Original Article

Plastic Surgery
2022, Vol. 30(3) 246–253

DOI: 10.1177/22925503211008445
journals.sagepub.com/home/psg

Something Stinks! Finding Ways to Manage Noxious Odours in the Operating Room and Other Clinical Settings A Randomized Controlled Trial

Ça sent mauvais ! Trouver des façons de gérer les odeurs nauséabondes en salle d'opération et en milieux cliniques : Un essai aléatoire et contrôlé

Lindsay Bjornson, MSc[1,*], Aaron C. Van Slyke, MD, MSc, FRCSC[2,*], Marija Bucevska, MD[3,4], Rebecca Courtemanche, MSc[3,4], Jeffrey Bone, MSc[5], Aaron Knox, MD, MSc, FRCSC[6], Cynthia Verchere, MD, FRCSC[3,4], and James C. Boyle, MD, FRCSC[7]

Abstract

Objectives: The hospital can be saturated with noxious smells. Anecdotally, medical staff apply products to surgical masks to lessen the impact of these smells. This study aimed to determine the odour-masking ability of 4 inexpensive and convenient products. **Methods:** A randomized, single-blinded crossover study was conducted in Vancouver, Canada. Participants, 19 to 30 years old, were invited to participate. Participants with active allergies, upper respiratory tract infection, alteration to sense of smell, or failure of olfactory screen were excluded from the study. An experimental odour was used in lieu of a noxious surgical odour. After smelling the experimental odour without barriers, participants were re-exposed to the odour using 5 surgical masks in randomized order. Each mask was lined with a test product (cherry lip balm, tincture of benzoin, Mastisol, mint toothpaste, and control [plain mask]). Participants rated the effectiveness of products at masking the experimental odour from 0 to 100 (0 = completely ineffective, 100 = completely effective). Participants also rated the pleasantness of the products, recorded if the products made them feel unwell, and identified their preferred product overall. **Results:** Eighty participants were included in the study (33 male, 47 female), averaging 24.2 years of age. Mean odour-masking effectiveness for cherry lip balm was 66.5 (±24.6), tincture of benzoin: 62.6 (±25.0), Mastisol: 61.3 (±23.9), mint toothpaste: 57.5 (±27.4), and control: 21.9 (±21.8). All products performed better than the control ($P < .001$), but there was no significant difference in performance between products. Cherry lip balm was the most preferred odour-masking product (29 participants), followed by mint toothpaste (22), Mastisol (14), tincture of benzoin (10), and control (5). **Conclusions:** All tested products demonstrated equivalent odour-masking abilities. If health care professionals choose to use an odour-masking product, they should consider their own olfactory preferences.

[1] Faculty of Medicine, University of British Columbia, Vancouver, Canada
[2] Division of Plastic Surgery, Department of Surgery, University of British Columbia, Vancouver, Canada
[3] Division of Pediatric Plastic Surgery, University of British Columbia, Vancouver, Canada
[4] Division of Pediatric Plastic Surgery, British Columbia Children's Hospital, Vancouver, Canada
[5] Department of Obstetrics and Gynecology, University of British Columbia, Vancouver, Canada
[6] Division of Plastic Surgery, Peter Lougheed Hospital, Calgary, Canada
[7] Division of Plastic Surgery, Department of Surgery, Vancouver General Hospital, British Columbia, Canada
* Co-First Authors, contributed equally to this work.

Received December 5, 2019. Revised February 17, 2021. Accepted March 7, 2021.

Corresponding Author:
James Boyle, Plastic Surgery, Vancouver General Hospital, Diamond Health Care Center, 3rd Floor, 2775 Laurel Street, Vancouver, Canada V5Z 1M9.
Email: jcboyle@mail.ubc.ca

