Burn injuries resulting from illegal cannabis oil manufacturing: review of 12 cases and a synthesis of the literature to guide Canadian cannabis policy.

Sarthak Sinha[1,3*], Kyle Ricord, MD[1,2*], Patricia Harasym, PhD[1,3], Waleed Rahmani[2,3], Jeff A. Biernaskie, PhD[3], Duncan Nickerson, MD[4,5], Vincent A. Gabriel, MSc, MD[1,4‡]

Affiliation(s) for each author:

[1] Division of Physical Medicine and Rehabilitation, Departments of Clinical Neurosciences, Pediatrics and Surgery, Faculty of Medicine, University of Calgary.

[2] Faculty of Medicine, University of Calgary.

[3] Department of Comparative Biology & Experimental Medicine, Faculty of Veterinary Medicine, University of Calgary.

[4] Calgary Firefighters' Burn Treatment Centre, Canada.

[5] Section of Plastic Surgery, Department of Surgery, University of Calgary, Alberta, Canada.

*Authors made equal contributions.

‡**Corresponding Author:** Vincent Gabriel, MD, MSc, FRCPC.

AC122 SSB, Foothills Medical Centre,

1403-29 Street NW Calgary, AB T2N 2T9, Canada.

Phone: 403-944-5917; Fax: 403-944-8578; Email: vince.gabriel@albertahealthservices.ca

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ABSTRACT (246/250 words):

Background: The increasing consideration of cannabis legalization in Canada and the US has motivated physicians to assess its prospective impact on the health care system. A particular concern within the burns community are injuries sustained as a result of the illegal manufacturing of cannabis oil. Cannabis oil is isolated from *Cannabis sativa* and *Cannabis indica* vegetation as a method to enhance its potency and involves highly flammable reagents.

Methods: We first synthesize clinical features unique to cannabis oil burn injuries from 5 published case series (4 from the US, 1 from New Zealand). We then expand this repertoire by analyzing 12 cannabis oil burn injuries treated over a 2-year review period at the Foothills Medical Centre in Alberta, Canada.

Results: 190 cases from 6 independent investigations converge in suggesting that cannabis oil burn patients (in comparison to all burn admissions): a) are younger, b) males are overrepresented, c) sustain a larger TBSA burns, d) require higher surgical management, and e) spend more time at the hospital.

Interpretation: Since Bell et al. found an increase in the frequency of cannabis oil burns following cannabis liberalization in Colorado, similar trends might recapitulate in Canada. To safeguard against this, we formulate a three-pronged approach to serve as an adjunct to cannabis liberalization policies. We recommend to: a) monitor trends in cannabis oil burn injuries, b) educate the public and tertiary burn units about cannabis oil burns, and c) encourage regulation of cannabis oil production to reduce risk of injury.

Key words: Burns, cannabis oil manufacturing, Canada, cannabis liberalization.

Abbreviations: δ-9-tetrahydrocannabinol (THC)**;** Total body surface area (TBSA)

1. INTRODUCTION:

Following their victory in the 2015 federal election, Prime Minister Justin Trudeau and his cabinet assembled a national task force to establish a framework for cannabis legalization in Canada. A key objective of this task force was to formulate evidence-informed policy recommendations by analyzing data from jurisdictions that legalized cannabis for non-medicinal use (i.e. Colorado, Washington State). A prominent recommendation of the task force was the need to assess how changes in cannabis availability will impact public health risks in Canada, and whether foreseeable changes in health care costs can be prospectively identified [1]. To this end, an analysis of how cannabis legalization might impact different aspects of Canadian's health is timely to guide the development of federal policy.

