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Original Article

Workforce Planning for Community-Based Palliative Care Specialist Teams Using Operations Research

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Abstract

Context. Many countries have aging populations. Thus, the need for palliative care will increase. However, the methods to estimate optimal staffing for specialist palliative care teams are rudimentary as yet.

Objectives. To develop a population-need workforce planning model for community-based palliative care specialist teams and to apply the model to forecast the staff needed to care for all patients with terminal illness, organ failure, and frailty during the next 20 years, with and without the expansion of primary palliative care.

Methods. We used operations research (linear programming) to model the problem. We used the framework of the Canadian Society of Palliative Care Physicians and the Nova Scotia palliative care strategy to apply the model.

Results. To meet the palliative care needs for persons dying across Nova Scotia in 2019, the model generated an estimate of 70.8 nurses, 23.6 physicians, and 11.9 social workers, a total of 106.3 staff. Thereby, the model indicated that a 64% increase in specialist palliative care staff was needed immediately, and a further 13.1% increase would be needed during the next 20 years. Trained primary palliative care providers currently meet 3.7% of need, and with their expansion are expected to meet 20.3% by 2038.

Conclusion. Historical, current, and projected data can be used with operations research to forecast staffing levels for specialist palliative care teams under various scenarios. The forecast can be updated as new data emerge, applied to other populations, and used to test alternative delivery models. J Pain Symptom Manage 2020;■:■−■. *Crown Copyright © 2020 Published by Elsevier Inc. on behalf of American Academy of Hospice and Palliative Medicine. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).*

Key Words

Palliative care specialist, primary care, health workforce, population-based planning, operations research, data analytics

Key Message

This article uses operations research to forecast community-based palliative care specialists staffing by geographic area for the first time. It uses projected deaths, a Canadian Expert Consensus White Paper, and models primary care substitution. Our innovative approach is population based, multifaceted, adaptable, and prompted hiring more palliative care social workers.

Introduction

Enhanced data-driven decision-making is needed to generate workforce planning models that can more adequately guide palliative care staffing. Those working in palliative care understand the importance of such models given limited resources and staffing challenges already being experienced, while populations age around the globe.[1,2] Many countries report unmet need for palliative care supports[3,4] requiring the scale-

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up of specialist and primary palliative care[3] based on population-based planning.[5,6] The coronavirus pandemic in 2020 has further demonstrated the importance of access to palliative care specialist support to address needs as they arise.

In 2016 in Canada, 16.8% of the population were seniors. By 2031, this is expected to be almost 25%.[7] In Canada, palliative care services have largely emerged from local initiatives[8] resulting in variation by geographic area and inequitable access.[9] The Canadian Society of Palliative Care Physicians highlighted the urgency to plan for palliative care services.[10]

Historically, palliative care was considered mainly for persons dying of cancer. Palliative care is now also recommended for persons living with advanced organ failure (e.g., congestive heart failure, chronic obstructive pulmonary disease) and frailty (e.g., dementia).[11,12] Although population-based studies have used death counts to estimate the number of persons expected to need palliative care,[13–17] no publications to date provide a multifaceted model to translate these numbers into community-based specialist palliative care staffing plans.

Operations research has been used for health care workforce planning at operational[18–20] and strategic[21–24] levels. Although often only one type of health care provider is considered, there are some multiprofessional studies.[25–27] None were found that focused on modeling team-based care. Studies of palliative care staffing in hospital[28,29] and recruitment and training[30,31] have been published, but none used operations research or focused on community-based specialist palliative care staffing.

Using operations research, we developed a population-need workforce planning model for community-based palliative care specialist teams and applied it to provide a 20-year forecast (2019–2038) to satisfy the needs of patients with terminal illness, organ failure, and frailty. As proof of concept, we generated two models: with and without the expansion of primary palliative care.

Methods

Framework

The 2019 Canadian Society of Palliative Care Physicians consensus paper[10] provided a framework for our model. This consensus paper says that palliative care should be delivered by teams consisting of nurses, physicians, and social workers working in interdependent roles and that the expected annual deaths in each geographic area should be used to estimate patient care needs.[10]

The consensus paper also says that because appropriately trained and supported primary palliative care providers should be able to manage most patients and families, in the future, specialist palliative care practitioners should focus on consultation to support those with the most complex needs.[10] The remaining palliative care need can be met by primary palliative care providers. By this, we mean family physicians, other primary care providers, and medical specialists such as internists and geriatricians[10] who have acquired core palliative care competencies[32] and have access to a specialist palliative care team and 24/7 home support.[10]

Setting

Nova Scotia (NS) has a population of almost one million people, which is the oldest in Canada with 20.6% who are 65 years and older.[33] By 2038, this is expected to reach 30.8%.[34] Appendix I provides a map of the 14 geographic networks used in our model.

Specialist palliative care teams are located in each network. The nurses and social workers are employees of Nova Scotia Health (NSH). Physician payment and working conditions are set by a collective agreement between Doctors Nova Scotia and the provincial government.