Résumé

Objectifs : L'hôpital peut être saturé d'odeurs nauséabondes. On rapporte que le personnel médical applique des produits sur leurs masques chirurgicaux pour atténuer l'impact de ces odeurs. Cette étude visait à déterminer l'efficacité de quatre produits masqueurs d'odeurs, et ce de façon pratique et peu couteuse. **Méthodes :** Une étude croisée a simple insu et a répartition aléatoire a été menée à Vancouver, Canada. Des participants âgés de 19 à 30 ans, ont été invités à participer. Les participants souffrant d'allergies actives, d'une infection des voies respiratoires supérieures, d'une altération olfactive, ou aillant échoué la procédure de sélection ont été exclus de l'étude. Une odeur expérimentale a été utilisée au lieu d'une odeur nauséabonde chirurgicale. Après avoir senti l'odeur expérimentale, les participants ont été réexposés à la même odeur à cinq reprises. A chaque reprise, le participant était muni d'un de 5 masques tapissé d'un agent masquant d'odeur (baume à lèvres aux cerises, teinture de benzoïne, mastisol, dentifrice à la menthe, et contrôle [masque standard]). L'ordre des masques a été déterminé de façon aléatoire. Les participants ont noté sur une échelle de 0 à 100 l'efficacité des produits à masquer l'odeur (0: complètement inefficace, 100: complètement efficace). Les participants ont également évalué la qualité plaisante des agents, si ceux-ci les rendaient nauséeux, et ont ensuite identifié leur produit préféré parmi l'ensemble. **Résultats :** Quatre-vingts participants ont été inclus dans l'étude (33 hommes, 47 femmes), âgés en moyenne de 24,2 ans. L'efficacité des produits à masquer l'odeur expérimentale étaient d'une moyenne de 66,5 (+24,6) pour le baume à lèvres aux cerises ; 62,6 (+25,0) pour la teinture de benzoine ; 61,3 (+23,9) le mastisol ; 57,5 (+27,4) pour le dentifrice à la menthe, et 21,9 (+21,8) le contrôle. Tous les agents testés ont reçu une note supérieure au contrôle ($P < .001$). Par-contre, il n'y avait pas de différence significative entre les agents. Le baume à lèvres aux cerises était le produit préféré (29 participants), suivi du dentifrice à la menthe (22), du mastisol (14), de la teinture de benzoine (10), et finalement du contrôle (5). **Conclusions :** Tous les produits testés ont démontré une efficacité similaire, celle-ci supérieure comparée au contrôle. Si les professionnels de la santé souhaitent d'utiliser un produit qui masque les odeurs, ils devraient tenir compte de leurs propres préférences.

Keywords

olfactory perception, smell, masks, health care, randomized controlled trial

Background

Noxious smells can be encountered practically everywhere, and the operating room (OR) and other clinical settings are certainly no exception. However, not all plastic surgeons encounter noxious odours in their practice, such odours are ubiquitous in the field of plastic surgery: from changing soiled dressings, to assessing or debriding necrotic wounds or burns, to draining infected abscesses. Moreover, literature suggests that odour can have a strong impact on emotion.[1] Ousey and colleagues have shown that the feelings of disgust and distress are common among health care providers who encounter unpleasant odours.[2] Studies have demonstrated that health care workers find hospital odours problematic.[3,4] Even more concerning is that many nurses find such odours in the hospital intolerable,[5] which may cause health care workers to distance themselves from their patients.[6] This shows a clear need for reducing the burden of noxious smells encountered by health care professionals.

To our knowledge, there is a paucity of literature dedicated to investigating ways to reduce noxious smells in the health care setting. Attempts to improve hospital odours by means of infrastructural changes including improved ventilation have been reported.[7] Anecdotally, health care workers have employed a variety of techniques to lessen the impact of noxious odours, including applying scented products such as toothpaste or Mastisol to surgical masks. However, the lack of evidence hinders informed decision-making about odour-masking methods that may be effective at overpowering the putrid pungence of the OR and other health care settings.

The primary objective of this study was to evaluate the odour-masking ability of 4 commonly used odour-masking products that are inexpensive, readily available, and can easily be used. Secondary objectives were to determine product pleasantness, tolerability of each product, and the most preferred product among the study participants. The findings from this study may inform a health care professional's choice of odour-masking product in surgical or other health care settings.

Methods

Design

The study was designed as a randomized, controlled, single-blinded crossover trial.

Participants

Health care students aged 19 to 30 years were invited via email newsletter, social media, and poster to participate. Eligibility did not necessitate experience in the OR. Participants with upper respiratory tract infection, active allergies, or any alteration to their sense of smell were excluded. Participants were screened for intact olfactory function using the Sensonics Quick Smell Identification Test (Q-SIT).[8] Participants who correctly identified all 3 or 2 of 3 odorants on the Q-SIT were included.[8] A sample size of 80 participants was calculated to detect a 10% difference in mean odour-masking scores between products at a

significance level of 0.05. The study recruitment stopped after the 80th eligible participant completed the study.

Experimental Odour

An experimental odour (Liquid ASS, Liquid Assets Novelties, LLC) was used in lieu of a true surgical odour. This product is a commercially available, colourless liquid with a scent reminiscent of feces that has previously been used to simulate health care odours in military training and research.[9,10] A small glass jar containing 4 cotton balls was treated with 2 sprays of the experimental odour.

