

Cardiovascular Complications of Acute Amphetamine Abuse

Cross-sectional study

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مضاعفات القلب والأوعية الدموية الناتجة عن إساءة تعاطي منبهات الأمفيتامين دراسة مستعرضة

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ABSTRACT: Objectives: This study aimed to evaluate cardiovascular complications among patients who abuse amphetamines. **Methods:** This cross-sectional study took place between April 2014 and April 2015 among 3,870 patients referred to the Toxicology Emergency Department of Baharlou Hospital, Tehran University of Medical Sciences, Tehran, Iran. Those with clinical signs of drug abuse and positive urine screening tests were included in the study, while cases of chronic abuse were excluded. Cardiac complications were evaluated via electrocardiography (ECG) and transthoracic echocardiography. **Results:** A total of 230 patients (5.9%) had a history of acute amphetamine abuse and positive urine tests. Of these, 32 patients (13.9%) were <20 years old and 196 (85.2%) were male. In total, 119 (51.7%) used amphetamine and methamphetamine compounds while 111 (48.3%) used amphetamines with morphine or benzodiazepines. The most common ECG finding was sinus tachycardia (43.0%), followed by sinus tachycardia plus a prolonged QT interval (34.3%). Mean creatine kinase-MB and troponin I levels were 35.9 ± 4.3 U/mL and 0.6 ± 0.2 ng/mL, respectively. A total of 60 patients (26.1%) were admitted to the Intensive Care Unit. The majority (83.3%) of these patients had normal echocardiography results. The mean aortic root diameter (ARD) was 27.2 ± 2.8 mm. Abnormalities related to the ARD were found in 10 patients (16.7%), three of whom subsequently died. **Conclusion:** According to these findings, cardiac complications were common among Iranian patients who abuse amphetamines, although the majority of patients had normal echocardiography and ECG findings.

Keywords: Amphetamines; Substance Abuse; Cardiovascular Abnormalities; Tachycardia; Echocardiography; Electrocardiography; Iran.

المخلص: الهدف: هدفت هذه الدراسة إلى تقييم مضاعفات جهاز القلب والأوعية الدموية لدى المرضى الذين يتعاطون الأمفيتامينات. **الطريقة:** تمت هذه الدراسة المستعرضة في الفترة ما بين أبريل 2014 وأبريل 2015 وتضمنت 3,870 مريضاً تم تحويلهم إلى قسم طوارئ السموم في مستشفى باهارلو بجامعة طهران للعلوم الطبية بإيران. وقد تم قبول المرضى في هذه الدراسة إذا كان لديهم علامات سريرية لتعاطي المخدرات وفحوصات إيجابية للبول، بينما تم استبعاد حالات التعاطي المزمن. تم فحص المضاعفات القلبية عن طريق جهاز تخطيط القلب الكهربائي وتخطيط القلب عن طريق الصدر بالصدى. **النتائج:** كان هناك إجمالي 230 مريضاً يشكلون نسبة (5.9%) من جميع المرضى من من يتعاطون الأمفيتامين وكانت فحوصات البول عندهم إيجابية، من بين هؤلاء كان عدد 32 (13.9%) مريضاً منهم دون سن العشرين وعدد 196 (85.2%) مريضاً من الذكور. وكان هناك مجملاً عدد 119 (51.7%) مريضاً من مستخدمي الأمفيتامين ومركبات الميثامفيتامين، بينما كان 111 (48.3%) مريضاً من مستخدمي الأمفيتامينات إضافة إلى المورفين أو البنزوديازيبينات. أظهرت النتائج أن أكثر مضاعفات القلب شيوعاً حسب تخطيط القلب هي تسرع القلب الجيبي بنسبة (43.0%)، يليها تسرع القلب الجيبي المصاحب باستتالة فترة QT الفاصلة (34.3%). كان متوسط الكرياتين كيناز-MB مقداره 35.9 ± 4.3 وحدة والتروبونين 0.6 ± 0.2 ملليغرام. تم إدخال ما مجموعه 60 (26.1%) مريضاً إلى وحدة العناية المركزة. وكانت نتائج فحوصات القلب بالصدى طبيعية لأغلبية هؤلاء المرضى (83.3%). كما كان متوسط قطر جذر الشريان الأبهر مقداره 27.2 ± 2.8 ملليمتر. وقد وجدت تشوهات متعلقة بجذر الشريان الأبهر في 10 مرضى (16.7%)، توفي ثلاثة منهم لاحقاً. الخلاصة: وفقاً لهذه النتائج يستنتج أن المضاعفات القلبية هي الأكثر شيوعاً بين المرضى الإيرانيين الذين يسيئون تعاطي الأمفيتامينات، لكن بالرغم من ذلك فإن أغلبية المرضى كان نتائج فحوصات القلب بالتخطيط الكهربائي وبالصدى عندهم طبيعية.

