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Functioning and Interpersonal Communication in a Victim of Carbon Monoxide Poisoning – A Case Study

Funkcjonowanie i komunikacja międzyludzka człowieka po zatruciu tlenkiem węgla – studium przypadku

Keywords:
carbon monoxide (CO) poisoning, coma, consciousness disorders, support activities for carbon monoxide poisoning

Summary: Carbon monoxide poisoning leads to the destruction of nerve cells and results in late neurological symptoms. The article presents the clinical symptoms of carbon monoxide poisoning and related consciousness disorders. A case study is analyzed which shows the characteristics of a person who, after carbon monoxide poisoning, was initially in a coma, then in a state of minimal consciousness, and is now in full consciousness. Rehabilitation and therapeutic activities are described, with particular emphasis placed on communication activities. The therapies undertaken have contributed to the better functioning of the examined person.

Słowa kluczowe:
zatrucie tlenkiem węgla (CO), śpiączka, zaburzenia świadomości, działania wspierające w zatruciu tlenkiem węgla

Streszczenie: Zatrucie tlenkiem węgla prowadzi do niszczenia komórek nerwowych i skutkuje późnymi objawami neurologicznymi. W artykule przedstawiono objawy kliniczne zatrucia tlenkiem węgla oraz zespół zaburzeń świadomości. Przedstawiono również studium przypadku ukazujące charakterystykę osoby po zatruciu tlenkiem węgla, będącej początkowo w śpiączce, następnie w minimalnej świadomości, a obecnie w pełnej świadomości. Opisano działania rehabilitacyjne i terapeutyczne ze szczególnym uwzględnieniem działań komunikacyjnych. Podjęte terapie przyczyniły się do lepszego funkcjonowania badanej osoby.

Introduction

Carbon monoxide (CO) is one of the most common toxic gases in nature, formed as a result of incomplete combustion of carbon-containing substances. The purpose of this article is to present the topic of carbon monoxide poisoning, i.e., to discuss the set of clinical symptoms and disturbances of consciousness characterizing it, as well as their impact on health and functioning in the context of interpersonal communication.

Due to its properties, carbon monoxide is non-irritating, odorless and colorless, and is easily mixed with air in all proportions; it is sometimes called the "silent killer" (Frydrych, 2017, p. 199), being one of the most common fatal causes of accidental poisoning worldwide. The source of carbon monoxide is the incomplete combustion of products containing hydrocarbons, as well as car exhaust fumes or gas stoves. The effects of CO poisoning are often tragic (Nieścior & Jackowska, 2013, p. 519).

Carbon monoxide enters the body through the respiratory tract and, in smaller amounts, through the skin and mucous membranes, while it is excreted through the respiratory system. In the blood, carbon monoxide combines with hemoglobin (Hb) to form carboxyhemoglobin (COHb). The rate of binding of carbon monoxide to hemoglobin in the initial period of exposure is high – until the balance between COHb in the blood and CO in the air is reached. After entering the blood, about 15% of carbon monoxide diffuses into tissues and binds to myoglobin and cytochrome C oxidase, thus impairing intracellular processes. Intravascularly, carbon monoxide releases nitric oxide from platelets, which begins the formation of platelet-neutrophil aggregates and the release of myeloperoxidase and proteases. As a consequence, nerve cells are destroyed, which results in late neurological symptoms (Nieścior & Jackowska, 2013, p. 520).

Carbon monoxide poisoning versus a set of clinical symptoms and areas of cognitive impairment

Clinical manifestations of carbon monoxide (CO) poisoning relate to different systems (cardiovascular, nervous, and respiratory) and organs (liver, kidneys, muscles, hearing, sight, and skin). The degree of body hypoxia can be determined on the basis of carboxyhemoglobin (COHb) levels (Table 1). Most often, symptoms appear at COHb levels above 20%.