Odour-Masking Products

Four odour-masking products were applied to surgical masks (PRIMAGARD 120 PG4-1092 Procedure Ear-Loop Masks by priMED Medical Products Inc):

- Cherry lip balm (ChapStick Classics Cherry by Pfizer Consumer Healthcare),
- Mint toothpaste (Crest Complete Whitening + Scope by Procter & Gamble),
- Mastisol (Mastisol Liquid Adhesive by Eloquest Healthcare, Inc), and
- Tincture of benzoin (Friar's Balsam by Rougier of Ratiopharm GmbH used under licence by Teva Canada Ltd).

These products were selected because they are commonly used anecdotally to cover up noxious smells in the OR, they are readily available in the hospital setting, inexpensive, and have low inhalational irritation potential. Standardized volumes of each product were determined via preliminary testing by 3 of the authors (L.B., M.B., and R.C.): 4 swipes of cherry lip balm (stick form), 1.0 mL of mint toothpaste, 0.1 mL of Mastisol, and 0.1 mL of tincture of benzoin. Each product was dispensed across a 5-cm by 2-cm area on the outside centre of the mask. No product was applied to the control mask.

Randomization and Blinding

Randomization was done by the statistician (J.B.). Two orthogonal Latin squares were used to create 10 prespecified test orders (where each order had 5 consecutive test periods, 1 period for 1 test product). The test orders ensured equal occurrence of each product in each period, as well as balance in carryover effects. Participants were enrolled by the research coordinators (M.B. and R.C.), and randomized to a test order by the medical student (L.B.) or plastic surgery resident (A.C.V.S.). Participants were blinded to the identity and sequence of the test products.

Setting

All procedures took place in well-ventilated patient examination rooms at British Columbia Children's Hospital (BCCH) and Vancouver General Hospital (VGH) in Vancouver, Canada from July to December, 2018. All rooms used were similar in size and ventilation characteristic and met the building code standards for outpatient clinical workspace.

Table 1. Participant Demographics.

Demographics (n = 80)	Mean (SD) or n (%)
Age (years)	24.2 (2.9)
Male	33 (41.3%)
QSIT score of 3	2.9 (0.4)
Smoking status	
Ex-smoker	1 (1.2%)
Current smoker	1 (1.2%)
Non-smoker	78 (97.5%)
Experimental odour pleasantness score	23.5 (14.1)
Experimental odour tolerability ("made me feel unwell")	
Agree or strongly agree	25 (31.3%)
Neither agree nor disagree	26 (32.5%)
Disagree or strongly disagree	29 (36.3%)

Procedure

Part I—Exposure to and rating of the experimental odour. Participants were given standardized instructions exposed to the experimental odour jar held 1 cm from their nose, smelled the experimental odour for 5 seconds, and ranked its pleasantness and tolerability on visual analogue and Likert scales, respectively.

Part II—Testing of odour-masking products. Participants smelled the odour through each of the 4 product-treated masks and the plain control mask in randomized order. Under specific guidance and observation from experimenters, participants carefully fitted their own mask without visualizing its outer surface. After being exposed to the odour, as in part I, participants rated each product's odour-masking effectiveness on a visual analogue scale. Product pleasantness and tolerability were rated on a Likert scale. At the end, the participants identified their preferred odour-masking product.

After each exposure, participants smelled coffee beans for 10 seconds as a "wash out,"[11,12] and a 60-second waiting period was used for olfactory recovery.[13,14]

Analysis

The primary outcome measure, odour-masking effectiveness (score from 0 to 100, 0 = completely ineffective and 100 = completely effective), of the test products and control was compared via a mixed effects model with a random effect for participant, and a fixed effect for product and period. Models including the sequence of products and possible carryover effects (and their possible interaction with the products) were compared to the period/product model via the likelihood ratio test. Sensitivity analysis included the baseline measurements as a covariate. The secondary outcome measures: pleasantness and tolerability of products, and the participants' choice of

Table 2. Odour-Masking Scores by Product.

Product	Mean odour-masking score (SD)	Estimated mean difference[a]	95% CI	*P* value
Cherry lip balm	66.5 (24.6)	44.6	38.1-51.0	<.001
Mint toothpaste	57.5 (27.4)	35.5	29.0-41.9	<.001
Mastisol	61.3 (23.9)	39.3	32.9-45.8	<.001
Tincture of benzoin	62.6 (25.0)	40.5	34.0-47.0	<.001
Control	21.9 (21.8)	Reference	Reference	Reference

[a]Estimated mean difference from a mixed effects model represents the difference between the mean odour-masking product score and the mean control score in all cases. *P* value is comparing each individual product versus control.

