International Journal of Biochemistry and Biotechnology Vol. 1 (2), pp.019-023,April, 2012.
Available online at http://internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Chronic, long-term presence of mercury due to a single injection of elemental mercury in human

Teresa Lech[1, 2], and Halina Goszcz[2]

[1] *Institute of Forensic Research, Krakow, Poland*
[2]*Department of Toxicology, Faculty of Pharmacy, Collegium Medicum Jagiellonian University, Krakow, Poland*

Received March 13, 2012; Accepted April 27, 2012

Elemental mercury, when injected, as opposed to inhaled, caused few of the effects typical of mercurialism; however, pleuritic chest pain was frequent, whereas renal and central nervous system symptoms were less common. In this work, five cases of intentional poisoning are presented: subjects (17–29 years) had injected themselves intravenously with a single dose of mercury in suicide attempts (one subject was a drug addict). In all cases the concentration of mercury (by cold vapor atomic absorption spectrometry) in blood, urine and hair samples was high, even a relatively long time after the injection, e.g.: case 5 (2.5 years after the incident) – blood: 27.7, urine: 74.0 µg/L, and hair: 0.09 µg/g; case 2 (5.5 years) – blood: 22.8, urine: 543 µg/L, and hair: 0.50 µg/g; case 1 (7 and 9 years) – blood: 79.5 and 94 µg/L, urine: 844 and 720 µg/L, and hair: 0.39 and 0.33 µg/g, respectively, and exceeded reference levels (blood – up to 10–15 µg/L, urine – 20 µg/L, hair – 0.20 µg/g) by several to 30 (blood), 50 (urine) or 7 (hair) times. Only in case 5 did concentrations drop to reference levels, but only after 10 years. The results revealed that the long-term presence of this metal was considerable.

Key words: elemental mercury, injection, long-term presence, concentration, body fluids, hair

INTRODUCTION

Mercury has many attractive and useful properties, but it also presents a risk of toxic effects (Clarkson et al., 2003; Berlin et al., 2007). The clinical effects of mercury intoxication depend on the route of administration, the chemical form of the metal, and the quantity (Clarkson et al., 2003; Berlin et al., 2007; Lech et al., 2006). Mercuric ions play a key role in the toxicology of most forms of mercury; these can react with free SH-groups of proteins (Clarkson et al., 2003; Winker et al., 2002; Deschamps et al., 2002). Metallic mercury intoxication is currently rather rare, except in the case of inhalation during environmental and occupational exposure (Clarkson et al., 2003). Suicidal attempts by means of metallic mercury are quoted by Wright et al., 1980, Sanemüller et al., 1996, Lech et al., 2006 and others. Parenteral self-administration of metallic mercury is extremely uncommon. A review of the literature of the years up to 2000 brought to light about 78 cases (Winker et al., 2002). Recently, most cases have concerned intentional injection: intravenous (Winker et al., 2002; Oliver al., 1987; Hannigan, 1978; Walter, 1986; Murray et al., 1988; Giombetti et al., 1988; Netscher et al., 1991; Anderson, 1993; Kedziora et al., 1995; Nalepa et al., 1996; dell`Omo et al., 1997; Torres-Alanis et al., 1997; Givica-Pérez et al., 2001; Chodorowski et al., 2002; Konopka et al., 2006; Gopalakrishna et al., 2008; Vallant et al., 2008; Wale et al., 2010) or subcutaneous (Deschamps et al., 2002; Wale et al., 2010; Krohn et al., 1980; Soo et al., 2003; Maynou et al., 2000; Prasad, 2004; Ansell et al., 2010; Kayias et al., 2003; Hagdoost et al., 2010), whereas previously there were often accidental poisonings. Most accidental 'injections' occurred after injury from broken thermometers (Anderson, 1993; Nalepa et al., 1996; Givica-Pérez et al., 2001).

