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ORIGINAL RESEARCH

Laryngoscope
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Carbon savings potential of virtual care in obstructive sleep apnea and otitis media with effusion

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Abstract

Objective: To determine the carbon savings potential of incorporating virtual care into surgical care pathways for pediatric patients with obstructive sleep apnea or otitis media with effusion.

Methods: Pediatric patients with obstructive sleep apnea or otitis media with effusion were not enrolled, instead, a modeling cohort study design was used. This study utilized the British Columbia healthcare system and geography to model emissions. Care pathways were developed for pediatric patients with obstructive sleep apnea or otitis media with effusion requiring care at a tertiary pediatric center. Home addresses were located at the geographical center of the two most populated municipalities within each of the 10 most populated regional districts in 2020. Virtual visits replaced up to three clinically equivalent in-person visits. Emissions ($kgCO_2e$) for transport and virtual visits were estimated. Population-weighted means and descriptive statistics were calculated.

Results: Utilizing 1, 2, or 3 virtual visits in the obstructive sleep apnea care pathway yielded potential emissions savings of 19.9%, 39.9%, and 59.8% respectively. Integrating 1, 2, or 3 virtual visits into the otitis media with effusion care pathway produced potential emissions savings of 16.6%, 33.2%, and 49.7%, respectively. Integrating 3 virtual visits can save up to 2156.8 $kgCO_2e$ per patient.

Conclusions: Appropriately conducting up to 50% of clinical encounters virtually for children with obstructive sleep apnea or otitis media with effusion reduced theoretical carbon emissions. For a single child, emission savings could reach over 2150 $kgCO_2e$.

Level of Evidence: Level 5.

KEYWORDS
carbon footprint, climate change, otolaryngology, telemedicine, virtual health

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1 | INTRODUCTION

Climate and ecological breakdown undermine the health and well-being of people and communities.[1,2] Health systems need to adapt to the resulting increase in burden of disease and address their contribution to environmental degradation. Canada's healthcare system contributes 4.6% of the country's total greenhouse gas (GHG) emissions and is the second highest emitting health system on a per capita basis worldwide.[3,4] Fortunately, Canada recently joined the World Health Organization's (WHO) commitment to developing low-carbon, sustainable, and resilient health systems.[5,6] MacNeill et al. developed a framework for low-carbon health systems around three principles: (1) reducing demand for health services, (2) matching supply of health services to demand, and (3) reducing emissions from the supply of health services.[7] This third principle involves decarbonizing healthcare delivery, which includes the strategic use of virtual care.

Virtual care, is defined as the remote diagnosis and treatment of patients by means of telecommunications technology.[8] It can reduce emissions from patient travel and resource utilization from in-person interactions across a variety of specialties.[9–12] Virtual care can also be more convenient and cost-effective for patients and improve healthcare access for rural and remote communities.[7,8,13] Even before the COVID-19 pandemic, it had been employed in otolaryngology for many years.[14,15] In particular, telecommunciation technologies can benefit patients with voice disorders by allowing for remote readings of strobovideolaryngoscopy and provision of voice therapy.[15] Substantial cost savings have also been shown relative to outpatient otolaryngology services, with high levels of patient satisfaction.[14,16] To ensure appropriate application of virtual care, these benefits must be weighed against its shortcomings, including diagnostic challenges caused by the absence of physical exams and non-verbal cues.[17]

Despite robust literature on virtual care in otolaryngology, no studies have investigated the environmental benefits of integrating virtual care into otolaryngology care pathways. The objective of this study was to determine the potential carbon savings from avoided patient travel with appropriate utilization of virtual care using modeling in two pediatric otolaryngologic conditions: obstructive sleep apnea (OSA) and otitis media with effusion (OME).

