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Interpretation of COHb concentrations in the left and right heart blood of cadavers*

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Summary. Carbon monoxide hemoglobin (COHb) concentrations in left and right heart blood samples from cadavers both exposed and not exposed to fire or CO gas were analyzed by the gas chromatographic method. The COHb concentration ratio between samples of left and right heart blood (L/R ratio) does not appear to be useful for establishing whether death has occurred before or after exposure to fire with the exception of cases where no soot can be detected in the airways by the naked eye and the COHb concentration in the blood sample is within the level considered normal for tobacco smokers.

Key words: Fire victim – Exposure before or after death – Carbon monoxide hemoglobin – Gas chromatography

Zusammenfassung. Mit Hilfe der Gaschromatographie wurde die Kohlenmonoxid-Konzentration im Blut des rechten und linken Herzens vergleichend untersucht. Das Material stammt von Leichen mit antemortaler oder nicht-antemortaler Feuer- oder CO-Exposition. Das Konzentrationsverhältnis von COHb zwischen linkem und rechtem Herzblut (L/R-Quotient) scheint ein nicht brauchbares Kriterium zu sein, um festzustellen, ob der Tod sich vor oder nach der Feuer-Exposition ereignet hat; mit der Ausnahme von solchen Fällen, wo bei makrokopischer Untersuchung kein Ruß in den Atemwegen gefunden wird und wo die COHb-Konzentration innerhalb jener Grenzen ist, welche für Zigaretten-Raucher als normal angesehen werden.

Schlüsselwörter: Brandopfer – Antemortale und postmortale Exposition – Kohlenmonoxid-Hämoglobin – Gaschromatographie

Introduction

The carbon monoxide hemoglobin (COHb) concentrations in blood samples collected at medicolegal autopsy from cadavers exposed to fire or CO gas can range from less than 1% to close to 100% [1–4]. When victims are found in the debris of fires, for example, it is very difficult to determine whether death has occurred before or after exposure to fire if the COHb concentration in the blood is within the level considered normal for tobacco smokers and soot in the airways can not be detected.

Exposure to CO immediately prior to death could produce a difference in COHb concentrations between left and right heart blood [4–6]. In order to interpret the results the COHb concentration ratio between samples of left and right heart blood (L/R ratio) were determined using blood samples collected at medicolegal autopsy from victims both exposed to and not exposed to fire or CO gas.

Materials and methods

Left and right heart blood samples were collected at medicolegal autopsy from 20 victims not exposed to fire or CO gas, 89 exposed immediately before death, 3 exposed after death, and 5 in which it was not known whether death had occurred before or after exposure to fire or CO gas.

COHb concentrations in blood samples were determined by the gas chromatographic method described previously [7, 8]. CO released from blood samples was analyzed by gas chromatography and total hemoglobin was measured as cyanmethemoglobin. COHb concentration was calculated by the ratio of CO content and CO-binding capacity.

Petroleum ingredients in the blood samples were analyzed by gas chromatography-mass spectrometry after extraction using organic solvent both with and without an Extrelut column [6].

Results

When control samples of blood containing 10%, 50% and 90% COHb were analyzed average recoveries determined by 5 separate measurements were 101.5%, 100.5% and 101.9% respectively, and coefficients of deviation were 3.4%, 3.3% and 3.6%, respectively [7].

1. Victims not exposed to fire or CO gas (Table 1).

This collective consisted of 20 deaths (for details see Table 1). COHb concentrations of the blood varied be-

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Table 1. COHb concentrations in left and right heart blood from victims not exposed to fire or CO gas

Smoking	Age Sex	Cause of death	COHb (%)		Ratio
			Left	Right	
−	51 F	Cold exposure	1.55	1.52	1.02
−	83 F	Asphyxia	0.50	0.49	1.02
−	53 M	Intracerebral h.	1.24	1.17	1.06
−	21 F	Drowning	0.21	0.18	1.17
−	85 F	Brain injury	0.99	0.83	1.19
−	.75 M	Drowning	0.20	0.15	1.33
+	44 M	Bleeding	1.43	1.47	0.97
+	31 M	Subarachnoid h.	4.31	4.27	1.01
+	40 F	Subdural hematoma	0.52	0.51	1.02
+	34 M	Neurotropic drug i.	0.44	0.41	1.07
+	21 F	Asphyxia	2.06	1.89	1.09
+	62 M	Neurotropic drug i.	0.68	0.62	1.10
+	71 M	Bleeding	1.84	1.62	1.14
+	51 F	Subarachnoid h.	0.37	0.32	1.16
+	31 M	Methamphetamine i.	1.16	0.99	1.17
+	54 M	Intracerebral h.	0.75	0.64	1.17
+	70 M	Starvation	0.46	0.37	1.24
?	ca 40 M	Brain injury	2.18	2.28	0.96
?	38 M	Hepatic insuf.	1.01	0.87	1.16
?	44 F	Alcohol i.	0.53	0.40	1.33
Average					1.12