Here, we focus on hydrocarbon burns as a result of explosions during illegal cannabis oil manufacturing and its potential to become a growing problem in Canada. Cannabis oil (or "hash oil") is a highly potent δ-9-tetrahydrocannabinol (THC) concentrate which contains up to 90% THC [2]. The most common method to concentrate THC employs compressed short-chain hydrocarbons (i.e. butane) as solvents. Since butane gas is heavier than the ambient air, in the absence of proper ventilation apparatus, butane vapors can reach ignitable range (2–8%) and can catch fire in the presence of static electricity and open flame sources [2]. The extracted oil may be further purified by alkali washing (using nonpolar solvents such as petroleum ether) to remove heavy aromatic carboxylic acids and to enhance its taste. Clandestine distilleries are particularly vulnerable to fire burns as safety measures necessary to prevent butane vapor accumulation (i.e. fume ventilation, hazardous waste disposal) are often neglected [3].

Evidence of clandestine distilleries proliferating in North America comes from butane cannabis oil confiscations between 2000 to 2007 being 3-fold higher compared to 1993 to 2000 period [4]. Additionally, the increased availability of cannabis (as a result of cannabis legalization or decriminalization) has been associated with a significant increase in the number of cases presented with such burns in US states like Colorado [5]. Cannabis is expected to become more accessible in Canada, but the impact of such policy changes on hydrocarbon burns is not known. This investigation reports the first Canadian case series asking what constitutes a cannabis oil burn patient. We found younger males were overrepresented in the cannabis oil burn patient population, and these burns covered larger TBSA and resulted in extended hospital stay. We expand our study by providing cost estimates of treating cannabis oil burn injuries, and formulate a three-pronged approach to safeguard against this potential public health risk.

2. METHORDS:

2.1. Literature Search Strategy.

The articles concerning cannabis oil burns were found by searching Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations (1966-March 2017) using the text words 'hash oil burns', 'cannabis oil burns', 'honey oil burns' and 'marijuana burns'. PubMed & PubMed Clinical Queries were also searched within the same dates. Reference lists of the journal articles returned were then hand searched. Only non-human and non-English language studies were excluded.

2.2. Retrospective Chart Review.

We performed a retrospective chart review of all burn admissions treated at the Firefighters Burn Treatment Centre at Foothills Medical Centre in Calgary, AB from

April 2012 to March 2014. This study was approved by the Conjoint Health Research Ethics Board at the University of Calgary. Charts were first reviewed for the description of event and cannabis oil burn patients were identified where there was evidence of combustion during cannabis oil manufacturing. We then reviewed for age, gender, burn anatomical site, %TBSA burn, burn depth, surgical procedures performed, admission duration, and post-discharge outcome.

2.3. Statistical Analysis.

Statistical analysis was performed using GraphPad Prism version 4.0 for Windows, and no samples were excluded from the dataset. Unpaired *t* tests, two-tailed, with Welch correction, was used to assess whether admission duration and % TBSA of the cannabis oil burns were significantly different from the total burn admission. Pearson's chi-square was used to assess differences in age and anatomical site distribution. Fisher exact test, two-sided, was used instead of χ^2 to assess association between gender.

3. RESULTS:

3.1. Case Series

Our chart audit found that 12 (7.5%) out of 161 patients sustained burns from cannabis oil manufacturing over the review period. Of the 12 patients identified, 10 were admitted by ground ambulance, 1 from air ambulance, and 1 was brought in by the local police (Table 2). In the total burn admission group, majority (19%) of burn victims were aged 41-50 years whereas 9 (75%) of cannabis oil burns were under the age of 41 ($p = 0.82$, Figure 1A, Table 2). Males constituted 83% of cannabis oil burn patients compared to 74% in the total burn admission group ($p=0.73$, Figure 1B). The mean TBSA of cannabis oil burn patients was 24% (interquartile range (IQR): 8, 37,

range 3–70%) compared to 9% (IQR: 2, 11, range 0.5-70%) in total burn admission (p = .043; Figure 1C, Table 2). The mean admission duration of cannabis oil burn patients was 32 days (interquartile range (IQR): 19, 49, range 3–69 days) compared to 17 days (IQR: 5, 19, range 1-138 days) in total burn admission (p = .021; Figure 1D, Table 2). Face (67%) and neck (67%) were the most frequently inflicted anatomical sites in cannabis oil burns whereas burns to the face (31%) and hand (28%) were most frequent in the total burn admission group (Figure 1E, Table 2). Surgical debridement, followed by split-thickness skin graft, were required in 9 (75%) cannabis oil burns. Inhalation injuries were sustained by 3 (25%) cannabis oil burn patients and 1 patient succumbed to his injuries.