Table 1
Clinical symptoms depending on carboxyhemoglobin (COHb) levels, and areas of cognitive impairment

COHb concentration, %	Clinical symptoms	Areas of cognitive impairment
5–10	slight, barely tangible	limited vision
10–20	slight headache, fatigue, vomiting, sluggishness, feeling unwell, indifference, shortness of breath, excessive sleepiness, palpitations	visual disturbances, hearing impairment, reduced attention span
20–30	dizziness, disturbed consciousness, flaccid paraparesis	visual field defect, worsening hearing loss, tinnitus, communication impairment
30–40	loss of consciousness, pink skin, shortness of breath and rapid breathing, shock symptoms	damage to sensory cells in the inner ear leading to hearing loss, loss of smell, loss of interpersonal communication
40–60	deep loss of consciousness, breath paralysis followed by its acceleration, lowering of body temperature	damage to sensory cells in the inner ear leading to deafness, temporary or permanent loss of smell
60–70	death occurs in a dozen or so minutes	

Source: own study based on Frydrych, 2017, p. 200; Nieścior & Jackowska, 2013, pp. 520–521.

Initial symptoms of carbon monoxide poisoning include headache, dizziness, and vomiting. A symptom which often goes unnoticed may be a sluggishness or excessive sleepiness. With more severe poisoning, there is loss of consciousness leading to a coma. In addition, carbon monoxide can cause blurred vision and visual field defects. As a result of hypoxia, hearing impairment, tinnitus and damage to sensory cells in the inner ear may occur, resulting in hearing loss or deafness. Hearing damage caused by carbon monoxide is irreversible and may get worse. Another result of poisoning can be the temporary or permanent loss of smell. There may be progressive indifference that prevents a sober assessment of the situation and the desire to save oneself. As a result of damage to the central nervous system, generalized convulsions, cerebral edema and perivascular hemorrhage may appear. In 10% of people poisoned with carbon monoxide, there are changes in the central nervous system, 40% have memory problems, and 30% have personality disorders. Carbon monoxide poisoning can also cause muscle damage. Myocardial hypoxia is particularly dangerous as atrial fibrillation or ventricular arrhythmias may follow. As a result of muscle damage and breakdown, myoglobinuria can occur, which, in turn, leads to acute renal failure. In a person poisoned with carbon monoxide, the skin color ranges from cherry red to bluish. About 20–30% of patients requiring intubation develop pulmonary edema (Frydrych, 2017, p. 201; Nieścior & Jackowska, 2013, pp. 520–521).

In the period of 2–40 days after intoxication, 3–23% of patients present new neurological symptoms. These can include a worse assessment of the situation, impaired concentration, weaker memory, urinary and stool incontinence, depression, parkinsonism, anger, slurred speech, leaning posture, dizziness, difficulty in swallowing, flaccid paralysis and mutism. Neuropsychiatric changes can occur many years after carbon monoxide poisoning. Loss of consciousness may occur, and changes in the pale knob and caudate nucleus, as well as disseminated changes in periventricular white matter, cerebellum and striatum are observed (Nieścior & Jackowska, 2013, p. 521).

Disturbances of consciousness and brain activity

Severe carbon monoxide poisoning can cause huge changes in one's consciousness. Disturbances of consciousness include disorders of attentiveness, awareness and self-awareness (Herzyk, 2017, p. 52). Their characteristic feature is the disruption of the relationship between the quantitative aspect of consciousness – understood as attentiveness, or the level of agitation – and its qualitative aspect – understood as awareness of oneself and the environment (Gosseries et al., 2011). The assessment of self-awareness and the environment is made thanks to repeated research of spontaneous purposeful behaviors and repetitive motor responses (after Kwiatkowska & Czyżewski, 2017, pp. 11–12). Communication of people with reduced awareness may relate to speaking and/or comprehension, as well as reading and writing disorders. Often, people with minimal awareness scream and cry, which, however, is not considered a message, but is associated with the expression of their emotional state (as: Kwiatkowska & Czyżewski, 2017, pp. 34–35).

The state of deeply disturbed consciousness is a coma (Białkowska, Sowa & Maksymowicz, 2011, p. 79), in which contact with the environment is eliminated (Pinkosz, 2017, p. 38). The most characteristic symptom of a coma is the disappearance of the normal cycle of sleep and wakefulness, which means that the patient only lies motionless with their eyes constantly closed (Giacino et al., 2014). This state is characterized by the lack of awareness and consciousness, as well as auditory, visual and motor functions. Communication and the expression of emotions are gone (Kwiatkowska & Czyżewski, 2017, p. 16). If the patient does not wake up from a coma within six weeks, they can fall into a so-called apallic state which can be vegetative (they are alive, but nothing reaches them), one of minimal consciousness, or one described as locked-in syndrome (they are fully aware of their surroundings but cannot communicate it in any way) (Pinkosz, 2017, p. 149). The difference between these states is huge although a person with locked-in syndrome looks almost the same as a patient in a coma (they do not move, do not speak, do not follow instructions; it seems that they do not understand anything and there is no contact with them). However, they can be fully aware but unable to communicate. After some time, they can regain consciousness because the brain is plastic, and present-day science does not know much about its ability to regenerate (Pinkosz, 2017, pp. 7–8).

