Nicotine Content from Cigarettes Submerged in Soda

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Abstract

Introduction Cigarettes and other tobacco products may be extinguished by submersion in liquids in beverage cans or bottles. Cases of nicotine poisoning in children have been reported following ingestion of such liquids. The aim of this study is to analyze the variability of nicotine concentrations with respect to number of cigarettes immersed and the duration of immersion in a soda can

Methods One unsmoked cigarette was immersed in a cola containing soda can. Three separate samples of the mixture were obtained at different intervals of time post immersion up to 1 week. At the same time, a set of four cola cans were immersed with an increasing number of unsmoked cigarettes and samples obtained. All the samples were then analyzed for nicotine concentrations using liquid chromatography-mass spectrometry.

Results The mean concentration of nicotine measured over the course of 6 hours from one full cigarette in 55 ml of a cola beverage was 0.48 mg/ml. Nicotine concentrations steadily increased in the first 6 hours following submersion, after which, the levels plateaued ($r = 0.530$, $n = 18$, $p = 0.024$). There was a strong positive correlation between nicotine concentrations and the number of cigarettes ($r = 0.967$, $n = 12$, $p = 3e-7$).

Conclusions The mean concentration of nicotine measured over the course of 6 hours from one immersed cigarette can be potentially toxic especially to children. Nicotine concentrations are positively correlated with the number of cigarettes and time of immersion.

Introduction

Cigarettes and other tobacco products may be extinguished by submersion in liquids in beverage cans or bottles. Many of the case reports and poison control data allude to significant nicotine poisoning caused from ingesting cigarette butts or

nicotine refill solution used in e-cigarettes or nicotine replacement products like chewing gums, lozenges and transdermal patches [1–5]. There are however instances where children have accidentally ingested soda dipped with cigarettes and consequently developed nicotine toxicity. In our clinical experience, a 10-month-old infant developed significant toxicity in the form of obtundation and hypoventilation following ingestion of a similar liquid mixture, requiring aggressive supportive care. Limited research has been performed analyzing nicotine levels in such mixtures possibly due to the paucity of such ingestions being reported in the literature. Our hypotheses were that the nicotine concentrations in the liquid will increase with the following: longer duration of cigarette submersion in liquid and an increase in the number of cigarettes in each container.

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Methods

In experiment 1 (Fig. 3), one unsmoked cigarette (Newport® full flavor hard pack (FF HP)) was immersed in a soda can containing 55 milliliters (ml) of a cola beverage (Coca Cola®). Each unsmoked cigarette of Newport FF HP contains

13.4 mg of nicotine which corresponds to a concentration of 1.9 mg/g of nicotine [6]. Newport is the second most popular brand of cigarettes used by Americans with Marlboro being the most popular [7], which has a slightly lower nicotine concentration of 1.6 mg/g. Newport brand was chosen for our experiment as it had the highest concentration of nicotine compared with all other popular brands [6]. This was with the intention of simulating the worst possible scenario of nicotine exposure in the event of an actual case of poisoning. Samples of the liquid from the mixture were obtained at 1, 2, 6, 12, and 24 hours and 1 week. Three separate samples were obtained per chosen time period, and as a control, we used soda without a cigarette. A total of 21 samples were studied.

Following the above experiment, in order to assess for nicotine concentration variation with increasing number of cigarettes, 4 cans containing 100 ml of a cola beverage, each having either 1, 2, 3, or 4 full, unsmoked cigarette(s) immersed in them, were prepared, and samples of the liquid from the mixture were obtained at the 6-hour mark (Fig. 4). This was repeated 3 times for a total of 12 samples. The 6-hour mark was chosen based on the findings from the first experiment that the nicotine concentrations plateaued at this time point.

In both experiments, the samples were analyzed using liquid chromatography-mass spectrometry (LCMS). Briefly, samples were diluted 1:100 in LCMS-grade water and 3 μ l injected on an Acquity I-Class UPLC system coupled to a Synapt G2Si HDMS mass spectrometer in positive ion mode with heated electrospray ionization (ESI) source in a Z-spray configuration. LC separation was performed on a Waters Acquity UPLC BEH 1.7 μ m $\times$ 2.1 $\times$ 50 mm column using a 0.6-ml/minute gradient of A/B 95/5 to 15/85 in 4 minutes followed by washing and reconditioning the column. Eluent A is 0.1% formic acid in water and B is 0.1% formic acid in acetonitrile. Masses were collected in resolution mode, at 0.2-s scan time, using an MSe ramp trap collision energy of 20–40 V. Masses were extracted from the TOF MS TICs using an abs width of 0.05 Da. Data were analyzed using Waters Masslynx and Waters Unifi. A calibration curve of a serial dilution of an authentic sample of nicotine (Sigma Aldrich N-008 1 ml) was used for quantification. Three control samples of the soda which had no cigarettes immersed were also analyzed for nicotine levels.