A few reports have described mercury poisoning from oral intake and/or intravenous injection (Winker et al., 2002), either accidental or intentional, mostly involving patients with psychiatric disorders (Murray et al., 1988;

*Corresponding Author's E-mail: tlech@ies.krakow.pl

Giombetti et al., 1988; Torres-Alanis et al., 1997; Givica-Pérez et al., 2001), or abusers of alcohol or drugs (Winker et al., 2002; Loranzo Dus et al., 2007). Sometimes people take mercury for doping, e.g. 0.5 mL of liquid/dose for 3 years (Chodorowski et al., 2002), or for recreational (Ellis et al., 2009) purposes. A recent report concerned surreptitious injection, in which mercury deposits in soft abdominal tissues were detected by scanning electron microscopy (SEM) and energy dispersive X-ray spectrum analysis (Ellis et al., 2009). In nearly all the remaining cases, the presence of metallic mercury in tissues was demonstrated by radiography (Winker et al., 2002; Deschamps et al., 2002; Oliver al., 1987; Walter, 1986; Netscher et al., 1991; Anderson, 1993; Kedziora et al., 1995; Nalepa et al., 1996; Torres-Alanis et al., 1997; Givica-Pérez et al., 2001; Konopka et al., 2006; Krohn et al., 1980; Maynou et al., 2000; Ansell et al., 2010; Kayias et al., 2003; Hagdoost et al., 2010; Loranzo Dus et al., 2007; Matushita et al., 2007), either at the site of introduction or in the form of emboli, particularly in the pulmonary (Oliver et al., 1987; Anderson, 1993; Lorenzo et al., 2007; Rogothaman et al., 2007) or cardiac (Kedziora et al., 1995) vasculatures. Additionally, in some cases CT scans and USG examination disclosed similar deposition of metal in other organs (Nalepa et al., 1996; Torres-Alanis et al., 1997). Relatively often in the case of toxic blood levels followed by a severe local inflammatory reaction at the injection site resulting from extravasation of mercury, surgical excision was undertaken (Winker et al., 2002; Oliver et al., 1987; Netscher et al., 1991). Subcutaneous elemental mercury injection also sometimes resulted in formation of a granuloma, which was treated with delayed resection (Prasad, 2004; Kayias et al., 2003). The long-term effects of chronically elevated blood, urine or hair mercury levels are not well known (Winker et al., 2002). Blood Hg levels remain elevated within the toxic range probably due to the continued absorption of embolized mercury (Deschamps et al., 2002; Oliver et al., 1987; Anderson, 1993, dell`Omo et al., 1997; Torres-Alanis et al., 1997; Konopka et al., 2006). According to recent knowledge, elemental mercury poisoning probably causes cortical myoclonus (Rogothaman et al., 2007).

In this work, five cases of intentional poisoning are presented. All the subjects, in the age range 17–29 years, had injected themselves intravenously, most often with a single dose of metallic mercury and generally in suicide attempts. Only one of the subjects was a drug addict.

Case Reports

These reports described five cases of self-injection of metallic mercury. Nearly all cases concerned a single intravenous injection of from a few to a dozen or so cm^3 of elemental mercury, except case no 2 – which involved the repeated suicide attempts of a patient. In most cases, mercury originated from broken thermometers.

***Case 1*:** A 29-year-old male, a drug addict, injected metallic mercury into a vein in the elbow region. After 2 weeks, he was hospitalised. In X-rays of the site of injection, pulmonary fields and abdominal cavity, “foreign metallic bodies“ were present. After 1 month, the patient received 5 days’ chelating treatment – d-penicillamine (300 mg twice a day) and vitamin B_6 (40 mg daily); a week later a surgical excision was undertaken. Tremors persisted for 3 years. 88 months after intravenous injection, the patient was treated with chelating therapy once again (4 days).

Case 2: An 18-year-old male was admitted to hospital due to elevated fever of over 39℃ and hemoptysis. Both symptoms presented 18 months following intravenous injection of metallic mercury in the elbow region. Radiological examination disclosed fine metallic interstitial shadowing in the lung parenchyma. Metallic shadows were also present in the subcutaneous region of the cubital fossa. CT scans and USG examination revealed similar deposition of metal in the other organs (liver, kidneys, lymph nodes and heart). The mercury, blood and urine levels exceeded the reference values by many times (Nalepa et al., 1996). The patient repeated the injection a few times. Finally, he committed suicide by hanging 11 years after the first injection. In the extraordinary autopsy, metallic mercury deposits within the cardiac muscle were found (Konopka et al., 2006). The results of examination for mercury in papers (Nalepa et al., 1996) and (Konopka et al., 2006) were obtained by the first authors of this article.

***Case 3*:** A 25-year-old male with suicidal intent intravenously self-administrated metallic mercury into the vein of his forearm.

Case 4: An 18-year-old female self-injected metallic mercury into the vein of the elbow. She suffered from leg pains. Metallic shadows in X-rays of lungs were observed.