3.2. Literature Review

We identified 190 patients with cannabis oil burns from 6 case series reported in the English literature for whom clinical data was available [3][5][6][7][8] (Table 1, Figure 3). These studies were published between 2004 – 2017 and majority (4 out of 6) were based on chart audits performed in American tertiary burn care centers. Based on studies which reported gender, there were 144 males and 15 females, giving an M:F ratio of 9.6:1. The age of cannabis oil burn patients ranged from 2 – 55 year, with a mean of 43 years (n=118). The TBSA ranged from 0.5 - 95%, with a mean of 23.9% (n=159). Admission duration ranged from 0 - 513 days, with a mean of 28.3 days (n=159). Skin grafting was performed in 55.3% (n=190) of cannabis oil burn cases and average mortality in this group was 2.6% (n=151).

4. INTERPRETATION:

Cannabis oil is isolated from *Cannabis* vegetation to concentrate THC. This extraction requires the raw cannabis to be boiled in volatile solvents such as butane. Since extractions are currently performed in non-regulated distilleries, improper butane ventilation makes them vulnerable to explosions resulting in fire burns. Such a risk is dramatically exacerbated if evaporation is hastened by heating the butane-cannabis mixture on a heat source. Here, we sought to characterize features unique to cannabis oil burn patients and discuss the potential impact of Canada's proposed cannabis legalization by July 1, 2018 [9] on these injuries. To our knowledge, this is the first Canadian chart audit, and we pooled findings from 6 case series to highlight emerging trends. We found converging evidence suggesting cannabis oil burn patients were: a) young (43 years), b) males were overrepresented (M:F = 9.6:1), c) sustained large TBSA burns (23.9%), d) required extensive surgical management (skin grafting in 55.3% of cases), and e) spent a significant amount of time (28.3 days) at the burn unit. To place these findings in context, American Burn Association's National Burn Repository (NBR) from 2006 to 2015 found M:F ratio of 2.1:1 based on 205,033 burn cases reported from 96 U.S. hospitals. Although an average TBSA is not reported, NBR found that more than 75% of total burn sizes were less than 10% TBSA and 90% of all cases had a burn surface area of 20% or less. Similarly, NBR found the average length of stay was around 9 days [10]. Our findings for cannabis oil burns parallel previously published reports on other illicit drug-associated burns. For example, methamphetamine production requires mixing volatile chemicals which can inflict burn injuries from explosions and chemical spills. These burn victims were also young (32 years), males were overrepresented by a similar proportion (M:F = 10.3:1), and average TBSA was 18.86% [11].

Of particular concern is that the frequency of cannabis oil burns may increase in Canada due to an increase in cannabis accessibility. Evidence for this comes from longitudinal retrospective chart reviews which found U.S. state liberalization in cannabis policy correlated with a dramatic increase in the number of patients presenting with cannabis oil burns [3] [5]. There are two suspected reasons for this increase. First, the market value of butane cannabis oil is significantly higher than trimmed cannabis buds ($700 USD per ounce vs. ≈$120 USD per ounce) [5]. Second, the perceived ease of extraction tempts people to set up their own distillation apparatus without exercising appropriate caution. Since an increase in cannabis oil burns can pose a significant economic and psychosocial burden on the Canadian burn centers, we propose a three-pronged approach which can serve as an adjunct to Canadian cannabis liberalization policy.

