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Impact of COVID-19 on cancer incidence, presentation, diagnosis, treatment and survival in Northern Ireland

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Abstract

The COVID-19 pandemic had a major impact on cancer patients and services but has been difficult to quantify. We examined how the entire cancer pathway—from incidence, presentation, diagnosis, stage, treatment and survival—was affected in Northern Ireland during April–December 2020 compared to equivalent 2018–2019 periods using retrospective, observational cancer registry data from the Northern Ireland Cancer Registry (NICR). There were 6748 cancer cases in April–December 2020 and an average 7724 patients in April–December 2018–2019. Incident cases decreased by 13% (almost 1000). Significant differences were found across age cohorts and deprivation quintiles, with reductions greatest for younger people (<55 years; 19% decrease) and less deprived (22% decrease). A higher proportion had emergency admission (16%-to-20%) with lower proportions diagnosed pathologically (85%-to-83%). There was a significant stage shift, with lower proportions of early stage (29%-to-25%) and higher late-stage (21%-to-23%). Lower proportions received surgery (41%-to-38%) and radiotherapy (24%-to-22%) with a higher proportion not receiving treatment (29%-to-33%). One-year observed-survival decreased from 73.7% to 69.8% and 1-year net-survival decreased from 76.1% to 72.9%, with differences driven by five tumours; Lung (40.3%-to-35.0%), Head-and-Neck (77.4%-to-68.4%), Oesophageal (53.5%-to-42.3%), Lymphoma (81.1%-to-75.2%) and Uterine cancer (87.4%-to-80.4%). Our study reveals profound adverse impact of COVID-19 on the entire cancer patient pathway, with 13% fewer cases, greater emergency admissions and significant stage-shift from early to more advanced-stage disease. There was major treatment impact with lower rates of surgery and radiotherapy and higher proportions receiving no treatment. There were significant reductions in 1-year survival. Our study will support service recovery and protect cancer services in future pandemics or disruptions.

KEYWORDS

cancer, COVID-19 impact, stage, survival, treatment

What's new?

Population-level assessments of the impact of the COVID-19 pandemic on the cancer patient pathway, from presentation to survival, are lacking. Here, the authors compared data on cancer incidence, presentation, diagnosis, stage, treatment and survival in Northern Ireland from April through December 2020 to equivalent time periods in 2018 and 2019. Overall, there were 13% fewer cancer cases and more emergency admissions in 2020. A significant shift from early to more advanced stage disease at time of diagnosis was observed, and higher proportions of patients went untreated. The findings could inform efforts to minimize cancer care disruptions in future pandemics.

1 | INTRODUCTION

On March 11, 2020, the World Health Organization declared coronavirus disease 2019 (COVID-19) a pandemic.[1] The COVID-19 pandemic overwhelmed health and cancer care systems and forced radical re-organization and redistribution of healthcare staff, treatment and patient care across the world, including Northern Ireland and the United Kingdom. Many non-essential healthcare services were adapted, suspended or shutdown, with concerns ongoing regarding the impact of the pandemic on the availability and usage of health and cancer care services.[2] The pandemic also caused huge societal disruption with multiple lockdowns and widespread restrictions.[3,4]

Cancer remains a leading cause of death and early intervention can improve patient outcomes.[5] However, restricted and disrupted access to healthcare services during the pandemic as well as altered health-seeking behaviour has impacted on the number of cancer cases diagnosed in Northern Ireland and will likely influence patient outcomes.[6–8] A range of international studies has reported delays and disturbances to aspects of cancer pathways including cancer screening and treatment, including surgery, radiotherapy and chemotherapy.[8–20]

Recent studies assessing COVID-19 impact in NI reported reductions in pathology-confirmed cancers compared to Scotland and Wales and reduced emergency hospital admissions for Northern Ireland cancer patients.[7,8] A recent study found reduced lung, breast and colorectal pathology-confirmed cancers in Northern Ireland and the Netherlands compared to Aotearoa/New Zealand, which reflect differences in disruptions to screening and healthcare services, patient presentations to primary and secondary care and wider societal restrictions.[21]