***Case 5*:** A 17-year-old girl injected metallic mercury into the vein of both forearms for suicidal purposes. On admission, vomiting, vertigo, restlessness, and locally, in the cubital fossa, flare and vesiculation, followed by necrosis, occurred. After 2.5, 31.5, and 32 months, the patient was treated with d-penicillamine (4, 6 and 10 days, respectively). Additionally, 31.5 months after the injection, a surgical excision was undertaken. In the lung parenchyma (X-ray), as well as at the heart valvula (echocardiography), metallic droplets were observed. After 5 years, in a control test, tremors, and after 9 years – decreased muscle power (muscle of shoulder girdle), were ascertained.

MATERIAL AND METHODS

Blood, urine, skin and hair samples taken from patients of the Toxicology Clinic at the Collegium Medicum, Jagiellonian University

Table 1: Concentrations of mercury found in blood, urine, hair and skin samples in cases of elemental mercury injection

Case No	Gender, age	Time after injection (months)	Concentration of Hg (µg/L or µg/g)			
			Blood	Urine	Hair	Skin
1	Male, 29	0.5	400	-	-	-
		1.0	120	-	-	-
		1.2	158	512	-	0.17
		1.6	201	889	-	-
		1.9	-	-	0.20	-
		2.2	256	-	-	-
		2.3	195	-	-	-
		80	39	-	0.45	-
		81	72	-	0.43	-
		88*	79.5	844	0.39	-
		89	81	556	-	-
		109	94	720	0.33	-
2	Male, 18	18	102	1146	-	-
		22**	222	2129	-	-
		31	133	-	-	-
		32	-	1389	-	-
		42	-	-	1.00	-
		65	22.8	543	0.50	-
3	Male, 25	1	-	960	-	-
4	Female, 18	11	38.5	163	-	-
5	Female, 17	2.5	56.2	906	1.12	-
		3	29.2	581	-	-
		5	29.9	185	0.80	-
		10	58.0	171	0.45	-
		14.5	7.5	95	0.04	-
		31.5***	27.7	74	0.09	-
		48	19.1	30	0.05	-
		54	20.0	10	0.13	-
		114	13.7	2.53	0.07	

- not determined;
* after 4 day`s chelation therapy: urine – 2338 µg/L;
** the results for mercury in blood and urine – after chelatation;
*** surgical excision followed by 6 day`s chelation therapy: blood – 18 µg/L, urine – 783 µg/L, and next 10 day`s chelation therapy: blood – 33 µg/L, urine – 265 µg/L

in Kraków were submitted for toxicological analyses. Total mercury was determined using cold vapor atomic absorption spectrometry (CV AAS) (Pye Unicam SP-9800 atomic absorption spectrometer with a unit for cold vapors, Cambridge, UK).

Prior to analysis, samples of biological material (blood: 1–10 mL, urine: 10–50 mL, hair: 0.1–0.5 g, skin: 0.2 g) were digested with concentrated nitric and sulfuric acids in closed glass apparatuses. Hg^{2+} ions in an acidic solution (concentrated sulfuric acid), in the presence of hydroxylamine hydrochloride and sodium chloride, were reduced by means of tin chloride(II) to metallic mercury. Hair samples were cleaned for analysis in accordance with the recommendations of the International Agency for Atomic Energy based in Vienna. All reagents were analytical grade from Merck (Darmstadt, Germany). Validation parameters of the applied analytical technique have been presented in previous papers (Lech et al., 2006). The detection limit was 15 ng Hg in a sample.

All measurements, as well as those which were presented in (Nalepa et al., 1996) and (Konopka et al., 2006), were carried out at the Institute of Forensic Research in Kraków.

