was performed to determine the degree of prevention efficacy necessary from home carbon monoxide alarms for their expense to be cost-effective.

Methods: Data regarding numbers of individuals affected in the United States annually from accidental, non-fire, residential non-fatal and fatal carbon monoxide poisoning were obtained from published literature. Federal governmental estimates of societal costs associated with medical care, lost wages and earnings, value of pain and suffering, and value of a statistical life were applied. The cost of uniform residential carbon monoxide alarm installation was compared to those societal costs in order to calculate what degree of efficiency makes alarms cost-effective.

Results: Societal costs for accidental, non-fire, residential CO poisoning are approximately $3.47 billion annually. With an estimated cost of $348 million annually for alarms, prevention of greater than 10% of residential CO poisoning costs must be achieved in order for alarms to be cost-effective.

Conclusions: While the true effectiveness of residential carbon monoxide alarms has yet to be determined, current state legislation requiring residential installation of CO alarms is probably cost-effective.

INTRODUCTION

Carbon monoxide (CO) poisoning is responsible for significant morbidity and mortality in the United States each year [1-4]. Many believe that accidental CO poisoning can be prevented largely through a combination of public education, CO emission limits, consumer product warning labels, and residential CO alarms. With regard to the latter, many states and localities have passed legislation requiring installation of residential CO alarms. As of March 2016, 30 states had enacted laws requiring CO alarms in at least one category of residence [5].

It is necessary to recognize the types of poisonings these laws have the potential to prevent. CO alarms will not prevent intentional CO poisoning, and smoke alarms already present should warn of fires. Residential CO alarms could only be expected to provide additional protection from accidental, non-fire related poisonings within the home. As such, it is necessary to estimate their effectiveness in preventing only this subset of CO poisonings in order to determine whether they are cost-effective.

Laboratory evaluation of residential alarm reliability [6] and surveys on alarm use [7] have been published. One study examined accidental CO poisoning-related hospitalizations and deaths in New York City before and after legislation mandated domestic CO alarm installation in 2004 [8]. Statistically non-significant decreases in both were seen. The true degree of effectiveness of residential CO alarms remains unknown. This analysis seeks to determine the effectiveness necessary for uniform alarm requirements to be cost-effective.

METHODS

Data from the published literature were utilized for the incidence of non-fatal and fatal CO poisoning [1-4, 9]. As can be seen in Figure 1, there are an estimated 95,000 CO exposures in the United States annually, of which approximately 92,000 are non-fatal and 2,700 fatal [9]. Estimates are available for the number of non-fatal poisonings treated medically, as well as the proportion of those that are accidental, non-fire, and residential [2, 3, 9-11]. Of the non-fatal, approximately 50,000 are managed medically [9, 11]. An estimated 27,500

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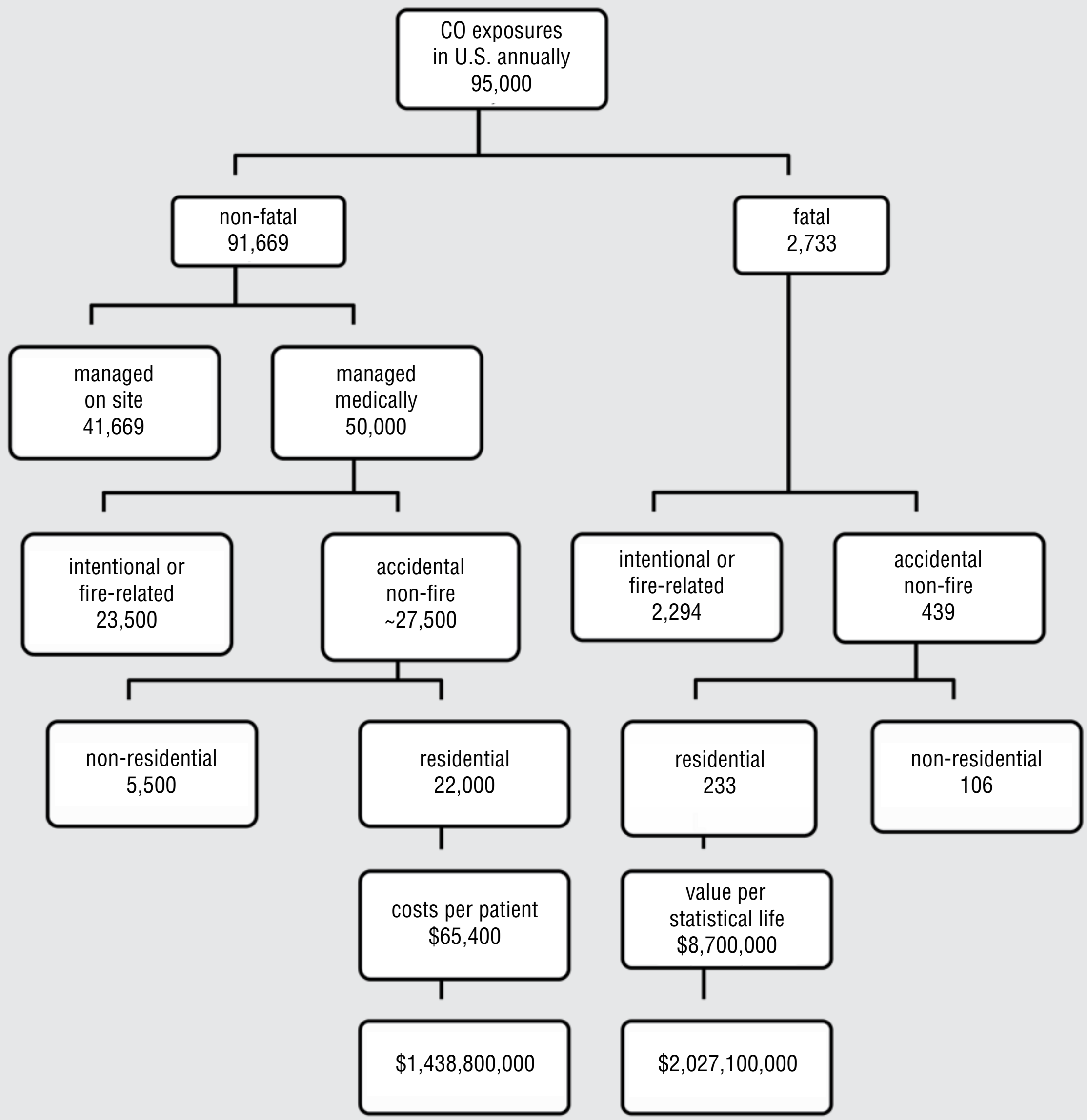