الكلمات المفتاحية: الأمفيتامينات؛ تعاطي المواد الكيميائية؛ تشوهات القلب والأوعية الدموية؛ تسرع دقات القلب؛ تخطيط القلب بالصدى؛ تخطيط القلب الكهربائي؛ إيران.

ADVANCES IN KNOWLEDGE

- Among Iranian patients, the most common cardiac abnormality following acute amphetamine abuse was sinus tachycardia followed by sinus tachycardia plus prolonged QT intervals.

APPLICATION TO PATIENT CARE

- The findings of this study may be used by emergency physicians to increase awareness of the potential cardiovascular complications of acute amphetamine abuse.

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PSYCHOACTIVE DRUG DEPENDENCE/ABUSE has become an increasing problem worldwide, with adverse physical, familial, social, mental and financial consequences.¹ In Iran, patterns of drug abuse have changed immensely in recent years, with drug use shifting from traditional opioids to new artificial opioids.² Moreover, the incidence of drug poisoning and toxicity due to the abuse of psychoactive drugs—such as amphetamines—has increased among younger individuals.³ Acute use of amphetamines results in increased brain activity and a feeling of euphoria; however, chronic use of these compounds can lead to psychological dependency, loss of appetite, depression, aggressive behaviour, irritability and sleep, memory and mood disorders.¹ In addition, amphetamine abuse may lead to increased stimulation of the sympathetic nervous system, which could in turn lead to hypertension, hyperthermia, subarachnoid haemorrhage and ventricular dysrhythmias, sometimes resulting in death.⁴

Depending on the type and form of the drug, central nervous system stimulants can be imbibed orally, injected, smoked or snorted. Direct injection of the stimulant into the blood stream or inhalation into the lungs enables the more rapid onset of the drug's effects.⁵ The stimulants increase the synaptic concentration of neural mediators (especially adrenaline, dopamine and serotonin), stimulating these mediators and inhibiting their reuptake. Amphetamine compounds stimulate the central and peripheral nervous systems, increasing catecholamine secretion and inhibiting their reuptake. At the synapse, the catecholamines lead to excessive cardiac stimulation and an increased heart rate.¹ Amphetamine compounds have good oral absorption and a wide range of distribution sizes (3–33 L/kg); they are primarily metabolised by the liver and excreted in acidic urine.¹

Cardiac complications are an important issue in the context of drug toxicity. Hypertension is the most common cardiovascular result of central nervous system stimulants.¹ With oral amphetamines, systolic and diastolic blood pressure increases, while heart rate decreases. The cardiovascular effect of the *laevus* isomer in amphetamines is greater than that of the *dexter* isomer.⁶ Chest pains, dysrhythmias, acute coronary syndrome, acute cardiac infarctions, vasospasms, irreversible cardiomyopathy and acute pulmonary oedema are among the cardiovascular manifestations of toxicity arising from psychoactive drugs.⁷ This study aimed to evaluate cardiovascular complications among Iranian patients who abuse amphetamines.