RESULTS

In the described cases, toxic blood, urine or hair mercury levels were found over a long period of time, even up to 9 years (case 1) after intravenous self-injection of mercury. In case 5, the concentrations of mercury in blood, urine and hair dropped to reference levels, but only after 10 years. The results are presented in Table 1 and in Fig. 1. In two cases (1 and 5), a surgical excision was

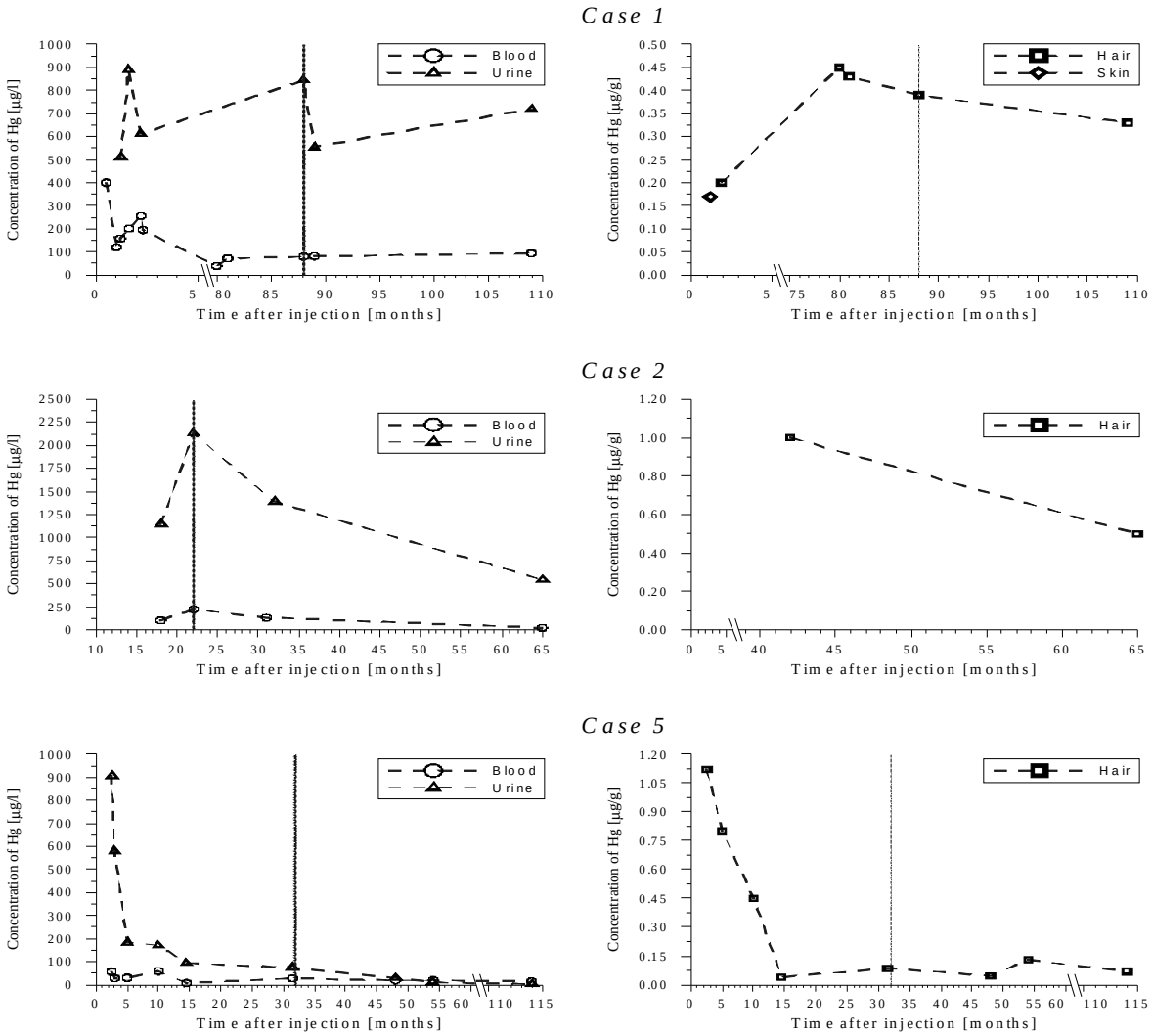

Figure 1: Concentrations of mercury in blood, urine, hair and skin in some cases of intravenous injection (vertical lines – time of chelation therapy).

performed; in three cases (1, 2 and 5) – chelation therapy was also used.

DISCUSSION

Although intravenous injection of mercury is a rare event, it is known that administration by this route may have several different consequences (Netscher et al., 1991). According to the literature (Winker et al., 2002), no lethal consequences from intravenous injected metal are to be expected; however, Murray and Hedgepeth (Murray et al., 1988) reported a complicated case where, in spite of dimercaprol therapy, the patient died within a few weeks. Long-term monitoring is lacking in most cases.

