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Abnormally High Concentrations of Amphetamine in Blood of Impaired Drivers

ABSTRACT: We present a case series ($N = 46$) of individuals apprehended in Sweden for driving under the influence of drugs (DUID). These cases were selected because the concentrations of amphetamine in blood were abnormally high (>5.0 mg/L), the highest being 17 mg/L. In comparison, the median blood-amphetamine concentration in a population of DUID offenders ($N = 6{,}613$) was 0.70 mg/L. Among the DUID suspects with extremely high blood-amphetamine concentrations there were 38 men (83%) with mean age of 37.8 y (SD 6.8 y) and 8 women (17%) with a mean age of 34.1 y (SD 4.3 y). All had previously been registered in our database (mean 12 times, median 9 times) for drug-related offences, including DUID. The concentration of amphetamine in blood of female offenders was slightly higher than the concentration in male offenders (6.6 mg/L vs. 5.8 mg/L), although this difference was not statistically significant ($p > 0.05$). The drugs other than amphetamine most frequently encountered in the blood samples were tetrahydrocannabinol and benzodiazepines (diazepam and nordiazepam). The commonest signs of drug use reported by the arresting police officers were bloodshot and glazed (watery) eyes, restlessness, talkativeness, exaggerated reflexes and slurred speech. Unsteady gait and dilated pupils were observed in some but not all individuals. These very high concentrations of amphetamine were tolerated without any fatalities indicating a pronounced adaptation to the pharmacologic effects of this central stimulant. Anecdotal information indicated that those with the very highest concentrations of amphetamine in blood had swallowed the drug to prevent being apprehended in possession of an illicit substance.

KEYWORDS: forensic science, blood-amphetamine, behaviour, driving, DUID, impairment, signs of drug use

Among abused drugs in Sweden, amphetamine and other central stimulant amines (e.g., phenmetrazine and phentermine) have dominated the scene for many decades (1,2). Amphetamine is also highly prevalent in people arrested for DUID (3,4) and in 15,783 cases submitted for forensic toxicology between 1992 and 2001, amphetamine was identified 8,891 times (56%). In comparison, methamphetamine was found in only 755 cases over the same time period (8.5%) although the popularity of this secondary amine is increasing in Sweden and other Nordic countries (5). The frequency distribution of blood-amphetamine concentration in a population of DUID suspects ($N = 6{,}613$) was highly skewed to the right with mean and median values of 0.89 mg/L and 0.70 mg/L, respectively. These concentrations can be compared with those found after therapeutic doses of amphetamine (e.g., for attention deficit-hyperactivity disorder or narcolepsy), which is usually below 0.2 mg/L (6–8).

In this paper, we present a case series of DUID suspects with abnormally high concentrations of amphetamine in blood (>5.0 mg/L) when compared with other traffic delinquents who abuse this central stimulant. We investigated age and gender-related differences as a function of the blood-amphetamine concentration, the kinds of other licit and illicit drugs present in blood, previous drug-related offences and the signs of drug-use reported by the arresting police officers.

Material and Methods

Selection of Cases

We searched our in-house database (ToxBase) belonging to the National Board of Forensic Medicine for DUID cases with unusually high blood-amphetamine concentrations. The search period was 1994–2004 and the main focus was on arrestees with blood-amphetamine concentrations of 5.0 mg/L or more. These cases were obvious outliers compared with a large population of DUID suspects who had also been taking amphetamine. Indeed, finding a blood-amphetamine of 5 mg/L or more is considered by some authorities to represent a lethal concentration (8). From the police reports we extracted information about the person's age and gender, the spectrum of other drugs verified present in blood and the signs of drug use and the general behaviour of the suspect when arrested by the police.

Analysis of Amphetamine in Blood

Blood samples from DUID suspects in Sweden are collected in Vacutainer tubes (2×10 mL) that contain sodium fluoride (100 mg) and potassium oxalate (25 mg) as preservatives. Whenever possible a urine specimen is also collected into a fluoride-treated tube and sent for analysis along with the blood samples. Gas chromatography-mass spectrometry (GC-MS) has a long tradition in Sweden as the method of choice for forensic toxicological analysis of sympathomimetic amines in biological specimens (9).