2 | MATERIALS AND METHODS

In 2022, a modeling cohort study design was used to project carbon savings associated with the incorporation of virtual visits. Research ethics board approval was not required due to the modeling nature of this study. Ideal care pathways were first generated by integrating surgical treatment algorithms for OSA and OME with current practice at British Columbia Children's Hospital (BCCH), the sole tertiary care pediatric hospital for the province of British Columbia (BC), located in Vancouver (Figure 1).[18,19] In the pediatric population, OSA is commonly caused by adenotonsillar hypertrophy and treated by adenotonsillectomy (AT).[18] Bilateral myringotomy with tubes is indicated for children 6 months to 12 years of age who have bilateral OME for ≥3 months with documented hearing difficulties.[20] The pathways were developed with a tertiary pediatric otolaryngologist (senior author), determining which in-person visits in the care pathways could be safely and equivalently replaced by virtual interactions. In the OSA pathway, the preoperative anesthesiology assessment, 3-month post-operative follow-up and 6–9-month post-operative follow up were deemed amenable to a virtual visit. The initial consultation, operation, and 2–3-week post-operative visit were felt to require in-person interactions with the surgical team. In the OME pathway, one of the otolaryngology visits, the preoperative anesthesiology assessment and the final 6–9-month post-operative follow-up appointments could safely and equivalently be conducted virtually. The latter is deemed safe as the in-person audiology visit could provide adequate information on tube placement and hearing. The initial otolaryngology consultation and/or 3-month post-op otolaryngology visit remained in-person to allow for otoscopic examination of the tympanic membrane, which is required for OME diagnosis and confirmation of tube placement respectively.[20]

Scenarios were modeled in which up to three visits in each care pathway were conducted virtually. Travel modeling was carried out by selecting the two most populated municipalities within each of the 10 most populated regional districts in BC in 2020 and using a home address located at the geographic center of each municipality (Table 1). Municipalities within 30 km of BCCH were excluded, given the minimal benefit that virtual care would offer these families. This resulted in patients traveling round-trip distances ranging from 441 to 9777 kilometers (km) (Table 1).

GHG emissions from car travel were estimated by measuring the total round-trip distance a patient would have to drive from their home to BCCH and multiplying this by an emissions factor (EF) for a standard passenger vehicle. A 2018 Corolla CE was chosen as the standard vehicle for simulated patient commutes, as this was the most popular vehicle registered with the Insurance Corporation of British Columbia in 2020, which provides mandatory coverage for all licensed vehicles in the province.[21] This vehicle is classified as a light-duty gasoline-powered vehicle as defined by Canada's National GHG Inventory Report with a corresponding EF of 2.462 $kgCO_2e/L$.[22] Utilizing the average 2018 Corolla CE fuel consumption for city and highway (7.55 L/100 km), we calculated an EF of 0.186 $kgCO_2e/km$.[23] GHG emissions for ferry transportation were obtained by multiplying the total work done by the respective vessel to make a round trip voyage by the carbon intensity (82.97 gCO2e/MJ) associated with the energy sources used by BC Ferries' fleet. The product was then divided by the ships' maximum passengers and crew, and the quotient was multiplied by 2, to represent the child and parent making the voyage.[24] Emissions from virtual visits were calculated assuming a low-tech set-up utilizing an overall energy cost of 0.341 kWh, which was calculated from the operational and embodied energy cost for a PC laptop.[25] This was used in combination with the British Columbia electrical grid intensity of 0.097 $kgCO_2e/kWh$ to determine carbon emissions associated with virtual visits, assuming a 30-min appointment.[26]

Avoided emissions were calculated for 1, 2, and 3 virtual visits compared to 0 virtual visits for both OSA and OME. To account for

