Supplemental File 1. Additional Methods

Model Data Inputs and Calibration

The numbers of patients included in the model were derived from the Ontario-Health Cancer Care Ontario (OH-CCO) Wait Time Information System (WTIS). The number of patients on the wait-list on day 1 of the pandemic was assigned according to the OH-CCO WTIS wait-list historical data (as of April 19, 2019). Daily new patients entering the model Monday through Friday were also based upon cancer surgery volumes, derived from OH-CCO WTIS estimates. All numbers were estimated per defined cancer disease sites (i.e. breast, gastrointestinal, genitourinary, gynecological, head and neck, hepatobiliary, lung, and prostate). Skin cancers were not included as many of these are resected in physician offices. Sarcomas, central nervous system tumors and thyroid cancers were not included given the rarity of these diagnoses. **Supplemental Table 1** provides additional data for the sub-types of cancers included within each cancer disease site.

For the pandemic analysis, the volume of simulated patients entering the model was adjusted to reflect the potential use of mitigation strategies in those who may experience a delay to surgery. Mitigation strategies included the use of systemic therapy prior to surgery (for instance, in breast, gastrointestinal, genitourinary, gynecological, lung or prostate cancer) or the use of radiation therapy to delay or replace surgery (for instance, in head and neck, lung cancer and/or prostate cancer). To estimate the use of systemic therapy as a mitigation strategy, Activity Level Reporting (ALR) and the New Drug Funding Program (NDFP) databases were used to identify systemic therapy use prior to surgery in 2019 (pre-pandemic) and in 2020 (pandemic) for each cancer type. Any relative increase in patients who received systemic therapy prior to surgery was used to estimate the volume of patients receiving systemic therapy as a mitigation

strategy. Expert opinion was used to estimate the volume of use of mitigation systemic treatment for prostate cancer given the inability to identify hormonal treatments with administrative databases, particularly for those under the age of 65 as they might have been covered by private insurance instead. ALR databases were used to identify radiation therapy volumes for curative-intent treatment for the first 6-months of 2019 which were compared to volumes in the first 6-months of 2020, with any increase in volume assumed to be used as a mitigation strategy to delay or replace cancer surgery. It was assumed that the use of a mitigation strategy would result in the exclusion of that patient from the wait-list in order to provide a conservative estimate of potential life-year lost, given that there is a general lack of evidence about the clinical efficacy of these mitigation strategies despite some adoption during the pandemic. **Supplemental Table 2** reports the volumes of simulated patients assumed to have received mitigation strategies in the pandemic analysis.

Patients entering the model on day 1 were assigned an existing time on the wait-list based upon historical estimates of mean wait-times for cancer surgery patients in Ontario, Canada. Calibration was used to refine this initial estimate such that the mean wait-time of the total modeled population, inclusive of day 1 patients and daily new patients, was in keeping with mean observed wait-times from OH-CCO WTIS wait-time estimates for cancer surgery patients in July 2019. **(Supplemental Table 3)** This was further adjusted to ensure the mean model wait-times reflected the mean wait-time estimates for cancer surgery during the first 6-months of the pandemic as derived from OH-CCO WTIS using the volume of real-world cancer surgery patients who proceeded through surgery between March 2020 and September 2020 . Calibration of this value was done for each cancer disease-site separately.

The number of designated cancer surgery operating rooms available in Ontario, Canada, per day for the base-case analysis was estimated to be 85. This estimate was based on historical data for the number of cancer surgeries performed in Ontario. This estimate was then calibrated to target the model population's simulated mean wait-time to observed mean wait-times as derived from OH-CCO WTIS estimates for all cancer surgery patients in July 2019.[1] It was assumed that 3 cancer surgeries could be completed per OR day, based on historical data for average cancer surgery times and an average 9 hour OR day.[1]