While studies have examined parts of the cancer patient pathway, we are not aware of a population-based study which examines the impact of the COVID-19 pandemic on the entire cancer patient pathway, from presentation to diagnosis through to treatment and finally to survival. Our study utilises pre-pandemic and inter-pandemic data to describe changes in finalised cancer registrations in Northern Ireland, to assess changes by demographic (age, sex) and socioeconomic (deprivation) characteristics, to investigate differences in mode of presentation, basis of diagnosis and stage distribution at diagnosis, to examine changes in treatments received and differences in overall and net survival 1-year following diagnosis.

2 | METHODS

Data on all cancer cases (excluding non-melanoma skin cancer [NMSC]) diagnosed in Northern Ireland in 2018–2020 were extracted from NICR; a population-based registry with complete coverage of Northern Ireland's population of 1.91 million people, which uses pathology reports, hospital admissions and death registrations to identify cancers. Date of cancer diagnosis, based upon European Network of Cancer Registries recommendations,[22] is the date of first histological or cytological confirmation of malignancy. Cancer data were coded using the International Classification of Diseases (ICD-10),[23] with codes C00–C97 (excluding C44) used to identify relevant cases, and specific cancer types classified using the codes outlined in Table S1. Staging classifications were based on TNM Version 8.[24] Socioeconomic deprivation was determined using the 2017 Northern Ireland multiple deprivation measure (NIMDM),[25] with patients assigned to deprivation quintiles based on postcode-derived area of residence,[26] ranging from quintile 1 (most deprived) to quintile 5 (least deprived). A very small proportion of records (0.03% in 2018–2020) had an unknown, incomplete or invalid postcode and deprivation quintiles could not be assigned to these areas. Method of admission to hospital was derived from the Patient Administration System (PAS) which includes records of all inpatient hospital admissions in Northern Ireland. Treatment data (surgery, chemotherapy, radiotherapy, hormone therapy) were determined from multiple systems including PAS, Regional Information System for Oncology & Haematology (RISOH), Radiotherapy information system (ARIA) and prescription information from the Business Services Organisation (BSO).

2.1 | Evaluating changes over time

To investigate if COVID-19 impacted cancer incidence, the number of cancer cases in Northern Ireland (ex NMSC) were compared for the period April to December 2020 with the average of equivalent periods for April to December 2018–2019, which were used for baseline comparison. The change in distribution over time for specific groups was evaluated using the χ^2 test. Statistical significance is reported for *P*-values <.05, but note is made of *P*-values which would not be significant if adjustments for multiple comparisons, using the Bonferroni correction, were applied.

TABLE 1 Number and proportion of all cancer cases diagnosed in April–December of 2018–2020 by sex, age bands, deprivation quintile, basis of diagnosis, stage at diagnosis, admission type and treatment received—comparing between April–December 2020 and April–December 2018–2019.