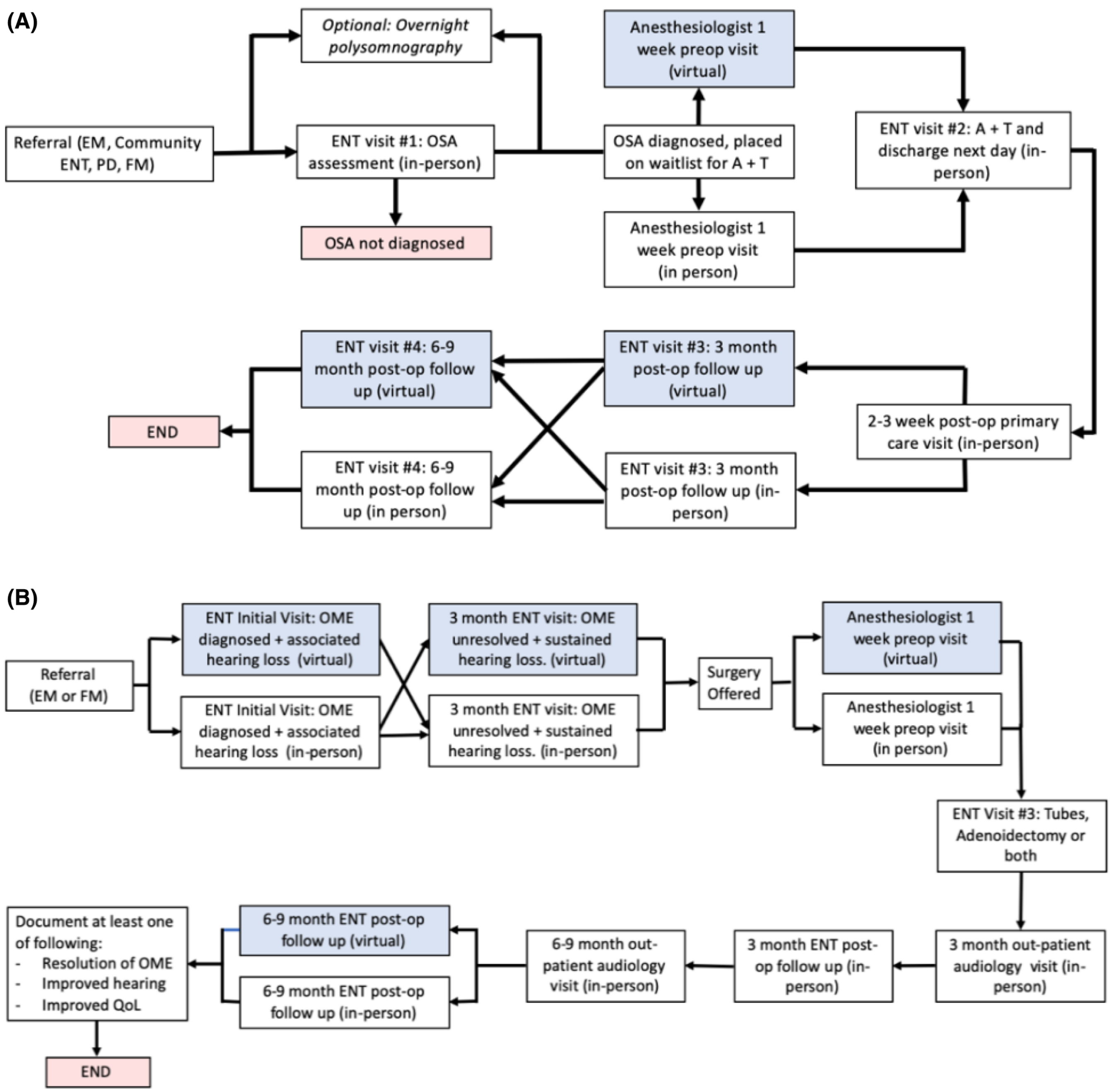

FIGURE 1 Surgical care pathways for pediatric patients diagnosed with (A) OSA or (B) OME. EM, Emergency Medicine Physician; ENT, ear, nose and throat; FM, family medicine doctor; OME, otitis media with effusion; OSA, obstructive sleep apnea; PD, pediatrician; QoL, quality of life.

the varying size of the pediatric populations in different municipalities, population-weighted estimates of province-wide avoided GHG emissions were calculated by multiplying GHG emissions by the municipality's relative proportion of the total pediatric population. Statistical analysis was performed using IBM SPSS™ Statistics for Mac.[27] Overall population-weighted medians, means, standard errors, and standard deviations for GHG emissions were calculated.

Multiple assumptions were made in this modeling cohort study. The GHG emissions associated with vehicle travel assumed that every individual transporting their child with OSA or OME made no detours during their return journey to Vancouver, British Columbia (BC). Ferry GHG emission calculations assumed that the same ship was used for the round-trip voyage, that each ship had the same carbon intensity, that the ship sailed at capacity and that one person accompanied the child to their visit. Virtual visit emissions were calculated assuming surgeons and patients both used a PC laptop.

3 | RESULTS

A total of 19 municipalities in 10 regional districts located in northern BC, interior BC, Vancouver Island, and the lower mainland were

TABLE 1 Included regional districts and the associated population and distance to BCCH from the two most populated municipalities within the respective district.