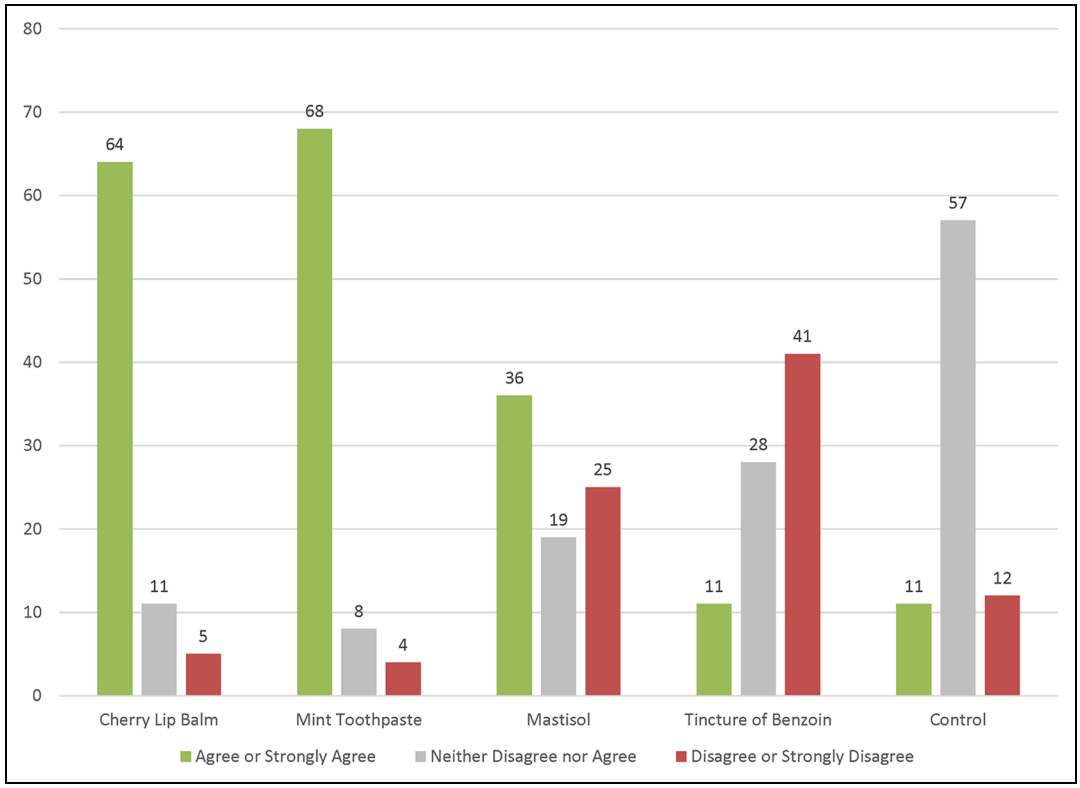

Figure 1. Product pleasantness: "The product was pleasant."

preferred product were analyzed descriptively. All analyses were performed after all data were collected using R statistical software and mixed effects models were fit with the lme4 package.[15,16] The denominator was consistent (n = 80) for all study analyses as there were no missing data; all participants completed all study tests and there were no withdrawals.

Results

Participant Demographics

A total of 81 participants were recruited. One participant was excluded following administration of the Q-SIT due to misidentification of 2 odorants, leaving a total of 80 eligible participants. Participants were on average 24 years old, predominately female (59%), and 78 had no history of smoking (Table 1). Participants included students in various health care-associated programs of study. None of the participants worked in the OR.

Experimental Odour

Initial exposure elucidated the participants' baseline response to the experimental odour. The mean pleasantness of the experimental odour was 23.5 (SD = 14.1) on a 100-point scale (0 = most unpleasant odour ever experienced; 100 = most pleasant odour ever experienced; Table 1). In addition, a similar number of participants rated the experimental odour as tolerable (25), not tolerable (29), and neutral (26). Together, these data suggest that participants generally found the experimental odour to be unpleasant, but some were able to tolerate the odour better than others. These findings help validate the selection of our experimental odour in lieu of a noxious surgical odour.

