Background: It is widely known that carbon dioxide (CO2) arc welding generates carbon monoxide (CO). However, to the best of our knowledge, no case reports have been published regarding CO poisoning in CO2 arc welders. Therefore, we aimed to report a case of CO poisoning-induced encephalopathy in a CO2 arc welder in the Republic of Korea to inform about the dangers of CO exposure among CO2 arc welders.

Case presentation: A 40-year-old man working as a CO2 arc welder for 15 years visited a local hospital with a tremor, involuntary urination, and speaking gibberish, on April 9, 2019. He stated that he had intermittent headache and forgetting symptoms for the last 5 years, and had been lost on the way to work several times. On April 9, 2019, he was diagnosed with CO poisoning-induced encephalopathy through brain magnetic resonance imaging. He received hyperbaric oxygen therapy, and some of his symptoms improved. According to the exposure assessment of his work environment, he was continuously exposed to high concentrations of CO for 15 years while operating CO2 arc welding machines.

Conclusions: After evaluating the patient’s work environment and evaluating his medical history, we concluded that his encephalopathy was caused by CO exposure during CO2 arc welding. Thus CO2 arc welders must be aware of the risk of CO poisoning and strive to avoid CO exposure.

Keywords: Carbon monoxide poisoning; Encephalopathy; Metal workers

BACKGROUND

Carbon monoxide (CO) is an odorless, tasteless, colorless, and non-irritating gas formed by the incomplete combustion of various fuels. Carbon dioxide (CO2) arc welding also produces significant amounts of CO.1 Particularly, the concentration of CO in the air may increase to dangerous levels when CO2 arc welding is performed in poorly ventilated areas.2 In this technique, the CO2 gas used as an inert gas shield or as carbonates of flux cored wire can decompose into high concentrations of CO gas. Therefore, proper ventilation conditions are required to prevent CO exposure.

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The clinical symptoms of CO poisoning are diverse, depending upon the level and duration of exposure. Patients with mild or moderate acute CO poisoning present constitutional symptoms, including headache, nausea, dizziness, drowsiness, vomiting. Severe CO poisoning can produce symptoms such as seizure, chest pain, syncope, or coma. Even minor cases of CO poisoning can cause serious complications including brain damage. Delayed encephalopathy after acute CO poisoning is defined by the recurrence of neurological or psychiatric signs after a transient symptom-free period following the acute phase. The latency period is usually 2 to 40 days. This clinical syndrome manifests as neurological or psychiatric symptoms, including memory loss, urinary and fecal incontinence, disorientation, confusion, parkinsonism, and other motor disturbances.

Although the risk of CO exposure in CO₂ arc welding is well-known, to the best of our knowledge, no studies have yet reported an encephalopathy case attributed to CO poisoning among CO₂ arc welders. Herein, we present a case of CO poisoning-induced encephalopathy in a CO₂ arc welder in the Korea.

CASE PRESENTATION

Patient information
The patient was a 40-year-old male.

Chief complaints
Memory loss.

Present illness
The patient visited a local hospital with a tremor, involuntary urination, and incoherent speech, on April 9, 2019. On April 1, 2019, he lost his way on the highway while driving a car on a familiar road on the way to work. He had a minor car accident, and stated that he did not remember the circumstances. The symptoms developed 2–3 days after the accident. He stated that he had intermittent headache and memory loss symptoms for the last 5 years.

Social history, family history, and past history
He was an ex-smoker of 10 pack-years and a heavy drinker who consumed 8–10 bottles of soju (Korean distilled beverage, 49 g of alcohol per bottle) per week for approximately 15 years. There was no relevant family history involving brain disorders. In addition, he and his wife stated that there was no circumstance outside workplace that could cause poisoning due to toxic substances, including CO. We also reviewed his medical records and the history of Korean National Health Insurance Service for the past 10 years. However, we did not find any evidence of acute poisoning with toxic substances besides that due to CO exposure from CO₂.
arc welding in his workplace. The patient also complained of difficulty in breathing during the welding operation due to several enclosed spaces in the workplace.