The scale used to assess the degree of the disturbances of consciousness is the Glasgow ComacScale (GCS) in which the following reactions are evaluated: eye opening (1–4 points), verbal reaction (1–5 points) and motor reaction (1–6 points). The maximum score, i.e., 15 points, corresponds to the full awareness of the patient. A GCS score of 8 or below indicates a state of coma in 90% of cases (Białkowska, Sowa & Maksymowicz, 2011, p. 79). Another behavioral scale is the CRS-R, in which motor, auditory, visual and verbal reactions are assessed, together with communication skills and the degree of consciousness (Górska et al., 2014, p. 196).

Patients who are in a coma with severe neurological disorders require multi-specialized medical care and frequent, repeated diagnostic and control tests

(Białkowska, Sowa & Maksymowicz, 2011, p. 88). The sooner the rehabilitation begins, the greater the chance of recovery.

The therapeutic program for people in a coma (in a vegetative state, with minimal awareness, and with the locked-in syndrome) is based on the use of polysensory (multi-sensory) stimulation, which consists in shaping stimuli to create planned impressions and feelings. This enables learning through looking, listening, touching, smelling and tasting – that is, creating a global multisensory image of a given concept. Providing as many stimuli as information about the surrounding world as possible is aimed at stimulating neurons to create new neuronal pathways and, as a consequence, restoring at least some of the lost activities, which can lead to the awakening of a person (see C-EYE Program).

Case study

What is important for this study is the existing research on the functioning of people with consciousness disorders, with particular emphasis on interpersonal communication. Katarzyna Pinkosz (2017) describes cases of people in the apallic state – their stories, their struggle for every small gesture (a finger movement, a blink of an eyelid, a smile and a word) to establish communication with their loved ones and with society.

The research of Agnieszka Kwiatkowska and Andrzej Czyżewski (2017) concerns the understanding of the nature and degree of reading and writing disorders following trauma or hypoxia of the brain in people awakened from a coma who did not regain full consciousness but maintained eye fixation (preserved eye fixation movements were used as an innovative method of diagnosis). Studies have shown that 86% of the respondents with reduced consciousness had completely or slightly impaired ability to read one- and two-syllable words; 54% of them showed a completely preserved ability to write sounds on dictation; and 34% were able to write syllables.

Maria Pąchalska (2012) studied a variety of cases. One of them was the case of a person with mutism and subsequent dysartria after a traffic accident. The man was in a coma for nine months. Comprehensive therapy was carried out according to a phased approach, together with intensive physical, neuropsychological and neurologopedic rehabilitation. After a few weeks, the patient's condition began to change markedly, speech disorders decreased and behavioral memory improved.

A communication code (blinking code, alphabetical code) used by patients with disturbed consciousness is the dominant tool of communication in their everyday life. Philippe Vigand (1999), a patient with locked-in syndrome, used a program that employs eye movement, thanks to which he was able to communicate with his environment. He described his experience using technological assistance which was difficult for him to control, but through systematic exercises, "communicating with the environment became as efficient as possible" (Vigand & Vigand, 1999, p. 41).

The research presented below is material for reflection on the functioning of a person after severe carbon monoxide poisoning. Analyses were undertaken to understand and describe the factors determining health (somatic) functioning and to study the interpersonal communication of a person after carbon monoxide poisoning. One of the determinants on which a person's functioning depends is the type of disability that arose after carbon monoxide poisoning. Efforts made in the field of treatment, rehabilitation and therapy are another determinant.

