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Case report

Toxicological and forensic aspects of a fatal 3-methylmethcathinone intoxication: A case report

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ABSTRACT

The spread of new psychoactive substances (NPS), particularly synthetic cathinones, poses growing challenges for forensic toxicology. Among them, metaphedrone (3-methylmethcathinone, 3-MMC) is a potent psychostimulant structurally related to mephedrone (4-MMC), acting as a monoamine transporter substrate with predominant dopaminergic and noradrenergic effects. Despite international control measures, 3-MMC remains widely available on illicit online markets and it is increasingly associated with severe intoxications and deaths.

We report a fatal case of isolated 3-MMC intoxication investigated at the Section of Legal Medicine and Forensic Toxicology of our University. Postmortem examination revealed nonspecific macroscopic and histological findings, including pulmonary edema, polyvisceral congestion, and myocardial alterations. Toxicological analysis identified 3-MMC as the sole detected substance, with concentrations of 966 ng/mL in peripheral blood and 25,549 ng/mL in urine, consistent with previously reported fatal cases. Standard immunochemical screening was negative, highlighting the limitations of routine toxicology panels and the need for targeted GC–MS/MS methodologies in NPS detection.

This case underscores the diagnostic challenges posed by 3-MMC-related deaths and reinforces the critical role of advanced analytical techniques in forensic investigations, emphasizing the need for continuous updating of toxicological protocols to address the evolving NPS landscape.

1. Introduction

The rapid proliferation of new psychoactive substances (NPS) has created major challenges for public health and forensic toxicology worldwide. NPS, also known as designer drugs, are synthetic compounds derived from traditional substances of abuse, and chemically modified to mimic their psychoactive effects while circumventing legal control measures.[1] Among these, synthetic cathinones have attracted particular attention due to their strong psychostimulant properties and unpredictable toxicity.[2]

Metaphedrone (3-methylmethcathinone, 3-MMC) is a synthetic cathinone that has emerged on the illicit drug market over the last decade. It is a positional isomer of mephedrone (4-MMC) and was initially introduced as a legal substitute following the control of 4-MMC in several countries. Marketed as a "*legal high*", 3-MMC rapidly gained popularity among recreational users and remains widely available through illicit online markets despite its classification as a controlled substance in many jurisdictions.[2] It is typically encountered as a white powder or crystals and can be administered via multiple routes, including nasal, oral, inhalation, or injection, either alone or in combination with other psychoactive substances.

The increasing diffusion of 3-MMC has been accompanied by a growing number of intoxications and fatalities reported in the scientific literature, particularly across Europe.[3–5] Users are often attracted by its stimulant and euphoric effects, while underestimating its toxic potential. International agencies, including the World Health Organization (WHO) and the European Union Drugs Agency (EUDA), have highlighted the high abuse liability and health risks associated with 3-MMC,

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emphasizing the need for enhanced surveillance and control strategies.[6]

Clinically, 3-MMC intoxication has been associated with a broad spectrum of manifestations, ranging from agitation, hyperthermia, and seizures to cardiovascular and psychiatric complications.[7] Severe and potentially fatal outcomes appear to be dose-related and may be exacerbated by repeated use or underlying medical conditions.[2,8,9] From a pharmacological standpoint, 3-MMC acts primarily on monoamine transporters, promoting dopamine and norepinephrine release and reuptake inhibition, a mechanism that contributes to its stimulant effects and its widespread recreational use.[2,4]

In recent years, 3-MMC has also been increasingly associated with sexualized drug use ("ChemSex"), a context characterized by repeated high-dose consumption and enhanced toxicological risk, which poses specific challenges for forensic interpretation and has become epidemiologically relevant in medico-legal investigations.[10]

Despite the growing number of reports, fatal cases involving 3-MMC alone remain relatively rare, and postmortem data are still limited. From a forensic standpoint, isolated fatalities involving 3-MMC represent a diagnostic challenge due to nonspecific autopsy findings, limited postmortem reference concentrations, and the frequent failure of routine toxicological screening to detect this substance. This lack of reference values and characteristic pathological findings complicates the forensic interpretation of deaths potentially related to this substance.