The provincial integrated palliative care strategy[35] identified the need to build capacity in primary palliative care. For purposes of applying our model, training newly emerging collaborative primary care practices,[36–38] the planned expansion of the INSPIRED program for persons with advanced chronic obstructive pulmonary disease,[39] and palliative and therapeutic harmonization (PATH) for the frail elderly[40] were incorporated as examples of the possible expansion of primary palliative care in NS.

Operations Research Model

Linear programming[24,41,42] was selected for the development of our operations research model (Fig. 1) because of its flexibility and ease of use when it comes to analyzing the sensitivity of solutions to changes in model parameters.[22,42] Our objective function was to minimize the cost (C) of specialist palliative care in the 14 networks (i) during the next 20 years (t) (Equation 1). To support shared care capacity with primary care,[43] a constraint was included to ensure at least one full-time equivalent specialist palliative care nurse (N) in each network (Equation 2). To model the ratio of the academic physician (AP) and other physicians (P) and social workers (S) to nurses, two further constraints were added (Equations 3 and 4). The next constraint ensured that the resources (R) provided meets or exceeds the hours (H) needed to care for the morbidity (M) demand, accounting for the expansion (E) of primary palliative care (Equation 5). The final constraint ensured that the full-time equivalent staff counts in the solution were positive numbers (Equation 6).

$$Minimum \sum_{t=1}^{20}\sum_{i=1}^{14}\left(C_{ti}^{AP}AP_{ti} + C_{ti}^{P}P_{ti} + C_{ti}^{N}N_{ti} + C_{ti}^{S}S_{ti}\right) \quad (1)$$

Subject to constraints:

$$N_{ti} \geq 1 \quad (2)$$

$$AP_{ti} + P_{ti} \geq \frac{N_{ti}}{3} \quad (3)$$

$$S_{ti} \geq \frac{N_{ti}}{6} \quad (4)$$

$$R_{ti}^{AP}AP_{ti} + R_{ti}^{P}P_{ti} + R_{ti}^{N}N_{ti} + R_{ti}^{S}S_{ti} \geq \sum_{D} H_{ti}^{D}(M_{ti}^{D} - E_{ti}^{D}) \quad (5)$$

$$AP_{ti},\ P_{ti},\ N_{ti},\ S_{ti} \in \mathbb{R}^{+} \quad (6)$$

Fig. 1. Linear program for operations research model to forecast specialist palliative care staffing.

Data Input and Sources

To forecast the demand in our operations research model, provincial vital statistics deaths from 2000 to 2016[44] were projected forward by year, network, and cause of death disease trajectory using population projections.[34] For this, STATA[45] Software by StataCorp and R[46] Software by the R Foundation, the Nova Scotia Civic Address File,[47] and CANPROJ[48] projection method were used. We also used heterogeneous data from a range of other credible sources: salaries, benefits, holidays, sick time, and hours from human resources departments; nurse survey[49] data to estimate workload by disease trajectory; and other metrics informed by national and provincial reports and practice. These input data and data sources are delineated in Table 1. As new information becomes available to inform future years, to test alternative scenarios, and to apply for other jurisdictions, our model can be adapted to produce a range of projections.

Reporting

The number of specialist palliative care nurse, physician, and social worker full-time equivalents needed were generated by network from the model for 2019 and then compared with the actual full-time equivalent staff numbers. Forecasted deaths were plotted by primary causes of nonsudden death corresponding to three disease trajectories (terminal illness including cancer, organ failure, and frailty)[11,50] using the Fassbender[51] taxonomy of *International Classification of Diseases, 10th Edition* codes.[52] Using five-year groups across the 20-year forecast, the percent change in specialist palliative care by staff type over time was reported. The two model solutions (one with and one without expanding primary palliative care) were provided to compare with their specialist staffing changes over time.

Results

To meet the palliative care needs for persons dying across NS in 2019, the model generated an estimate of 70.8 nurses, 23.6 physicians, and 11.9 social workers (Table 2), a total of 106.3 staff. The actual full-time equivalent staff available was much lower at 46.0, 16.2, and 2.8, respectively, totaling 65.0 staff. Thus, according to the model, the province was operating with 0.61 (65.0 of 106.3) of the staff needed, or in other words, a 64% staff increase was needed ([106.3/65.0 × 100] −100). The shortage was greatest for social workers with the actual being 0.24 of the model solutions.

Fig. 2 shows the expected increase in the number of persons needing palliative care during the next 20 years. By 2035, both organ failure and frailty deaths are expected to become greater than cancer deaths.

Assuming that specialist palliative care staffing and the primary palliative care resources were in accord with the model for 2019, a further increase of 13.1% in specialist palliative care staffing would be needed during the next 20 years (Table 3) in addition to the expansion of primary palliative care.

The model shows that in 2019, 3.7% of the palliative care needs were being met by primary palliative care providers (Table 4). This percentage increased steadily over time to 20.3% in 2038. The projected increase was mainly because of the plan for an additional five collaborative family physician practices trained and supported in palliative care each year.