The aim of the research, therefore, is to show therapeutic activities aimed at improving the health and functioning in the field of interpersonal communication of a person after carbon monoxide poisoning. The realization of the assumed goal requires the formulation of research questions:

– How does a person after carbon monoxide poisoning function in the context of their health and communication?
– What support actions were taken in the therapy after carbon monoxide poisoning to improve the patient's health and communication functioning?

The research method used is the individual case method. Documents were analyzed, based on which the functioning of the examined person was described. An interview with the patient's mother was also used to obtain information on his health and communication functioning.

The person examined was a 26-year-old man who had been poisoned with carbon monoxide.

Characteristics of a person after carbon monoxide poisoning – Wiktor, 29

Wiktor was born in 1991 (he is now 29 years old). He graduated from one of Silesia's universities in the field of nanotechnology and material process technology, and then was a doctoral student and employee of the Polish Academy of Sciences; he was writing a doctoral dissertation on graphene.

An interview with his mother shows that an unfortunate accident occurred on January 2, 2017. Wiktor had a cold and around 12:00 he wanted to warm himself in warm water. He took a bath, and at 16:30 (having returned from work) his mother found him unconscious. It turned out to be carbon monoxide poisoning.

The analysis of documents (information card of the Hospital of the Independent Public Health Care Facility of the Ministry of the Interior and Administration of the Republic of Poland in Katowice) shows that the patient was poisoned while taking a bath. The first medical record indicates respiratory and circulatory failure – the patient was intubated. The concentration of carbon monoxide in the body was 32.8%. Above the lungs, a follicular murmur appeared; ECG showed supraventricular tachycardia. The neurological examination found symmetric small pupils reactive to light, symmetrical floating of the eyeballs, bilateral Babinski symptom; Glasgow Coma Scale (GCS) = 4, extension to painful stimuli, redness of the left forearm and both knees.

The patient was then taken to a hospital in Sosnowiec and treated in the intoxication toxicology department, where the clinical diagnosis was of acute accidental carbon monoxide poisoning, including toxic encephalopathy, acute respiratory failure, acute bronchitis, shock in the course of intoxication, toxic myocardial tachycardia, supraventricular tachycardia in the course of intoxication, acute kidney damage in the course of intoxication, rhabdomyolysis, secondary anemia, convulsions in the course of intoxication. A CT of the head was performed (January 5, 2017) which showed no signs of intracranial bleeding, white and gray matter tissue density normal. CT scan of brain structures – normal.

On the fifth day of his stay in the hospital, Wiktor regained consciousness and was in total contact. He remembers wanting to wash himself and that when he got up to take a shower he suddenly felt that he was "flying away to Ibiza." After regaining consciousness, he asked his mother to bring him dinner, talked to medical staff and exercised his arm but, unfortunately, that night at 2:00 he lost consciousness and fell into a coma again.

On January 12, 2017, he was taken to the hospital in Murcki, where the examination showed he was without any logical contact and his eyes opened spontaneously. Other symptoms included extension to painful stimuli, equal, reactive pupils, no nystagmus, Babinski symptom absent bilaterally, left forearm wound (focal myolysis). During hospitalization, massive vegetative disorders persisted, such as increases in temperature, confluent sweats, tachycardia and increases in systemic pressure. The course of the disease suggested the development of a vegetative state. The patient was in a palliative-vegetative coma. On January 24, 2017, an MRI of the head was performed, which indicated diffuse brain damage involving both cerebral hemispheres and the corpus callosum.

On February 21, 2017, the patient was transported to the Clinical Hospital in Ochojec, where, in addition to carbon monoxide poisoning, toxic leukoencephalopathy and massive four-limb pyramidal paresis with pathological symptoms were diagnosed. There were also contractures in the lower limbs, clubfoot position and tetraplegia.