We report cases in which toxic blood and urine mercury levels were found a long time after intravenous self-injection of mercury – up to 9 years (case 1). Elemental mercury, when injected, as opposed to inhaled, caused few of the effects typical of mercurialism (because only a part of mercury is transported into the central nervous system; most of it is deposited in internal organs, lungs, kidneys, aortic valve, as well as at the site of injection), e.g. mercurial tremors and leg pains; however pleuritic chest pain was frequent, whereas renal and central nervous system symptoms were less common. In case 1, approximately two weeks after the incident, and in case 5, a year and a half after the incident, a routine pre-operative examination – a chest radiograph – showed a large number of metallic particles in the pulmonary parenchyma, and only mild clinical symptoms appeared (tremors for 3 years in case 1, and after 5 years in case 5, as well as later muscular weakness in case 5). One additional and noteworthy finding in our cases was that the concentration of mercury in blood, urine and hair samples was high (several to 50 times above the “normal

values"), even a relatively long time after the injection, for example: case 5 – 2.5 years after the incident – blood: 27.7 µg/L, urine: 74.0 µg/L and hair: 0.09 µg/g; case 2 – 5.5 years after the incident – blood: 22.8 µg/L, urine: 543 µg/L and hair: 0.50 µg/g; case 1 – 7 and 9 years after the incident – blood: 79.5 and 94 µg/L, urine: 844 and 720 µg/L and hair: 0.39 and 0.33 µg/g, respectively; reference values: blood – up to 10 (Winker et al., 2002; Murray et al., 1988) or 15 (Winker et al., 2002; Oliver et al., 1987) µg/L, urine – up to 20 µg/L (Winker et al., 2002; Oliver et al., 1987; Murray et al., 1988; Krohn et al., 1980), hair – 0.20 µg/g (Lech et al., 2006). In case 2, after 3.5 years the mercury level in hair was about 7 times and after 5.5 years – still 3 times higher than the levels in hair in non-exposed people. In only one case (case 5), the concentrations of mercury in blood, urine and hair dropped to references levels, but only after 10 years. After the chelation therapy, in case 1, urinary mercury concentrations increased significantly to 889 (1.2 months after injection), and next decreased to 844 (88 months after injection) µg/L; however, in case 5, oral penicillamine was administrated without evidence of benefit, which confirms the thesis that the role of chelation in the treatment of mercury injection is controversial. According to Deschamps et al., 2002, chelation therapy is performed usually when one observes central nervous system or renal function toxic reactions. In our second case, however, the increase in blood and urine mercury concentrations was due to repeated injection of mercury.

For comparison, Winker et al., 2002 found in a 22-year-old man 6 months after injection of mercury, greater whole-blood mercury and urine concentrations – 680, and 140 µg/L, respectively, but in this case, however, mercury injection (0.6 mL) was accompanied by oral intake (100 mL) of mercury. At the same time, the abdomen showed no pathological signs, and no intercardial mercury deposits were detectable either. In another case, reported by Anderson, 1993, in a 26-year-old woman, serum and urinary mercury levels were

monitored over a three year follow-up. Blood mercury levels which were initially 1000 rapidly fell to 300–400 nmol/L (normal – less than 25 nmol/L) after administration of 2,3-dimercaptopropane-1-sulfonate (DMPS), and remained at that level following the discontinuation of this treatment. Urinary mercury rose during treatment to nearly 13000 when DMPS was commenced, and fell to 3000 nmol/L in a few weeks (normal – less than 100 nmol/L), then remained fairly constant.

Most patients in reported cases of administration of intravenous metallic mercury have remained well. Some patients develop a reduction in transfer factor. Variable renal and neurological sequelae have also been documented (Anderson, 1993). From 24 reports reviewed by Giombetti et al., 1988, of intravenous injection of metallic mercury, at least 12 patients were followed up and remained asymptomatic throughout. Seven patients reported pleuritic chest pain, but only four complained of dyspnoea; five patients had evidence of renal disease, varying from proteinuria to a decline in the creatinine clearance and elevation of urea. In one of our cases (case 2), mercury is thought to have passed through shunts or pulmonary capillaries to aggregate in the left ventricle where it may have embolised into systemic circulation, which was confirmed by postmortem findings (large metallic mercury deposits within the cardiac muscle).