Each of the two detailed projections, with and without primary palliative care expansion, have 840 cells (20 future years × 14 geographic areas × 3 staff types). The unabridged solution that includes primary palliative care expansion is provided in Appendix II.

Table 1

Methods Used to Apply Our Operations Research Model to NS

Parameter	Category	Symbol	Initial Value[a]	Creation Method or Formula	Forecasting Method	Data Sources
Annual per capita *cost* (C) of salaries and benefits in Canadian dollars		C				
	Nurses[b] (N)	C^N	$78,827	Based on collective agreements for 2014–2020	2.5% increase annually	Human resources, NSH
	Social workers[b] (S)	C^S	$76,197			
	Academic[c] physicians[b] (AP)	C^{AP}	$273,481	Based on contract to 2023 with NS government	2.0% increase annually	Doctors NS
	Other physicians[b] (P)	C^P	$273,481			
Annual per capita *resources* (R) in hours available for direct patient care		R				
	Nurses[b]	R^N	1010.0	1684[d] hours minus 20% administration and 20% travel = 60% patient care		Human resources, NSH for total hours; nurse survey for administration and travel
	Social workers[b]	R^S	1010.0		Assumed no change over time	
	Academic[c] physicians[b]	R^{AP}	517.5	1725 hours minus 50% academic and 20% travel = 30% patient care		Doctors NS for total hours; 50% academic from Henderson et al.[10] assumed other physicians 10% teaching; 20% travel given nurse survey results
	Other physicians[b]	R^P	1207.5	1725 hours minus 10% for teaching and 20% for travel = 70% patient care		
Palliative care *hours* (H)[e] to care for a person expected to die, by disease decline trajectory[11,50] (*D*)		H^D				
	Terminal illness, e.g., cancer		14.40	The nurse survey provided ratios of time for organ failure and frailty compared with terminal illness. Hours were computed using an equation[f]	Assumed no change over time	Annual patient load from the nurse survey.[g] Assumed 70% terminal illness, 20% organ failure, and 10% frailty from historic study data[66]
	Organ failure, e.g., congestive heart failure, chronic obstructive pulmonary disease		12.8			
	Frailty including dementia		10.8			
Mortality (M) (or death count) is the projected number of deaths by disease trajectory[11,50] (*D*)		M^D				
	Terminal illness		2940	The first cause of death ICD-10 codes[52] for NS historical (2000–2016) mortality was grouped by disease trajectory[51] and age group.[h] Then NS death counts by trajectory were projected for 2019 onward using CANPROJ[48]	To estimate death counts by geographic area,[i,j] projected populations by area were multiplied by death rates and trajectory to give death counts by network and trajectory	Vital statistics death data;[k] historical (2000–1016) population by 18 age groups;[33] NS population projection (2019–2038) using M1 scenario[34]
	Organ failure		3135			
	Frailty		2330			

Expanded (E) primary palliative care[l] capacity in patient equivalents	E^D				
	Collaborative family physician practices[36,37]	32	Two collaborative practices[m] were assumed to be LEAP[67] trained in 2019. Each is estimated to provide palliative care for the equivalent of 16 patients[n]	Five additional practices[o] are expected to be trained and supported each year[p] in randomly assigned locations	Palliative Care Division, NSH
	INSPIRED for persons with advanced COPD[68]	100	COPD patients across three networks[q]	Add 100 patients per year across six networks[r]	INSPIRED Program CFHI[69] report (2018)[70]
	PATH[40] for elderly persons with frailty including dementia	130	100 frailty patients in three networks[q] plus 30 via Web portal[71,s] in 2019.	Add 15 Web portal patients per year	PATH[40] and Frailty Web portal[71]

NS = Nova Scotia; NSH = Nova Scotia Health; ICD-10 = *International Classification of Diseases, 10th Edition*; COPD = chronic obstructive pulmonary disease; CFHI = Canadian Foundation in Healthcare Improvement.

[a]As of January 01, 2019.

[b]Palliative care specialist.

[c]Academic physicians spend 50% of their time on teaching, administration, and research;[10] the remaining 50% is directly or indirectly on patient care. Our assumption of 20% travel may be high—further research on this is needed. We assumed that only 10 academic physicians were needed, and that their location should be prioritized to locations with tertiary care, teaching centers, and larger population density, that is, five in Halifax, three in Cape Breton, and one each in the other two zones in networks with the largest population.

[d]Paid hours minus allowable statutory, holidays, vacation, and sick days.

[e]Palliative care hours are hours for direct patient care, that is, excluding all travel time and administrative duties as reported in the nurse survey findings.

[f]In this equation, x is the palliative care time a patient with cancer needs: $70x + 20(0.9x) + 10(0.75x) = 1010$ hours per year.

[g]Annual patient load of 100 from nurse survey is consistent with Canadian Palliative Care Society estimates of 25 patients on typical nurse caseload[10] if patients receive care for an average of three months.

[h]Ages are in 18 five-year age groups from 0 to 4 years to 85+.

[i]For our model, we generated staffing for each of the 14 individual (i) networks across the province (see map in Appendix I).