Analytical Procedure

Blood and/or urine are initially subjected to a broad screening analysis by immunoassay methods (EMIT/CEDIA) with focus on the main classes of psychoactive substances. The EMIT cut-off concentrations for presence of amphetamine are currently set at 0.3 mg/L for urine samples and 0.05 mg/L for blood samples. All positive results from the screening analysis are verified with more specific analytical methods. Amphetamine is determined in whole blood after liquid-liquid extraction at alkaline pH followed by derivatization and quantitative analysis by gas

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chromatography-mass spectrometry (GC-MS) with deuterium labelled amphetamine as internal standard (10).

The current analytical method entails adding 100 μL d_8-amphetamine (2 mg/L) as internal standard to 1 g blood mixing and then making the blood alkaline by adding 0.5 mL sodium hydroxide (2M). The amines are extracted from the biological matrix by adding ethyl acetate (5 mL) and mechanical shaking for 5-min and centrifugation. The organic phase is transferred into a clean tube and the solvent is evaporated to near-dryness under a stream of nitrogen without applying heat. To facilitate chromatographic analysis the trifluroacyl derivative of amphetamine is prepared by adding trifluroacetic anhydride (TFAA) to the tubes and allowing them to stand in a warm block (60°C) for 15 min. After the tubes have cooled to room temperature, the excess reagent is evaporated under a constant stream of nitrogen without heating. The residue is reconstituted in 40 μL of ethyl acetate, vortexed briefly and aliquots are then transferred into micro-vials for GC-MS analysis.

GC-MS was done with equipment from Hewlett Packard (HP)—Agilent Technologies (HP5890A or HP 6890N) and HP 7693 autosampler. The mass spectrometer was HP (Agilent) 5971/5973 and the MS Chemstation was used. Chromatography was accomplished with a DB-5 capillary column (J & W Ltd.) and the temperature program was run from 60°C to 270°C in 3 stages. For selected ion monitoring m/z 118 was used for amphetamine with m/z 140 as a qualifier ion and m/z 126 for internal standard (d_8-anphetamine) and 143 as qualifier ion. The standard curve for determination of amphetamine in blood was linear from 0.02 to 2 mg/L and the limit of quantitation (LOQ) in routine casework was taken as 0.03 mg/L. When blood-amphetamine concentrations exceed the upper limit of the standard curve the assay is repeated starting with a smaller quantity of blood (e.g., 0.25 or 0.5 g) and dilution with drug-free whole blood.

Other licit and illicit drugs in blood including opiates and tetrahydrocannabinol (THC) were determined by GC-MS and the most common benzodiazepines were determined by a capillary GC and a nitrogen-phosphorous detector (N-P) (10).

Results

Table 1 gives a breakdown of the blood amphetamine concentrations according to age and gender of the 46 DUID suspects. Men dominated (83%) compared with women (17%) although their mean ages were similar 34–38 years. The blood-amphetamine concentration was slightly higher in women than in men (median 6.6 vs. 5.8 mg/L) but the difference was not statistically significant ($P > 0.05$) according to Mann-Whitney test.

Table 2 lists the 46 DUID cases in rank order according to increasing concentrations of amphetamine in blood. According to police reports, there was no smell of alcohol on the suspect's breath and a roadside breath-screening test gave a negative result. Many of the individuals were already known to the police as drug abusers and they also had many previous drug-related offences on their record, including DUID. The 46 DUID suspects in Table 2 were registered in our database a total of 577 times for previous drug-related offences (mean 12.5 times, median 9.5, range 1–56 times), either for DUID or use of illicit drugs not in connection with driving. Some individuals were in possession of drugs or drug paraphernalia (syringe and needle) when they were arrested. Others freely admitted using amphetamine and some even had fresh needle marks on the arms. There was no correlation ($r = 0.033$) between the number of previous drug-related offences and the blood-amphetamine concentrations in Table 2. Neither was there a correlation between the drug addicts age and the blood-amphetamine concentration ($r = 0.052$).