The present study reports a fatal case of acute 3-MMC intoxication investigated at the Section of Legal Medicine and Forensic Toxicology of our University. The case is of particular forensic interest due to the absence of other co-intoxicants and the nonspecific autopsy findings. Postmortem toxicological analyses were performed using targeted analytical methodologies, and the detected 3-MMC concentrations were compared with those reported in previously published fatal poisoning cases to support the determination of cause of death. For this reason, the main aim of this paper is to describe a fatal intoxication due to isolated exposure to 3-MMC, including autopsy, histology and toxicological analysis, contextualising the case within existing mortality reports in the context of NPS.

2. Case history and autopsy findings

A 46-year-old man was found dead by his partner in his bedroom. The body was lying on its back with legs at 90° resting on the bed. Upon external examination, a traumatic injury to the head was noted. No farewell letters or syringes were found near the body. During the on-site inspections several sex toys and lubricants were found on the bed near the body. Two days after the initial discovery, an autopsy was performed. The body was stored at 4 °C prior to the autopsy.

The body was 182 cm in length and medium in build. Dark red colored hypostasis were noted on the neck, back and posterior surface of the lower limbs. Rigor mortis was present, involving both upper and lower limbs. On external examination no needle marks were noted. It was observed a traumatic injury on left the parieto-occipital area. The bones of the vault and base appeared intact upon opening the cranial cavity.

Autopsy examination revealed some nonspecific features. The brain was normal in size and weight (1500 g; reference range ~1300–1500 g) and appeared congested and edematous. The lungs were normal in size; the left lung showed increased weight (800 g; reference range ~400–600 g). On sectioning, the pulmonary parenchyma appeared congested, and a pink foamy fluid was noted at squeezing. The blood was fluid. The heart was enlarged and augmented in weight (700 g; reference range ~300–400 g). It was noted a scarce pericardial liquid effusion. At cut, the cardiac chambers appeared dilated and the myocardium was red in colour. No obstructions or thrombi were observed in the coronary vessels. Liver and renal congestion have also been reported. No other relevant findings were identified during macroscopic examination. Toxicological samples were collected from the femoral vein (peripheral blood) and the urinary bladder (urine).

Histological samples were collected from the brain, lungs, heart, kidney, liver and spleen. Following the autopsy, all the samples were fixed in formalin for 3 days and embedded in paraffin wax. From each block, serial sections were taken, subjected to hematoxylin–eosin staining (H&E).

Histological examination of lung tissue revealed aspecific findings such as pulmonary edema, as well as congestion of the interalveolar and septal capillaries (Fig. 1). Additionally, a lymphomonocytic inflammatory infiltrate was observed. The myocardial tissue showed focal areas of waving of the myocardial fibrils and areas of fibrosis and myofiber break-up and rupture of the intercalated discs (Fig. 2). Additionally, microvesicular steatosis was noted in the liver sample (see Fig. 2).

3. Materials and methods

3.1. Samples

Toxicological analyses were performed on peripheral blood (10 mL) and urine (20 mL), collected during the autopsy and stored at −20 °C until the analysis. All biological samples were collected, handled, stored and analyzed following established forensic chain-of-custody procedures, ensuring sample integrity, traceability and documentation from collection to instrumental analysis.

3.2. Chemicals and reagents

Reference standards for 4-Methylmethcathinone-d3 and Diazepam-d5 were purchased from Lipomed® (Cambridge, United States). Ethyl acetate from PanReac AppliChem® (Monza, Italy) and N-Methyl-bis (trifluoroacetamide) (TFA) were purchased from Sigma-Aldrich® (Milan, Italy). Mephedrone-d3 was used as the internal standard in place of 3-MMC-d3 because this study originated from the urgent need to produce a technical report for the Public Prosecutor's Office. Owing to the limited time frame and the immediate availability of mephedrone-d3, whereas 3-MMC-d3 was not readily obtainable, this approach was adopted. The choice was supported by the close structural similarity between mephedrone and 3-MMC, as well as by verification of their comparable chemical and analytical behavior. Validation checks and analytical controls were performed to ensure the suitability of mephedrone-d3 for quantitative purposes. Several methods have been used for the extraction of cathinones from both blood and urine. The approach we applied was suitable for the searched substances. The extraction and derivatization procedures were selected to ensure adequate selectivity, sensitivity and reproducibility for the determination of 3-MMC in blood and urine, in accordance with the analytical performance requirements defined by the applied international validation criteria.[11]