Statistical analysis included first outlining the null hypotheses. Our first null hypothesis was that the concentration of nicotine in soda following immersion of cigarettes is independent of the time for which the cigarettes were immersed. The second null hypothesis was that the concentration of nicotine in the soda is independent of the number of cigarettes immersed at 6 hours.

Spearman's rank correlation analysis was used to analyze the correlation between nicotine concentration and the duration of immersion and hence disprove the first null hypothesis.

Pearson's correlation coefficient was used to analyze the correlation between nicotine concentration and the number of cigarettes immersed and hence disprove the second null hypothesis.

The study was deemed exempt by the Institutional Review Board since there are no human subjects involved in the study.

Results

The nicotine levels in the beverage samples with respect to time of immersion and number of cigarettes have been described in Tables 1 and 2 respectively and summarized in scatter plots Figs. 1 and 2 respectively. The mean concentration of nicotine measured over the course of 6 hours from one full cigarette in 55 ml of a cola beverage was found to be 0.48 mg/l (Figs. 3 and 4). Nicotine concentrations steadily increased in the first 6 hours following submersion, after which, there was no significant increase (Table 1). A Spearman correlation coefficient was computed to assess the relationship between the time of submersion of the cigarettes and the nicotine concentration, even though the correlation coefficient is less meaningful due to the non-linear relationship between the two variables (line graph 1). There was a positive correlation between the two variables ($r = 0.629$, $n = 21$, $p = 0.002$). There was also a steady increase in nicotine concentrations with an increasing number of cigarettes. A Pearson coefficient computed showed a positive correlation between the two variables ($r = 0.967$, $n = 12$, $p = 3e-7$). Figure 1 (one-week value excluded for the sake of simplifying the scale of the graph) and Fig. 2 summarize the findings.

Discussion

Our study confirms that a significant amount of nicotine is measurable when cigarettes are allowed to soak for at least 6 hours in a can of cola. The mean nicotine concentration after 6 hours of a single cigarette immersion was found to be 0.48 mg/ml. The oral LD₅₀ of nicotine from earlier studies has been estimated to be 6.5 to 13 mg/kg [8]. The estimated minimum pediatric lethal dose of nicotine is 1 mg/kg [9]. In children, ingestion of as little as 2 mg has been reported to cause toxicity [10]. Based on our findings from the experiment, in a child with a weight of 5 kg, toxicity could therefore be expected with ingestion of as little as 4 to 5 ml of cola dipped with cigarettes, an amount that would be consistent with an exploratory ingestion.

We have previously treated children following exploratory ingestion of such liquids. One such case was that of a 10-month-old male with no significant past medical history who presented to the emergency department after ingesting water

Table 1 Nicotine concentration and time.

SODA, key	Time	Cigarette	55 ml soda	Nicotine/ soda (mg/ml)	Absolute level (mg × 55 ml)
1A: control	0 hours	No cigarette	Soda alone	0.00	0.00 mg
1B: control	0 hours	No cigarette	Soda alone	0.00	0.00 mg
1C: control	0 hours	No cigarette	Soda alone	0.00	0.00 mg
7A	1 hour	1 cigarette	Soda	0.23	12.6 mg
7B	1 hour	1 cigarette	Soda	0.21	11.5 mg
7C	1 hour	1 cigarette	Soda	0.53	29.2 mg
3A	2 hours	1 cigarette	Soda	0.45	24.8 mg
3B	2 hours	1 cigarette	Soda	0.40	22.0 mg
3C	2 hours	1 cigarette	Soda	0.39	21.4 mg
6A	6 hours	1 cigarette	Soda	0.41	22.5 mg
6B	6 hours	1 cigarette	Soda	0.51	28.1 mg
6C	6 hours	1 cigarette	Soda	0.52	28.6 mg
5A	12 hours	1 cigarette	Soda	0.48	26.4 mg
5B	12 hours	1 cigarette	Soda	0.50	27.5 mg
5C	12 hours	1 cigarette	Soda	0.47	25.8 mg
4A	24 hours	1 cigarette	Soda	0.46	25.3 mg
4B	24 hours	1 cigarette	Soda	0.49	26.9 mg
4C	24 hours	1 cigarette	Soda	0.47	25.85 mg
2A	1 week	1 cigarette	Soda	0.48	26.40 mg
2B	1 week	1 cigarette	Soda	0.45	24.75 mg
2C	1 week	1 cigarette	Soda	0.55	27.50 mg

from an ashtray containing two used cigarette butts. The infant was lethargic and progressively became obtunded with hypoventilation requiring intubation. The toxicological analysis of blood was positive for nicotine only. He gradually improved with close observation and supportive care, including an infusion of intravenous normal saline for tachycardia, and was discharged after 4 days.

Nicotine is an alkaloid present in tobacco that may cause toxicity with acute exposure.