Medical test results and progress
After undergoing brain magnetic resonance imaging (MRI), the T2 weighted and fluid-attenuated inversion recovery (FLAIR) images (Figs. 1 and 2) showed lesions with high signal intensity in the bilateral globus pallidus. Subtle high signal intensity lesions were also seen in the bilateral cerebral white matter. Brain magnetic resonance angiography was performed on April 9, 2019, and an approximately 3-mm vascular outpouching lesion was suspected in the anterior communicating artery from the images, with mild stenosis in the mid portion of the basilar artery. Images from the diffusion MRI on April 9, 2019, revealed multifocal acute infarction in the centrum semiovales, parietal lobes, and occipital lobes bilaterally. The scans from brain computed tomography (CT), performed on April 15, 2019, showed that both the size and shape of the ventricle were normal. Furthermore, no brain atrophy or abnormalities in the brain parenchyma were noted. CT arteriography scans were also normal. Subsequently, the patient was diagnosed with CO-induced encephalopathy due to the high signal intensity in the bilateral globus pallidus in the T2 weighted and FLAIR images of brain MRI. From April 11, 2019, for about one month, he received hyperbaric oxygen therapy and rehabilitation treatment for CO-induced encephalopathy, and his symptoms improved.

A mild cerebral dysfunction was observed in an electroencephalogram performed on April 15, 2019. On April 18, 2019, he was diagnosed with moderate dementia due to encephalopathy, revealed from the neurological examination results, which were as follows: Mini-Mental State Examination (MMSE) score was 10; Global Deterioration Scale was 5; Neuropsychiatric Inventory-Questionnaire score was 4; Korean Dementia Screening Questionnaire score was 18; Consortium to Establish a Registry for Alzheimer’s Disease score was 15; Instrumental Activities of Daily Living score was 27; Barthel Activities of Daily Living Index was 13. The results also improved after hyperbaric oxygen therapy and rehabilitation treatment. His MMSE score was 13 on April 22, 2019, and 24 on May 2, 2019.

Past results of his specialized health examinations showed that the level of carboxyhemoglobin (COHb) in blood was 6.0% (normal range: 0%–5%), 4.3%, 5.7%, 5.9%,

![Fig. 1. T2 weighted brain magnetic resonance imaging of the patient shows the lesions with high signal intensity in the bilateral globus pallidus (white arrows).](https://aoemj.org)
and 7.6% in 2011, 2012, 2014, 2015, and 2016, respectively. The above COHb results were measured when the patient was an active smoker.

**Occupational history**

The patient worked as a welder for approximately 15 years at several cooperative companies and performed CO₂ arc welding for ship blocks. He worked for 6 days a week from 8 am to 6 pm. On busy days, the work lasted until 10 pm. He holds a CO₂ welding certificate and has worked exclusively with this type of welding. Owing to the characteristics of the ship block, there were several closed spaces with inappropriate ventilation during welding, possibly exposing the welders to fumes and gases. According to the patient’s colleague, the workplace was mainly inside the ship block and there was an indoor ventilation system. However, the colleague added that that ventilation was improper due to the closed space, and the workspace air was cloudy. In some cases, welding and painting were performed in the same space, exposing the welders to hazardous substances generated during both the processes.

**Exposure assessment**

Based on the working environment measurement in the patient’s workplace from 2010 to 2018 (Table 1), the time weighted average (TWA) of CO measurements ranged from 3.58 to 25.72 ppm. The maximum CO concentrations measured were 1,533.33 ppm in 2011 and 58.33 ppm in 2017. In 2017, 36 samples exceeded the acceptable exposure limit. Furthermore,

![Image](https://aoemj.org)

**Fig. 2.** Fluid-attenuated inversion recovery brain magnetic resonance imaging of the patient shows the lesions with high signal intensity in the bilateral globus pallidus (white arrows).