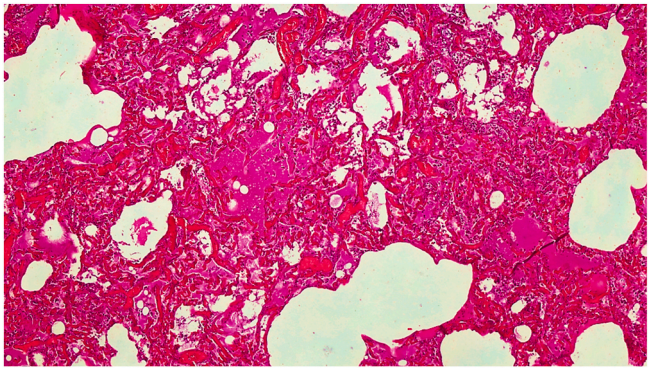

Fig. 1. Pulmonary edema and vascular congestion with accumulation of fluid in alveolar spaces (H&E).

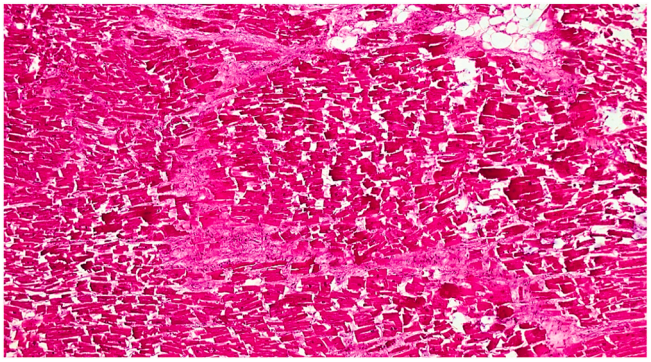

Fig. 2. Myocellular segmentation and bundles of fibrosis (H&E).

3.3. Qualitative analysis

Immunochemical screening (ILab Taurus, Werfen®, Milan, Italy) was performed on both urine and peripheral blood samples, after deproteinization process. The samples were both negative for the following classes of substances: cocaine, Δ9-tetrahydrocannabinol (THC), amphetamines, MDMA, benzodiazepines, opioids, and barbiturates. Routine toxicological screening of blood and urine through chemical immunoassay provided negative results for common drugs of abuse. Ethanol was not detected in both blood and urine, and the analysis for volatile substances was negative.

A Systematic Toxicological Analysis (STA) on peripheral blood and urine was performed using gas chromatography–mass spectrometry (GC/MS) Agilent Technologies GC coupled with an MS Agilent Technologies 5975 MSD Series as part of the standard investigative protocol. A general unknown analysis was performed on aliquots of 250 µl of peripheral blood and 250 µl of urine, added with 400 ng of diazepam-d5 used as the internal standard, for the search of non-volatile organic compounds, at a controlled pH value. Two aliquots of sample (250 µl of peripheral blood and 250 µl of urine) were brought to an alkaline pH value (pH = 8.5-9, by addition of phosphate buffer pH 7.4 and NaOH 0.1 M); two other sample aliquots (250 µl central blood and 250 µl urine) were adjusted to an acidic pH value (pH = 5-5.5 by addition of acetate buffer 1 M). All the samples were extracted with ethyl acetate; at the end of the extraction phase, the samples were centrifuged and the supernatant phases were recovered and collected in a glass tube. Samples were dried under nitrogen flow in a thermoblock and collected with ethyl acetate.

Following the first injection, the samples were dried under nitrogen flow in a thermoblock. They were derivatized with N-Methyl-bis (trifluoroacetamide) (TFA) for 30 minutes in a thermoblock at 70 °C and injected in the chromatographic system.

Spectra were obtained by working with electron impact ionization (EI) in full-scan mode.

The mass spectra obtained in GC/MS and related to the extracts for alkaline and acidic substances of the peripheral blood Fig. 3 and urine were, compared with those of the reference library (*NIST library 23*).