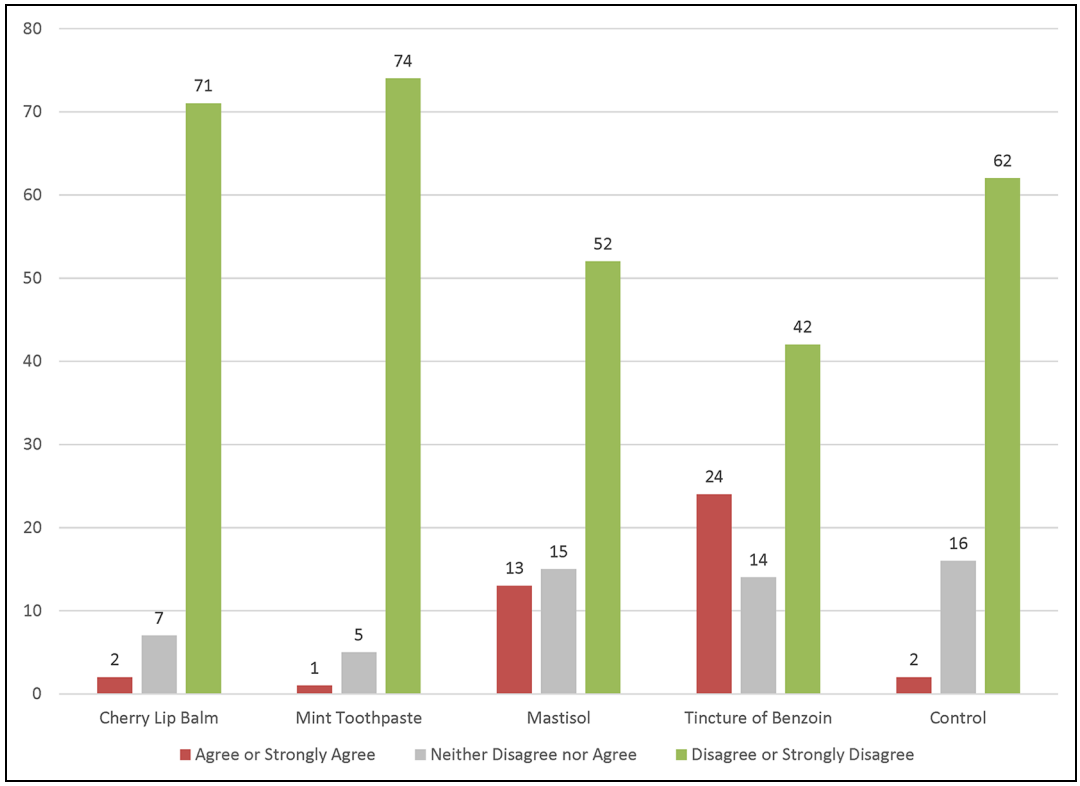

Figure 2. Product tolerability: "The product made me feel unwell."

Table 3. Top Choice Product by Gender.

Odour-masking Product	Female n (%)	Male n (%)	Total n (%)
Cherry lip balm	12 (15.0%)	17 (21.3%)	29 (36.3%)
Mint toothpaste	15 (18.8%)	7 (8.8%)	22 (27.5%)
Mastisol	12 (15.0%)	2 (2.5%)	14 (17.5%)
Tincture of benzoin	5 (6.3%)	5 (6.3%)	10 (12.5%)
Control	3 (3.8%)	2 (2.5%)	5 (6.3%)

Odour-Masking Products

Participants rated the odour-masking ability, pleasantness and tolerability of each product, and identified which product they would use to mask odours in the OR.

All odour-masking products performed better than the control at masking the experimental odour ($P < .001$ for all 4 products, Table 2), but none of the between-product differences were significant. Cherry lip balm had the highest mean effectiveness score (66.5), followed by tincture of benzoin (62.6), Mastisol (61.3), mint toothpaste (57.5), and the control (21.9). Adjustment for the baseline odour score did not significantly impact these findings. There was no evidence of a period effect on product efficacy ($P = .19$, likelihood ratio test).

Most participants rated mint toothpaste and cherry lip balm as pleasant (85% and 80%, respectively). Mastisol received mixed results in terms of pleasantness; it was rated pleasant by 45% and unpleasant by 31% of participants. Tincture of benzoin was generally rated unpleasant (51% of participants). The control was mostly rated as neutral in terms of pleasantness (71% of participants; Figure 1).

Tincture of benzoin and Mastisol made 30% and 16% of participants feel unwell, respectively (Figure 2). Mint toothpaste, cherry lip balm, and the plain control were considered more tolerable; only 1%, 3%, and 3% of participants felt unwell using these products, respectively.

Overall, participants most frequently selected cherry lip balm (n = 29) as their preferred odour-masking product, followed by mint toothpaste (n = 22), Mastisol (n = 14), and tincture of benzoin (n = 10; Table 3). Five participants selected the plain control mask as their preferred odour-masking product. There was some evidence that the order of products impacted overall top choice as 27 (33.8%) of the 80 participants selected the first product tested as their preferred option (Table S1), but this was not statistically significant ($P = .64$, χ^2 test).