[j]We used the NS Civic Address File, which includes civic addresses of places where people live to create the network boundaries for population estimates for 2019–2038. This method is used by Maritime Health Atlas (Maritime SPOR SUPPORT Unit, http://healthatlas.ca).

[k]Canadian Vital Death Statistics Database accessed through the Atlantic Research Data Centre.

[l]Primary palliative care providers include family physicians, other primary health care providers, and medical specialists such as internists and geriatricians.[10]

[m]One practice in Antigonish/Guysborough was trained before our project start date. The training for the next (in Eastern Shore/Musquodoboit) was completed in 2019.

[n]We estimated that a collaborative family physician cares for an average of 20 persons per year who experience nonsudden deaths. From discussion with the EXTRA project[38] investigators, with primary palliative care training and support, they can provide 80% of their palliative care (20% by specialist palliative care).

[o]There were 1316 family physicians in NS. We assumed that each practice had an average of three physicians. We assigned practices to networks based on network populations. Given the annual number of nonsudden deaths per year, and that 10% of the population are without family physicians, the average annual number of deaths per practice was 20. Given the assumption that collaborative practices will provide 80% of the palliative care, this is the equivalent of 100% of time to care of 16 patients. We randomly selected the five newly trained practices per year that would now provide primary palliative care.

[p]Adding five trained collaborative primary care practices each year translates to the equivalent of 80 (80% of 100) patients not needing specialist palliative care.

[q]Because the INSPIRED COPD and the onsite PATH clinic programs operated in Halifax, their patients were assigned to these three networks: Bedford/Sackville, Dartmouth/Southeastern, and Halifax Peninsula/Chebucto. We assumed that INSPIRED and onsite PATH clinic patients will not require any specialist palliative care.

[r]The distribution of COPD patients forecast to be served by INSPIRED was informed by the distribution of projected COPD deaths, and Canadian Foundation for Health Innovation funding to expand INSPIRED[70] into nine health centres, of which two are located in West Hants, three in Eastern Shore, one in each of Cumberland, Lunenburg, and Queens, Cape Breton, and Bedford/Sackville. We assumed the expansion would occur during three years and that there would be no further expansion.

[s]The frailty Web portal was designed to support collaborative family physician practices. Therefore, we assumed that LEAP-trained collaborative practices using the frailty Web portal could provide care for 80% of the palliative care for frail patients who die (20% by specialist palliative care support). We assumed no additional geriatricians will be hired to increase access to onsite PATH clinics across the province.

Table 2
Actual and Model-Estimated Full-Time Equivalent Specialist Palliative Care Staff Needed as of January 1, 2019

		Nurses		Physicians		Social Workers	
Zones	Networks	Actual	Model	Actual	Model	Actual	Model
Western	Annapolis and Kings	3.0	6.3	1.5	2.1	0.0	1.1
	Lunenburg & Queens	4.5	4.2	1.0	1.4	1.0	0.7
	Yarmouth, Shelburne, & Digby	3.0	4.1	0.5	1.4	0.8	0.7
	Total	10.5	14.6	3.0	4.9	1.8	2.5
Northern	Colchester/East Hands	3.9	6.2	2.0	2.0	0.0	1.0
	Cumberland	3.2	2.4	1.0	0.8	0.0	0.4
	Pictou	2.0	3.2	1.0	1.1	0.0	0.5
	Total	9.1	11.8	4.0	3.9	0.0	1.9
Eastern	Antigonish & Guysborough	4.5	1.8	1.0	0.6	1.0	0.3
	Cape Breton, Inverness, and Victoria[a]	9.9	10.0	4.4	3.3	0.0	1.7
	Total	14.4	11.8	5.4	3.9	1.0	2.0
Central	Halifax region[a]	10.0	30.1	3.8	10.0	0.0	5.1
	Eastern Shore/Musquodoboit	1.0	1.1	0.0	0.4	0.0	0.2
	West Hants	1.0	1.4	0.0	0.5	0.0	0.2
	Total	12.0	32.6	3.8	10.9	0.0	5.5
Total NS		46.0	70.8	16.2	23.6	2.8	11.9
Ratio of actual to model staff		0.65		0.69		0.24	

NS = Nova Scotia.
[a]In Halifax, three networks were combined and two in Cape Breton to reflect actual staff counts on January 1, 2019 obtained from the Nova Scotia Health.

Discussion

We used operations research with varied historical, current, and projected data to develop a multifaceted population-need workforce planning model to forecast the community-based palliative care specialist team staffing (Fig. 1). This is a novel and substantial methodological step forward.

We also applied our model to forecast the specialist palliative care staff needed, with and without the expansion of primary palliative care, across NS for all persons expected to die of terminal illness, organ failure, and frailty during the next 20 years. Table 1 provides the details of how the application was carried out, as well as being a template to guide others in the future in reporting their application methods. Similarly, Tables 2–4 provide a template for succinctly synthesizing the large data output (Appendix II) into meaningful reporting. Our 20-year forecast can readily be updated with new or alternate data, be applied in other provinces and countries, and be adapted to test alternative delivery models.