4. Quantitative analysis of 3-methylmethcathinone

4.1. Samples preparation

Two aliquots of sample (250 µl of peripheral blood and 50 µl of urine diluted 1:100) were adjusted to an alkaline pH (pH = 8.5-9, by addition of phosphate buffer pH 7.4 and NaOH 0.1 M) and added with 200 ng of 4-methylmethcathinone-d3 used as reference standard. The samples were extracted with 2 ml of ethyl acetate; at the end of the extraction phase, they were centrifuged and the supernatant phases were recovered and collected in a glass tube. Samples were dried under nitrogen flow, derivatized with N-Methyl-bis (trifluoroacetamide) (TFA) for 30 minutes in at 70 °C and injected into the chromatographic system.

4.2. Instrumentation and conditions

An 8890 GC system with a HP 5MS Ultra Inert capillary column (30 m × 0.25 mm, 0.25 µm), both supplied by Agilent Technologies (Santa Clara, CA, USA), were used for chromatographic separation. The injector port temperature was set at 260 °C. Helium was used as carrier gas at a constant flow rate of 1 mL/min. The oven temperature was set as follows: the initial GC oven temperature was set at 90 °C (1 min) and increased with a ramp at 20 °C/min up to 300 °C. The transfer line and ion source temperatures were both set at 300 °C. The injection volume was set to 1 µL in splitless mode. The total run time was 21.5 min.

The GC instrument was interfaced to a 7000E triple quadrupole mass spectrometer (Agilent Technologies, Santa Clara, CA, USA) operating in selective ion monitoring (SIM). The ionization source was an electron impact ionization (EI). The mass spectra obtained in GC-MS/MS and related to the extracts of the peripheral blood and urine were, compared with those of the reference library (*NIST library 23*). No co-eluting isomers were detected.

For quantitative analysis, the mass analyzer was operated by electron impact (70 eV) in selected ion monitoring (SIM). Quantitative analysis of 3-metylmetcathinone (3-MMC) was carried out recording ions *m/z* 109.9, 118.9, 154 for 3-MMC and *m/z* 119, 157 for mephedrone-d4 (4-MMC). The underlined ions were used for quantitative analysis (target/qualifier).

A new analytical method, used in an individual case study, was validated for both blood and urine in accordance with revised international criteria.[11]

The parameters of validation include the assesment of selectivity, linearity, accuracy, precision, limit of detection (LOD) and lower limit of quantification (LLOQ) for blood and urine. Selectivity was evaluated by analyzing matrix blanks to exclude endogenous interferences and by monitoring potential interference from the internal standard (mephedrone-d4) in zero samples. Linearity was produced by calibration curve prepared by spiking in blank human blood (six concentration levels) and blank human urine (five concentration levels) with an appropriate amount of pure standard (3-MMC) in a concentration range from 3.2 to 1000 ng/mL, showing satisfactory coefficients of determination (r^2), for both blood and urine, across the entire range. Accuracy and precision for all the analytes were assessed at different concentration levels and met the acceptance criteria, with coefficients of variation below 15% for all analytes and matrices, while bias never exceeded ±15%, as seen in Table 1.

LOD and LLOQ evaluated for blood and urine are reported in Table 2. The latter values fit the purpose of the current case.

5. Results

As the death occurred in the context of a judicial investigation conducted on behalf of the Public Prosecutor's Office, toxicological analyses followed a standardized forensic workflow, including an initial immunochemical screening covering the most common classes of abused substances, followed by a comprehensive general unknown analysis. Illicit substances commonly used were not detected in both blood and urine collected during the autopsy. This approach allowed the detection of 3-MMC and the exclusion of other substances of toxicological interest, including additional synthetic cathinones and their related compounds. Furthermore, ethanol was not identified in any of the specimens analyzed. 3-MMC was detected in peripheral blood and urine, as seen in Fig. 4, at concentrations of 966 ng/mL and 25,549 ng/mL, respectively, as seen in Table 3. The standardized toxicological approach (STA), combining immunochemical screening with an untargeted general unknown analysis, provided sufficient analytical specificity to reliably distinguish 3-MMC from structurally related synthetic cathinone