| Year | Number of samples | Minimum value (ppm) | Maximum value (ppm) | Geometric mean (ppm) | Number of samples over half of the exposure limit | Number of samples over the exposure limit | Exposure limit (ppm) |
|------|-------------------|---------------------|---------------------|---------------------|-----------------------------------------------|----------------------------------------|---------------------|
| 2010 | 49                | 1.13                | 23.30               | 6.98                | 8                                             | -                                      | 30                  |
| 2011 | 53                | 2.00                | 1533.33             | 7.41                | 2                                             | 1                                      |                     |
| 2012 | 44                | 1.26                | 13.02               | 4.63                | -                                             | -                                      |                     |
| 2013 | 68                | 1.25                | 11.38               | 3.58                | -                                             | -                                      |                     |
| 2014 | 65                | 1.67                | 20.67               | 7.64                | 8                                             | -                                      |                     |
| 2015 | 70                | 2.33                | 20.50               | 9.67                | 12                                            | -                                      |                     |
| 2016 | 115               | 2.50                | 20.83               | 9.05                | 18                                            | -                                      |                     |
| 2017 | 83                | 5.00                | 58.33               | 25.72               | 69                                            | 36                                     |                     |
| 2018 | 24                | 5.00                | 25.67               | 13.40               | 11                                            | -                                      |                     |
samples exceeding half of the acceptable exposure limit were confirmed in all years, except 2012 and 2013. Therefore, it was inferred that the patient was exposed to dangerous levels of CO while working as a CO₂ arc welder for 15 years.

Consequently, the CO level generated during CO₂ arc welding of the ship block at the patient’s workplace was measured using a Dräger X-am® 8000 Multi-Gas Detector (Dräger, Lübeck, Germany). This was performed for approximately 5 minutes in the breathing zones of 2 workers (A and B) in the ship where the CO₂ arc welding was in progress (Fig. 3). For worker A, the measurement was performed at his shoulder line, while for B, it was performed near the grating where the fume rose while welding under it. The range of CO levels for workers A and B were 18.3–133.2 ppm and 90.2–818.5 ppm, respectively. The maximum CO levels for workers A and B were 133.2 ppm and 818.5 ppm, respectively (Table 2). However, these CO levels cannot be directly compared with the CO exposure standard (TWA 30 ppm, short-term exposure limit 200 ppm) because welders may be instantaneously exposed to high concentrations of CO. Also, the sites were open spaces with good airflow; therefore, it is estimated that greater exposure to CO was possible in places with poor ventilation. No work other than welding was performed at these sites.

CO concentrations measured at the relevant site in the past were confirmed to reach a maximum of 1,533.33 ppm and exceed the exposure limit several times in 2011 and 2017. Contrastingly, the CO concentration detected during the epidemiological investigation only reached a maximum of 818.5 ppm. There are several confined spaces in the ship block where ventilation is poor. The average CO concentrations during CO₂ arc welding in domestic shipyards were 21.4 ppm (maximum, 103.7 ppm) in 1997 and 7.72 ppm (maximum, 107.90 ppm) from 2012 to 2014. Thus, the patient would have been constantly exposed to significant levels of CO for approximately 15 years.

![Fig. 3. Work environment of workers A and B during carbon monoxide measurements in 2020.](image)

![Table 2. Carbon monoxide measurement results from workers A and B working for the carbon dioxide welding process at the patient’s workplace in 2020](table)

| Worker | Measurement location | Minimum value (ppm) | Maximum value (ppm) | Measuring device          |
|--------|----------------------|---------------------|---------------------|---------------------------|
| A      | Shoulder line        | 18.3                | 133.2               | Dräger X-am® 8000*        |
| B      | Near the grating     | 90.2                | 818.5               |                           |

*Multi-Gas Detector (range: 0–2,000 ppm).
Ethics statement
This study was approved by the Institutional Review Board (IRB) of the Occupational Safety and Health Research Institute (IRB No. OSHRI-202102-HR-014), and written informed consent was obtained from the patient for the publication of this report and the use of his personal data.

DISCUSSION AND CONCLUSION

The patient worked for 15 years as a CO₂ arc welder since January 2001. On July 22, 2019, the Korea Worker’s Compensation & Welfare Service requested the Korea Occupational Safety and Health Agency to assess this case to examine the work-relatedness of encephalopathy development. The work-relatedness between CO₂ arc welding and encephalopathy was approved by the Epidemiological Investigation and Evaluation Committee on August 7, 2020. In this study, the ship block where CO₂ arc welding was performed had a maximum CO concentration of 818.5 ppm, although the space was relatively open. According to the statement of the colleague, the patient’s workplace was mainly inside the ship and despite the functional mechanical ventilator, there was cloudy air. In addition, the patient's brain MRI results showed high signal intensity in the bilateral globus pallidus in T2 weighted and FLAIR images, a typical image of CO poisoning. The subtle high signal intensity of cerebral white matter observed in the patient’s brain MRI can also appear in the CO-intoxicated patients. His symptoms and MMSE scores improved after receiving hyperbaric oxygen therapy.