Methods

This descriptive cross-sectional study took place between April 2014 and April 2015 among 3,870 patients referred to the Toxicology Emergency Department of Baharlou Hospital, Tehran University of Medical Sciences, Tehran, Iran. Only those individuals with positive urine drug screening test results and a history of acute amphetamine abuse were included in the study. Patients with a history of underlying cardiovascular disease or a family history of cardiac disease and those with diabetes mellitus, proven hypertension or hyperlipidaemia were excluded from the study. In addition, chronic drug users without any evidence of recent abuse were not included.

A predesigned checklist was used to collect existing data, including the demographic characteristics and laboratory and clinical findings of the patients. Rapid urine drug screening tests (ACON Laboratories Inc., San Diego, California, USA) were performed. Following this, blood samples were taken from each patient. Patients were evaluated using cardiac and vital sign monitoring, routine laboratory examinations and cardiac biomarker tests, including levels of troponin I (AiA-360 benchtop immunoassay analyser, Tosoh Bioscience, San Francisco, California, USA) and creatinine kinase (CK)-MB (Architect System STAT CK-MB chemiluminescent microparticle immunoassay, Abbott Diagnostics, Wiesbaden, Germany). Normal cut-off troponin I and CK-MB levels were set at 0.1 ng/mL and 24.0 U/mL respectively, as per the manufacturers' recommendations.

Cardiac complications were evaluated via electrocardiography (ECG) and transthoracic echocardiography (TTE). All ECG and TTE scans were performed by an emergency physician. Each patient underwent three ECG recordings to measure the following variables: heart rate, rhythm, QT interval (intervals of >0.44 milliseconds were considered prolonged), supraventricular and ventricular arrhythmias, atrioventricular and ventricular cardiac blocks, tall T-waves and myocardial *ischaemia* (i.e. ST segment and T-wave changes).⁸ Tachycardia was defined as a heart rate of >100 beats/minute.¹ Moreover, for patients admitted to the Intensive Care Unit (ICU) due to tachycardia or very abnormal ECG findings, additional echocardiography was performed to measure their ejection fraction (EF), regional wall motion abnormalities, aortic root diameter (ARD), cardiac wall size (including right ventricular end-diastolic volume, left ventricle end-systolic volume, left ventricular end-diastolic volume, left ventricular

Table 1: Characteristics of patients referred to a toxicology emergency department following acute amphetamine abuse in Tehran, Iran (N = 230)

Characteristic	n (%)
Age in years	
<20	32 (13.9)
21–30	86 (37.4)
31–40	62 (27.0)
41–50	33 (14.3)
>50	17 (7.4)
Gender	
Male	196 (85.2)
Female	34 (8.7)
Drugs taken	
Amphetamine and methamphetamine	119 (51.7)
Amphetamine and morphine/benzodiazepines	111 (48.3)
Method of drug administration	
Smoking	161 (70.0)
Oral	20 (8.7)
Injection	10 (4.3)
Combination	39 (17.0)
Time to admission in hours	
0–6	174 (75.7)
>6	56 (24.3)
Agitation	
Present	131 (57.0)
Absent	99 (43.0)
ECG finding*	
Normal	104 (45.2)
Sinus tachycardia	99 (43.0)
Sinus tachycardia plus prolonged QT interval	79 (34.3)
Arrhythmia	8 (3.5)
Arrhythmia plus first-degree atrioventricular block	6 (2.6)
Tall T-wave	4 (1.7)
Arrhythmia, ST segment elevation plus anterior MI	4 (1.7)
Arrhythmia plus ST segment elevation	3 (1.3)
ST segment elevation	1 (0.4)
Anterior MI	1 (0.4)
Mean BP $\pm$ SD	
Systolic BP in mmHg	129.9 $\pm$ 4.2
Diastolic BP in mmHg	82.1 $\pm$ 3.4

Mean HR in beats/minute	109.1 $\pm$ 9.3
Mean CK-MB level in U/mL	35.9 $\pm$ 4.3
Mean troponin I level in ng/mL	0.6 $\pm$ 0.2

ECG = electrocardiography; MI = myocardial infarction; BP = blood pressure; SD = standard deviation; HR = heart rate; CK-MB = creatinine kinase-MB.