FIGURE 1

Incidence of accidental, non-fire, residential carbon monoxide poisoning in the U.S. each year and associated societal costs

are accidental, non-fire poisonings [9]. A nationwide surveillance program conducted by the U.S. Centers for Disease Control and the Undersea and Hyperbaric Medical Society found that 80% of significant accidental, non-fire poisonings are residential [10], reducing the potentially protected group from 27,500 to 22,000.

Similar data are available for the number of accidental, non-fire related CO poisoning fatalities [1, 4]. Of 2,700 annual CO fatalities, approximately 233 are accidental, non-fire, and residential [4,9]. The proportion dying in the home was acquired from CDC WONDER using methods previously described [4].

For non-fatal poisoning, cost to society was estimated by applying a federal government estimate of $65,400 for expenses associated with a case of CO poisoning (medical and hospital costs, ancillary costs,

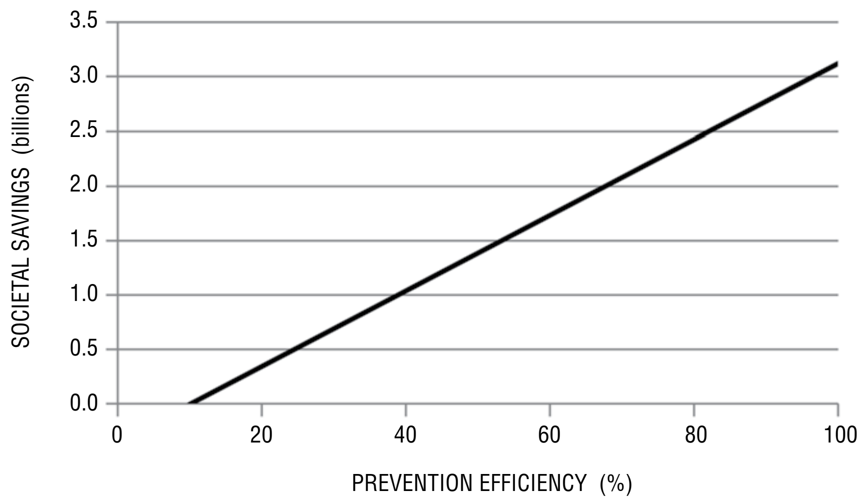

FIGURE 2

Annual savings to society in billions of U.S. dollars in relation to prevention efficiency (effectiveness) of residential carbon monoxide alarms

health insurance processing costs), work losses (foregone earnings of victim, parents and visitors, long-term work losses of the permanently impaired victim, employer productivity losses), and intangible injury costs (pain and suffering) [12].

For fatalities, the value of a statistical life (VSL) of $8.7 million recently utilized in a federal government report on CO deaths was applied [12, 13]. VSL is the amount of money society is willing to pay to save a life, estimated by economists through surveys or observed human behavior in risky environments.