Deschamps et al., 2002, reported a case of an attempted suicide of a 41-year-old man who was examined for long-term mercury toxicity – five years after elemental self-poisoning. First he had injected the elemental mercury into the subcutaneous tissues of his left forearm and next into the veins of the fold of the left elbow. Over a 5-year follow up, the patient showed no clinical evidence of damage to any organs. Lesions of the left forearm were never excised. However, radiographs obtained 5 years after the initial results of the incident showed widespread tiny opacities of metallic density in both lungs, and fewer opacities in the kidneys and subcutaneous tissue. Also, the presence of mercury in the arm was confirmed. Even though the patient had high concentrations of mercury in the urine and blood (263 nmol/mmol of creatinine and 800 nmol/L, respectively; normal values: <2.8 nmol/mmol of creatinine and <50 nmol/L, respectively), only mild clinical symptoms appeared. The concentrations of mercury in the urine and blood were more than twice as high, and 16 times as high, respectively, as in a case reported by dell`Omo et al., 1997, concerning an assessment of mercury toxicity 12 years after injection. Torres-Alanis et al., 1997, observed in a case with a 5-year follow-up no biochemical abnormalities in hepatic or renal function nor clinical pulmonary malfunction. The only persistent symptoms were tremor and lower extremity weakness, because of the persistence of metallic densities in the body (X rays showed globules of metallic density in the lungs and abdomen, and at the site of the abscess). At five years after the original exposure, the urinary mercury concentration was 907 µg/L, i.e. similar to the values in our study for case 1 (1.6 months after injection), 2 (about 4 years), 3 (on admission a short time after injection), and 5 (2.5 months).

Generally, it is concluded that the high concentrations of blood and urinary mercury resulted from continued absorption of embolized mercury, and its slow oxidation to the more soluble mercuric cation, whose salts are excreted by the kidneys. As was revealed, however, the persistence of elevated mercury concentrations in body fluids and hair due to amounts of metal stored in the body depends not only on how much time has elapsed since the injection and the administrated amounts of mercury, but perhaps also on various individual factors, such as catalase activity, kidney efficiency, bioaccumulation in

target organs etc.

CONCLUSION

The results of the monitoring in all examined cases revealed that chronic presence of mercury was considerable even a very long time (9 years) after injection of metallic mercury. The concentrations of this metal in blood, urine and hair exceeded the normal levels before treatment by many times (blood – up to 30, urine – 50, hair – 7) and were comparable to the toxic mercury concentrations reported by other authors. In only one case, the concentrations of mercury in blood, urine and hair dropped to references levels, but only after 10 years. It seems that their persistence may be due not only to amounts of metal stored in the body and time elapsed after injection, but also to various individual factors, such as catalase activity, kidney efficiency, bioaccumulation in target organs etc.

References

Anderson WJA (1993). Intravenous mercury: a three year follow-up. Case report. Ulster Med. J., 63: 180–183.

Ansell J et al (2010). Subcutaneous mercury injection into scrotum: Case report and review of literature. Brit. J. Med. Surg. Urol., 3: 36–38.

Berlin M, Zalups RK, Fowler BA. Mercury. In: Nordberg GF, Fowler BA, Nordberg M, Friberg L. eds., (2007). Handbook on the toxicology of metals, third edition, Amsterdam: Elsevier Holland, 675–729.

Chodorowski Z, Sein Anand J (2002). Repeated intravenous injection of metallic mercury for doping. Przeglad Lekarski, 59: 377–378.

Clarkson TW, Magus L, Myers GJ (2003). The toxicology of mercury: Current exposures and clinical manifestations. New Engla J. Med., 349: 1731–1737.

dell`Omo M, Musi G, Filibert ABS (1997). Long-term pulmonary and systemic toxicity following intravenous mercury injection. Archives of Toxicology, 72: 59–62.

Deschamps F et al (2002). Five years of follow-up after elemental mercury self-poisoning. Am. J. Forensic Med. Pathol, 23: 170–172. Ellis LS, Mullins ME, Galvin N, Scalzo AJ (2009). Detection of elemental mercury in abdominal wall. J. Med. Toxicol., 5: 205–208.

Giombetti RJ, Rosen DH, Kuczmierczyk AR, Marsh DO (1988). Repeated suicide attempts by the intravenous injection of elemental mercury. Int. J. Psychiatr in Med., 18: 153–167.

Givica-Pérez A et al (2001) . Deliberate, repeated self administration of metallic mercury injection: case report and review of the literature. Eur. J. Radiol, 11: 1351–1354.