The signs of drug use and abuse recorded by the arresting police officers differed considerably from case to case (Table 2). The most consistent finding was bloodshot and glazed (watery) eyes, slurred speech, sweeping arm movements and restlessness. Some but not all suspects had unsteady gait. The presence of dilated pupils, which is a classic sign of central stimulant abuse, was observed for many but not all individuals despite high blood-amphetamine concentrations. Indeed, the police sometimes reported that the pupil size was normal or constricted. One male suspect (42 yr), with a blood-amphetamine concentration of 6.6 mg/L was also examined by a physician who observed a red-face, dilated pupils and bloodshot eyes but concluded that the person was not under the influence of drugs. By contrast, the police observed bloodshot eyes, nystagmus and the suspect also admitted he had been taking amphetamine. The highest concentration of amphetamine in blood was 17.0 mg/L (mean result from aliquots from two Vacutainer tubes), for a 42-year-old male with 7 previous drug-related offences. This concentration represents a new Swedish record and anecdotal evidence emerged that this person had swallowed the drug to avoid being arrested in possession of an illicit substance. He developed severe symptoms of drug overdose and required hospitalization but survived.

In Table 3, the 46 DUID suspects with abnormally high blood-amphetamine concentrations were compared with a larger population of DUID suspects ($N = 6{,}613$), autopsy cases with amphetamine present in blood ($N = 227$) and also people apprehended for petty drug offences ($N = 3{,}546$). The median blood-amphetamine concentrations were very similar (0.5 to 0.7 mg/L) for the three forensic materials. However, in the medical examiner cases the mean concentration was considerably higher (1.39 mg/L) indicating the presence of some abnormally high concentrations in these fatalities.

TABLE 1—*Age, gender and blood-amphetamine concentrations in DUID suspects having abnormally high concentrations of this central stimulant in venous whole blood.*

Suspects*	N (%)	Age (SD)	Blood Amphetamine, mg/L Mean, Median, and Range
Men	38 (83%)	37.8 (6.8)	6.6, 5.8, and 5–17
Women	8 (17%)	34.1 (4.3)	7.2, 6.6, and 5–12
Both sexes	46 (100%)	37.2 (6.6)	6.7, 6.1, and 5–17

* Four of these individuals had died by 2004 according to forensic autopsy reports.

Discussion

Amphetamine and methamphetamine are controlled substance (schedule II) having only a few legitimate therapeutic applications, e.g narcolepsy and attention deficit-hyperactivity disorder (7,11–13). Alternative medication exists for these conditions (e.g., methylphenidate) so for all practical purposes amphetamine and methamphetamine are considered illicit substances in Sweden (10). Therapeutic doses of amphetamine and methamphetamine range from 2.5–20 mg and when taken orally yield a peak plasma concentration of 0.2 mg/L or less (7,8,12,14). The daily intravenous (i.v.) dose for an amphetamine abuser is usually 200 mg whereas during an amphetamine binge 1–5 g might be taken daily (13,15,16). In routine forensic toxicology casework, an elevated concentration of amphetamine in blood almost certainly means that the drug was being abused even when relatively low blood-concentrations (0.1–0.2 mg/L) were measured.