Our work and results have directly informed staffing decisions across the province. The nursing survey and operations research findings helped to identify and

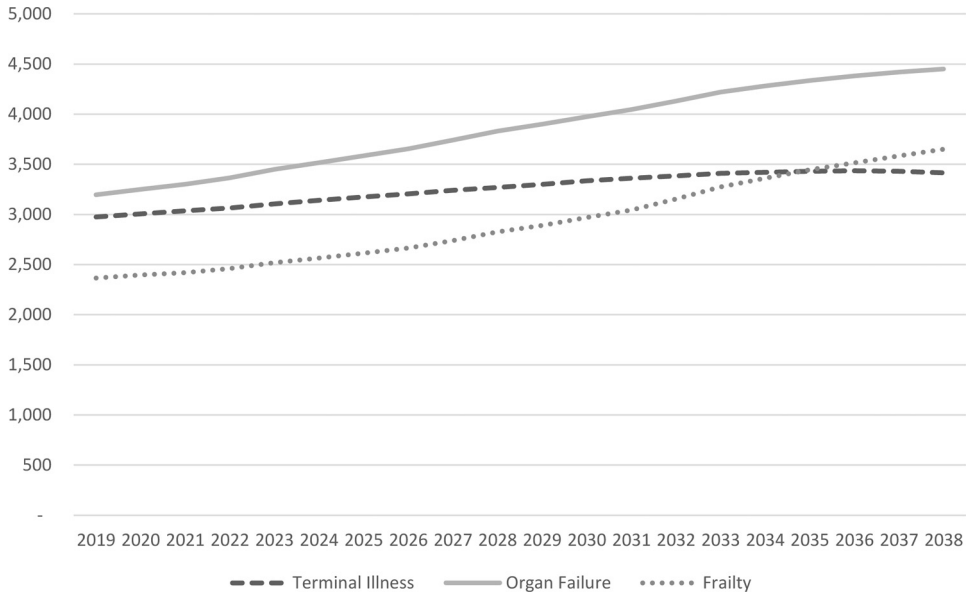

Fig. 2. Death count projection by disease trajectory for Nova Scotia.

Table 3
Forecasted Specialist Palliative Care Staff Percent Changes in Full-Time Equivalents in Five-Year Increments and the Total Across the 20 Years

	Percent Change in Specialist Palliative Care Staff in Full-Time Equivalents				
Palliative Care Staff	2019–2023 (%)	2024–2028 (%)	2029–2033 (%)	2034–2038 (%)	2019–2038 (%)
Nurses	1.7	3.9	4.6	0.8	13.4
Physicians	1.7	4.6	4.4	1.1	13.1
Social workers	1.7	2.5	4.0	−0.8	10.9
Total	1.7	3.9	4.5	0.7	13.1

validate staffing gaps. In response, by January 2020, additional specialist palliative care staff were hired as follows: 5.2 nurses, 3.8 physicians, and 4.5 social workers, corresponding to increases of 11.3%, 23.5%, and 160.7%, respectively. Thereby, the actual to model staff ratios increased from 0.65, 0.69, and 0.24 on January 1, 2019 to the higher ratios of 0.72, 0.84, and 0.61, respectively, a year later. The increase in social workers was particularly noteworthy. Beyond this, we also quantified (Table 3) the potential for primary palliative care to play a role in reducing the need for specialist palliative care professionals.[9]

Our work provides a framework for international discussion on relevant parameters, comparisons between countries,[53] and data development for a multifaceted evidence-based means to forecast palliative care staffing. Hopefully, thereby, we will discover hidden relationships, byproducts, and otherwise unavailable intelligence.[54] Ultimately, the intent is that policy and practice will increasingly be data driven (albeit interpreted with caution because expecting 100% accuracy is unrealistic) and improve patient care.[55]

Disease type has been used in Canadian and international metrics reports for over a decade,[15,16,56,57] and our nurse survey[49] revealed that most nurses viewed disease type as a factor affecting the amount of the palliative care time that is required. However, the nurses reported that many other factors should also be considered such as nature and severity of symptoms, access to a family physician, and expertise and availability of help from family and friends. Operations research is well suited to the ongoing incorporation of alternative, improved, and expanded parameter inclusion in modeling.

Various operations research methods have been used in health care workforce planning. We chose linear programming because of its flexibility and ease of use in sensitivity analysis and decision support when entering alternative parameters into the model.[24,42] System dynamics[58–62] is another operations research method that should be considered when modeling several modules (supply, demand, etc.) within a system. Markov chains[63] is an option when the probability of each event depends on the state obtained in the previous event. For example, Markov chains might be useful if forecasting is based on past referrals and expands further based on prior referrals.[10] Instead of modeling on referrals expected, our model is based on an estimate of all need, both met and unmet, as advised in Australia.[6] Thereafter, we compared actual to forecast (Table 2).

