SurgiColl
SURGICAL COLLECTIVE

Wint AB, Mangan JJ. Vaping and Orthopedic Surgery: Perioperative Management.
SurgiColl. 2024;2(3). doi:10.58616/001c.90489

Current Concepts

Vaping and Orthopedic Surgery: Perioperative Management

Asa B. Wint, BS[1][a], John J. Mangan, MD MHA[2]

[1] Penn Medical School, University of Pennsylvania Philadelphia, PA 19104, [2] Thomas Jefferson University Hospital, Philadelphia, PA, USA

Keywords: vaping, e-cigarettes, nicotine, orthopedic surgery, preoperative management, perioperative

https://doi.org/10.58616/001c.90489

SurgiColl

Vol. 2, Issue 3, 2024

The growing use of electronic cigarettes (ECs) as a perceived safer alternative to traditional combustible smoking has significant implications for orthopedic surgery patients. Surgeons need to recognize the harms and risks associated with ECs beyond their nicotine content. EC aerosols contain cytotoxic elements, including harmful chemicals, carcinogens, heavy metals, and flavoring agents. They can induce oxidative stress, resulting from an imbalance between cell antioxidant defense and reactive oxygen species (ROS). These effects can compromise bone repair, particularly with skeletal system disorders. Furthermore, ECs' impact on wound healing and surgical site infection (SSI) have been well-documented. Smoking can reduce the inflammatory healing response, impair oxidative bacterial killing mechanisms, delay the proliferation healing response, and alter collagen metabolism. Some surgical practices remain unchanged despite physicians' efforts to inquire about EC use. Most orthopedic surgeons do not delay surgery due to nicotine consumption, and urine tests for nicotine are rarely used. However, preoperative smoking cessation interventions offer a unique opportunity to help patients stop consuming nicotine. Therefore, it is crucial for orthopedic surgeons to understand the harms of ECs and communicate the associated risks to patients.

INTRODUCTION

ECs are battery-operated devices that heat a metal coil to vaporize e-liquid without tobacco or combustion.[1] The act of inhaling the resulting aerosol is commonly referred to as "vaping".[1] While combustible smoking rates have declined, e-cigarettes have risen due to their perceived safety.[1] In 2020, 68 million people vaped globally,[2] with 3.7% of U.S. adults using ECs.[3] By 2022, 3.3% of middle schoolers and 14.1% of high schoolers had used ECs in the past 30 days.[3] ECs have evolved into over 200 brands, generating a $1.7 billion industry projected to reach $10 billion in the next decade.[4] While EC use is growing, its long-term consequences and perioperative risks remain poorly documented. Orthopedic surgeons must gain a comprehensive understanding of ECs to make surgical decisions, effectively communicate risks, and improve clinical outcomes.[4] By addressing these challenges, surgeons contribute to the optimal care of their patients.

RELEVANCE TO ORTHOPEDIC SURGERY

Optimizing patient outcomes in orthopedic surgery require surgeons to address both traditional tobacco and e-cigarette usage prior to the procedure.[5] However, despite being aware of the importance of nicotine cessation, surgical practices often remain unchanged. Lilley *et al.,* revealed that 41% of orthopedic surgeons never delayed surgery due to nicotine use, while 39% delayed surgery less than three months.[6] Surprisingly, urine tests for nicotine cessation were rarely used, with 79% of respondents almost never administering them to elective surgery patients. Due to cost consideration, Ellis *et al.* suggested that serum cotinine testing should only be used for high-risk patients with elevated urine cotinine levels.[7] Further, more than half (53%) spent less than five minutes on preoperative counseling about the increased risk nicotine poses on postoperative outcomes.[6] Only a mere 20% of responding physicians frequently or almost always used cessation programs during the perioperative period.[6,7]

Nicotine cessation is challenging, and although an estimated 40% of patients attempt to quit yearly, less than 5% are successful.[8] A surgical encounter is a "teachable mo-

a Corresponding author:
Asa Wint, BS
Penn Medical School, University of Pennsylvania Philadelphia, PA 19104
asawint@sas.upenn.edu

ment" that may provide extra motivation for patients to permanently cease use.[8,9] Evidence supports the effectiveness of preoperative smoking cessation interventions, with a rate ratio for quitting of 2.02 in patients undergoing major surgery, and patients who received such interventions being 2.7 times more likely to achieve long-term cessation.[8] Even without intervention, cessation rates range from 47 to 462 per 1000.[8] However, most orthopedic surgeons do not delay surgery due to nicotine consumption despite patient's desire to stop smoking before surgery.