TABLE 2—*Abnormally high concentrations of amphetamine in blood in DUID suspects arrested in Sweden in relation to their age, gender, number of drug-related offences and the other drugs verified present in blood samples as well as comments and observations made by the arresting police officers.*

Case	Age (gender)	Number of Offences	Amphetamine (mg/L)	Other Drugs in Blood (mg/L)	Comments and Observations About the Suspect Reported by the Arresting Police Officers
1	39 (F)	12	5.0	None	Involved in traffic accident, glazed eyes, dilated pupils, difficulties walking straight and sweeping arm movements, known drug abuser.
2	43 (M)	12	5.0	None	Nervous, very talkative, small pupils, walking normal.
3	37 (F)	56	5.0	THC (0.0004), nordiazepam (0.1)	Blank eyes, small pupils, and slow reaction to light could not walk straight with incoherent and slurred speech. Admitted drug abuse and was in possession of drugs when arrested
4	38 (M)	2	5.1	Data not available	No information available
5	31 (M)	9	5.1	Methamphetamine (0.04)	Glazed eyes, large pupils slow reaction to light, unsteady gait, obvious signs of drug abuse
6	38 (M)	8	5.1	THC (0.004)	Obvious signs of drug abuse and in possession of drugs. Watery and bloodshot eyes and enlarged pupils.
7	59 (M)	6	5.1	None	Bloodshot eyes, pupils small, injection marks, uncontrollable jaw-movements
8	47 (M)	9	5.2	None	No information
9	43 (M)	1	5.2	Phenazone* (1.0)	Obvious signs of drug abuse, admitted using amphetamine.
10	40 (M)	5	5.3	Diazepam (0.05), 7-amino flunitrazepam (0.05)	Bloodshot and glazed eyes, dilated pupils, unsteady gait admitted to using amphetamine
11	27 (M)	16	5.4	MDMA (0.06), diazepam (0.1) nordiazepam (0.3)	Traffic accident, difficulties keeping eyes open.
12	25 (M)	17	5.4	Benzoylecognine (0.12)	No information given
13	38 (M)	9	5.4	THC (0.006)	Bloodshot and glazed eyes, pupils showed slow reaction to light and the suspect admitted using amphetamine a few days earlier. In possession of syringe and needle.
14	37 (M)	18	5.5	None	Obvious signs of impairment, bloodshot and glazed eyes, dilated pupils, fresh injection marks on arm, sluggish and bleak appearance. Admitted taking amphetamine 5-h earlier
15	43 (M)	5	5.5	None	Bloodshot eyes and blank eyes, gaze nystagmus, pupil size normal slow reaction to light, walk normal, in possession of syringes and admitted use of amphetamine
16	23 (M)	17	5.5	Diazepam (0.07)	Obvious signs of drug abuse, small pupils. Tired and admitted using amphetamine.
17	38 (M)	1	5.6	Data not available	No information available
18	36 (M)	26	5.6	THC (0.0009) diazepam (0.07) nordiazepam (0.1)	Glazed eyes, enlarged pupils, circular arm movements, no unsteady gait.
19	33 (M)	7	5.6	None	Nervous and tense behaviour, glazed eyes, small pupils, walking was not impaired.
20	30 (M)	7	5.7	THC (0.008)	Bloodshot and glazed eyes, dilated pupils, walking normal but was in possession of illicit drugs
21	38 (M)	27	5.8	Nordiazepam (0.06) tramadol (0.2)	Glazed eyes, drug paraphernalia in pockets.
22	37 (M)	5	5.8	Nordiazepam (0.06)	Bloodshot and glazed eyes, dilated pupils, slurred speech, in possession of drugs.
23	39 (F)	1	6.0	7-Amino-flunitrazepam (0.008)	Dangerous driving, difficulties in sitting still, very talkative, slow body movements, unsteady gait and glazed eyes.
24	27 (M)	22	6.1	None	Admitted taking amphetamine, bloodshot eyes, glazed appearance and enlarged pupils, walking not noticeable impaired.
25	34 (F)	5	6.3	THC (0.008) diazepam (0.5) nordiazepam (0.2)	Nervous and very talkative, temperamental
26	42 (M)	5	6.4	THC (0.001), nordiazepam (0.1), carbamazepine (5)	Bloodshot eyes, unsteady gait and fresh needle marks on arm veins
27	41 (M)	15	6.4	None	Dangerous driving, suspect had injection marks on under-arm, bloodshot eyes, normal pupil size and walk was considered normal.
28*	42 (M)	12	6.6	None	Bloodshot eyes, horizontal and vertical nystagmus, pupil size normal, admitted taking amphetamine.