First, Canadian burn centers are encouraged to initiate prospective monitoring of cannabis oil-related injuries and promptly report changes in frequency or demographics of patients with this burn mechanism. This is important because a major tenet of the current government's policy proposal is to reduce clandestine cannabis production and restrict cannabis access for kids and young adults [1]. An increase in cannabis oil burns or an increased representation of the younger demographic with such burns can serve as an indicator of policy's efficacy in achieving its mandate. Second, burn centers should be encouraged to design public educational programs aimed at increasing awareness about the risks of butane cannabis oil extraction in collaboration with national drug enforcement and health agencies such as the Royal Canadian Mounted Police and Health Canada. First responders and medical staff at burn centers should also be made aware of

features unique to cannabis oil burn patients so resources can be allocated appropriately. Third, and most importantly, cannabis oil production and distribution should be addressed in the proposed legislation to reduce the incentive of operating high-risk distilleries. Currently, there are 41 licensed cannabis producers in Canada who are authorized to sell cannabis-related products (including cannabis oil) to people with valid medical prescriptions [12]. Either expanding their license to include selling hash oil for recreational use or mandating retailers to only sell products from approved distributors can diminish the demand for high-risk clandestine distilleries. Additionally, the regulation on manufacturing should include provisions for adequate workplace safety if using butane as a solvent or alternative measures such as high-pressure CO2 should be employed for mass manufacturing. Taken together, inclusion of these policy adjuncts can promote health messaging, standardize the manufacturing process, and ensure safety of distillery workers to reduce the risk of significant burn injuries.

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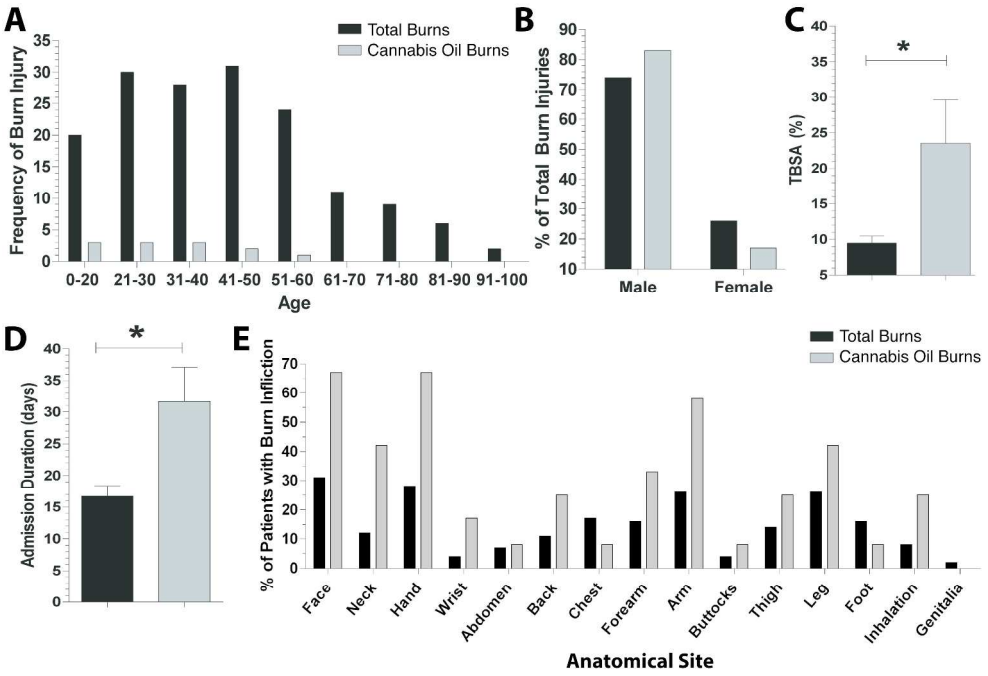
Figure 1 – Differential features of cannabis oil burn patients compared to 161 adult patients admitted over the 2-year review period. The age distribution of cannabis oil burn patients is compared to the total burn population by plotting the frequency of patients which fall within the identified 10-year age range (A). The gender distribution highlights a bias towards male burn victims and this bias is especially pronounced in the cannabis oil burn group (B). Cannabis oil burn patients, on average, sustain a significantly higher % TBSA burn (C) and spend a greater number of days at the burn unit (D). Anatomical sites inflicted with burns is compared between the two groups by plotting the percentage of patients which sustained burns to the identified site (E). Error bars represent SEM. * = $p < 0.05$.