Regional district	Municipality[a]	Municipality population (2021)	Population (0–19 years)	Round-trip distance (km) to BCCH (car, ferry)
Metro Vancouver	Surrey	568,322	129,040	70.4 (70.4, 0)
Fraser Valley	Abbotsford	153,524	35,920	144 (143.6, 0)
	Chilliwack	93,203	23,350	206 (206, 0)
Central Okanagan	Kelowna	144,576	26,945	780 (780, 0)
	West Kelowna	36,078	7895	774 (774, 0)
Thompson-Nicola	Kamloops	97,902	20,030	710 (710, 0)
	Merritt	7051	1420	542 (542, 0)
Fraser-Fort George	Prince George	76,708	17,430	1566 (1566, 0)
	Mackenzie	3281	685	1932 (1932, 0)
North Okanagan	Vernon	44,519	8070	882 (882, 0)
	Coldstream	11,175	2505	884 (884, 0)
Okanagan-Similkameen	Penticton	36,885	5905	836 (836, 0)
	Summerland	12,042	2145	804 (804, 0)
Capital	Saanich	117,735	21,680	214 (121, 93)
	Victoria	91,867	11,160	220 (128, 93)
Nanaimo	Nanaimo	99,863	18,760	174 (60, 114)
	Parksville	13,642	1735	243 (129, 114)
Cowichan Valley	North Cowichan	31,990	6000	272 (158, 114)
	Lady Smith	8990	1600	225 (111, 114)

[a]Unincorporated areas were not considered municipalities. Population data were from 2020 for all municipalities except for Coldstream, Saanich, Victoria, Nanaimo, which each used 2021 Statistics Canada census data.
Abbreviations: BCCH, British Columbia Children's Hospital; Km, kilometers.

included after excluding Vancouver due to its proximity to BCCH. The maximum absolute emissions for a single patient with no virtual visits varied based on location (Table 2). Those living in Mackenzie, BC (1932 km round trip) (northern BC) produced maximum emissions of 1796.7 kgCO_2e/child and 2156.8 kgCO_2e/child for OSA and OME pathways, respectively (Table 2). Similarly, patients living in interior BC demonstrated elevated emissions with the maximum emissions in Kelowna (780 km round trip) being 725.9 kgCO_2e/child and 871.9 kgCO_2e/child for OSA and OME, respectively. Those living in Victoria, located on Vancouver Island, (220 km round trip, including ferry travel), had maximum emissions of 205.2 kgCO_2e/child and 247.0 kgCO_2e/child for OSA and OME, respectively. Lastly, the maximum emissions for those living in Surrey, BC (70.4 km round trip) had maximum emissions of 66.4 kgCO_2e/child and 80.4 kgCO_2e/child for OSA and OME, respectively.

The incorporation of virtual visits produced considerable emissions reductions in both OSA and OME surgical care pathways. The incorporation of 1, 2, or 3 virtual visits into the surgical care pathway for OSA yielded population-weighted emission savings of 19.9%, 39.9%, and 59.8%, respectively, over an entirely in-person scenario (Figure 2). Similarly, incorporating 1, 2, or 3 virtual visits into the surgical care pathway for OME generated population-weighted emission savings of 16.6%, 33.2%, and 49.7%, respectively (Figure 2). This translates to 20% and 16.6% emissions savings per virtual visits for OSA and OME clinical care pathways respectively, which equates to an average population-weighted emission savings of 63.86 kgCO_2e per virtual visit for both pathways (Table 3).

4 | DISCUSSION

This is the first study in pediatric otolaryngology to estimate the potential environmental benefits of integrating virtual care into surgical care pathways. The modeled scenarios demonstrate that replacing up to 50% of in-person encounters with virtual care for children with OSA or OME requiring tertiary care could reduce carbon emissions. However, the number and specific visits replaced remain flexible (Figure 1). For a single child, emission savings can reach 2156.8 kgCO_2e, which is greater than the emissions associated with the average Canadian's home energy usage over 6 months.[28] Overall, emissions could be reduced by up to 60% and 50% for OSA and OME, respectively, with average population-weighted emission savings per virtual visit being 63.9 kgCO_2e (Table 3). These emissions savings are larger for those living further away from BCCH, which supports the high threshold for referral to BCCH for OME and OSA, and the encouragement of management by local otolaryngologists.