TABLE 2—*Contniued*.

Case	Age (gender)	Number of Offences	Amphetamine (mg/L)	Other Drugs in Blood (mg/L)	Comments and Observations About the Suspect Reported by the Arresting Police Officers
29	36 (M)	20	6.8	None	Obvious signs of drug abuse; bloodshot eyes, horizontal nystagmus, normal sized pupils but slow reaction to light, had injection marks on arm. In possession of drugs in the car.
30	34 (F)	2	6.8	None	Admitted drug abuse, bloodshot and glazed eyes with enlarged pupils, walk almost normal
31	40 (M)	4	6.9	Data not available	No information available.
32	43 (M)	12	6.9	None	Known drug abuser, dangerous driving, dilated pupils.
33	36 (M)	33	7.1	None	Difficulties in sitting still, incoherent speech, dilated pupils, nystagmus.
34	40 (M)	10	7.3	Carboxy-THC in urine	Bloodshot eyes enlarged pupils and slow reaction to light, not unsteady gait but seemed restless and complained of dry-mouth and admitted using drugs.
35	39 (M)	5	7.7	None	Unable to sit still, heavy sweating large pupils, unsteady gait, hallucinations.
36	36 (M)	26	7.7	THC (0.002) nordiazepam (0.1)	Difficulty in speaking, bloodshot and glazed eyes and injection marks on arm,
37	30 (M)	1	7.7	None	Fresh injection marks on the arms, involved in traffic accident.
38	26 (F)	13	7.9	Data not available	No information available.
39	30 (M)	20	8.0	MDMA (0.09), diazepam (0.3), nordiazepam (0.07)	Traffic accident, bloodshot eyes, dilated pupils, unsteady gait, known drug abuser.
40	39 (M)	11	8.2	Diazepam (0.1) nordiazepam (0.2)	Enlarged pupils, dull eyes, walk unsteady,
41	45 (M)	28	8.3	Phenazone* (2.4)	Glazed eyes, large pupils, unsteady gait, nervous behaviour and circular arm movements
42	39 (M)	10	8.4	None	Obvious signs of drug abuse, in possession of amphetamine, glazed eyes, dilated pupils, sweating in the face, known as a drug abuser and admitted using amphetamine during the day
43	31 (F)	3	8.5	None	Traffic accident, obvious signs of drug abuse, driver behaved oddly, slow movements, unsteady gait
44	47 (M)	2	11.0	Diazepam (0.2) dextropropoxyphen (0.1)	Bloodshot and glazed eyes, difficulties in speaking clearly, large pupils, walk not impaired but the suspect admitted taking amphetamine by mouth.
45	33 (F)	35	12.3	Norephedrine (0.06), phenazone* (1.3)	Eyes normal, slurred speech and admitted "drinking" amphetamine the day before.
46	42 (M)	7	17.0	THC (0.0005)	Bloodshot and glazed eyes, dilated pupils, unsteady gait, difficulties in sitting still and was sweating profusely. Swallowed a large amount of amphetamine and was admitted to hospital for observation.

* Common adulterant in street amphetamine sold in Sweden.

Information about the toxic and fatal blood-concentrations of amphetamine and methamphetamine comes from various sources including medical examiner cases, DUID suspects, prison inmates and drug-abuse treatment clinics (15–23). The blood-amphetamine concentrations in these Swedish DUID suspects are among the highest ever reported in the forensic toxicology literature and the analytical methods used were highly reliable (10). None of the DUID suspects died as a result of reaching these very high blood-amphetamine concentrations, which indicates an appreciable development of tolerance to the pharmacological effects (6,7,13,14). The variable degree of physiological tolerance and dependence on the drug makes it difficult to establish a blood-amphetamine concentration that causes death (18). Much depends on route of administration, frequency of use (binge vs recreational use), pattern of dose escalation and the individual's general state of health (13).