Surgery offers a unique opportunity to help patients stop consuming nicotine permanently. Various techniques, including nicotine replacement therapies, medication, and behavioral interventions, may be employed to facilitate cessation.[8] Interestingly, several studies reported the accuracy of self-reported non-smoking status on intake forms may underestimate true smoking incidence by up to 45%, despite a 97.6% accuracy rate reported by Ellis *et al*.[7] The optimal timing of nicotine cessation is crucial for the orthopedic surgeon, with a longer period of abstinence associated with fewer postoperative complications.[10] Research suggest that at least 4 weeks of smoking abstinence before surgery reduce complications, and the preoperative period can serve as an opportunity to improve long-term cessation rates.[11] However, despite patient education on the dangers of nicotine use, a significant number of patients reported increased vaping on the day of surgery compared to smoking.[12]

CYTOTOXICITY

Despite the perception that EC aerosol is safe, it contains harmful chemicals including carcinogens, heavy metals, and flavoring agents. With over 8,000 different flavors on the market, the health effects of flavoring agents remain mostly unknown. Cinnamon-flavored e-liquids exhibit high cytotoxicity, an increased inflammatory response, and impaired neutrophil phagocytotic function.[13] Cinnamaldehyde, has gained special attention, since being identified as the most potent chemical in e-liquid.[13]

E-liquids and aerosols may induce cytotoxicity through oxidative stress, resulting from an imbalance between cell antioxidant defenses and reactive oxygen species (ROS).[13] Shaito *et al.,* reported high ROS production and inhibition of osteogenic differentiation in response to e-cigarette extract exposure.[14] Furthermore, e-cigarette aerosol extract exposure has been found to impair both proliferation and osteoblastic differentiation of bone marrow-derived mesenchymal stem cells (MSCs).[14] These detrimental effects on cellular function and bone repair have significant implications, particularly for individuals with skeletal system disorders such as osteoarthritis, osteoporosis, and scoliosis.[14, 15]

SURGICAL SITE INFECTION AND WOUND HEALING

Smoking's impact on wound-healing and surgical site infection (SSI) has been well- documented. Sørensen found that smokers were four times more likely to experience necrosis than nonsmokers, while surgical site infection, dehiscence, and healing delay were twice as common in smokers.[16] The acute vasoactive effect can lead to the development of postoperative necrosis in tissues with fragile blood supply, such as reconstructive tissue flaps. Furthermore, smoking has been shown to reduce the inflammatory healing response, impair oxidative bacterial killing mechanisms, delay the proliferative healing response, and alter collagen metabolism, which can result in complications like dehiscence, incisional hernia, and lack of fistula or bone healing.[16] Moller *et al.,* found that four weeks of smoking abstinence significantly reduced the incidence of incisional wound infection, although its impact on SSI varied among patients. Therefore, the required abstinence time prior to surgery may fluctuate per patient and necessitates individualized considerations.[17]

Carbon monoxide, a component unique to traditional combustible cigarettes, was identified as a potential mechanism that not only binds to hemoglobin but also shifts the oxyhemoglobin dissociation curve left, leading to decreased oxygen supply and potentially contributing to SSI.[18] Troiano *et al.,* studied wound healing in rats exposed to EC vapor or cigarette smoke and found substantially higher rates of flap necrosis in both groups compared to unexposed rats, even at similar nicotine levels, indicating that EC vaping is not safer than cigarette smoking for surgical wound healing.[19]

CIRCULATION

Daftari *et al.,* conducted a study in which autologous cancellous bone was transplanted to the eyes of 24 rabbits, half of which received nicotine and the other half received a placebo. The results indicated that nicotine is associated with delayed revascularization and a smaller percent area of revascularization, with a larger number of grafts showing necrosis.[20] Inhaling nicotine leads to increased circulating catecholamines, which can impair microcirculation in areas such as the hand.[21] Pywell *et al.,* discovered that smokers experience increased superficial microcirculation after using 0 mg ECs, attributed to components like glycerol present in e-liquids. However, a 24-mg nicotine EC significantly reduced hand microcirculation during and up to 20 minutes after inhalation. Interestingly, it was found that nicotine inhalation, rather than smoking, reduced blood flow in the hand, as demonstrated by inhaling on a 0-mg nicotine EC.[21] Thus, ECs have been shown to reduce cutaneous blood flow in peripheral circulation in humans, so orthopedic surgeons should be aware of the circulation reductions in patients using ECs.[22]