The only other study in otolaryngology-head and neck surgery to characterize the emission savings of virtual health was Dorian et al.[29]

TABLE 2 Absolute patient travel emissions for each municipality and avoided emissions with incorporation of virtual care.

		Travel emissions ($kgCO_2e$/child) [avoided emissions ($kgCO_2e$/child)]							
		0VV		1VV		2VV		3VV	
Regional district	Municipality	OME	OSA	OME	OSA	OME	OSA	OME	OSA
Metro Vancouver	Surrey	80.38 [0.0]	66.37 [0.0]	67.31 [13.07]	53.30 [13.07]	54.24 [26.14]	40.23 [26.14]	41.17 [39.21]	27.15 [39.21]
Fraser Valley	Abbotsford	162.03 [0.0]	134.41 [0.0]	135.35 [26.68]	107.73 [26.68]	108.67 [53.36]	81.05 [53.36]	81.99 [80.04]	54.37 [80.04]
	Chilliwack	231.63 [0.0]	192.41 [0.0]	193.35 [38.28]	154.13 [38.28]	155.07 [76.56]	115.85 [76.56]	116.79 [114.84]	77.57 [114.84]
Central Okanagan	Kelowna	871.87 [0.0]	725.94 [0.0]	726.89 [144.99]	580.95 [144.99]	581.90 [289.97]	435.97 [289.97]	436.91 [434.96]	290.98 [434.96]
	West Kelowna	865.18 [0.0]	720.36 [0.0]	721.31 [143.87]	576.49 [143.87]	577.44 [287.74]	432.62 [287.74]	433.57 [431.61]	288.75 [431.61]
Thompson-Nicola	Kamloops	793.79 [0.0]	660.88 [0.0]	661.82 [131.97]	528.90 [131.97]	529.85 [263.95]	396.93 [263.95]	397.88 [395.92]	264.96 [395.92]
	Merritt	606.41 [0.0]	504.72 [0.0]	505.66 [100.74]	403.98 [100.74]	404.92 [201.48]	303.24 [201.48]	304.18 [302.22]	202.50 [302.22]
Fraser-Fort George	Prince George	1748.58 [0.0]	1456.53 [0.0]	1457.47 [291.10]	1165.42 [291.10]	1166.37 [582.21]	874.32 [582.21]	875.27 [873.31]	583.22 [873.31]
	Mackenzie	2156.81 [0.0]	1796.72 [0.0]	1797.67 [359.14]	1437.58 [359.14]	1438.53 [718.29]	1078.44 [718.29]	1079.39 [1077.43]	719.30 [1077.43]
North Okanagan	Vernon	985.64 [0.0]	820. 75 [0.0]	821.69 [163.95]	656.80 [163.95]	657.75 [327.89]	492.85 [327.90]	493.80 [491.84]	328.91 [491.84]
	Coldstream	987.87 [0.0]	822.61 [0.0]	823.55 [164.32]	658.29 [164.32]	659.23 [328.64]	493.97 [328.64]	494.92 [492.96]	329.65 [492.96]
Okanagan-Similkameen	Penticton	934.33 [0.0]	777.99 [0.0]	778.94 [155.40]	622.60 [155.40]	623.54 [310.79]	467.20 [310.79]	468.15 [466.19]	311.80 [466.19]
	Summerland	898.64 [0.0]	748.25 [0.0]	749.19 [149.45]	598.80 [149.45]	599.75 [298.89]	449.35 [298.89]	450.30 [448.34]	299.91 [448.34]
Capital	Saanich	240.07 [0.0]	199.44 [0.0]	200.38 [39.68]	159.75 [39.68]	160.70 [79.37]	120.07 [79.37]	121.01 [119.06]	80.38 [119.06]
	Victoria	246.98 [0.0]	205.20 [0.0]	206.15 [40.84]	164.36 [40.84]	165.31 [81.68]	123.53 [81.68]	124.47 [122.51]	82.69 [122.51]
Nanaimo	Nanaimo	161.87 [0.0]	134.27 [0.0]	135.22 [26.65]	107.62 [26.65]	108.57 [53.30]	80.97 [53.30]	81.91 [79.96]	54.32 [79.96]
	Parksville	228.79 [0.0]	190.04 [0.0]	190.99 [37.81]	152.24 [37.81]	153.18 [75.61]	114.43 [75.61]	115.38 [113.42]	76.62 [113.42]