No other evidence of acute poisoning with toxic substances was found from his occupational and medical history. It is difficult to estimate the specific time point of CO exposure which caused the encephalopathy. However, the patient was frequently exposed to high concentrations of CO for approximately 15 years while he worked as a CO₂ arc welder. Intermittent headaches and amnesic symptoms over the past 5 years are also supporting evidence. However, considering that there was no history of hospitalization for CO poisoning in the past, it is estimated that the level of CO exposure was not severe enough to cause unconsciousness.

The COHb level of the patient after examination was not high enough to conclude that CO exposure is the cause of the lesion. However, previous literature reported that the half-life of COHb in room air is 4 to 5 hours.12,13 Also, the level of CO exposure may be low when welding in an open space. Therefore, our patient’s annual COHb level may not accurately reflect the degree of CO exposure. However, a high concentration of CO was recorded on measuring the CO concentration in the workplace, leading to the possibility of acute CO poisoning.

Over time after CO poisoning, the general condition of a patient may progress into the following forms: only temporary symptoms in the acute stage (approximately 70% of the patients); or persistent symptoms in the chronic stage (20% of the patients); or a recurrent neuropsychiatric symptom and delayed neurologic sequelae even after acute symptoms have completely disappeared (remaining 10% of the patients).14-17 In this case, delayed encephalopathy due to CO poisoning, often referred to as delayed neurologic sequelae, can even occur in patients with mild symptoms of acute CO poisoning without loss of consciousness. This is possibly due to brain tissue hypoxia, oxidative stress, lipid peroxidation, and catecholamine crisis rather than direct hypoxia-induced damage.18-20 The severity of the initial CO intoxication does not necessarily correspond with the development of neurological damage.21
In several studies, a constant feature in MRI of patients diagnosed with delayed encephalopathy after CO poisoning is hyperintensity in the subcortical white matter and globus pallidus, as seen on diffusion, FLAIR, and T2-weighted sequences. The areas most affected in the cerebral white matter were the centrum semiovale and periventricular white matter. These lesions in the bilateral cerebral white matter were identified as symmetric or asymmetric high-intensity signals on T2 images. The MRI results in this case were consistent with those typically observed in and indicative of CO poisoning.

A wide range of diseases, conditions, and toxins cause high signal intensity lesions in bilateral basal ganglia. However, after interviewing the patient and examining his medical records and work environment, we could not find any other causes. The white matter hyperintensity signal becomes more common with increasing age. Therefore, it is not a specific hallmark of CO poisoning. As our patient was a heavy drinker, we also had to consider alcohol-related dementia. In cases of alcohol-related dementia, the frontal cortex is primarily affected, and frontal atrophy is observed in brain MRI. However, there was no frontal lobe atrophy on the brain MRI in this case.

After considering the results of the brain MRI imaging, neurological and psychiatric symptoms, response to hyperbaric oxygen therapy, and work environment conditions, we concluded that delayed encephalopathy after acute CO poisoning of patient was caused by exposure to CO during CO2 arc welding in the course of his occupation. Our study makes a significant contribution to the protection of welders’ health because although the risk of exposure while CO2 arc welding is well-established, no studies have yet reported the incidence of CO-poisoning induced encephalopathy in a CO2 arc welder.

This study confirms the typical MRI finding of CO poisoning-induced encephalopathy in CO2 arc welders, and it will be highly valuable to researchers and clinicians in the future. However, there could be cases in which work-related encephalopathy can be confirmed only by monitoring the working environment or clinical manifestations without a typical MRI finding. A case series reported that COHb levels in CO poisoned patients with mental status change varied between 8.3% and 34.8% in the acute phase. However, brain MRI of CO poisoned patients showed mainly bilateral globus pallidus lesions regardless of whether they were in the acute or chronic phase. Therefore, if high CO concentrations are suspected in the work environment and clinical symptoms related to CO poisoning are observed, we suggest that brain MRI should be considered in addition to the COHb test in blood.

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