*Patients with more than one abnormality have been included in several categories.

end-diastolic pressure [LVEDP], left ventricular end-diastolic diameter [LVEDD] and left ventricle end-systolic diameter [LVESD]) and other abnormalities.

Data were analysed using the Statistical Package for the Social Sciences (SPSS), Version 22 (IBM Corp., Chicago, Illinois, USA). Chi-squared, analysis of variance, Student's t-test, Mann-Whitney U and Kruskal-Wallis tests were performed, as appropriate. A *P* value of <0.050 was considered statistically significant. Interquartile ranges and correlations were also calculated.

Ethical approval for this study was granted by the Tehran University of Medical Sciences. Prior to being enrolled in the study, all of the patients gave conscious informed consent. If the competency of the patient was in doubt, informed consent was given by a relative. Data confidentiality and security were ensured throughout the study period.

Results

Of the 3,870 patients referred to the Toxicology Emergency Department during the study period, 460 (11.9%) had a history of amphetamine use. Among these, 395 cases (10.2%) had positive urine drug screening results; however, 165 cases (4.3%) were excluded due to a history of chronic abuse. Therefore, a total of 230 patients (5.9%) were enrolled in the study. The mean age of the participants was 34.4 ± 11.4 years (range: 15–68 years old) and the majority were male (85.2%). Amphetamines were smoked by 161 patients (70.0%), taken orally by 20 patients (8.7%), injected by 10 patients (4.3%) and taken via a combination of methods by 39 patients (17.0%). A total of 119 patients (51.7%) used amphetamines in combination with methamphetamine compounds while 111 (48.3%) used amphetamines with morphine or benzodiazepines. The referral time to the emergency ward was ≤ 6 hours of use for 174 patients (75.7%) and >6 hours of use for 56 patients (24.3%) [Table 1].

The ECG results were normal for 104 patients (45.2%). Sinus tachycardia was observed in 99 patients (43.0%), while 34.3% of patients had sinus tachycardia plus a prolonged QT interval. Arrhythmias were

Table 2: Selected echocardiographic measurements according to age group among patients admitted to an intensive care unit following acute amphetamine abuse in Tehran, Iran (N = 60)

Mean ± SD	Age in years					P value
	<20 (n = 6)	21–30 (n = 17)	31–40 (n = 15)	41–50 (n = 5)	>50 (n = 17)	
RVESv in mL/m ²	24.3 ± 3.2	25.1 ± 3.4	28.1 ± 3.4	26.6 ± 3.5	26.2 ± 3.7	0.144
LVEDD in mm	43.2 ± 4.4	43.5 ± 4.3	46.6 ± 4.5	43.8 ± 4.6	47.7 ± 4.7	0.034
LVESD in mm	28.8 ± 3.2	29.8 ± 3.4	29.1 ± 3.6	30.4 ± 3.5	28.6 ± 3.7	0.433
EF in %	54.2 ± 5.8	50.6 ± 5.6	48.2 ± 5.5	50.1 ± 5.5	48.8 ± 5.2	0.012
LVEDP in mmHg	8.8 ± 3.4	8.3 ± 3.7	8.4 ± 3.5	8.4 ± 3.2	8.8 ± 3.5	0.042
ARD in mm	24.8 ± 2.4	26.3 ± 2.7	25.7 ± 2.6	28.8 ± 2.9	29.7 ± 3.3	0.032

SD = standard deviation; RVESv = right ventricle end-systolic volume; LVEDD = left ventricular end-diastolic diameter; LVESD = left ventricle end-systolic diameter; EF = ejection fraction; LVEDP = left ventricular end-diastolic pressure; ARD = aortic root diameter.