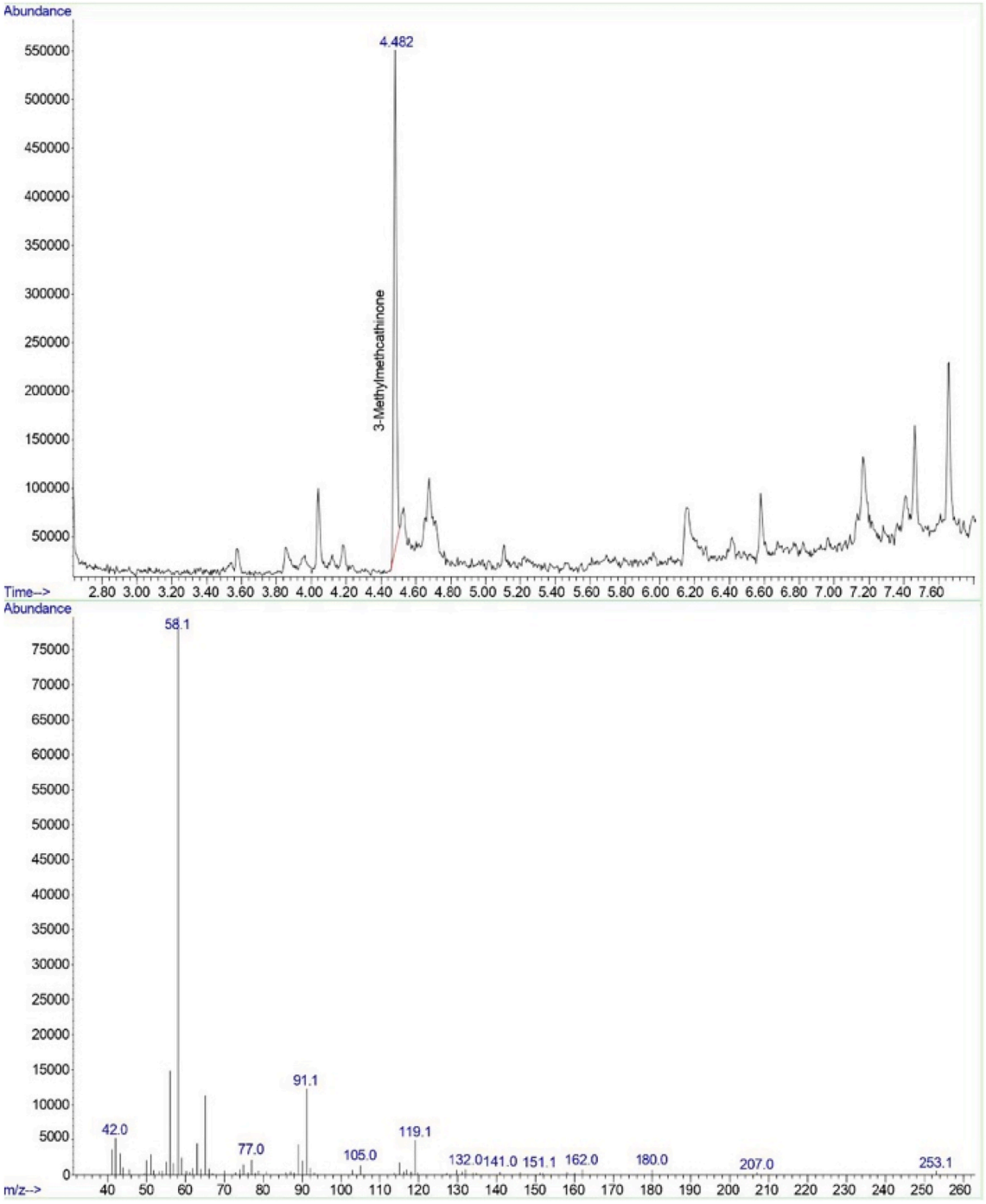

Fig. 3. Full scan mode chromatogram and mass spectra obtained from peripheral blood analysis.

Table 1
Linearity, r^2, precision and accuracy in blood and urine.

Matrix	Linearity range (ng/mL)	r^2	Precision (CV %)	Accuracy (Bias %)
Blood	3.2–1000	≥0.99	<15%	within ±15%
Urine	3.2–1000	≥0.99	<15%	within ±15%

Table 2
LOD and LLOQ for 3-MMC in blood and urine.