Age: Years, Left: Left heart blood, Right: Right heart blood, Ratio: The ratio of the COHb concentration in the left heart blood to that in the right heart blood, F: Female, M: Male, h.: hemorrhage, i.: intoxication, insuf.: insufficiency

Table 2. COHb concentrations in left and right heart blood from victims exposed to fire or CO gas after death

Smoking	Age Sex	Cause of death	COHb (%)		Ratio
			Left	Right	
−	14 F	Asphyxia	0.21	0.24	0.88
−	8 F	Asphyxia	1.30	1.05	1.24
+	52 M	Asphyxia	2.30	1.78	1.29
Average					1.14

Keys are the same as those in Table 1

tween 0.15% and 4.31% L/R ratios ranged from 0.96 to 1.33, and were above 1.00 in 18 out of 20 cases.

2. Victims exposed to fire after death (Table 2).

COHb concentrations in the left and right heart blood samples ranged from 0.21% to 2.30%, and L/R ratios ranged from 0.88 to 1.29.

3. Victims exposed to fire or CO gas prior to death (Fig. 1 and Table 3).

COHb concentrations in left and right heart blood samples ranged from 0.15% to 103.9% (this exceptionally high value is explained in the discussion), and L/R ratios ranged from 0.85 to 2.58 (mean 1.09).

Table 3. COHb concentrations in left and right heart blood from victims exposed to fire or CO gas before death (COHb concentrations in the right heart blood < 10%)

Age Sex	Soot (P)	COHb (%)		Ratio	Situation of death from burning
		Left	Right		
86 F	+	6.90	8.14	0.85	House fire
37 M	+	4.93	5.72	0.86	Accidental automobile fire
75 F	+	0.72	0.79	0.91	House fire
76 M	+	5.15	5.42	0.95	House fire
76 F	+	1.92	1.99	0.96	House fire
59 M	+	4.81	4.90	0.98	House fire
45 F	+ (+)	1.58	1.59	0.99	House fire
33 F	+	3.91	3.87	1.01	House fire
78 F	+ (+)	3.75	3.56	1.05	House fire
47 F	− (+)	2.51	2.40	1.05	Suicide by kerosene fire
40 F	+ (+)	2.72	2.51	1.08	Suicide by kerosene fire
33 F	− (+)	5.04	4.61	1.09	Murder by kerosene fire
19 M	+ (+)	4.81	4.34	1.11	House fire
61 F	+ (+)	1.13	1.00	1.13	House fire
41 M	− (+)	2.79	2.40	1.16	Accidental automobile fire
29 M	+ (−)	0.18	0.15	1.20	Suicide by gasoline fire
79 M	− (+)	2.09	0.81	2.58	Murder by kerosene fire
Average				1.12	

Soot: Soot in the airway found (+) or not found (−) by the naked eye, (P): Ingredients of petroleum were detected (+) or not detected (−) in the left heart blood sample, House fire: Unknown situation. Other keys are the same as those in Table 1

This collective consisted of 89 cadavers and could be subdivided according to the COHb in the right heart as follows: (a) $n = 72$ cases with concentrations higher than 10% (Fig. 1); (b) $n = 17$ cases with concentrations less than 10% (Table 3).

L/R ratios in subgroup (a) ranged from 0.88 to 1.45 (mean 1.09), and in 8 cases were lower than 1.00. In only one case was the ratio higher than 1.33 (see Fig. 1).

L/R ratios in subgroup (b) ranged from 0.85 to 2.58 (mean 1.12) and in 7 cases were lower than 1.00. In only one case was the ratio higher than 1.33 (see Table 3).

In 13 cases COHb concentrations were less than 5% (Table 3).

In 4 cases, no soot could be detected in the airways by the naked eye. Petroleum ingredients in the left heart blood samples were detected in 9 out of 10 cases in which inflammable substances had been used.

4. Cases in which it was not known whether death had occurred before or after exposure to fire (Table 4).

COHb concentrations in the left and right heart blood samples of 5 victims were analyzed. In all cases, no soot was detectable in the airways by the naked eye. In 2 cases where it was suspected that inflammable substances had been used to start the fires, petroleum ingredients could not be detected in the left heart blood samples.

COHb concentrations in the left and right heart blood samples ranged from 0.27% to 5.68%, and L/R ratios from 0.94 to 1.79. In 2 out of the 5 cases ratios were higher than 1.33.