observed in eight patients (3.5%). Other cardiac abnormalities included arrhythmias plus a first-degree atrioventricular block (2.6%), tall T-waves (1.7%), arrhythmias, ST segment elevation plus anterior myocardial infarctions (1.7%), arrhythmias plus ST segment elevation (1.3%), anterior myocardial infarctions (0.4%) and ST segment elevation (0.4%). Mean CK-MB and troponin I levels were 35.9 ± 4.3 U/mL and 0.6 ± 0.2 ng/mL, respectively [Table 1]. For the

patients with arrhythmias, this complication was followed by ventricular tachycardia, premature atrial contractions, paroxysmal supraventricular tachycardia and premature ventricular contractions.

A total of 60 patients were admitted to the ICU; of these, the majority were 21–30 years old (28.3%). Mean LVEDD and LVESD measurements were 45.4 ± 4.4 mm (range: 39–56 mm) and 29.2 ± 3.5 mm (range: 22–36 mm), respectively. Mean LVEDD measurements were significantly higher in patients who were >50 years old ($P = 0.034$). Although there was no significant difference in LVESD measurements among age groups ($P = 0.433$), the highest value was observed in patients between 41–50 years old. The mean LVEDP value was 8.5 ± 3.5 mmHg (range: 6–10 mmHg) and there was a significant difference in LVEDP value according to age group ($P = 0.042$), with the highest values noted in patients <20 years old and >50 years old. The highest mean EF was observed in patients <20 years old and the lowest mean EF was found in patients aged 31–40 years old ($P = 0.012$). The mean ARD was 27.2 ± 2.8 mm (range: 22–32 mm) with a significant difference according to age group ($P = 0.032$). Patients >50 years of age had the highest mean ARD and patients <20 years old had the lowest mean ARD [Table 2].

Of the 60 patients admitted to the ICU, the majority had normal echocardiography findings (83.3%). However, four patients (6.7%) had left ventricular systolic and/or diastolic dysfunction. The most common abnormality of the cardiac valves was related to the mitral valve (MV); 21.7% of patients had mild MV regurgitation, 3.3% had moderate MV regurgitation and 3.3% had MV prolapse. Tricuspid regurgitation and mild aortic regurgitation were found in 3.3% and 1.7% of patients, respectively. Right ventricular function was abnormal in two patients (3.3%). Anterior *akinaesia* and pulmonary hypertension plus *cor pulmonale* were each reported

Table 3: Cardiac function according to echocardiography among patients admitted to an intensive care unit following acute amphetamine abuse in Tehran, Iran (N = 60)

Finding	n (%)
Normal	50 (83.3)
LVS or LVD dysfunction alone	5 (8.3)
LVS and LVD dysfunction combined	1 (1.7)
Anterior <i>akinaesia</i>	3 (5.0)
PAH plus <i>cor pulmonale</i>	1 (1.7)
RV function	
Normal	58 (96.7)
Abnormal	2 (3.3)
MV dysfunction	
Normal	43 (71.7)
Mild regurgitation	13 (21.7)
Moderate regurgitation	2 (3.3)
Prolapse	2 (3.3)
Other valvular dysfunctions	
None	57 (95.0)
Tricuspid regurgitation	2 (3.3)
Mild aortic regurgitation	1 (1.7)

LVS = left ventricular systolic; LVD = left ventricular diastolic; PAH = pulmonary artery hypertension; RV = right ventricular; MV = mitral valve.