There were some differences by gender as males tended to give higher odour-masking scores by an average of 10 points (95% CI = 3.2-18.9, $P = .001$). This was consistent across all products (Figure S2). Furthermore, there were some differences in terms of the top chosen odour-masking product with men clearly preferring the lip balm, while women were more varied in response ($P = .06$, χ^2 test, Table 3). There were no adverse events reported.

Discussion

This study identified 4 products that can be applied to a surgical mask to effectively mask unpleasant odours, all of which are

inexpensive and readily available in most hospital settings. Cherry lip balm, mint toothpaste, Mastisol, and tincture of benzoin all produced superior odour-masking results when compared with a plain control surgical mask. Although all 4 products were equivalently effective at masking the experimental odour, cherry lip balm and mint toothpaste were generally preferred and were considered more pleasant and tolerable than Mastisol and tincture of benzoin. During experimentation, we found subjectively that the application of cherry lip balm was the easiest, and the application and use of mint toothpaste was the messiest.

This study was a randomized control trial with sufficient power and no participant withdrawals or protocol violations. Nonetheless, there were some notable limitations. Firstly, this study took place in a brief, simulated experimental setting with an experimental odour. The experiments were all conducted in well-ventilated patient examination rooms. Although this setting is likely quite similar to that of a bedside debridement in the ward or in the emergency department, it is evident that an examination room is not the same as an OR. Nonetheless, the proximity of operating personnel immediately adjacent to and in contact with their patient in the OR exposes them to noxious odours even in the setting of appropriate ventilation and larger room size. Regarding the experimental odour, a commercial product was used rather than a true health care odour in order to ensure consistency through all trials. This commercial product has been validated for use in the experimental setting to simulate noxious health care odours.[9,10] Although attempts were made to simulate real-life, experimental settings are unable to completely mimic reality. In a true clinical environment, such as the OR or at the bedside, health care providers are exposed to unpleasant odours for a greater duration. Our exposures were for a total of 5 seconds at a time; however, we were able to see that odour-masking products were more effective than the control mask even in this short exposure. Furthermore, in clinical settings, health care providers are focused on completing tasks rather than solely on odours. Recently, it has been demonstrated that when individuals are presented with a visually demanding task, they fail to notice odours in their environment.[17] Participants in our study were instructed to focus on olfactory stimuli, which may have heightened their awareness of the experimental odour.

We attempted to blind participants to the identity of all products by withholding identification of product names, removing cues such as product containers, and applying the product to the outside of the mask, to prevent visualization of products. Nonetheless, some products such as cherry lip balm and mint toothpaste have familiar scents. Participants' reactions to the products and the generalizability of our findings might have been affected by individual tolerances and preferences.

Participants were not re-exposed to the unpleasant odour before each mask application. Instead, the order of masking agents, including the control mask, was randomized and showed no significant impact on the effectiveness of the products. To prevent olfactory habituation, a "resting" period of 60 seconds was included in-between products to allow olfactory recovery.[13,14] Participants were provided with coffee beans to smell for 10 seconds as a potential means of "re-setting" olfaction, though this is contested in the literature.[11,12]

Given the lack of evidence on odour-masking techniques used in the OR, we cannot directly compare our results with existing literature. Our observations show that participants display individual variability in terms of olfactory sensitivity and preference. Although generally considered unpleasant, the experimental odour caused some, but not all, participants to feel unwell. Similarly, all odour-masking products were considered pleasant by some, and unpleasant by others, and all products made some participants feel unwell. A variety of factors can influence one's subjective olfactory experience. Substantial differences in the affective importance of odours—the degree to which smells impact approval or disapproval of new items—are present on the individual level.[18] In addition, certain medical conditions including migraine and neuropsychiatric disorders can alter tolerance for olfactory stimuli,[19-21] while increasing age and current smoking status are associated with decreased olfactory function and rapid habituation to smells.[12,22-26] Cultural experiences, such as cuisine, can also lead to differences in olfactory perception,[27] as can personal experiences. Olfactory stimuli trigger highly emotionally salient memories, given the neuroanatomic link between the olfactory cortex and the emotional processing limbic system.[1,28] Considering the above, individual differences and personal preferences likely play an important role when selecting an odour-masking product.