Historical survival data for cancer-surgery patients who underwent surgery between 2010 – 2019 was obtained from the Ontario Cancer Registry using appropriate cancer site diagnostic codes. (**Supplemental Table 1)** To characterize survival for patients who did not experience a pandemic-related increase in wait-time to cancer surgery, historical cancer-specific overall survival estimates from patients who underwent cancer surgery within 6-months of cancer diagnosis was utilized. (**Table 1**) The cancer-specific Kaplan-Meier overall survival curves were digitized with Plot Digitizer software (http://plotdigitizer.sourceforge.net) to derive estimates of pseudo-individual patient data, which were then used to fit parametric survival distributions in the proportional hazards family (i.e. exponential, gamma, Weibull). The type of parametric curve was selected according to the best statistical fit (using the Akaike Information Criterion), visual-inspection and clinical plausibility with the Weibull distribution chosen for all cancer survival outcomes. (**Supplemental Figure 2**) The best-fitting parametric curves were used to extrapolate survival beyond the 5-year survival estimates to 10-years.[2] For all survival curves, the Weibull parametric distribution demonstrated best fit. Model calibration of the shape and scale parameters for the Weibull distribution were undertaken to minimize the difference between modeled survival curves for pre-pandemic patients to observed cancer-specific survival curves.

The statistical analysis for curve generation and fitting was completed using R software (R Core Team 2013. R: A language and environment for statistical computing. R foundation for Statistical Computing, Vienna, Austria).

The per-day hazard ratios (HR) utilized were from previous models conducted to evaluated cancer survival implications from COVID-19 related increases in wait-times to cancer surgery, as derived from prior literature characterizing the association between wait-time to cancer surgery and mortality.[3-11] Using the approach taken by Sud and colleagues, three distinct per-day HR were applied to three groups of cancer disease-sites, whereby cancer sites were grouped based upon their similarity in 5-year survival as being at low risk of progression (5-year survival > 90%), moderate risk of progression (5-year survival 50-90%) or high risk of progression (5-year survival < 50%). (**Table 1**). (Sud 2020) Similar to previous analyses, the per-day HR for cancers with moderate risk of progression was applied to those cancers with high risk of progression, given the absence of high-quality data to inform on the increase in mortality with increase in wait-times for these cancers. These per-day HR estimates were favored to promote cross-country comparability of modeling methods and to facilitate cross-country comparisons in modeled output.

Probabilistic Sensitivity Analysis

A probabilistic sensitivity analysis was conducted to account for uncertainty in model input parameter for estimates of time including time on the wait-list for cases entering on day 1, and incremental increases in wait-times to cancer surgery (between the pre-pandemic and pandemic base-case or scenario analyses). These time parameters were modeled as gamma distributions fit according to the method of moments from the mean and standard deviation, per

cancer disease site. The standard deviation for mean-time on the wait-list for cases entering on day 1 was derived from OH-CCO WTIS database for wait-times in July 2019. (**Table 1**) The gamma distribution parameters for the incremental increase in wait-times were estimated from the modeled mean incremental wait-time along with the variance of the modeled pre-pandemic population and pandemic analyses. For each simulation, distributions were sampled 100 times to generate mean values for model outcomes.

[1]Wang J, Vahid S, Milroy S, et al. Clearing the surgical backlog caused by COVID-19 in Ontario: a time series modeling study. *CMAJ.* 2020. doi: https://doi.org/10.1503/cmaj.201521.

[2]Guyot P, Ades, AE, Beasley M, et al. Extrapolation of Survival Curves from Cancer Trials Using External Information. *Med Decis Making*. 2017(4):353-366.

[3]Sud A, Jones ME, Broggio J, et al. Collateral damage: the impact on outcomes from cancer surgery of the COVID-19 pandemic. *Ann Oncol*. 2020;31(8):1056-1074.

[4]Lee Y, Kung P, Wang Y, Kuo W, Kao S, Tsai W. Effect of length of time from diagnosis to treatment on colorectal cancer survival: A population-based study. *PLoS One*. 2019;14(1):e0210465.

[5]Richards MA, Westcombe AM, Love SB, Littlejohns P, Ramirez AJ. Influence of delay on survival in patients with breast cancer: a systematic review. *Lancet.* 1999;353(9159):1119-1126.

[6]Mano R, Vertosick EA, Hakimi AA, et al. The effect of delaying nephrectomy on oncologic outcomes in patients with renal tumors greater than 4cm. *Urol Oncol*. 2016;34(5):239.e1-8.