BONE HEALTH

Smoking increases the risk of bone fracture, slows healing, and nonunion.[23] While genetics explain 60-80% of bone mineral density (BMD), modifiable factors such as smoking play a significant role in the remaining percentage.[23] Smoking harms BMD by decreasing calcium absorption, vitamin D levels, body mass, and altering hormone levels. The harmful components of combustibles, such as nicotine and cadmium damage bone cells.[23]

Nicholson *et al.* investigated the effect of EC vapor on bone in vivo, exposing mice to aerosols for up to 6 months. While no significant effect on cortical bone strength, stiffness, or hydroxyapatite content was reported, microfractures were evident in the femur of mice. Moreover, microfractures occurred with aerosols containing only propylene glycol and vegetable glycerol, suggesting an effect not entirely mediated by nicotine or flavoring chemicals.[24]

Recent studies suggest that e-liquid ingredients may harm the body's ability to produce healthy bone structures, increasing the risk of osteoporosis, and potentially promoting other musculoskeletal diseases like rheumatoid arthritis and osteoarthritis.[25] This highlights the importance of considering the impact of ECs on adolescents and young adults, who make a significant portion of EC users. Prolonged use of ECs may lead to reduced bone mineral density into adulthood.[15] It was found that nicotine-rich EC vapor reduced the mineralization and alkaline phosphatase activity of Saos-2 osteoblasts, while inducing apoptosis.[24] Additionally, nicotine-rich EC vapor had more pronounced negative effects on osteoblast function than nicotine-free EC vapor, suggesting that nicotine plays a significant role in the impact of EC vapor on new bone synthesis.[24]

E-liquids have been shown to harm osteoblasts. Some e-liquids were applied to human Saos-2 and MG- 63 cells, causing reduced cellular viability, even when nicotine-free. Besides, formaldehyde and acetaldehyde decreased proliferation and increased cell death in U2Os. In addition, both acetaldehyde and acrolein also inhibited osteoblast alkaline phosphatase activity and mineralization.[24] Carbonyl compounds following EC use can adversely affect osteoblast function. Prolonged exposure to cadmium from ECs may also be harmful to bone health, similar to smoking. A Swedish study found that even low levels of cadmium exposure had a negative effect on bone health.[25]

FRACTURES AND HEALING

Studies have shed light on the impact of smoking on orthopedic outcomes. For instance, Kanis *et al.* conducted a study involving 60,000 smokers, and identified a 25% increased risk for fractures among this population.[26] Tucker *et al.*, observed no significant difference in a rat femur fracture model between smoking and vaporized nicotine, but trends indicated concerns regarding the impact of vaporized nicotine on bone formation. The vaporized nicotine groups, exhibited lower levels of total mineralized and immature bone volume, indicating potential adverse effets.[27] Donigan *et al.*, showed that transdermal nicotine decreased the mechanical strength of healing fractures and resulted in an increased rate of nonunion compared to controls in a rabbit model.[28] Furthermore, Agoons *et al.*, found a 46% higher prevalence of fractures in EC users compared to non-users, with a graded increase in prevalence for traditional cigarette smokers and dual users of traditional and e-cigarettes, indicating that e-cigarette use may harm bone health.[29]

Although the mechanisms by which e-cigarettes affect bone health are unclear, several factors have been identified. EC aerosols have been linked to the suppression of cellular antioxidant activity, oxidative stress, and DNA damage.[29] Moreover, nicotine is present in both traditional cigarettes and ECs and may have direct cytotoxic effects on the activity of bone-forming osteoblast. Cigarette smoking has been shown to dysregulate hormones, resulting in reduced BMD and increased the risk of fractures.[29]

CONCLUSION

Orthopedic surgeons must recognize that vaping is not a healthier alternative to smoking when it comes to infection, circulation, and bone health/healing. E-liquid, used in vaping devices, has its own negative consequences, and efficiently delivers nicotine to consumers. Although vaping avoids the known harm caused by combustible cigarette smoke, it has its own impact on orthopedic patients. Surgeons must approach vaping in the same way as they have treated smoking. There is a biological basis for surgeons to increase their awareness of its effects of vaping, while advocating for nicotine cessation for their surgical patients.