Most health care workers at some point encounter hospital-based odours that are felt to be intolerable.[5] Studies have demonstrated that such physical distractions in the work environment can negatively impact the performance of health care professionals and teams.[29-31] This can lead to decreased communication and functioning, which can result in health care errors.[30,31] Although it is unclear if noxious odours can affect health care workers enough to compromise patient care, what is clear is that that they are unpleasant, and in many cases, unnecessary aspects of a patient encounter. This study addresses the need for determining how best to manage noxious olfactory distractions so that health care professionals, such as plastic surgeons, can provide uninterrupted, focused care to patients even in notoriously malodourous encounters such as wound debridement or abscess drainage. We identified 4 equally effective, odour-masking products that may be applied to a surgical mask to lessen the impact of noxious smells in the OR: cherry lip balm, mint toothpaste, Mastisol, and tincture of benzoin. Two of these products, cherry lip balm and mint toothpaste, were generally perceived as pleasant and did not make participants feel unwell. If health care professionals choose to use an odour-masking product, they should consider their own olfactory preferences. For those who are unsure which product to use, we recommend that individuals try cherry lip balm first, since it was preferred in our study cohort, and its stick form allows for easy application and storage. For individuals who prefer the scent of mint, mint lip balm may be

a reasonable option to try instead of toothpaste, which is messier and more difficult to apply.

Our findings represent a good starting point for individuals hoping to combat foul health care odours. Future studies would be needed to determine whether masking products are effective in clinical practice, where there is a need to mask odours for a longer duration, and where other stimuli are present. This is especially true in the OR setting, where rooms are large and ventilated. Additional research could also evaluate the effectiveness of other techniques such as mouth breathing or using alternative masks (eg, N95 mask or surgical cone facial mask), or the effect of various scents of lip balm on masking noxious smells.

Authors' Note

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5). The study was approved by the University of British Columbia Children's & Women's Research Ethics Board, approval #H16-01416. Informed consent was obtained from all individual participants included in the study.

Acknowledgments

The authors would like to acknowledge Tesnim Sairi, Plastic Surgery Research & Microsurgery Lab Coordinator for her help with study recruitment and advertising. The authors would like to acknowledge Morgan Wu, Emily Potkonjak, and John Potkonjak for their help with running experiments.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by a grant from the University. The sponsors or funders had no involvements in any parts of this study. All authors confirm the independence of researchers from funding sources.

ORCID iDs

Jeffrey Bone, MSc https://orcid.org/0000-0001-7704-1677
Cynthia Verchere, MD, FRCSC https://orcid.org/0000-0002-8284-1975
James C. Boyle, MD, FRCSC https://orcid.org/0000-0002-6582-6044

Supplemental Material

Supplemental material for this article is available online.

References

1. Kadohisa M. Effects of odor on emotion, with implications. *Front Syst Neurosci*. 2013;7(October):1-6. doi:10.3389/fnsys.2013.00066
2. Ousey K, Roberts D.Exploring nurses' and patients' feelings of disgust associated with malodorous wounds: a rapid review. *J Wound Care*. 2016;25(8):438-442.
3. Hellgren U, Reijula K. Indoor-air-related complaints and symptoms among hospital workers. *Scand J Work Environ Health Suppl*. 2006;2:47-49.
4. Itakura T, Mitsuda M. Survey of characteristics of the odor in medical facilities. In: *The 6th International Conference on Indoor Air Quality, Ventilation & Energy Conservation in Buildings IAQVEC*; October 28-31, 2007; Sendai, Japan:28-31.
5. Horiguchi M, Shudo E, Sato K, Nakamura M, Sai W, Ohinata T. Nurse odor perception in various Japanese hospital settings. *Int J Nurs Sci*. 2015;2(4):355-360. doi:10.1016/j.ijnss.2015.08.009
6. Prior D, Mitchell A, Nebauer M, Smith M. Oncology nurses' experience of dimethyl sulfoxide odor. *Cancer Nurs*. 2000;23(2):134-140.
7. Choi N, Yamanaka T, Kobayashi T, Ihama T, Wakasa M. Influence of vertical airflow along walls on temperature and contaminant concentration distributions in a displacement-ventilated four-bed hospital ward. *Build Environ*. 2020;183:107181.
8. Jackman AH, Doty RL. Utility of a three-item smell identification test in detecting olfactory dysfunction. *Laryngoscope*. 2005;115(12):2209-2212. doi:10.1097/01.mlg.0000183194.17484.bb
9. Foley KE. An unusual medical training tool got its start as a childish prank. *Quartz*. 2018. Accessed April 24, 2019. https://qz.com/1321817/an-unusual-medical-training-tool-got-its-start-as-a-childish-prank/
10. Reynolds LM, MCambridge SA, Bissett IP, Consedine NS. Trait and state disgust: an experimental investigation of disgust and avoidance in colorectal cancer decision scenarios. *Heal Psychol*. 2014;33(12):1495-1506. doi:10.1037/hea0000023
11. Biswas D, Labrecque L, Lehmann D, Markos E.Making choices while smelling, sensory (dis)similarity when tasting, and listening: the role of sequentially sampling products. *J Mark*. 2014;78(1):112-126.
12. Grosofsky A, Haupert ML, Versteeg SW. An exploratory investigation of coffee and lemon scents and odor identification. *Percept Mot Skills*. 2011;112(2):536-538. doi:10.2466/24.PMS.112.2.536-538
13. Stuck BA, Fadel V, Hummel T, Ulrich Sommer J. Subjective olfactory desensitization and recovery in humans. *Chem Senses*. 2014;39(2):151-157. doi:10.1093/chemse/bjt064
14. Pellegrino R, Sinding C, de Wijk RA, Hummel T. Habituation and adaptation to odors in humans. *Physiol Behav*. 2017;177(August 2016):13-19. doi:10.1016/j.physbeh.2017.04.006
15. Bates D, Mächler M, Bolker B, Walker S. Fitting linear mixed-effects models using lme4. *J Stat Softw*. 2015;67(1):1-48. doi:10.18637/jss.v067.i01
16. R Core Team. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. 2019. Accessed June 20, 2019. https://www.R-project.org/
17. Forster S, Spence C. "What smell?" Temporarily loading visual attention induces a prolonged loss of olfactory awareness. *Psychol Sci*. 2018:29(10):1642-1652. doi:10.1007/1-4020-0613-6_16551
18. Wrzesniewski A, Mccauley C, Rozin P, Arbor A. Odor and affect: individual differences in the impact of odor on liking for places, things and people. *Chem Senses*. 1999;24(6):713-721. doi:10.1093/chemse/24.6.713