Then, on March 14, 2017, the patient was transferred to the Upper Silesian Rehabilitation Center "Repty" for rehabilitation. He was admitted in a state of minimal awareness with spastic four-limb paralysis in the course of toxic leukoencephalopathy after carbon monoxide poisoning. The following comorbidities were listed: rhabdomyolysis, multi-organ failure in the course of intoxication, chronic sinusitis. Upon admission, the patient's condition was defined as severe; Wiktor was bedridden, in the state of minimal awareness. He periodically looked around, reacted to strong external stimuli, e.g., auditory – crying, to questions – winks. Anisocoria was observed. His pupils were round, with preserved reaction to light and convergence. The medical record listed the following additional symptoms: soft symmetrical palate, guttural and palatine reflexes absent, swallowing coughs, symmetrical tongue, barely moving at the bottom of the oral cavity, covered with dense, whitish discharge, present four-limb paralysis 0 in Lovett's scale (assessment on Barthel's scale – at admission 0, at discharge 0), with increased muscle tone L > R, positive pathological symptoms of the upper limbs, generalized muscular atrophy of the limbs, flexion contractures of the interphalangeal joints, contractures of the Achilles tendons with clubfoot position, catheterized urinary tract, fed intragastric probe, required the help of others in all activities of everyday life, including body position change. Wiktor did not control physiological functions – a Foley catheter was fitted, secured with diaper pants. He also had to be assisted with pharmacological treatment. He stayed in the "Repty" Center until July 4, 2017. Afterwards, the patient was discharged to his home.

Wiktor qualified for a stem cell transplant at the Better Being Hospital (BBH) in Bangkok. The stay lasted from the end of February to the end of March 2020. During his stay in the clinic in Bangkok, he had eight stem cell transfers – five to the spinal cord and three to the bloodstream. In addition, he was monitored by specialists all the time and underwent intensive rehabilitation which included physical therapy, occupational therapy, acupuncture and hyperbaric oxygen therapy. A special diet was also prepared for him.

Rehabilitation and therapeutic activities undertaken

Rehabilitation activities – the course of rehabilitation was limited by the severity of Wiktor's general condition. Comprehensive physiotherapeutic treatment (patient trained individually; Bobath method; PNF; passive limb exercises; mobilization of contracted joints) brought no visible improvement in functional status. When put up in a wheelchair without central control, the patient required support of the head and torso, did not help with the transfer to the wheelchair; he was first set up in the upright position at the tipping table, then in the standing frame with about 20 minutes tolerance.

Speech therapy – during the first speech therapy examination, it was determined that Wiktor was conscious but without verbal and non-verbal contact; he did not fixate his eyes, nor did he follow simple instructions. However, he answered questions by blinking his eyelids. Other symptoms included hypomimic face, open mouth, shallow breathing, lifted palatopharyngeal reflexes, tongue covered with white coating and limited mobility of articulatory organs. Therapy was implemented as part of daily meetings. Polysensory therapy (aromatherapy, taste therapy, music therapy, visual stimulation and touch therapy) was implemented. A method of activating the patient's psychological abilities was used by affecting his environment (photo gallery, colorful props, the patient's favorite items). Stimulation of the orofacial tract was undertaken in order to normalize muscle tone and prepare the articulatory apparatus for speech and swallowing. For this purpose, intra- and orofacial vibration massages, ice massages and Castillo-Morales orofacial regulation therapy were implemented. Efforts were made to improve functions directly related to speech (elements of breathing and articulation exercises by manually opening the way for sounds).

C-Eye system[1] was used in the course of therapy to assess Wiktor's level of consciousness and neurorehabilitation of cognitive and language functions,

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1 C-Eye involves the use of sight to control a computer – an infrared camera tracks the eyesight, thanks to which a person can communicate with the environment, as well as perform special tasks based on multimedia content. The software uses three modules. The first is the patient's condition assessment module, used for:
– eye (sight range) and hearing (comfort level) tests;

and to stimulate his emotions and motivation. The C-Eye system registered some possibilities in speech understanding and cognitive efficiency, and first communication attempts by means of writing in the "daily communication" module. The patient's responses in many trials were adequate; however, many erroneous responses were also recorded, even at a basic level. New ways of contact with the environment have emerged through vocalizing the "a" or "e" vowels, nasal sounds and snorting and stretching of the whole body in the situation of strong emotions experienced by the patient. The C-Eye system made it possible for Wiktor to communicate with the world; all he had to do was look at the monitor screen and focus his eyes on a specific point, so that the computer could sense and track his pupil movement. Through pictures, pictograms and a virtual keyboard, Wiktor could express what he thought and felt. The C-Eye system enabled neurorehabilitation and alternative communication.

As a result of the therapies, functional capabilities were improved, non-verbal contact with the environment, eyesight fixation, and even periodically carrying out simple instructions were all registered.