Figure 2 – Schematic summary of cannabis oil extraction from cannabis trimmings and clinical features unique to cannabis oil burn patients as identified from 190 cases reported in the literature.

Table 1 – Summary of findings from 190 patients reported in 6 published case series.

Table 2 – Clinical features of 12 unique cannabis oil burn patients admitted over the review period. F: face, N: neck, H: hand, W: wrist, C: chest, A: arm, B: back, T: thigh, L: leg, I: inhalation injury, RUE: right upper extremity, LUE: left upper extremity, LE: lower extremity, UE: upper extremity, EOB: excision of burns, STSG: split thickness skin graft, DL: decompressive laparotomy, DC: discharge.



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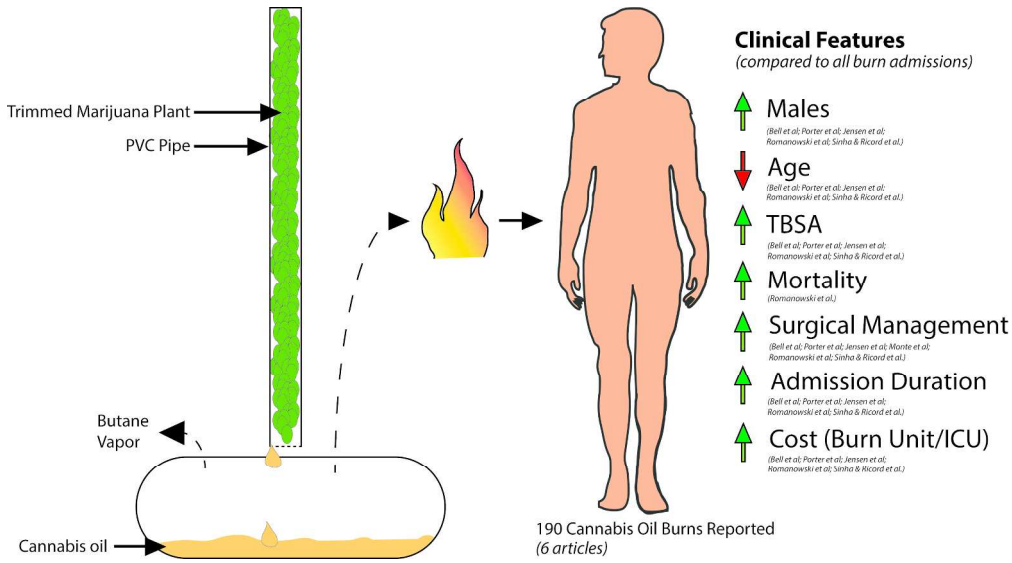
Authors	Year	# of Cases	Hospital	Location	Gender	Ethnicity	Race	TBSA	Admission Duration	Treatment	Mortality
Bell et al. [5]	2015	29	University of Colorado Hospital Burn Center	Colorado, US	Males (89.7 %)	Hispanic (10.3%); Non-Hispanic (82.8%); Other (6.9%)	Caucasian (72.4%); African American (17.2%); Asian (0%); American Indian (6.9%); Hawaiian (3.5%)	10% (1-90)	10 days (1-53)	Skin grafting (65.5%); Wound care only (27.6%); Surgical fracture repair (3.4%); Surgical debridement (3.4%)	0%
Porter et al. [6]	2004	9	Christchurch Hospital	Christchurch, New Zealand	Males (75%)	N.R.	N.R.	13.3% (2-50)	16.7 days (1-57)	Skin grafting and debridement (66.7%); Wound care only (33.3%)	0%
Jensen et al. [3]	2015	8	University of California Davis Medical Center and Shriners Hospitals for Children	Northern California, US	Males (87.5%)	N.R.	N.R.	49.9% (16-96)	118.3 days (5-472)	Skin grafting (75%)	N.R.
Romanowski et al. [7]	2017	101	Shriners Hospital	Northern California, US	Males (93.1%)	N.R.	N.R.	26.8% (0.5-95)	27.1 days (0-513)	Skin grafting (44.6%)	3%
Monte et al. [8]	2015	31	University of Colorado burn center	Colorado, US	N.R.	N.R.	N.R.	N.R.	N.R.	Skin grafting (67.7%)	N.R.
Sinha & Ricord et al.	2017	12	Foothills Medical Centre	Alberta, Canada	Males (83.3%)	N.R.	N.R.	23.5% (3-70)	31.7 days (3-69)	Excision of burns (91.7%); Skin grafting (66.7%)	8.30%