DECLARATION OF CONFLICT OF INTEREST

The authors do NOT have any potential conflicts of interest for this manuscript.

DECLARATION OF FUNDING

The authors received NO financial support for the preparation, research, authorship, and publication of this manuscript.

DECLARATION OF ETHICAL APPROVAL FOR STUDY

Approval not required.

DECLARATION OF INFORMED CONSENT

There is no information (names, initials, hospital identification numbers, or photographs) in the submitted manuscript that can be used to identify patients.

Submitted: April 16, 2023 EDT, Accepted: November 22, 2023 EDT

REFERENCES

1. Polosa R, Casale TB, Tashkin DP. A Close Look at Vaping in Adolescents and Young Adults in the United States. *J Allergy Clin Immunol Pract*. 2022;10(11):2831-2842. doi:10.1016/j.jaip.2022.06.005

2. Jerzyński T, Stimson GV, Shapiro H, Król G. Estimation of the global number of e-cigarette users in 2020. *Harm Reduct J*. 2021;18(1). doi:10.1186/s12954-021-00556-7

3. Cooper M, Park-Lee E, Ren C, Cornelius M, Jamal A, Cullen KA. *Notes from the Field:* E-cigarette Use Among Middle and High School Students — United States, 2022. *MMWR Morb Mortal Wkly Rep*. 2022;71(40):1283-1285. doi:10.15585/mmwr.mm7140a3

4. Kempton SJ, Burish NM, Rao VK. Electronic cigarettes: have you asked your patients about vaping? Plast Reconstr Surg. *Plast Reconstr Surg*. 2014;133(6):907e. doi:10.1097/prs.0000000000000196

5. Krishna A, Mathieu W, Mull E, Tobias JD. Perioperative Implications of Vaping. *J Med Cases*. 2020;11(5):129-134. doi:10.14740/jmc3451

6. Lilley M, Krosin M, Lynch TL, Leasure J. Orthopedic Surgeons' Management of Elective Surgery for Patients Who Use Nicotine. *Orthopedics*. 2017;40(1):10392801477447-20160901-20160902. doi:10.3928/01477447-20160901-02

7. Ellis ST, Rao BM, Kohlrieser D, Kollmorgen RC, Sochacki KR. Validation of Self-Reported Smoking Status Among Orthopedic Hip Surgery Patients. *Cureus*. 2020;1;12(10):e10753. doi:10.7759/cureus.10753

8. Lumb AB, Panesar PH. Is There an Optimal Timing for Smoking Cessation? In: *Evidence-Based Practice of Anesthesiology*. Elsevier; 2009:144-152. doi:10.1016/b978-0-323-77846-6.00018-5

9. Thomsen T, Villebro N, Møller AM. Interventions for preoperative smoking cessation. *Cochrane Database of Systematic Reviews*. 2010;7:CD002294. doi:10.1002/14651858.cd002294.pub3

10. Wei DH, Strauch RJ. Smoking and hand surgery. *J Hand Surg Am*. 2013;38(1):176-179. doi:10.1016/j.jhsa.2012.08.018

11. Wong J, Lam DP, Abrishami A, Chan MTV, Chung F. Short-term preoperative smoking cessation and postoperative complications: a systematic review and meta-analysis. *Can J Anaesth*. 2012;59(3):268-279. doi:10.1007/s12630-011-9652-x

12. Gricourt Y, Ghezal H, Claret PG, et al. Preoperative vaping prevalence and behavior of French surgical patients: A multicentre study. *Tob Induc Dis*. 2019;17(November). doi:10.18332/tid/114068

13. Wavreil FDM, Heggland SJ. Cinnamon-flavored electronic cigarette liquids and aerosols induce oxidative stress in human osteoblast-like MG-63 cells. *Toxicol Rep*. 2019;7:23-29. doi:10.1016/j.toxrep.2019.11.019