From the very beginning, the therapy used the Tomatis method.[2] Wiktor listened to music – not just Mozart – three times a day for 1.5 hours. At first,

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– research on language functions: understanding words (single words, simple sentences, complex sentences), reading words with understanding, reading sentences with understanding, writing skills, identifying sounds with a picture;
– research on cognitive functions: visual-spatial (object recognition study, size perception study, color perception study, object structure perception study – letters, objects); memory test (semantic memory test, visual material memory test); thinking study (study of cause and effect thinking, classification of objects); testing communication skills (situational language skills, pragmatic language skills, expressing needs).

The second module – neurorehabilitation – consists of five groups of tasks: exercises of language functions, visual-spatial functions, memory, thinking and imagination. The goal of the last module – communication and entertainment – is to provide a person with functional tools for communication and entertainment (Kochanowicz, 2019, pp. 114–115).

2 For people in coma, the Tomatis method is used, which stimulates the brain with music and voice. It is a technique of sensory sound stimulation. According to Alfred Tomatis, hearing is dependent on external stimuli, while listening is related to human mental activity (Kurkowski, 2001, p. 198). The hearing organ ensures constant communication with the surroundings, and allows for recognition of many phenomena. The ability to listen contributes to how we perceive the surrounding world (Ratyńska, 2013, p. 18). On the one hand, sound is transmitted through bone conduction, by means of vibration exerted in the upper part of the skull; on the other hand; it is transmitted through air conduction, passing through the ear canal. As a result of sound vibration, the muscles stimulate the inner ear organs – the cochlea and the

it was his mother's recorded voice, and when he woke up from a coma and was in a state of minimal awareness, the stimulation consisted of listening to the recorded voice of his sister, childhood memories and then recordings of his friends. In June 2017, Wiktor showed the first signs of understanding, eye contact was more frequent, he tried to communicate, his reactions were varied, he laughed and cried. Continuing stimulation therapy allows him to work on long-term memory, his pronunciation is improving, and he is also beginning to read simple words.

Conclusion

The effects of carbon monoxide poisoning can be tragic, which is why it is extremely important to undertake multi-specialist rehabilitation and therapeutic care after an accident. The functioning of the injured person will depend on how quickly the stimulation begins.

Based on the case study, the following conclusions can be made:

1. As a result of multi-specialized therapeutic activities, the functioning of the examined person in the field of health and interpersonal communication after carbon monoxide poisoning has significantly improved. Wiktor is functioning better and better: he speaks full sentences, understands and answers questions, begins to read simple sentences, solves crosswords and mathematical problems of varying degrees of difficulty. He still does not walk and does not sit alone, but secured in his wheelchair and with some help, he can eat a sandwich.
2. Right after carbon monoxide poisoning was diagnosed, supporting activities were undertaken to improve Wiktor's health and communication functioning. Rehabilitation methods included the Bobath method, upper and lower limb exercises, setting him up in a wheelchair and

vestibule. Both the cochlea and the atrium dynamize the brain (http://www.klinikabudzik.pl/pl/klinika/ponadstandardowe-zabiegi-rehabilitacyjne [accessed: 25.04.2020]). Tomatis created an original device called the "electronic ear." This device enables stimulation of perception with sounds of a specific frequency band given in appropriate sequences, as well as the use of properly regulated balance of sound intensity for the right and left ear. In addition, the transmission of sounds by air and bones (via an additional bone receiver) is modified in order to stimulate microgymnastics of the middle ear muscles. An important element of therapy is the ability to perceive your own sounds properly filtered – so that the voice, undergoing a favorable change (through a filter system), affects the less active spheres of perception (Kurkowski, 2001, p. 199).

a tilting table. As part of speech therapy, polysensory therapy, a method of activating mental capabilities, as well as Castillo-Morales orofacial regulation therapy were used. Activities directly related to speech improvement were undertaken, The C-Eye system and the Tomatis method were used. Constant, multi-specialist, long and arduous rehabilitation and neurologopedic therapy, as well as all other support activities aimed at bettering health and communication functioning, should be continued – possibly until the end of the patient's life.

The development of knowledge and medical technology enables the saving of lives and keeping people alive after neurological episodes. The supporting and stimulating actions described in this paper give hope for better prognoses for recovery and, ultimately, for improving the quality of a patient's life.

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