[7]Smith EC, Ziogas A, Anton-Culver H. Delay in surgical treatment and survival after breast cancer diagnosis in young women by race/ethnicity. *JAMA Surg*. 2013;148(6):516-523.

[8]Chu AT, Holt SK, Wright JL, et al. Delays in radical cystectomy for muscle-invasive bladder cancer. *Cancer*. 2019;125(12):2011-2017.

[9]May M, Nitzke T, Helke C, Vogler H, Hoschke B. Significance of the time period between diagnosis of muscle invasion and radical cystectomy with regard to the prognosis of transitional cell carcinoma of the urothelium in the bladder. *Scand J Urol Nephrol*. 2004;38(3):231-235.

[10]Samson P, Patel A, Garrett T, et al. Effects of delayed surgical resection on short-term and long-term outcomes in clinical stage I non-small cell lung cancer. *Ann Thorac Surg*. 2015;99(6):1906-1912.

[11]Yang CJ, Wang H, Kumar A, et al. Impact of timing of lobectomy on survival for clinical stage IA lung squamous cell carcinoma. *Chest*. 2017;152(6):1239-1250.

Supplemental Table 1. Cancer types included in major cancer sites evaluated in the study and diagnostic codes used to identify patients with these cancers in Ontario health administrative databases.

Major cancer site group	Cancer type	ICD-10-CA diagnostic codes
Breast	Breast	C5020, C5091, C5099, C5011, C5010, C5019, C5021, C5029, C5030, C5031, C5039, C5040, C5041, C5049, C5050, C5051, C5059, C5090, C5089, C5080, C5081, C7980, D050, D051, D057, D059, D486, D24, N608, N609, N63
Gastrointestinal	Colorectal Esophagus Gastric	C150, C151, C152, C153, C154, C155, C158, C159, C160, C161, C162, C163, C164, C165, C166, C168, C169, C170, C171, C172, C173, C178, C179, C180, C181,C182, C184, C185, C186, C187, C188, C189, C19, C210, C211, C212, C20, C260, C268, C269, C451, C457, C459, C480, C481, C482, C488, C785, C784, C786, C788, C883, D001, D002, D010, D011, D012, D013, D014, D017, D019, D120, D121, D122, D123, D124, D125, D126, D127, D128, D129, D130, D131, D133, D139, D191, D197, D199, D200, D201, D371, D372, D373, D375, D374, D377, D379, D379, D483, D484
Genitourinary	Bladder Renal Penile Testis	C600, C601, C602, C608, C609, C6200, C6201, C6209, C6210, C6211, C6219, C6290, C6291, C6299, C630, C632, C637, C638, C639, C64, C65, C66, C676, C670, C671, C672, C673, C674, C675, C678, C679, C680, C681,C688, C689, C790, C791, D074, D076, D090, D290, D292, D293, D294, D297, D299, D300, D302, D303, D304, D307, D309, D401, D407, D409, D410, D411, D412, D413, D414, D417, D419
Gynecological	Cervical Endometrial Ovarian	C510, C511, C512, C518, C519, C52, C530, C531, C538, C539, C540, C541, C542, C543, C548, C549, C55, C560, C569, C5700, C5701, C5709, C571, C572, C573, C574, C577, C578, C579, C58, C796, D0000, D060, D061, D067, D069, D070, D071, D072, D073, D25, D27,