	(April–December)			
	2018–2019	2020	Percentage change (%)	*P*-value
Total				
All persons	7724	6748	−12.6% (976 patients)	
Gender				
Male	3908 (50.6%)	3480 (51.6%)	−11.0% (428 patients)	$P = .181$
Female	3816 (49.4%)	3268 (48.4%)	−14.4% (548 patients)	
Age group				
0–54	1359 (17.6%)	1106 (16.4%)	−18.6% (253 patients)	$P = .020$*
55–64	1498 (19.4%)	1308 (19.4%)	−12.7% (190 patients)	
65–74	2252 (29.2%)	1918 (28.4%)	−14.8% (334 patients)	
74 and over	2617 (33.9%)	2416 (35.8%)	−7.7% (201 patients)	
Deprivation quintile				
Most deprived	1411 (18.3%)	1307 (19.4%)	−7.4% (104 patients)	$P = .003$**
Quintile 2	1594 (20.6%)	1400 (20.7%)	−12.2% (194 patients)	
Quintile 3	1542 (20.0%)	1412 (20.9%)	−8.4% (130 patients)	
Quintile 4	1568 (20.3%)	1368 (20.3%)	−12.8% (200 patients)	
Least deprived	1608 (20.8%)	1257 (18.6%)	−21.8% (351 patients)	
Basis of diagnosis				
Pathological diagnosis	6574 (85.1%)	5585 (82.8%)	−15.0% (989 patients)	$P < .001$**
Clinical diagnosis	1068 (13.8%)	1026 (15.2%)	−3.9% (42 patients)	
Specific tumour marker	11 (0.1%)	14 (0.2%)	+27.3% (3 patients)	
Death certificate only/unknown	72 (0.9%)	123 (1.8%)	+70.8% (51 patients)	
Stage at diagnosis				
Stage I	2260 (29.3%)	1696 (25.1%)	−25.0% (564 patients)	$P < .001$**
Stage II	1182 (15.3%)	1060 (15.7%)	−10.3% (122 patients)	
Stage III	1320 (17.1%)	1213 (18.0%)	−8.1% (107 patients)	
Stage IV	1580 (20.5%)	1566 (23.2%)	−0.9% (14 patients)	
Unknown	1383 (17.9%)	1213 (18.0%)	−12.3% (170 patients)	
Method of admission to hospital				
Emergency admission	1212 (15.7%)	1315 (19.5%)	+8.5% (103 patients)	$P < .001$**
Elective admission	2996 (38.8%)	2663 (39.5%)	−11.1% (333 patients)	
No emergency/elective admission recorded	3517 (45.5%)	2770 (41.0%)	−21.2% (747 patients)	
Treatment type				
Surgery	3190 (41.3%)	2579 (38.2%)*	−19.2% (611 patients)	$P < .001$**
Chemotherapy	1986 (25.7%)	1806 (26.8%)	−9.1% (180 patients)	$P = .098$
Radiotherapy	1858 (24.1%)	1506 (22.3%)*	−18.9% (352 patients)	$P = .005$*
Hormone therapy	1457 (18.9%)	1215 (18.0%)	−16.6% (242 patients)	$P = .131$
None of these treatments	2251 (29.1%)	2253 (33.4%)*	+0.1% (2 patients)	$P < .001$**

*Statistically significant without correction for multiple comparisons.
**Statistically significant after correction for multiple comparisons.

2.2 | Survival analysis

Patient survival up to 1-year post diagnosis was evaluated using two measures. Observed survival examines the time between diagnosis and death from any cause, while age-standardised net survival provides an estimate of patient survival which has been adjusted to take account of deaths unrelated to cancer. Observed survival is calculated using the Kaplan–Meier approach with statistically significant

TABLE 2 Number and proportion of cancer cases diagnosed in April–December of 2018–2020 by stage at diagnosis and period of diagnosis—comparing between April–December of 2020 and April–December 2018–2019 (Stage at diagnosis only available for certain tumour types).

