

# Variable and potentially fatal amounts of nicotine in e-cigarette nicotine solutions

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Experimental research on electronic cigarettes (e-cigarettes) is sparse. Regulated as *tobacco products* by the US Food and Drug Administration, e-cigarette safety has not been determined. This enables the sale of e-cigarettes and tobacco-derived nicotine solution to consumers without rigorous safety regulations that would be required if the products were regulated as *drug delivery devices*.<sup>1</sup> As such, despite the recent popularity of e-cigarettes as an alternative to cigarette smoking, consumers currently do not have industry-regulated information on the concentration of e-cigarette solutions or their safety.<sup>1</sup> The present study reports the nicotine concentration of several of these solutions.

## METHODS

A convenience sample of seven e-cigarette nicotine solutions was analysed. Samples ranged from pre-packaged and sealed with concentration levels printed on the labels to blank bottles with handwritten labels with no concentration level, warning statements or directions for use. Samples A and G were marked as 24 mg/ml and unmarked samples (B–F) were analysed using the expected nicotine concentration levels for ‘Super High’, ‘High’, ‘Medium’ and ‘Low’ categories based on information from the manufacturer’s website (see table 1). Triplicate 0.05 ml aliquots were taken from each sample of nicotine solution and then serially diluted with Milli-Q water. Samples were analysed by liquid chromatography-electrospray ionisation-tandem mass spectrometry.<sup>2</sup>

## RESULTS

All e-cigarette nicotine solutions assayed contained nicotine, as advertised. For all samples, the amount

of nicotine present (mg/ml) was equivalent to or lower than what was marked or expected given the manufacturer concentration ranges provided (see table 1). Even at lower levels of nicotine than expected given manufacturer specifications, these nicotine solutions could be toxic or lethal if taken other than directed.

## DISCUSSION

The nicotine concentration range of e-cigarette solutions varies by manufacturer, as there is no standard dose for each strength category (eg, low, high). A consumer purchasing nicotine solution marked as ‘high’ could receive a solution with substantial variability in nicotine concentration depending on manufacturer/distributor. Similar variability in nicotine concentrations was also found in a recent study.<sup>3</sup> Together, these findings support calls to improve standardisation and manufacturing practices.<sup>4</sup>

The fatal dose of nicotine is estimated at 30–60 mg in adults and 10 mg in children (see Etter *et al*, 2011, p. 245).<sup>4</sup> Our results confirm e-cigarette solutions contain nicotine doses that are potentially lethal in adults and children. For example, a 5 ml vial of a 20 mg/ml solution contains 100 mg of nicotine. Reports of unintentional poisoning in children via tobacco (cigarette butts)<sup>5</sup> and smokeless tobacco products (Orbs, snus)<sup>6</sup> suggest minor toxicity (eg, vomiting, nausea, tachycardia) in most cases. However, the amount of nicotine in commonly sold 5, 10 or 20 ml vials poses a greater toxicity or fatality risk in children if ingested orally or absorbed transdermally. This is particularly concerning as e-cigarette nicotine

**Table 1** Replicate and mean nicotine concentration analyses for e-cigarette nicotine solutions

Sample ID	Brand*	Expected concentration level	Nicotine (mg/ml)			
			Replicate analyses			
			1	2	3	Mean (±S.D.)
A	Vapour liquid (high)	24 mg/ml (marked)	19.8	21.2	16.3	19.1 (±2.52)
B	No brand, hand-labelled liquid (high)	25–36 mg/ml (est.)	12.4	12.1	12.4	12.3 (±0.17)
C	Smart smoke liquid (high)	25–36 mg/ml (est.)	13.2	13.5	12.7	13.1 (±0.40)
D	Smart smoke liquid (med)	10–18 mg/ml (est.)	12.7	11.2	11.9	11.9 (±0.75)
E	Smart smoke liquid (low)	6–14 mg/ml (est.)	8.3	8.6	8.5	8.5 (±0.16)
F	BE112 prefilled cartridge (super high)	25–36 mg/ml (est.)	19.8	20.4	19.5	19.9 (±0.46)
G	Vapour prefilled cartridge (high)	24 mg/ml (marked)	22.4	22.7	21.5	22.2 (±0.62)

Precision and accuracy of the LC-MS analyses for the quality control test solutions were as follows: Low: target concentration=20 ng/ml, measured nicotine mean (SD)=18.5 (±0.95); Medium: target concentration=300 ng/ml, measured nicotine mean=301.4 (±6.05); High: target concentration=1300 ng/ml, measured nicotine mean=1314 (±42.5).

\*Nicotine solutions were obtained from local vendors in Spokane, Washington, USA. All labelled brands (Vapour, Smart Smoke, BE112) were also found available for purchase on the internet. Information on country of manufacture was only found for Vapour (USA).

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solutions come in flavours attractive to children (eg, cotton candy, bubble gum).

We believe nicotine solutions should be regulated and accurately labelled with appropriate warnings and recommend health-care providers screen for use of e-cigarettes and warn of potential dangers, particularly of toxicity risk in children.

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