(Continues)

TABLE 2 (Continued)

Regional district	Municipality	Travel emissions (kgCO$_2$e/child) [avoided emissions (kgCO$_2$e/child)]							
		0VV		1VV		2VV		3VV	
		OME	OSA	OME	OSA	OME	OSA	OME	OSA
Cowichan Valley	North Cowichan	260.92 [0.0]	216.81 [0.0]	217.76 [43.16]	173.65 [43.16]	174.60 [86.32]	130.49 [86.32]	131.44 [129.48]	87.33 [129.48]
	Lady Smith	208.05 [0.0]	172.75 [0.0]	173.70 [34.35]	138.40 [34.35]	139.35 [68.70]	104.06 [68.70]	105.00 [103.04]	69.71 [103.04]

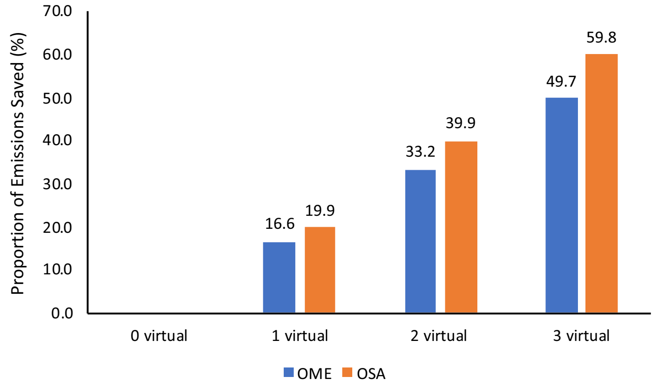

FIGURE 2 Proportion of population-weighted mean emissions saved with integration of virtual visits into OSA and OME care pathways.

This study demonstrated emissions savings of 123 kgCO$_2$e per patient that underwent tele-endoscopy for head and neck cancer assessment.[29] That work, in keeping with the present study, underestimated the true carbon reduction potential for a partial virtual care transition. This is because GHG emissions calculations omitted any emissions associated with supply chains (e.g., medical equipment, food, and catering), delivery of care (e.g., water, waste, and building energy), and staff travel.[30] Instead, these studies exclusively considered patient travel which made up only 5% of total system emissions of the National Health Services in 2020.[31] British Columbia is a vast province that is much larger than England (approximately 945,000 km^2 vs. 130,000 km^2), hence patient travel emissions are likely to represent a larger proportion of GHG emissions for BC healthcare.[32] Despite this, we did not capture all forms of patient travel due to air travel being excluded. This form of travel may be a more viable option for the approximately 50% of BC's residents living in remote rural areas.[33] Unfortunately, this can incur substantial patient costs, and result in much higher GHG emissions. The latter is evidenced by the carbon emissions conversion factor for domestic air travel (0.255 kgCO$_2$e/km/passenger) being about 27% greater per km than the 2018 Corolla CE (0.186 kgCO$_2$e/km) used in this study.[34] Thus, while the modeled carbon savings associated with virtual health in this study are sizeable, the real-world carbon savings are likely greater.

This study provides a prototype for low-carbon service delivery in pediatric otolaryngology and beyond. The surgical care pathways were created using evidence-based guidelines and expert input. The OSA post-operative care pathway was greatly influenced by the practice patterns of Otolaryngologists at BCCH due to the minimal guidance provided by the utilized pediatric tonsillectomy guideline. As a result, it may not be 100% reflective of practice at different institutions, but the premise of virtual care's environmental benefits remains evident. Furthermore, systematically applying the OSA and OME prototypes could assist with the safe integration of virtual care into modern healthcare. However, this must be implemented with consideration for the patient experience and the adequacy and quality of patient/provider interactions. Interestingly, a recent study demonstrated that

TABLE 3 Average weighted emissions and emissions saved with the incorporation of up to three virtual visits into OSA and OME surgical care pathways.