Case #	Cause of Injury	Burn Sites	Burn Depth	TBSA (%)	Surgery	Admission Duration	Outcome
1	Explosion due to cannabis oil manufacturing	L A	FT, DPP SPT	14.75	EOB (legs) STSG (thighs)	24	DC Jail
2	Explosion due to cannabis oil manufacturing	A L H (LEFT)	S-DPT S-DPT DPT	10	EOB (L arm)	16	DC Home
3	Explosion due to cannabis oil manufacturing	F,N H (LEFT) H (RIGHT) I	DPT DPT DPT	12	EOB on hands (bilateral) STSG (from thighs) EOB (ant. Scalp and face)	38	DC Home
4	Explosion due to cannabis oil manufacturing	A L B F I	FT FT FT DPT	70	DL Allograft STSG (from scalp)	29	Died in hospital
5	Explosion due to cannabis oil manufacturing	RUE LUE C/Abd H/W (RIGHT) H/W (LEFT) F (RIGHT) F (LEFT) N T	FT, DPT FT, DPT FT FT FT FT DPT SPT	27	Escharotomies (bilateral UE) EOB (right arm/hand/wrist) STSG (from R thigh and calf) EOB (left arm/hand/wrist) STSG (from L thigh and calf) STSG (C and Abd)	52	DC Home
6	Explosion due to cannabis oil manufacturing	H (RIGHT) H (LEFT) F	DPT, SPT DPT, SPT	5	EOB (bilateral hands) EOB (right arm/hand/wrist)	20	DC Home

			SPT				
7	Explosion due to cannabis oil manufacturing	H (RIGHT) H (LEFT) F	FT FT DPT, SPT	7	EOB (bilateral hands) EOB (right arm/hand/wrist)	20	DC Home
8	Explosion due to cannabis oil manufacturing	F H	SPT DPT, SPT	3		3	DC Home
9	Explosion due to cannabis oil manufacturing	T, L (RIGHT T, L (LEFT) RUE LUE F,N	DPT, SPT DPT, SPT DPT, SPT DPT, SPT SPT	25	EOB (arms/hands/legs) STSG (bilateral legs)	18	DC Home
10	Explosion due to cannabis oil manufacturing	F,N B RUE LUE H,W (RIGHT) H,W (LEFT)	FT FT FT FT FT FT	53.5	Faschiotomy (bilateral arms and hands) EOB (L arm/shoulder/hand wrist) STSG (bilateral LE) EOB (bilateral shoulders/back/buttocks) STSG (from neck/back/buttocks) EOB (scalp/face/neck) STSG (chest/head/feet)	69	DC Home
11	Explosion due to cannabis oil manufacturing	F,N B RUE LUE H,W	FT FT FT FT FT	40	EOB (L hand/wrist) STSG (L hand/wrist) EOB (face/scalp/neck) STSG (chest) EOB (bilateral UE)	53	DC Home

		(RIGHT) H,W (LEFT) L I	FT SPT				
12	Explosion due to cannabis oil manufacturing	H F,N C A (RIGHT) A (LEFT)	FT SPT SPT SPT SPT	15	EOB (bilateral hands/forearms) STSG (L thigh)	38	Transfer to another hospital



Schematic summary of cannabis oil extraction from cannabis trimmings and clinical features unique to cannabis oil burn patients as identified from 190 cases reported in the literature.

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