It is one of many xenobiotics present in tobacco products that may be potentially dangerous if consumed in large amounts. Early symptoms of acute nicotine poisoning include gastrointestinal symptoms like nausea and vomiting, respiratory symptoms such as bronchorrhea and tachypnea,

Table 2 Nicotine concentration and number of cigarettes.

SODA, key	Time	Cigarette	100 ml soda	Nicotine/soda (mg/ml)	Absolute level (mg × 100 ml)
1A	6 hours	1 cigarette	Soda	0.28	28 mg
1B	6 hours	1 cigarette	Soda	0.25	25 mg
1C	6 hours	1 cigarette	Soda	0.25	25 mg
2A	6 hours	2 cigarettes	Soda	0.38	38 mg
2B	6 hours	2 cigarettes	Soda	0.41	41 mg
2C	6 hours	2 cigarettes	Soda	0.41	41 mg
3A	6 hours	3 cigarettes	Soda	0.45	45 mg
3B	6 hours	3 cigarettes	Soda	0.43	43 mg
3C	6 hours	3 cigarettes	Soda	0.50	50 mg
4A	6 hours	4 cigarettes	Soda	0.52	52 mg
4B	6 hours	4 cigarettes	Soda	0.55	55 mg
4C	6 hours	4 cigarettes	Soda	0.56	56 mg

Fig. 1 A scatter plot depicting the mean concentration of nicotine (mg/ml) versus time of immersion of cigarettes (hours).

autonomic disturbances of tachycardia and hypertension, and neurological manifestations including agitation, anxiety, blurred vision, headache, and hyperactivity. This can progress to hypoventilation, apnea, bradycardia, hypotension, dysrhythmias, weakness, and paralysis [11]. Not only is nicotine toxic via the oral route, but it can also be absorbed by the skin

or mucous membrane making them hazardous even if not ingested [12].

One cigarette contains 10 to 30 mg of nicotine and one cigarette butt contains a minimum of 5 to 7 mg of nicotine [10]. This number may differ depending on many factors including the amount of tobacco in a cigarette, how it is smoked,

Fig. 2 A scatter plot depicting the mean nicotine concentration (mg/ml) versus the number of cigarettes immersed.

Fig. 3 Diagram describing the methodology for experiment 1.

the efficiency of the filters, and how much of it is not smoked prior to disposing of it. From our study, we found that approximately 75% of the nicotine was leached into the fluid within 2 hours. Given that many variables can affect how much nicotine is in the remainder of a used cigarette, this number is not constant.

The risk of toxicity and potentially death increases with larger consumptions, or if more cigarettes are soaked in the remaining beverage. This is not unlike exposure to liquid nicotine in electronic cigarettes or vaping cartridges, the

difference being that there may be instances the cause of toxicity may be obscured by the opaque nature of the soda cans or bottles. The sweetness of the soda beverage in which the cigarettes are submerged may also encourage higher quantities to be consumed by children, thereby increasing the risk of more severe toxicity.

To ensure the accuracy of the nicotine concentrations that were measured, we used high-resolution mass spectrometry that can differentiate molecules that are as small as 0.001 Da. This is well below the molecular mass of nicotine

Fig. 4 Diagram describing the methodology for experiment 2.

ensuring excellent sensitivity of detection. We also verified the identity of the nicotine molecules utilizing an “authentic standard.” Using the mass of an authentic standard that was run as a separate sample during the same batch analysis makes this method of analysis highly specific for the measurement of nicotine concentration, ruling out the possibility of detecting “similar-looking molecules.”

There are potential limitations to this study. We performed the experiment using just one brand of cigarettes and one brand of soda. It is likely that the nicotine concentrations would vary depending on varying nicotine content in the different brands of cigarettes available. It is also likely that the leaching efficiency would fluctuate with the kind of solvent used. Hence, the nicotine concentrations might have been different if other brands of soda were used.

The amount of nicotine that leaches into the soda can vary depending on the particle size of the cigarette powder, the resistance offered to leaching by the tipping paper that wraps the cigarette, the temperature of the solvent, any prior agitation of the solvent, homogeneity of the solute which in this case would be the tobacco powder and other additives, and the crystalline structure of the cigarette powder [13, 14]. Hence, it is likely that our experiment may have generated a different set of results had the above variables been altered.

Another potential limitation is the fact that we used cigarettes that were not smoked. In real-life poisonings, partially smoked cigarettes or cigarette butts are likely the ones to be immersed in soda. This can obviously lead to a different set of values if nicotine concentrations are measured. Similar studies in the future need to focus on nicotine concentrations in solvents under different environmental conditions using smoked cigarettes of varying lengths and how each of those variables would affect the nicotine concentrations measured.

Conclusion

The mean concentration of nicotine in a can of soda after 6 hours of immersion of a single cigarette could potentially cause significant nicotine toxicity on ingestion, especially in children. The concentration of nicotine in the soda increased with the increasing number of cigarettes soaked and with increasing duration of immersion.

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Compliance with Ethical Standards

Conflicts of Interest None.

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