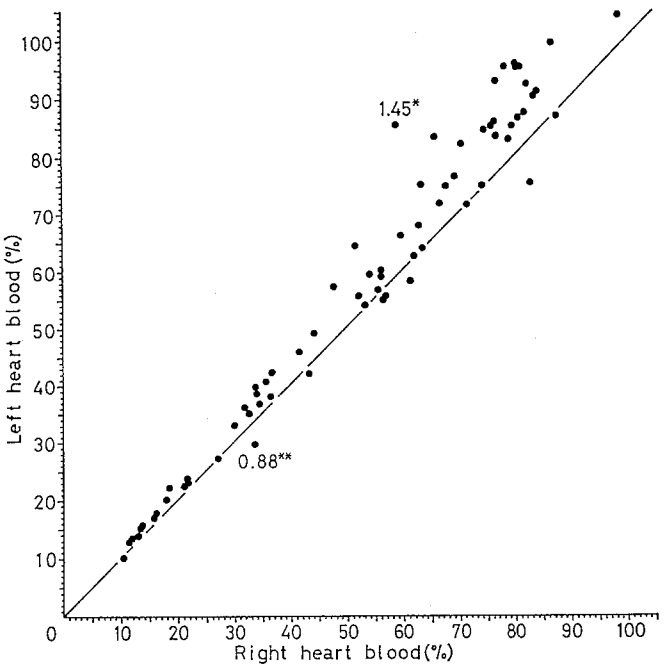

Fig. 1. Correlation between COHb concentrations in left and right heart blood of victims exposed to fire or CO gas before death (COHb concentrations in the right heart blood ≧10%). *The highest and **the lowest ratio of the COHb concentration in the left heart blood to that in the right heart blood

Table 4. COHb concentrations in left and right heart blood from victims in cases in which it was unknown whether death had occurred before or after exposure to fire or CO gas

Smoking	Age Sex	COHb (%)		Ratio	Remarks
		Left	Right		
–	30 M	1.57	1.67	0.94	Traffic accident, severe burns
–	46 F	0.38	0.27	1.41	Injuries by compression in the neck, (P): –
+	50 M	3.63	3.91	0.93	Alcohol concentration (mg/g): heart blood 3.95, urine 4.76, stomach contents 5.68, (P): –
+	49 F	5.68	5.15	1.10	Alcohol concentratin (mg/g): heart blood 4.04, urine 3.91, stomach contents 13.8
+	61 M	3.22	1.80	1.79	Fatal cardiac infarction

Keys are the same as those in Table 3

Discussion

COHb concentrations in blood collected from a cadaver with extensive burns or from a putrefied body should be determined by gas chromatography [9, 10]. Many gas chromatographic methods have been developed, and Iffland et al. [11] have recently reported a sensitive and accurate method where the CO content is measured by gas chromatography and the iron content by atomic absorption spectrometry. In the present study, COHb concentrations were determined using the amount of CO analyzed by gas chromatography and the total Hb measured by a cyanmethemoglobin method. This method used for determination of COHb concentration is very accurate and reliable. In control samples of blood containing 10%, 50% and 90% COHb average recoveries and coefficients of deviation, determined by 5 separate measurements, ranged from 100.5% to 101.9% and 3.3% to 3.6%, respectively [7]. In the present study, COHb concentration in one left heart blood sample was found to be more than 100% (i.e. 103.9%). This was not due to a calculation error, but was considered to be due to measurement error and/or supersaturation of CO dissolved in the blood.

Some studies on COHb concentrations in left and right heart blood samples collected from victims exposed to fire or CO gas immediately before death have been reported [3–5, 12]. According to Yoshida et al. [4] and Matsubara et al. [5] a higher concentration of COHb in the left heart blood as compared to right heart blood indicates that the victim has been exposed to CO gas before death. However, the mean value of the L/R ratio obtained from cadavers exposed to fire or CO gas before death was not significantly different from that obtained from victims not exposed to fire or CO gas before death. This seems to indicate that the blood continues to circulate after the cessation of respiration in many cases of fire victims, and this leads to an equilibration of left and right levels. Even after death, postmortem blood movement from lungs to left and right heart cavities [13–15] will lead to a further levelling of COHb concentrations.

L/R ratios of 20 victims not exposed to fire or CO gas ranged from 0.96 to 1.33. In all 3 cases where the victims had been set on fire after death, L/R ratios were less than 1.33. These results would suggest that the L/R ratios in victims not exposed to fire or CO gas immediately before death are lower than 1.33. In only 2 cases out of 89 in which victims had been exposed to fire or CO gas before death, were L/R ratios higher than 1.33. According to these results the L/R ratio would not appear to be useful for determining whether death has occurred before or after exposure to fire.

On the other hand, obvious differences were found in a case of murder by kerosene fire (the last case in Table 3) and in the case of death from cardiac infarction. (The last case in Table 4). In these 2 cases, it was suspected that the blood circulation had been stopped by ventricular fibrillation before the cessation of respiration. It was presumed that the COHb concentration in the left heart blood was significantly higher than that in the right heart blood at the time of cardiac arrest, and that the postmortem movement of blood did not lead to a levelling of left to right concentration differences.

It would appear that the L/R ratio is not useful for establishing whether death has occurred before or after exposure to fire with the exception of cases where no soot can be detected in the airways by the naked eye and COHb concentration in the blood sample is within the level considered normal for tobacco smokers.

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