	Total cases	Stage I	Stage II	Stage III	Stage IV	Unknown	Sig
All cancers (excl NMSC)							
2018–2019	7724	2260 (29.3%)	1182 (15.3%)	1320 (17.1%)	1580 (20.5%)	1383 (17.9%)	$P < .001$
2020	6748	1696 (25.1%)	1060 (15.7%)	1213 (18.0%)	1566 (23.2%)	1213 (18.0%)	
Diff	−12.6% (976 patients)	−25.0% (564 patients)	−10.3% (122 patients)	−8.1% (107 patients)	−0.9% (14 patients)	−12.3% (170 patients)	
Head and neck							
2018–2019	298	75 (25.2%)	39 (13.1%)	50 (16.8%)	117 (39.3%)	19 (6.4%)	NS
2020	230	43 (18.7%)	38 (16.5%)	39 (17.0%)	96 (41.7%)	14 (6.1%)	
Diff	−22.8% (68 patients)	−42.7% (32 patients)	−2.6% (1 patients)	−22.0% (11 patients)	−17.9% (21 patients)	−26.3% (5 patients)	
Oesophageal							
2018–2019	165	18 (10.9%)	13 (7.9%)	36 (21.8%)	66 (40.0%)	33 (20.0%)	NS
2020	130	7 (5.4%)	5 (3.8%)	37 (28.5%)	54 (41.5%)	27 (20.8%)	
Diff	−21.2% (35 patients)	−61.1% (11 patients)	−61.5% (8 patients)	+2.8% (1 patient)	−18.2% (12 patients)	−18.2% (6 patients)	
Lung							
2018–2019	1029 (13.3%)	196 (19.0%)	102 (9.9%)	236 (22.9%)	439 (42.7%)	57 (5.5%)	$P = .003$
2020	952 (14.1%)	160 (16.8%)	59 (6.2%)	225 (23.6%)	456 (47.9%)	52 (5.5%)	
Diff	−7.5% (77 patients)	−18.4% (36 patients)	−42.2% (43 patients)	−4.7% (11 patients)	+3.9% (17 patients)	−8.8% (5 patients)	
Melanoma							
2018–2019	334 (4.3%)	212 (63.5%)	49 (14.7%)	21 (6.3%)	9 (2.7%)	44 (13.2%)	NS
2020	205 (3.0%)	117 (57.1%)	40 (19.5%)	15 (7.3%)	7 (3.4%)	26 (12.7%)	
Diff	−38.6% (129 patients)	−44.8% (95 patients)	−18.4% (9 patients)	−28.6% (6 patients)	−22.2% (2 patients)	−40.9% (18 patients)	
Female breast							
2018–2019	1118 (14.5%)	463 (41.4%)	442 (39.5%)	116 (10.4%)	60 (5.4%)	37 (3.3%)	NS
2020	995 (14.7%)	367 (36.9%)	408 (41.0%)	123 (12.4%)	63 (6.3%)	34 (3.4%)	
Diff	−11.0% (123 patients)	−20.7% (96 patients)	−7.7% (34 patients)	+6.0% (7 patients)	+5.0% (3 patients)	−8.1% (3 patients)	
Uterine							
2018–2019	213 (2.8%)	144 (67.6%)	9 (4.2%)	29 (13.6%)	23 (10.8%)	10 (4.7%)	NS
2020	176 (2.6%)	105 (59.7%)	5 (2.8%)	27 (15.3%)	23 (13.1%)	16 (9.1%)	
Diff	−17.4% (37 patients)	−27.1% (39 patients)	−44.4% (4 patients)	−6.9% (2 patients)	0.0% (0 patients)	+60.0% (6 patients)	
Prostate							
2018–2019	1035 (13.4%)	452 (43.7%)	60 (5.8%)	236 (22.8%)	178 (17.2%)	111 (10.7%)	$P < .001$
2020	885 (13.1%)	365 (41.2%)	88 (9.9%)	168 (19.0%)	178 (20.1%)	86 (9.7%)	
Diff	−14.5% (150 patients)	−19.2% (87 patients)	+46.7% (28 patients)	−28.8% (68 patients)	0.0% (0 patients)	−22.5% (25 patients)	

TABLE 2 (Continued)

	Total cases	Stage I	Stage II	Stage III	Stage IV	Unknown	Sig
Kidney							
2018–2019	237 (3.1%)	132 (55.7%)	15 (6.3%)	40 (16.9%)	37 (15.6%)	14 (5.9%)	$P = .033$
2020	161 (2.4%)	70 (43.5%)	8 (5.0%)	40 (24.8%)	35 (21.7%)	8 (5.0%)	
Diff	−32.1% (76 patients)	−47.0% (62 patients)	−46.7% (7 patients)	0.0% (0 patients)	−5.4% (2 patients)	−42.9% (6 patients)	
Lymphoma							
2018–2019	320 (4.1%)	45 (14.1%)	61 (19.1%)	66 (20.6%)	114 (35.6%)	34 (10.6%)	NS
2020	280 (4.1%)	29 (10.4%)	55 (19.6%)	51 (18.2%)	121 (43.2%)	24 (8.6%)	
Diff	−12.5% (40 patients)	−35.6% (16 patients)	−9.8% (6 patients)	−22.7% (15 patients)	+6.1% (7 patients)	−29.4% (10 patients)	