Table 4: Right ventricular wall mobility and function abnormalities according to age group among patients admitted to an intensive care unit following acute amphetamine abuse in Tehran, Iran (N = 60)

	n (%)			
	Right ventricular wall motion abnormalities		Right ventricular function	
	Normal	Abnormal	Normal	Abnormal
Age in years				
<20	6 (10.0)	0 (0.0)	6 (10.0)	0 (0.0)
21–29	17 (28.3)	0 (0.0)	17 (28.3)	0 (0.0)
30–39	13 (21.7)	2 (3.3)	13 (21.7)	2 (3.3)
40–41	5 (8.3)	0 (0.0)	5 (8.3)	0 (0.0)
>50	16 (26.7)	1 (1.7)	17 (28.3)	0 (0.0)
Total	57 (95.0)	3 (5.0)	58 (96.7)	2 (3.3)

in 1.7% of patients, respectively [Table 3]. Right ventricular wall movement abnormalities was noted only among patients who were 30–39 years old and >50 years old. In addition, abnormal right ventricular function was seen only among those aged 30–39 years old [Table 4].

Unfortunately, 10 patients (16.7%) died among those admitted to the ICU. While left ventricular end-diastolic volume and diameter values were normal in all of the admitted patients, two living patients (3.3%) and one deceased patient (1.7%) had abnormal interventricular systolic diameters. Moreover, abnormal EF was noted in four of the patients who died (6.7%) and three living patients (5.0%), with abnormal EF significantly more prevalent among the deceased patients ($P = 0.011$). The ARD was abnormal in seven living patients and three deceased patients (11.7% versus 5.0%; $P = 0.211$) [Table 5]. The frequency of severe right ventricle end-diastolic volume disorder was higher among the deceased patients

Table 5: Echocardiographic findings among deceased and living patients admitted to an intensive care unit following acute amphetamine abuse in Tehran, Iran (N = 60)

Finding	n (%)		P value
	Living patients (n = 50)	Deceased patients (n = 10)	
LVEDv	0 (0.0)	0 (0.0)	-
IVSD	2 (3.3)	1 (1.7)	0.427
LVEDD	0 (0.0)	0 (0.0)	-
Abnormal EF	3 (5.0)	4 (6.7)	0.011
ARD	7 (11.7)	3 (5.0)	0.212

LVEDv = left ventricle end-diastolic volume; IVSD = interventricular systolic diameter; LVEDD = left ventricular end-diastolic diameter; EF = ejection fraction; ARD = aortic root diameter.

Table 6: Frequency of right ventricle end-diastolic volume disorder among deceased and living patients admitted to an intensive care unit in Tehran, Iran, following acute amphetamine abuse (N = 60)

Classification	n (%)	
	Living patients (n = 50)	Deceased patients (n = 10)
Normal	42 (84.0)	9 (90.0)
Fair	7 (14.0)	0 (0.0)
Moderate	0 (0.0)	0 (0.0)
Severe	1 (2.0)	1 (10.0)

than the survivors (10.0% versus 2.0%) [Table 6].

Discussion

According to the findings of the current study, amphetamine abuse occurred mostly among individuals aged 21–40 years old (64.4%), with fewer participants being <20 years old (13.9%) or >41 years old (21.7%). Other studies have shown that drug abuse is more prevalent among young people.^{9,10} Barooni *et al.* found that 18.5% of young adults who went to coffee shops in Tehran had a history of psychoactive drug abuse, in the form of ecstasy abuse.³ As with the present study, previous research has indicated that the mean age of drug abusers is low in Iran.^{11,12} A study of drug abuse cases in Taiwan reported a mean age of 26.7 years among those who abused drugs for the first time.¹³ In a study of methamphetamine-related fatalities in Australia, Kaye *et al.* found that the mean age of patients was 32.7 years and that 77% were male.¹⁴ In the current study, the vast majority of the subjects were male (85.2%). Other researchers have also reported more frequent drug abuse practices among men.^{13,15,16}

In the current study, approximately half of the patients exclusively used amphetamine and methamphetamine, while the rest used other drugs in combination with amphetamines. In addition, most patients administered the drugs via inhalation. Kaye *et al.* found that 89% of their subjects had used drugs other than methamphetamine, including benzodiazepines (41%) and morphine (36%).¹⁴ Moreover, administration of amphetamine is usually reported to be intravenous.^{14,17} In the current study, 10 patients (4.3%) died after being admitted to the ICU, presumably due to drug-related toxicity. Knudsen *et al.* reported an amphetamine-related mortality rate of 12.3% among γ -hydroxybutyrate poisoning cases in Sweden.¹⁸