Limitations

The proposed model is an initial model to demonstrate the feasibility of using operations research for specialist palliative care team workforce planning. Therefore, the staffing results from our model should be seen as a proof of concept, not a strident call to action based on the forecasted numbers that we generated. Many factors, such as variation of staff travel times to rural and remote areas, are not as yet included, and some may view travel to patients as patient care time. Bereavement support was excluded to simplify this initial model. Inpatient and clinic care by hospital-only staff were excluded because

Table 4
Specialist Palliative Care Full-Time Equivalent Staff Needed With and Without Expansion of Primary Palliative Care, and Percent Less Specialist Staff With the Expansion, by Period

Years	2019 (%)			2028 (%)			2038 (%)		
Expand Primary Palliative Care?	No	Yes	Less	No	Yes	Less	No	Yes	Less
Nurses	73.5	70.8	3.8	84.4	75.2	12.2	96.4	80.3	20.1
Physicians	24.5	23.6	3.8	28.1	25.1	12.0	32.1	26.7	20.2
Social workers	12.2	11.9	2.5	14.1	12.5	12.8	16.1	13.2	22.0
Total	110.2	106.3	3.7	126.7	112.8	12.3	144.6	120.2	20.3

they are beyond the organizational mandate of community-based care in NS. Also, we selected an aspirational approach in our modeling by focusing on meeting all needs, rather than including budget limitations and estimates of persons who refuse community-based palliative care or receive palliative care in hospital, hospice, or nursing home. We see the forecasting process as iterative and informative rather than absolute and final.

If more primary palliative care is provided by oncologists, internists, geriatricians, and other medical specialists who are trained in palliative care and have access to specialist palliative care team consultation, the need for specialist palliative care team members would be lower. The need might also become lower by improving home care nursing through enhanced palliative care training and much greater continuity of care. To model the expansion of primary palliative care providers, we estimated that five newly trained practices would be added each year, and their location was randomly assigned; these assumptions are likely to differ from what actually will occur. Also, we did not include the impact of retirements, constraints in the supply of replacement staff, or substitution across types of staff. Another limitation is that we did not include major events like a pandemic or an economic crisis, which could increase the need for palliative care while at the same time limiting resources. Other major events are less likely to affect palliative care planning for NS in the foreseeable future but should be considered if the model is to be used elsewhere where war or other disruptions could be an issue.

Next Steps

Additional factors can be added to the model. For example, a palliative care specialist nurse practitioner substitutes for specialist physician care in one part of the province, but our model did not incorporate this role. Other team members could be included, such as pharmacists, dietitians, and spiritual care providers. The role of volunteers and community capacity development could be incorporated as well as the costs of education and training. We could also consider the randomness in demand using stochastic approaches and the availability and cost of further innovations such as patient consultations through virtual technology already being used by many nurses to continue care planning. Although our model relates to specialist palliative care team staffing, it could be extended to a more general optimization model for other instances where health care services are delivered by teams.

Conclusion

In this study, we showed how operations research can be used to find a high-quality estimation of the specialist palliative care team workforce needed. Although operations research is a well-known analytical tool for workforce planning, this is the first time it has been used for specialist palliative care workforce planning and team-based care. The results can readily be updated as new data emerge, applied to other populations, and used to test alternative delivery models.

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The authors declare that there is no conflict of interest with respect to the research, authorship, and publication of this article.

Ethical approval: Because the Canadian Research Data Centres[64] follow the strict ethics and disclosure protocols of the Statistics Act, the Canadian Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS2) article 2.2 (a)[65] exempts the centre's approved projects from further research ethics board review. The nurse survey was exempt from ethics approval because it was an NSH quality improvement study.[49] Other data were not person specific, and thus, their release was exempt from the need for ethics review.

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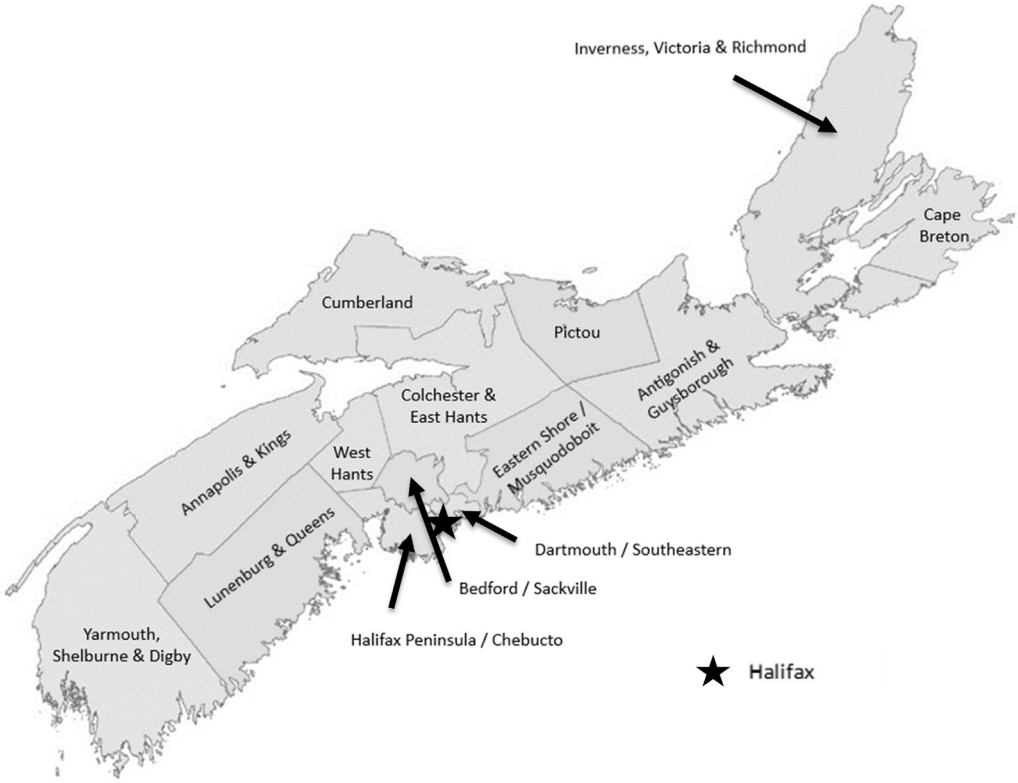
Appendix. I:
Map of Networks in NS