	Number of VV	Mean (± SD) Weighted Emissions (kgCO_2e)	Mean weighted emissions avoided per patient (kgCO_2e)
OSA	0	320.13 ± 238.62	0
	1	275.32 ± 256.43	63.86 (19.9%)
	2	192.48 ± 161.57	127.71 (39.9%)
	3	128.72 ± 153.15	191.57 (59.6%)
OME	0	385.09 ± 459.45	0
	1	321.24 ± 382.87	63.86 (16.6%)
	2	257.38 ± 306.30	127.71 (33.2%)
	3	193.52 ± 229.72	191.57 (49.7%)

Abbreviations: Kg, kilograms; OSA, obstructive sleep apnea; OME, otitis media with effusion; VV, virtual visit.

pediatric otolaryngology telemedicine appointments were equally well received by patients as compared to traditional live assessments.[35] Virtual health could also confer cost savings to families and to the healthcare system. A 6-year prospective health economic analysis by the Mayo Clinic demonstrated that video telemedicine follow-ups for various surgical specialties saved patients $888–$1501 per visit.[36] These cost savings came from mitigating the cost of travel, accommodations, meals, and missed work.[36] This was also demonstrated in Otolaryngology, with the highest cost savings occurring in head and neck cancer surgery.[37] Collectively, virtual health reduces the social and monetary costs to patients, mitigates healthcare spending and could reduce the carbon footprint of the Canadian healthcare system.[38]

The utilization of this technology could also provide more equitable care to rural, remote communities across Canada. This is important because rural communities often experience disproportionate challenges in accessing healthcare, with only 7.6% of practicing physicians serving the 16% of Canadians living in these rural communities.[39,40] These challenges contribute to patients from rural clinics having worse health outcomes than their urban counterparts.[41] These effects are compounded by race, gender, and lower median household income resulting in rural areas with majority Black or Indigenous populations suffering higher rates of premature death.[42] Addressing this lack of healthcare access with virtual health could be beneficial provided that the community has access to digital technologies and have adequate digital literacy. Unfortunately, only 41% of people in rural communities have access to download speeds (50 megabits/s) and upload speeds (10 megabits/s) compatible with streaming a virtual health visit.[43] This introduces a barrier to virtual care that could be addressed by following action 13 from the 2020 Canadian Rural Road Map for Action report. This action expresses the importance of partnering with rural communities and healthcare professionals while developing strategies to guide distance technology.[44] These strategies should include the infrastructure to provide audiovisual capabilities for virtual visits which has been deemed critical to virtual health satisfaction.[45] Adopting a similar strategy to healthcare delivery in rural Canadian areas could help Canada achieve health equity and environmental justice.

Despite the panoply of virtual care benefits, there remain challenges. Virtual care should only be offered if it is clinically equivalent to in-person care. There are obvious instances where a peri-operative physical examination is essential, for instance, the otoscopic examination of the tympanic membrane in a patient with otalgia.[20] In such a scenario, ensuring that all required in-person appointments are coordinated and occur over a limited time period (e.g., 1 day) could offer similar benefits as virtual care. Some studies have raised the concern that the loss of face-to-face communication would change the provider-patient relationship and result in worse health outcomes.[17,46] Moreover, patients who have language barriers, cognitive deficits, or lack technological competence may experience enhanced difficulties in a virtual setting. This highlights the importance of using virtual care judiciously and following the WHO recommendation to use "client-to-provider telemedicine to complement…the delivery of health services."[46] In the future, additional visits could be conducted virtually using novel devices such as Entraview, a telemedicine-enabled otoscope and audiometry screening device.[47] This would particularly benefit patients who are immunocompromised or have reduced mobility, due to reduced likelihood of healthcare-acquired infections and less travel, respectively.[30]

5 | CONCLUSION

Virtual health can offer substantial benefits to patients, the healthcare system, and the environment, and should be encouraged in situations where in-person and virtual visits are clinically equivalent. This study demonstrated that replacing up to 50% of in-person tertiary center encounters for children with OSA or OME with virtual visits could substantially reduce carbon emissions. Given the multifold benefits of virtual visits, we would encourage providers to adopt this blended virtual health pathway of care whilst taking patient experience and health equity into consideration. However, as the study used a modeling cohort design the resulting emission estimates may not be entirely representative. Therefore, prospective studies that evaluate the impact of virtual care in otolaryngology on the patient, healthcare system, and the environment are needed to confirm that it meets patients' needs whilst contributing to health system sustainability.

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CONFLICT OF INTEREST STATEMENT

Authors have no conflicts of interest to disclose.

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