Troponin I and CK-MB levels were very high among amphetamine users in the present study, indicating

cardiac damage; these findings were consistent with those of various previously published research.^{19–22} In a case report, Khattab *et al.* described a 54-year-old man with chest pains after amphetamine use, increased troponin I and CK-MB levels and complete obstruction of the left circumflex coronary artery due to acute thrombosis.²³ The most commonly observed abnormal ECG findings in the current study were sinus tachycardia (43.0%) and sinus tachycardia plus a prolonged QT interval (34.3%). Haning *et al.* observed prolonged QT intervals among 27.2% of patients abusing methamphetamines in the USA.²⁴ Other researchers have reported various arrhythmias associated with the use of amphetamines or other psychoactive drugs, such as QT interval fluctuations, right bundle branch block and ST segment changes, particularly ST segment elevation.^{25–28} Westover *et al.* found a significant relationship between acute myocardial infarction and amphetamine abuse.²⁹ Moreover, Kaye *et al.* found use of amphetamines to be associated with high pathological cardiac risk; however, this was possibly due to the presence of pre-existing chronic disorders and hence not limited to amphetamine use.¹⁴

According to TTE findings in the current study, left ventricular systolic dysfunction was noted in three cases, abnormal EF in seven cases and abnormal ARD in 10 cases; additionally, right ventricle end-diastolic volume disorder was observed among both living and deceased patients admitted to the ICU. To the best of the authors' knowledge, no similar studies have been published in which amphetamine users were evaluated using echocardiographical parameters. However, various case reports have shown different cardiac abnormalities following abuse of amphetamine, such as reverse Takotsubo cardiomyopathy.³⁰ Yeo *et al.* reported that cardiomyopathy was related to methamphetamine use among young adults in Hawaii.³¹ Moreover, Wijetunga *et al.* found that 84% of crystal methamphetamine users had cardiomyopathy and global ventricular disorders.³² In another study, Maeno *et al.* found that methamphetamine use directly led to cellular hypertrophy and could potentially result in disorders of cardiac function among adult rats.³³ Varner *et al.* demonstrated that methamphetamine administration could significantly change cardiovascular responses and lead to severe cardiac pathology; moreover, they also showed that methamphetamine elicited biphasic heart rate responses consisting of initial bradycardia followed by tachycardia.³⁴ According to a review of methamphetamine-induced cardiac complications by

Paratz *et al.*, dilated, hypertrophic and stress cardiomyopathies are the most common methamphetamine-associated cardiomyopathies.³⁵ Additionally, intranasal administration of d-amphetamine reportedly lead to a more rapid response compared with oral administration.⁵

This study is subject to certain limitations. Although the statistical significance of the findings in this study could not be determined due to the small sample size, these findings may pave the way for future research focusing on echocardiography findings among amphetamine users. Also, as there are few studies in the current literature on this topic, it was difficult to compare the findings of this study with those of previous research. In the current study, most of the subjects were referred to the hospital in the acute phase of drug abuse and the researchers did not have access to each patient's prior medical history relating to heart disease. As such, distinguishing heart problems due to drug abuse from those resulting from pre-existing cardiac disorders was not possible. In addition, most of the patients who were admitted did not consent to undergo echocardiography. Another limitation of this study was the lack of a control group with which to compare results. More studies are needed to assess the true pathogenicity of amphetamine abuse.

Conclusion

Although the majority of patients had normal TTE and ECG scans, cardiac complications were common among Iranian patients who abuse amphetamines, particularly sinus tachycardia and sinus tachycardia plus prolonged QT intervals. Emergency physicians should therefore be aware of these as potential cardiovascular complications of acute amphetamine abuse.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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