		D280, D281, D282, D287, D289, D390, D391, D392, D397, D399, N890, N891, N892, N893
Head and Neck (excl. endocrine)	Head and neck Nasopharyngeal	C020, C021, C022, C023, C024, C028, C029, C030, C031, C039, C040, C041, C048, C049, C050, C051, C052, C058, C059, C061, C060, C062, C068, C069, C070, C080, C081, C088, C089, C090, C091, C098, C099, C100, C101, C102, C103, C104, C108, C109, C110, C111, C112, C113, C118, C119, C12, C130, C131, C132, C138, C139, C140, C142, C3000, C3001, C301, C310, C311, C312, C313, C318, C319, C320, C321,C322, C323, C328, C329, C4100, C4101, C411, C432, C442, C462, C752, C770 D0001, D0002, D0003, D0004, D0005, D0006, D0007, D0008, D0009, D020, D032, D042, D105, D106, D107, D109, D110, D117, D119, D140, D141, D164, D165, D353, D3702, D3705, D3708, D380, D444, D37031, D3703, D37032, D37039, D3704
Hepatobiliary	Biliary Hepatic Pancreas	C170, C183, C220, C221, C222 C223, C224, C227, C229, C23, C240, C241, C248, C249, C250, C252, C253, C257, C258, C259, C281 C787, D015, D134, D135, D136, D376
Lung	Lung	C3400, C3401, C3409, C3410, C3411, C3419, C33, C37, C381, C382, C383, C388, C342, C3430, C3431, C3439, C3480, C3481, C3489, C3490, C3491, C3499, C390, C398, C399, C413, C451, C457, C459, C4671, C480, C481, C482, C488, C761, C780, C783, C786, C384, C450, C781, C782, D021, D022, D023, D024, D142, D143, D144, D150, D152, D157, D159, D167, D190, D191, D197, D199, D200, D201, D381, D382, D383, D384, D385, D386, D483, D484
Prostate	Prostate	C61, D075, D291, D400

Supplemental Table 2. Proportions of simulated cases removed from wait list due to use of mitigation strategy with either systemic therapy or radiotherapy prior to cancer surgery.

Cancer site	Mitigation strategy	Proportion of patients excluded
Breast	Systemic therapy	18%
GI	Systemic therapy	15%
GU	Systemic therapy	7%
Gyne	Systemic therapy	0
HN	Radiation therapy	9%
HPB	Systemic therapy	20%
Lung	Systemic therapy and radiotherapy	15%
Prostate	Systemic therapy and radiotherapy	10%

Abbreviations: GI: gastrointestinal; GU: genitourinary; Gyne: gynecological; HN: head and neck; HPB: hepatobiliary.

Supplemental Table 3. Observed mean wait-times for cancer surgeries in Ontario compared with simulated wait-times from the pre-pandemic model, by disease site.*

Cancer site	Observed real-world wait time	Simulated model wait time
All cases	25	25
Breast	18	18
GI	22	21
GU	29	30
Gyne	27	26
HN	29	28
HPB	24	23
Lung	22	22
Prostate	51	52

*From July 2019, as reported in the Ontario Health Cancer Care Ontario – Wait Time Information System database.

Abbreviations: GI: gastrointestinal; GU: genitourinary; Gyne: gynecological; HN: head and neck; HPB: hepatobiliary.

Supplemental Table 4. Wait-time mortality scenario analyses exploring uncertainty in expected mortality with increases in wait-time to cancer surgery*