NSH is made up of four geographic management zones, and each management zone includes several networks (total of 14) as follows:

- Zone 1, Western: Annapolis and Kings, Lunenburg & Queens, Yarmouth, and Shelburne and Digby
- Zone 2, Northern: Colchester/East Hants, Cumberland, and Pictou
- Zone 3, Eastern: Antigonish & Guysborough, Cape Breton, and Inverness, Victoria, and Richmond
- Zone 4, Central: Bedford/Sackville, Dartmouth/Southeastern, Eastern Shore/Musquodoboit, Halifax Peninsula/Chebucto, West Hants

Halifax is the capital city and has a tertiary health center.



Appendix Fig. 1. Nova Scotia networks map.

Appendix. II: Solutions by Specialist Palliative Care Team Member

Appendix Table 1

Model Solution for Specialist Palliative Care Nurse Distribution During the Next 20 Years With Expansion of Primary Palliative Care Support

Zone	Networks	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Western	Annapolis and Kings	6.3	6.4	6.3	6.4	6.4	6.4	6.4	6.4	6.5	6.5	6.4	6.4	6.3	6.4	6.4	6.3	6.4	6.5	6.5	6.5
	Lunenburg & Queens	4.2	4.1	4.1	4.1	4.1	4.1	4.2	4.2	4.3	4.4	4.4	4.3	4.4	4.3	4.3	4.3	4.4	4.4	4.4	4.4
	Yarmouth, Shelburne, & Digby	4.1	4.1	4.1	4.0	4.0	4.0	4.1	4.1	4.0	4.0	4.0	4.0	4.0	3.9	3.8	3.8	3.8	3.8	3.8	3.8
	Total	14.6	14.6	14.5	14.5	14.5	14.5	14.7	14.7	14.8	14.9	14.8	14.7	14.7	14.6	14.5	14.4	14.6	14.7	14.7	14.7
Northern	Colchester/East Hands	6.2	6.1	6.2	6.3	6.3	6.4	6.5	6.5	6.6	6.6	6.7	6.7	6.8	6.9	7.1	7.1	7.1	7.2	7.3	7.3
	Cumberland	2.4	2.4	2.3	2.3	2.3	2.2	2.2	2.2	2.3	2.3	2.2	2.2	2.2	2.3	2.3	2.2	2.2	2.2	2.2	2.2
	Pictou	3.2	3.2	3.2	3.1	3.2	3.2	3.1	3.1	3.0	3.1	3.1	3.1	3.0	3.1	3.1	3.1	3.2	3.2	3.2	3.2
	Total	11.8	11.7	11.7	11.7	11.8	11.8	11.8	11.8	11.9	12.0	12.0	12.0	12.0	12.3	12.5	12.4	12.5	12.6	12.7	12.7
Eastern	Antigonish & Guysborough	1.8	1.8	1.8	1.8	1.7	1.7	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9
	Cape Breton	7.7	7.7	7.5	7.5	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.1	7.0	7.0	7.0	7.0	6.9	6.8
	Inverness, Victoria, & Richmond	2.3	2.2	2.1	2.1	2.2	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.5	1.4	1.3	1.3	1.3	1.3	1.2	1.2
	Total	11.8	11.7	11.4	11.4	11.5	11.3	11.3	11.2	11.1	11.0	10.9	10.8	10.5	10.4	10.2	10.2	10.2	10.2	10.0	9.9
Central	Bedford/Sackville	7.5	7.7	7.9	8.0	8.2	8.5	8.7	9.0	9.3	9.6	9.8	10.1	10.4	10.7	11.1	11.4	11.4	11.4	11.5	11.5
	Dartmouth/ Southeastern	8.8	8.8	8.9	8.9	9.1	9.3	9.4	9.5	9.6	9.8	9.9	10.1	10.3	10.5	10.8	10.9	11.0	11.0	10.8	10.7
	Eastern Shore/ Musquodoboit	1.1	1.1	1.1	1.1	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.3
	Halifax Peninsula/ Chebucto	13.8	14.0	14.2	14.3	14.5	14.7	14.9	15.0	15.4	15.6	15.9	16.3	16.6	17.0	17.4	17.7	17.8	17.8	17.9	18.0
	West Hants	1.4	1.4	1.3	1.3	1.4	1.3	1.3	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.4	1.4	1.5	1.5	1.5
	Total	32.6	33.0	33.4	33.6	34.2	34.8	35.4	35.8	36.6	37.3	38.0	39.0	39.8	40.8	42.0	42.7	42.9	43.0	43.0	43.0
Total NS		70.8	71.0	71.0	71.2	72.0	72.4	73.2	73.5	74.4	75.2	75.7	76.5	77.0	78.1	79.2	79.7	80.2	80.5	80.4	80.3