Unlike the situation in USA, where methamphetamine-abuse is the norm (18–20,23), in Sweden and other Nordic countries amphetamine is the dominant central stimulant amine among drug abusers and DUID suspects (1,2,13,15,17). Amphetamine is mostly smuggled into the country from Holland and/or Eastern Europe as opposed to clandestine production within Sweden. The relative pharmacological effects (central and peripheral) of amphetamine vs. methamphetamine has not been well studied although the more lipid soluble secondary amine might penetrate the blood-brain-barrier faster and thus prove to be more potent. Whether these sympathomimetic amines differ in terms of their acute or chronic toxicity remains an open question (7,8,15).

TABLE 3—*Blood-amphetamine concentrations in three different forensic materials, DUID suspects, medical examiner cases and people arrested for drug use but not in connection with driving (petty drug offences) over a 2-year period.*

Forensic Material	N	Mean Conc. mg/L	Median Conc. mg/L	Range mg/L*
DUID cases	6,613	0.89	0.70	0.03–8.5
Autopsy cases	227	1.39	0.60	0.03–22.0
Petty drug offences	3,546	0.72	0.50	0.03–9.4

* The limit of quantitation for amphetamine in blood was 0.03 mg/L.

The effects of therapeutic doses of amphetamine on performance and behaviour cannot be compared with abuse doses for obvious reasons. Indeed, a few early reports suggested that low clinical doses of amphetamine might improve a person's ability to perform skilled tasks resembling driving (24,25). Chronic use of amphetamine or methamphetamine is another story and, indeed, impairment might be more pronounced several days after taking the drug because of fatigue, restlessness and lack of sleep during the acute phase of drug intake (19). During the withdrawal phase, the blood-amphetamine concentrations might have decreased appreciably compared with those prevailing during the acute phase of intoxication. This complicates even further any attempt to relate the blood-concentration with central nervous system effects of this stimulant.

In a survey of DUID suspects in Norway ($N = 380$), the highest amphetamine concentration in blood was 2.7 mg/L, being considerably less then the 46 cases we now report here (12). The drugs most frequently encountered in blood along with amphetamine in this Norwegian study were tetrahydrocannabinol (THC) and diazepam, which agrees with our findings (Table 2). Polydrug use is commonplace in DUID suspects apprehended in the Nordic countries and THC and various benzodiazepines are the most common co-existing psychoactive substances in this population (26).

According to Baselt and Cravey (16), the mean blood-amphetamine concentrations in 11 fatalities were 8.6 mg/L (range 0.5 to 41 mg/L). Whether other drugs were also present in the victims was not indicated. A well-documented case report cited 54 mg/L of methamphetamine in peripheral blood at autopsy in a person who had swallowed 1–1½ g of street-methamphetamine (purity not specified) just before being arrested (21). Swallowing a large amount of methamphetamine or amphetamine to avoid being arrested in possession of an illicit substance is not uncommon as documented in these Swedish DUID cases. In deaths considered to be a direct result of methamphetamine abuse ($N = 13$), the median concentration in blood (central or peripheral not specified) was 0.96 mg/L (range 0.09–18 mg/L) (18). In one non-fatal DUID case when methamphetamine was taken orally, the concentration in blood was 9.46 mg/L (19). Baselt and Cravey (16) reported blood-concentrations of 4.3 mg/L and 5.6 mg/L methamphetamine in two fatalities after the deceased had swallowed unspecified amounts of the drug.

In a recent report from Japan, blood-methamphetamine concentrations ranged from 3.4 to 25.4 mg/L in four fatal poisonings, which compared with 0.6 to 5.6 mg/L when death was attributed to other causes ($N = 9$) (22). A large sample of methamphetamine-related deaths ($N = 413$) from San Francisco were reported by Karch et al. (23). The mean blood-methamphetamine concentration was 2.08 mg/L when abuse of the stimulant was related to the cause of death compared with 1.78 mg/L when presence of the drug was an incidental finding. The deceased were mainly middle aged (mean 36.8 y) being mainly men (85%) very similar to the demographics of the Swedish DUID suspects described in the present article (mean 37.8 y, 83% male). Long-term abuse of methamphetamine was strongly associated with coronary artery disease and subarachnoid hemorrhage (23).