19. Friedman DI, De Ver Dye T. Migraine and the environment. *Headache*. 2009;49(6):941-952. doi:10.1111/j.1526-4610.2009.01443.x
20. Ryo Y, Takeuchi M, Ueda N, et al. Olfactory function in neuropsychiatric disorders. *Psychiatry Res*. 2017;252:175-179. doi:10.1016/j.psychres.2017.02.058
21. Andersson L, Bende M, Millqvist E, Nordin S. Attention bias and sensitization in chemical sensitivity. *J Psychosom Res*. 2009; 66(5):407-416. doi:10.1016/j.jpsychores.2008.11.005
22. Stevens JC, Cain WS, Oatley MW. Aging speeds olfactory adaptation and slows recovery. *Ann N Y Acad Sci*. 1989;561:323-325.
23. Stevens JC, Cain WS, Schiet FT, Oatley MW. Olfactory adaptation and recovery in old age. *Perception*. 1989;18(2):265-276. doi:10.1068/p180265
24. Doty RL, Kamath V.The influences of age on olfaction: a review. *Front Psychol*. 2014;5(feb):1-20. doi:10.3389/fpsyg.2014.00020
25. Ajmani GS, Suh HH, Wroblewski KE, Pinto JM. Smoking and olfactory dysfunction: a systematic literature review and meta-analysis. *Laryngoscope*. 2017;127(8):1753-1761. doi:10.1002/lary.26558
26. Hummel T, Kobal G, Gudziol H, Mackay-Sim A. Normative data for the "Sniffin' Sticks" including tests of odor identification, odor discrimination, and olfactory thresholds: an upgrade based on a group of more than 3,000 subjects." *Eur Arch Otorhinolaryngol*. 2007;264(3):237-243. doi:10.1007/s00405-006-0173-0
27. Ayabe-Kanamura S, Schicker I, Laska M, et al. Differences in perception of everyday odors: a Japanese- German cross-cultural study. *Chem Senses*. 1998;23(1):31-38. 98189450.
28. Herz RS. Are odors the best cues to memory? A cross-modal comparison of associative memory stimuli. *Ann N Y Acad Sci*. 1998;855:670-674.
29. Applebaum D, Fowler S, Fiedler N, Osinubi O, Robson M. The impact of environmental factors on nursing stress, job satisfaction, and turnover. *J Nurs Adm*. 2010;40(7-8):323-328. doi:10.1097/NNA.0b013e3181e9393b
30. Liu W, Manias E, Gerdtz M. The effects of physical environments in medical wards on medication communication processes affecting patient safety. *Heal Place*. 2014;26:188-198. doi:10.1016/j.healthplace.2013.12.017
31. Mahmood A, Chaudhury H, Valente M. Nurses' perceptions of how physical environment affects medication errors in acute care settings. *Appl Nurs Res*. 2011;24(4):229-237. doi:10.1016/j.apnr.2009.08.005