NS = Nova Scotia.

Appendix Table 2

Model Solution for Specialist Palliative Care Physician Distribution During the Next 20 Years With Expansion of Primary Palliative Care

Zone	Networks	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Western	Annapolis and Kings	2.1	2.1	2.1	2.1	2.2	2.1	2.1	2.1	2.2	2.2	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.2	2.2	2.2
	Lunenburg & Queens	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5
	Yarmouth, Shelburne, & Digby	1.4	1.4	1.4	1.3	1.3	1.3	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
	Total	4.9	4.8	4.8	4.8	4.9	4.8	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.9	5.0	5.0	5.0
Northern	Colchester/East Hands	2.0	2.0	2.1	2.1	2.1	2.1	2.2	2.2	2.2	2.2	2.2	2.2	2.3	2.3	2.4	2.3	2.4	2.4	2.4	2.4
	Cumberland	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.7	0.8	0.8	0.8	0.7	0.7	0.7	0.7
	Pictou	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.0
	Total	3.9	3.9	4.0	4.0	4.0	3.9	3.9	3.9	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.1	4.2	4.2	4.2	4.1
Eastern	Antigonish & Guysborough	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	Cape Breton	2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3
	Inverness, Victoria, & Richmond	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
	Total	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.6	3.6	3.5	3.5	3.3	3.3	3.3	3.3	3.3	3.3
Central	Bedford/Sackville	2.5	2.6	2.6	2.7	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.8	3.8	3.8	3.8
	Dartmouth/ Southeastern	2.9	2.9	3.0	3.0	3.0	3.1	3.1	3.2	3.2	3.3	3.3	3.4	3.4	3.5	3.6	3.6	3.7	3.7	3.6	3.6
	Eastern Shore/ Musquodoboit	0.4	0.4	0.4	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Halifax Peninsula/ Chebucto	4.6	4.7	4.7	4.8	4.8	4.9	5.0	5.0	5.1	5.2	5.3	5.4	5.5	5.7	5.8	5.9	5.9	5.9	6.0	6.0
	West Hants	0.5	0.5	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Total	10.9	11.1	11.1	11.3	11.3	11.5	11.8	12.0	12.2	12.5	12.7	13.0	13.2	13.7	14.0	14.2	14.3	14.3	14.3	14.3
Total NS		23.6	23.7	23.7	23.9	24.0	24.0	24.4	24.5	24.8	25.1	25.2	25.5	25.6	26.1	26.3	26.4	26.7	26.8	26.8	26.7

NS = Nova Scotia.

Appendix Table 3

Model Solution for Specialist Palliative Care Social Worker Distribution During the Next 20 Years With Expansion of Primary Palliative Care

Zone	Networks	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Western	Annapolis and Kings	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
	Lunenburg & Queens	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
	Yarmouth, Shelburne, & Digby	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6
	Total	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.4	2.4
Northern	Colchester/East Hands	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	Cumberland	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Pictou	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Total	1.9	1.9	1.9	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Eastern	Antigonish & Guysborough	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Cape Breton	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.1
	Inverness, Victoria, & Richmond	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Total	2.0	2.0	2.0	2.0	2.0	1.9	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.7	1.7	1.7	1.7	1.7	1.6	1.6
Central	Bedford/Sackville	1.3	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	1.9	1.9	1.9
	Dartmouth/ Southeastern	1.5	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	Eastern Shore/ Musquodoboit	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Halifax Peninsula/ Chebucto	2.3	2.3	2.4	2.4	2.4	2.4	2.5	2.5	2.6	2.6	2.7	2.7	2.8	2.8	2.9	3.0	3.0	3.0	3.0	3.0
	West Hants	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Total	5.5	5.5	5.6	5.6	5.7	5.8	6.0	6.0	6.1	6.2	6.3	6.5	6.6	6.8	6.9	7.1	7.1	7.1	7.1	7.1
Total NS		11.9	11.9	12.0	12.0	12.1	12.2	12.3	12.3	12.4	12.5	12.6	12.8	12.9	13.1	13.1	13.3	13.3	13.3	13.2	13.2

NS = Nova Scotia.