The dividing line between toxic and fatal concentrations of a drug like amphetamine is poorly defined and much depends on the degree of tolerance in the individual concerned and also the route of administration used. When taken orally very large doses can seemingly be tolerated without a fatal outcome. Amphetamine is a stimulant of the central nervous system (CNS) and might be taken orally, inhaled or injected intravenously (1,2,7,13). After recreational doses of amphetamine the user experiences elation, lessened fatigue, loss of appetite, more rapid thought processes and heightened sensory perception. Repetitive intake of large doses leads to psychoses and personality disturbances akin to schizophrenia including delusions, persecutions and auditory and visual hallucinations (6,7). Fatalities are more likely after i.v. administration of amphetamine as a consequence of the sudden increase in blood pressure and pulse rate, hyperthermia and cardiac arrhythmias that might lead to the person's demise. Autopsy reports of fatal poisonings after taking central stimulants like amphetamine show evidence of ischemic myocardial changes and tachycardia before death (27,28). People dying with low concentrations of amphetamine in blood have probably lost their tolerance following a period of abstinence, e.g., after imprisonment or hospitalization for drug abuse (28).

Evaluating blood concentrations of amphetamine in relation to the observations made by the arresting police officers regarding typical signs of impairment is hampered by inability to guarantee the care taken by individual officers in completing the report forms. Some police are more conscientious than others in the way they might examine a suspect and in the care taken in filling out the report forms. Such things are hard to control by the toxicology laboratory. Nevertheless, the arresting police officers were confident that those apprehended were under the influence of drugs based on moving-traffic offences or involvement in a crash as well the appearance and behaviour of the suspect when questioned. The most common findings were bloodshot and glazed eyes and sometimes (but not always) dilated pupils, and slurred speech. An unsteady gait was observed in some but not all suspects whose walk was considered normal despite very high blood-amphetamine concentrations. Nervousness, erratic arm movements, restlessness and sweating were well documented in these individuals. Some of the DUID suspects were known as drug abusers from earlier encounters with the police whereas others freely admitted they had taken amphetamine and some had fresh needle marks on the arms or were in possession of the drug as well as syringe and needle.

Since 1st July 1999, Sweden has enforced a zero-concentration limit for controlled substances in blood of motorists, which means that the forensic toxicology report constitutes the main piece of evidence for a successful DUID prosecution (26). However, observations about the driving, the behaviour of the driver when questioned, appearance of the eyes (bloodshot and glazed), pupil size and reaction to light provide the clues necessary to proceed with sampling of blood and urine for toxicological analysis. It is an open question whether more sophisticated clinical tests or even examination by a physician or drug recognition expert (DRE) would have been more effective in identifying these DUID suspects. It seems that the intent of a zero-limit law is to punish a deviant behaviour, namely use and abuse of banned psychoactive substances particularly when skilled tasks like driving are involved. The advantage of this kind of legislation is that it avoids the need to relate the concentration of a drug in blood with a certain degree of impairment or a diminished capacity to drive safely.

Establishing statutory concentration limits for drugs of abuse in blood is seemingly difficult to achieve owing to the uncertain relationship between the concentrations present and the signs and symptoms of impairment in any individual case. Drawing definite conclusions about a person's ability to perform skilled tasks like driving based on the concentration of a drug (e.g., THC or amphetamine) in blood is fraught with difficulties. Few toxicologists would have qualms about designating a blood-amphetamine concentration of 5 mg/L as being dangerously high even fatal, but this was not the case. Those who tolerate such high blood-concentrations of this stimulant are binge users of the drug with a pronounced adaptation to the central nervous and cardiovascular effects. From this study and various literature reports it seems that acute fatalities from abuse of amphetamine are not very common, especially in chronic users who are able to tolerate escalating doses.

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