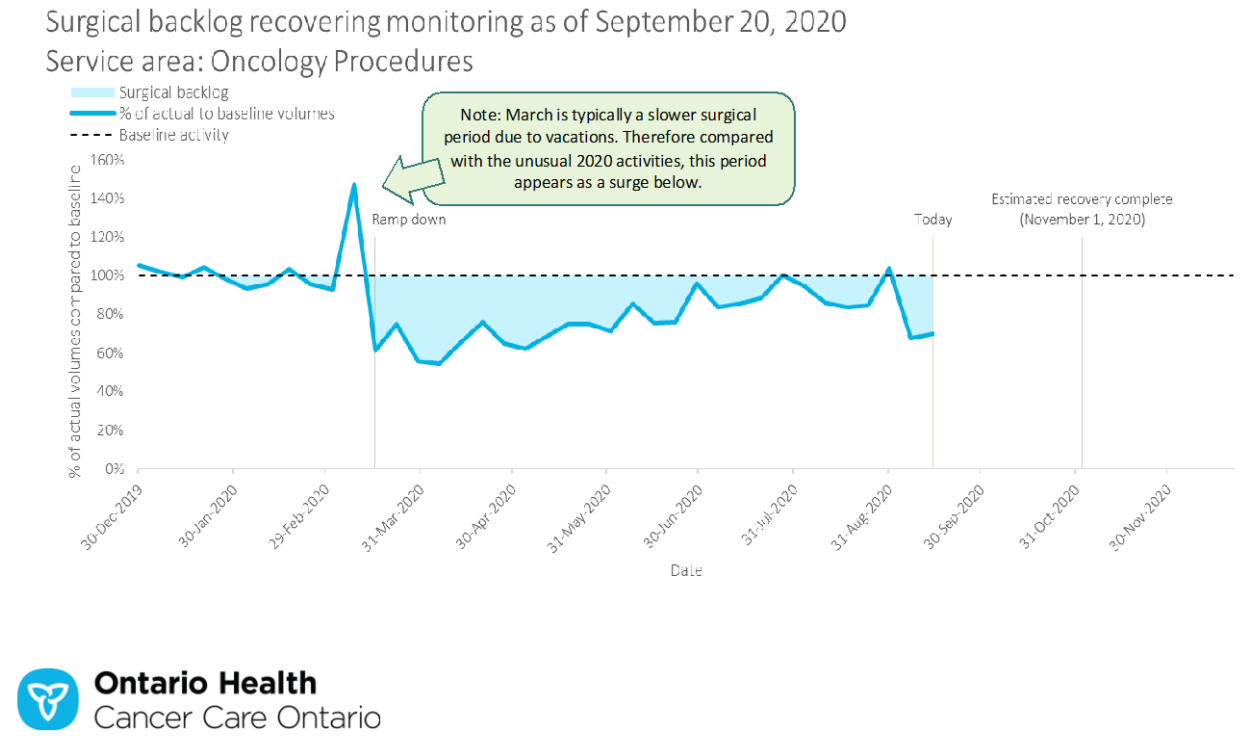
Cancer site	Life-years lost per patient		
	WM-1	WM-2	WM-3
Breast	0.00 (0.00,0.01)	0.01 (0.00,0.01)	0.01 (0.00,0.01)†
GI	0.05 (0.04,0.05)	0.05 (0.05,0.06)	0.05 (0.05,0.06)†
GU	0.06 (0.06,0.07)	0.07 (0.06,0.07)	0.07 (0.06,0.07)†
Gyne	0.04 (0.03,0.04)	0.04 (0.04,0.06)	0.04 (0.02,0.05)†
HN	0.05 (0.04,0.06)	0.06 (0.05,0.07)	0.09 (0.08,0.10)
HPB	0.02 (0.02,0.03)	0.02 (0.02,0.04)	0.03 (0.02,0.06)
Lung	0.04 (0.04,0.05)	0.05 (0.04,0.06)	0.04 (0.04,0.05)†
Prostate	0.02 (0.01,0.03)	0.02 (0.02,0.03)	0.02 (0.02,0.03)†

* Scenario analyses were conducted by varying the daily hazard ratio that was used to model increased mortality due to increase in wait-times to cancer surgery. The life-years lost, as compared to modeled pre-pandemic populations is shown using hazard ratios that reflect lower risk of mortality due to increases in wait-times for all cancers (WM-1), higher risk of mortality due to increases in wait-times for all cancers (WM-2), or higher risk of mortality due to increases in wait-times for cancers with low 5-year survival (WM-3).

†In this scenario, the daily hazard ratio was the same as the base-case analysis.

Abbreviations: GI: gastrointestinal; GU: genitourinary; Gyne: gynecological; HN: head and neck; HPB: hepatobiliary.

Supplemental Figure 1.



Ontario Health
Cancer Care Ontario

Figure legend. Data from Ontario Health – Cancer Care Ontario depicting oncology surgical volumes in the first 6-months of the pandemic, relative to baseline values (depicted as 100%). This data informed the surgical slow-downs for our model's simulated pandemic operating room resources such that the resources were simulated at 60% for the first month post-pandemic declaration, 70% for the second month and 85% for months 3-6.

Supplemental Figure 2.