	Blood		Urine	
Compound	LOD (ng/mL)	LLOQ (ng/mL)	LOD (ng/mL)	LLOQ (ng/mL)
3-MMC	1.1	3.2	1.1	3.2

analogues, which were not detected in any of the analyzed specimens.

The marked difference observed between peripheral blood and urine concentrations of 3-MMC is consistent with postmortem distribution phenomena and with the pharmacokinetic characteristics of synthetic cathinones. In particular, the high urinary concentration relative to blood may reflect recent or repeated intake prior to death, predominant renal excretion of largely unmetabolized 3-MMC, and postmortem concentration effects within the urinary bladder. Although peripheral blood was analyzed to minimize redistribution artifacts, postmortem redistribution cannot be completely excluded and should be considered

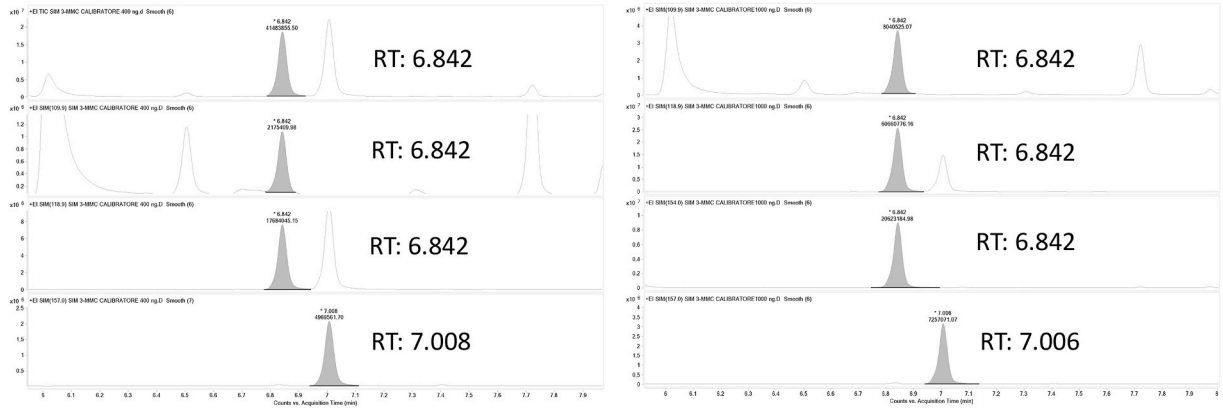

Fig. 4. Chromatographic spectrum of 3-MMC with 3-MMC d3 (ISTD) in blood and urine matrices, respectively, with retention times (RT).

Table 3
Analytical results in biological matrices (quantitative analysis).

Samples	3-MMC (ng/mL)
Peripheral Blood	966
Urine	25,549

when interpreting quantitative findings. Quantitative analysis was performed exclusively on peripheral blood samples, while central blood was not considered for quantitative analysis, in order to minimize the potential impact of postmortem redistribution on the measured concentrations.

6. Discussion

There is limited clinical, autopsy, and toxicological data on deaths caused exclusively by 3-MMC. In the present case, the observed toxicological findings are consistent with systemic exposure to 3-MMC at concentrations within the upper range reported in fatal cases, supporting the interpretation of a severe intoxication. The mechanism of action of 3-MMC is relatively short-lasting: initial effects typically appear within the first hour and last for approximately 4–6 hours, which explains the frequent pattern of repeated administrations within a single session.[8] In severe cases, hyperthermia, rhabdomyolysis, seizures, acute kidney injury, and cardiovascular collapse may occur.[3,9] Notably, rectal administration of 3-MMC, particularly reported in sexualized drug use, has been associated with rapid absorption and life-threatening toxicity, including fatal outcomes.[12] In vitro studies and animal models have shown that 3-MMC can induce mitochondrial dysfunction, oxidative stress, and apoptotic cell death in hepatocytes, suggesting systemic cytotoxic potential beyond its central nervous system effects. These findings are consistent with reports of organ failure and multiorgan toxicity in severe human intoxications, as supported by postmortem findings. In addition, neurotoxic effects related to oxidative stress and dysregulation of the dopaminergic system have been hypothesized, although they have not yet been sufficiently investigated in humans.[4]