14. Shaito A, Saliba J, Husari A, et al. Electronic Cigarette Smoke Impairs Normal Mesenchymal Stem Cell Differentiation. *Sci Rep*. 2017;7(1). doi:10.1038/s41598-017-14634-z

15. Nicholson T, Davis L, Davis ET, Newton Ede M, Scott A, Jones SW. e-Cigarette Vapour Condensate Reduces Viability and Impairs Function of Human Osteoblasts, in Part, via a Nicotine Dependent Mechanism. *Toxics*. 2022;10(9):506. doi:10.3390/toxics10090506

16. Sørensen LT. Wound healing and infection in surgery. The clinical impact of smoking and smoking cessation: a systematic review and meta-analysis. *Arch Surg*. 2012;147(4):373-383. doi:10.1001/archsurg.2012.5

17. Møller AM, Villebro N, Pedersen T, Tønnesen H. Effect of preoperative smoking intervention on postoperative complications: a randomised clinical trial. *Lancet*. 2002;359(9301):114-117. doi:10.1016/s0140-6736(02)07369-5

18. Nolan MB, Martin DP, Thompson R, Schroeder DR, Hanson AC, Warner DO. Association Between Smoking Status, Preoperative Exhaled Carbon Monoxide Levels, and Postoperative Surgical Site Infection in Patients Undergoing Elective Surgery. *JAMA Surg*. 2017;152(5):476. doi:10.1001/jamasurg.2016.5704

19. Troiano C, Jaleel Z, Spiegel JH. Association of Electronic Cigarette Vaping and Cigarette Smoking With Decreased Random Flap Viability in Rats. *JAMA Facial Plast Surg*. 2019;21(1):5-10. doi:10.1001/jamafacial.2018.1179

20. Daftari TK, Whitesides TEJr, Heller JG, Goodrich AC, McCarey BE, Hutton WC. Nicotine on the revascularization of bone graft. An experimental study in rabbits. *Spine*. 1994;19(8):904-911. doi:10.1097/00007632-199404150-00007

21. Pywell MJ, Wordsworth M, Kwasnicki RM, Chadha P, Hettiaratchy S, Halsey T. The Effect of Electronic Cigarettes on Hand Microcirculation. *J Hand Surg Am*. 2018;43(5):432-438. doi:10.1016/j.jhsa.2017.12.003

22. Page F, Hamnett N, Wearn C, Hardwicke J, Moiemen N. The acute effects of electronic cigarette smoking on the cutaneous circulation. *J Plast Reconstr Aesthet Surg*. 2016;69(4):575-577. doi:10.1016/j.bjps.2015.12.015

23. Hernigou J, Schuind F. Tobacco and bone fractures: A review of the facts and issues that every orthopaedic surgeon should know. *Bone Joint Res*. 2019;8(6):255-265. doi:10.1302/2046-3758.86.bjr-2018-0344.r1

24. Nicholson T, Scott A, Newton Ede M, Jones SW. The impact of E-cigarette vaping and vapour constituents on bone health. *J Inflamm*. 2021;18(1):16. doi:10.1186/s12950-021-00283-7

25. Fiani B, Noblett C, Nanney JM, et al. The Impact of "Vaping" Electronic Cigarettes on Spine Health. *Cureus*. 2020;12(6):e8907. doi:10.7759/cureus.8907

26. Kanis JA, Johnell O, Oden A, et al. Smoking and fracture risk: a meta-analysis. *Osteoporos Int*. 2004;16(2):155-162. doi:10.1007/s00198-004-1640-3

27. Tucker J, McCullen A, Kennedy P, et al. The effect of cigarette smoke versus vaporized nicotine on healing of a rat femur. *Injury*. 2022;53(10):3102-3108. doi:10.1016/j.injury.2022.08.040

28. Donigan JA, Fredericks DC, Nepola JV, Smucker JD. The effect of transdermal nicotine on fracture healing in a rabbit model. *J Orthop Trauma*. 2012;26(12):724-727. doi:10.1097/bot.0b013e318270466f

29. Agoons DD, Agoons BB, Emmanuel KE, Matawalle FA, Cunningham JM. Association between electronic cigarette use and fragility fractures among US adults. *American Journal of Medicine Open*. 2021;1-6:100002. doi:10.1016/j.ajmo.2021.100002