Census data provided the number of U.S. households [14]. Annual cost per residence of a CO alarm was calculated by dividing the cost of a CO alarm powered with a 10-year battery by its warranteed lifespan [15].

RESULTS

At a per-injury cost of $65,400 for medical care, lost wages, lost productivity, and pain and suffering [12], societal cost for non-fatal, accidental, non-fire, residential CO poisoning is estimated at $1.44 billion. The U.S. Consumer Product Safety Commission recently applied the figure of $8.7 million (in 2014 dollars) as the value of a statistical life in a report on deaths from CO poisoning from electrical generators [12]. Using that figure, fatalities account for approximately $2.03 billion in costs, bringing the total societal cost from accidental, non-fire, residential CO poisoning to $3.47 billion. A CO alarm that lasts 10 years can be acquired for under $30 [15] and would therefore cost $3 per household per year. Installation of one CO alarm in each of the 116 million U.S. households would cost $348 million annually. Figure 2 integrates the costs of poisoning and uniform alarm application, estimating the cost savings to society at any level of prevention efficiency of the devices. The benefit-to-expense ratio becomes positive at an efficiency of 10%.

DISCUSSION

Fatal and non-fatal residential CO poisonings account for significant societal cost. A slight majority of state governments have elected to address this with requirements for mandatory installation of CO alarms in one or more category(ies) of domicile. This has been done without data on the effectiveness of CO alarms in preventing poisoning, possibly on the assumption that the level of protection afforded by CO alarms will approximate that which smoke alarms have demonstrated in preventing morbidity and mortality from fires.

Smoke alarms have been in use much longer than

CO alarms and are present in 96%-97% of U.S. homes [16]. The long history of smoke alarm use has allowed collection of extensive data regarding their performance. The risk of injury or death from home fires is reduced 88% in residences with operational smoke alarms, as compared to those without [16].

No long-term studies are available demonstrating the effectiveness of residential CO alarms. As noted, a 2015 study on the impact of mandatory alarms in New York City found statistically non-significant reductions in accidental, non-fire, residential CO-related hospitalizations and death rate associated with their use (minus 25% and minus 50%, respectively), despite the fact that only one-half of survey respondents had changed their alarm batteries in the preceding six months [8]. It was speculated that small numbers and detection bias might have limited the discovery of significant decreases in poisoning outcomes. Nonetheless, the magnitude of prevention reported is notable in light of the current calculation that residential alarms are cost-effective from a societal standpoint if more than 10% of the total home CO poisoning burden is prevented (Figure 2).

It does not seem unreasonable to expect operational residential CO alarms to exhibit prevention effectiveness far in excess of 10%. With smoke alarms preventing 88% of fire morbidity and mortality, even an estimate of 50% efficiency for CO alarms would result in yearly cost savings to society of more than $1.25 billion. A British cost-benefit analysis of home CO alarms used an estimate of 75% efficiency [17]. If that level of effectiveness were applied to the current analysis, more than $2 billion would be saved annually.

A number of factors could affect the present calculations, either positively or negatively. Less expensive CO alarms are available. However, an alarm must be functional to prevent poisoning. If an alarm is hard-wired and powered only by AC current, the household power supply cannot be disrupted by natural disasters or disconnected by the utility company. In the case of devices with battery backup or primary battery power, batteries must be installed and they must be fresh. While this may be seemingly obvious, missing or dead batteries cause 70% of smoke alarm failures (16). To circumvent those issues, a maintenance-free device with a sealed 10-year battery was chosen for this analysis.

Additionally, the number of alarms required per home could vary. The present analysis used one per household. If two were required, the cost savings would be reduced unless the presence of two alarms improved prevention efficiency and thereby resulted in additional cost reductions. Also, combination smoke/CO alarms are available, typically costing about 20% more than CO alarms alone. Uncalculated cost savings could result from their use.

It is possible or even likely that residential CO alarms would provide differential levels of protection against death as compared to injury. Preservation of one $8.7 million life equals prevention of 133 $65,400 non-fatal poisonings. A differential level of protection would affect the cost savings, but it is not currently possible to estimate the direction or magnitude because of the number of variables involved. An example of such a variable is alcohol. A 1998 study found that 15 of 80 (19%) persons dying from accidental, non-fire, residential CO poisoning were both asleep and intoxicated at the time of poisoning, potentially reducing their chances for rescue by an auditory alarm [18].

While legislation requiring home installation of CO alarms may not currently be supported by cost-effectiveness studies, this analysis demonstrates that the benefit:cost ratio of residential CO alarms is likely very positive. Studies are still needed demonstrating the actual effectiveness of residential CO alarms, but it appears that they will demonstrate the magnitude of societal savings associated with the devices and not whether the benefit:cost ratio is positive or negative.

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Conflict of interest statement

The author declares that no conflicts of interest exist with this submission.

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