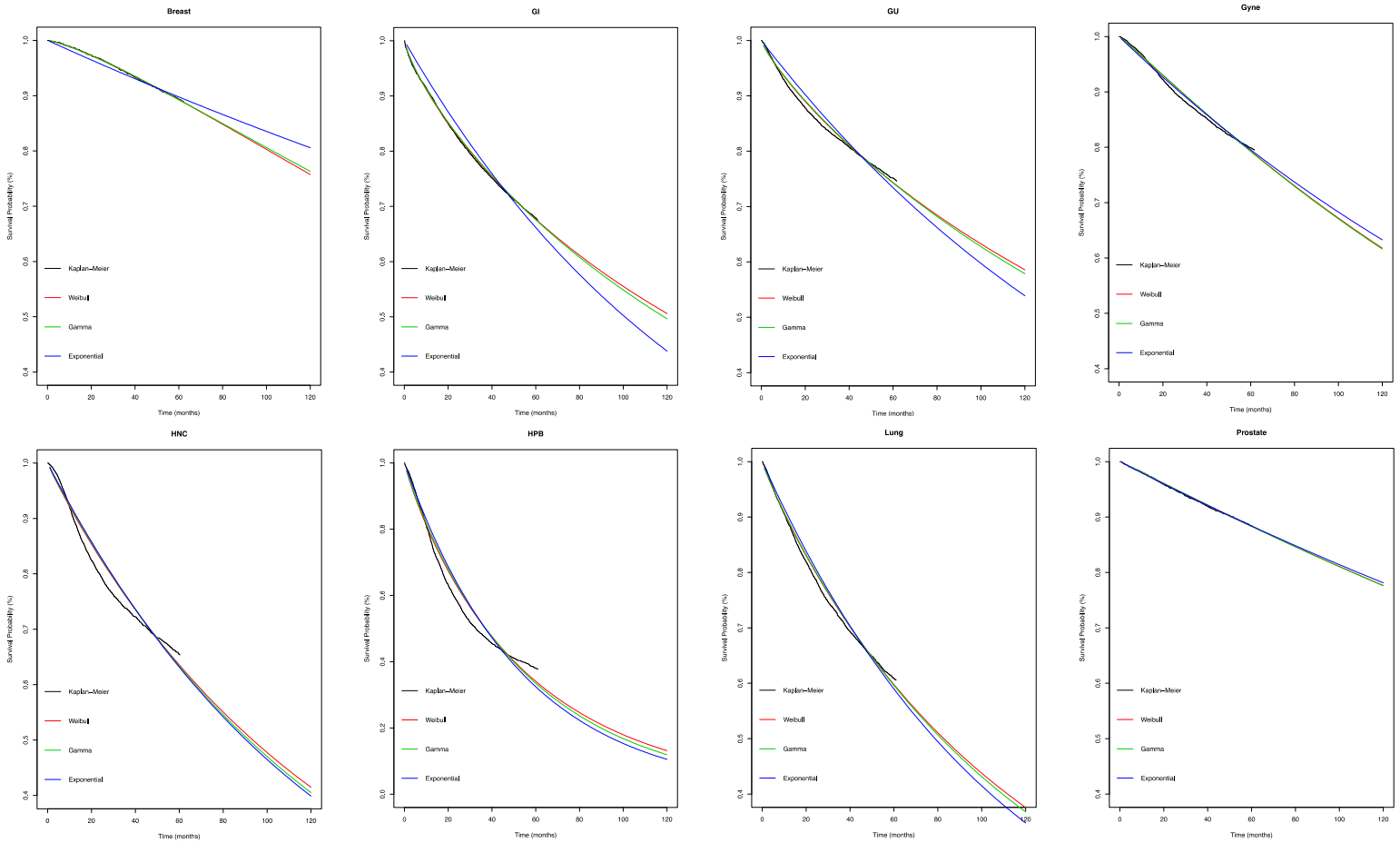


Figure Legend. Parametric distributions fitted to observed survival data for each major cancer disease site. Parametric distributions in the proportional hazards family (i.e. Weibull, gamma, exponential) were fitted to observed survival data from the Ontario cancer population. For all survival curves, the Weibull parametric distribution demonstrated best fit.

Abbreviations: GI: gastrointestinal; GU: genitourinary; Gyne: gynecological; HN: head and neck; HPB: hepatobiliary.