This case provides valuable postmortem data for isolated 3-MMC fatalities, contributing to the limited reference information available for forensic interpretation. The main autopsy findings consisted of pulmonary edema and polyvisceral congestion. Histological examination revealed myofibrillar rupture and focal waving, while diffuse myocardial fibrosis was identified as a pre-existing condition that may have contributed to the fatal outcome. Some authors have suggested that death following synthetic cathinone use may resemble hyperthermia-related fatalities associated with serotonergic syndrome, given that some victims reported sensations of warmth and tachycardia prior to death.[13] Synthetic cathinones are known to reduce serotonin reuptake, leading to increased serotonin concentrations in the central nervous system.[14] Pre-existing cardiac conditions may further exacerbate the toxic effects of these substances. The presence of diffuse myocardial fibrosis and cardiac enlargement in this case may have lowered the threshold for fatal arrhythmias following acute 3-MMC exposure, suggesting a synergistic interaction between pre-existing structural heart disease and the substance's sympathomimetic effects. In this regard, Groenewegen et al. (2024) reviewed more than 30 scientific articles involving 3-MMC and described up to 40 cases of cathinone use associated with severe cardiac complications, including cardiac arrest and ventricular or supraventricular tachycardia. In previously reported cases, coronary atherosclerosis with superimposed thrombus or complete occlusion was identified in 8 out of 18 cases where coronary imaging or autopsy data were available, supporting the presence of a structural substrate predisposing to sudden cardiac events. Among 35 patients with known outcomes, 27 were fatal, and 16 deaths occurred following sudden cardiac arrest.[15] These findings support a synergistic interaction between the acute sympathomimetic effects of 3-MMC and underlying cardiovascular pathology, which is highly relevant to the present case.

Consistent with previous reports, 3-MMC consume is strongly related to the enhancement of sexual activities. The international literature consistently reports an association between the use of synthetic cathinones, including 3-MMC, and the practice of “ChemSex,” defined as the use of psychoactive substances to intensify sexual experiences.[10] Substances commonly involved include cathinones, gamma-hydroxybutyrate (GHB) and its precursors, ecstasy, cocaine, and phosphodiesterase inhibitors such as sildenafil or tadalafil. ChemSex is associated with significant health risks, including infectious diseases and severe drug-related toxicity.[12] The popularity of 3-MMC in these settings is linked to its stimulant and empathogenic effects, including increased libido, euphoria, and enhanced sociability.[16] One of the first fatal intoxications involving 3-MMC was reported in France in 2017, describing a young man found dead several hours after nasal intake of the substance purchased online. Autopsy findings were nonspecific, and toxicological analysis revealed 3-MMC concentrations of 249 ng/mL in peripheral blood and 29.94 ng/mL in urine.[17] Subsequent studies have confirmed the wide variability of postmortem 3-MMC concentrations. Adamowicz et al. analyzed 95 postmortem cases, reporting blood concentrations ranging from 1 ng/mL to 1600 ng/mL. The highest concentration (1600 ng/mL) was observed in a 20-year-old man who died following polysubstance abuse, including 3-MMC, 5-APB, and ethanol.[9] Another fatal case reported a blood concentration of 249 ng/mL.[18] Concurrently with the toxicological findings, during the judicial inspection, several sex toys were discovered near the area where the body was found. This element, together with the presence of 3-MMC, may potentially suggest the involvement of ChemSex practices.

In the present case, the peripheral blood concentration of 3-MMC (966 ng/mL) falls within the upper range of values reported in fatal

intoxications and exceeds those described in early isolated cases, supporting a significant systemic exposure. The extremely high urinary concentration (25,549 ng/mL) is particularly noteworthy and markedly higher than values previously reported in fatal cases.[17] This finding may be explained by recent or repeated intake shortly before death, rapid renal excretion of largely unmetabolized 3-MMC, and postmortem concentration effects within the bladder. Synthetic cathinones are known to undergo limited metabolism, with a substantial fraction excreted unchanged in urine, particularly following acute high-dose exposure. Postmortem redistribution phenomena may have further contributed to the elevated urinary levels observed. The combination of diffuse myocardial fibrosis and cardiac enlargement likely predisposed the heart to arrhythmogenic events under acute sympathomimetic stress from 3-MMC. Pulmonary edema observed at autopsy may reflect acute cardiac decompensation, while the markedly elevated urinary concentration indicates recent or repeated intake, resulting in high systemic exposure. Together, these findings support a mechanistic scenario in which acute stimulant toxicity precipitated cardiovascular collapse in a structurally compromised heart.