Gopalakrishna A, Pavan Kumar TV (2008). Intravenous injection of elemental mercury: A report of two cases. Indian J. Plast Surg., 41: 214–218.

Haghdoost M, Poorhasan A, Ghabili K, Mashrabi O (2010). Subcutaneous injection of metallic mercury mimicking bacterial cellulites: A case report. Am. J. Infect. Dis., 6: 54–56.

Hannigan BG (1978). Self-administration of metallic mercury by intravenous injection. Brit Med. J., 2: 933.

Kayias EH, Drosos GI, Hapsas D, Anagnostopoulou GA (2003). Elemental mercury-induced subcutaneous granuloma. A case report and review of the literature. Acta Arthopaedica Belgica, 69: 280–284.

Kedziora A, Duflou J (1995). Attempted suicide by intravenous injection of mercury: a rare cause of cardiac granulomas. A case report. American Journal of Forensic Medicine and Pathology, 16: 172–176.

Konopka T, Nalepa P, Rzepecka-Woźniak E (2006). Long-term survival after a suicidal intravenous injection of mercury. Archiwum Medycyny Sadowej i Kryminologii, 56: 267–270.

Krohn IT, Solof A, Mobini J, Wagner DK (1980). Subcutaneous injection of metallic mercury. J. Am. Med. Association, 243: 548–549.

Lech T, Goszcz H (2006). Poisoning from aspiration of elemental mercury. Clinical Toxicology, 44: 333–336.

Lorenzo Dus MJ et al(2007). Pulmonary embolism caused by elemental mercury. Archives of Bronconeumol., 43: 585–587.

Matushita JP et al (2007). Embolism caused by metallic: a case report. Radiologia Brasileira; 40: 217–219.

Maynou C, Mathieu-Nolf M, Mestdagh H, Gillas-Buron G (2000). Accidental subcutaneous injection of elemental mercury. A case report. Acta Orthopedica Belgica 66: 292–296.

Murray KM, Hedgepeth JC (1988). Intravenous self-administration of elemental mercury: efficacy of dimercaprol therapy. Drug Intelligence and Clinical Pharmacy, 22: 972–975.

Nalepa P, Lech T, Kotucha W (1996). Intravenous injection of metallic mercury – case report. Pneumonologia i Alergologia Polska, 64: 88–92.

Netscher DT, Friedland JA, Guzewicz RM. Mercury poisoning from intravenous injection: treatment by resection. Annals of Plastic Surgery 1991; 26: 592–596.

Oliver RM, Thomas MR, Cornaby AJ, Neville E (1987). Mercury pulmonary emboli following intravenous self-injection. Brit. J. Dis. Chest 81: 76–79.

Prasad VL (2004). Subcutaneous injection of mercury: “warding off evil”. Environmental and Health Perpectives 12: 1326–1328.

Rogothaman M et al (2007). Elemental mercury poisoning probably causes cortical myoclonus. Movement Disorders, 22: 1964–1968. Sannemüller U, Romanowski U, Stiller D (1996). Erweiterter Suizidversuch mittels oraler Aufnahme von metallischen Quecksilber. Rechtsmedizin, 6: 185–187.

Soo YOY, Wong CH, Griffith JF, Chan TYK (2003). Subcutaneous injection of metallic mercury. Human and Experimental Toxicol., 22: 345–348.

Torres-Alanis O, Garza-Ocañas L, Piñeyro-López A (1997). Intravenous self-administration of metallic mercury: report of a case with a 5-years follow-up. J. Toxicol Clini. Toxicol., 35: 83–87.

Vallant B, Deutsch J, Muntean M, Goessler W (2008). Intravenous injection of metallic mercury: case report and course of mercury during chelation therapy with DMPS. Clinical Toxicol., 46: 566–569.

Wale J, Yadav PK, Garg S (2010). Elemental mercury poisoning caused by subcutaneous and intravenous injection: An unusual self-injury. Indian J. Radiol. Imaging, 20: 147–149.

Walter E (1986). Long-term observation of a case of intravenous injection of elemental mercury. Radiology, 26: 40–46.

Winker R, Schaffer AW, Konnaris C, Barth A (2002) Health consequences of an intravenous injection of metallic mercury. International Archives of Occupational and Environmental Health, 75: 581–586.

Wright N, Yeoman WB, Carter GF (1980). Massive oral ingestion of elemental mercury without poisoning. Lancet, 1:206.