The absence of other exogenous substances in blood, including ethanol and commonly abused drugs, strengthens the causal link between 3-MMC intake and death. Alternative causes of death were carefully evaluated and reasonably excluded: no traumatic injuries incompatible with life were identified, coronary vessels were patent, and no acute natural disease other than chronic cardiac pathology was documented. Considering the toxicological findings and autopsy results, death is most plausibly attributed to acute 3-MMC intoxication, with the pre-existing cardiac pathology likely lowering the threshold for fatal arrhythmias. Therefore, the fatal outcome likely resulted from a combination of systemic stimulant toxicity and arrhythmogenic susceptibility rather than either mechanism in isolation.

Several limitations must be acknowledged. Detection of 3-MMC is complicated by its structural similarity to other synthetic cathinones and by the limited sensitivity of routine immunochemical screening panels, as confirmed by the negative screening results in this case. Targeted GC-MS and GC-MS/MS analyses were therefore essential for identification and quantification. Interpretation of these findings is limited by factors inherent to postmortem toxicology, including the postmortem interval, potential analytical uncertainties, and the absence of metabolite data, which collectively introduce some degree of uncertainty in quantifying systemic exposure and establishing a definitive cause-effect relationship. Additionally, the lack of vitreous humor analysis and the limited availability of postmortem reference data for 3-MMC introduce inherent uncertainty in quantitative interpretation. Nonetheless, the analytical findings are consistent with previously reported fatal cases and provide robust support for the proposed cause of death.

Despite the growing diffusion of 3-MMC, toxicological and forensic data remain scarce, posing significant challenges for forensic pathologists and toxicologists. The present case contributes valuable postmortem concentration data and underscores the importance of advanced analytical methodologies in the investigation of deaths involving new psychoactive substances.

7. Conclusion

This case underscores several key forensic considerations. First, routine immunochemical screening may fail to detect synthetic cathinones, highlighting the inherent limitations of standard toxicological panels. Second, the identification and quantification of NPS require advanced instrumental techniques, such as GC-MS and GC-MS/MS, which are essential for reliable forensic interpretation. Third, the contextual evaluation of substance use, including the ChemSex setting, may provide crucial circumstantial information and should be carefully considered during medico-legal investigations. Finally, the interpretation of cathinone-related toxicology remains inherently complex due to limited reference data, postmortem redistribution phenomena, and frequent interindividual variability.

Overall, this case emphasizes the need for updated analytical strategies and a multidisciplinary approach in forensic practice, in order to improve the recognition and interpretation of deaths involving synthetic cathinones and other emerging psychoactive substances. In this case, the autopsy findings of pulmonary edema and cardiac enlargement with diffuse myocardial fibrosis align with the toxicological evidence of high systemic 3-MMC exposure, supporting a mechanistic link between acute stimulant toxicity and fatal cardiovascular compromise.

Finally, in this case, the findings support that death was attributed to acute 3-MMC intoxication, with pre-existing chronic cardiac disease likely acting as a contributory factor, as indicated by the histological evidence of myocardial fibrosis.

Author contributions

Conceptualization, F.M., R.T. and L.S.; validation, L.R.; formal analysis, F.M., F.S. and G.P.; investigation, F.M., L.S. and G.P.; data curation, P.*P. and* R.T.; writing—original draft preparation, M.*P. and* L. S.; writing—review and editing, R.T., L.R.; visualization, F.S. and M.P.; supervision, R.T. All authors have read and agreed to the published version of the manuscript.

Ethics statement

We did not need the approval of Ethics Committee since the tests are mandatory and requested by the Judicial Authority.

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Declaration of interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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