differences evaluated using the log-rank test. Net survival is calculated using the Pohar–Perme method,[27] with calculations completed using the stns module in STATA.[28] Given that survival from cancer is dependent upon age at diagnosis, net survival estimates are also age-standardised using the direct method with the standard populations suggested by Corazziari et al,[29] but collapsed to four age groups due to the small number of events in the Northern Ireland population for specific age ranges. Observed and net survival values are both accompanied by 95% confidence intervals.

Data on lung, breast, prostate and colorectal cancer and skin melanoma alongside data on tumour sites that had significant survival differences (head and neck, oesophageal, uterine cancer and lymphoma), are shown in Tables 1–4 and Figure 1A–C, with complete data on all cancers reported in Tables S1–S8 and Figures S1–S40.

3 | RESULTS

Overall, there was a 12.6% (976 patients) decrease in the number of cancer cases in April–December 2020 (6748 patients) compared to the same period in 2018–2019 (7724 patients) (Table 1).

3.1 | Patient characteristics and demographics

The number of male cases decreased by 11.0% (3908 in 2018–2019 to 3480 in 2020) and female cases by 14.4% (3816–3268), but this change was not significant (Table 1). The number of cases aged 0 to 54 decreased by 18.6%, from 1359 in 2018–2019 to 1106 in 2020, while the number of cases aged 75 and over decreased by 7.7% (2617–2416) and this change was significant without correction for multiple comparisons ($P = .020$) (Table 1). The largest proportional decrease in cases (−21.8%) occurred in the least deprived quintile while the smallest decrease (−7.4%) occurred in the most deprived quintile. Consequently, there was a smaller proportion of cases from the least deprived quintile in 2020 compared to 2018–2019 (18.6% vs 20.8%), and a larger proportion from the most deprived quintile (19.4% in 2020 vs 18.3% in 2018–2019), and this change was significant after correction for multiple comparisons ($P = .003$) (Table 1).

3.2 | Hospital admission type and basis of diagnosis

A significant change in the pattern of hospital admission was found with a higher proportion diagnosed following emergency admission (15.7% in 2018–2019 and 19.5% in 2020; $P < .001$). A reduced proportion of patients had pathologically diagnosed cancers (85.1% in 2018–2019 and 82.8% in 2020), an increased proportion had clinical diagnosis (13.8%–15.2%) and an increased proportion were diagnosed by death certificate only (0.9%–1.8%), with the change in case distribution by basis of diagnosis statistically significant ($P < .001$) (Table 1). There was a significant change in the basis of lung cancer diagnoses

TABLE 3 Number and proportion of cancer cases diagnosed in April–December of 2018–2020 by treatment received and period of diagnosis—comparing between April–December of 2020 and April–December 2018–2019 (Treatment data only available for certain tumour types).

	Total cases	Surgery	Chemotherapy	Radiotherapy	None of these treatments	Hormone therapy
All cancers (excl NMSC)						
2018–2019	7724	**3190 (41.3%)**	1986 (25.7%)	**1858 (24.1%)**	**2251 (29.1%)**	1457 (18.9%)
2020	6748	**2579 (38.2%)***	1806 (26.8%)	**1506 (22.3%)***	**2253 (33.4%)***	1215 (18.0%)
Diff	−12.6% (976 patients)	−19.2% (611 patients)	−9.1% (180 patients)	−18.9% (352 patients)	+0.1% (2 patients)	−16.6% (242 patients)
Head and neck						
2018–2019	298	136 (45.6%)	60 (20.1%)	184 (61.7%)	**36 (12.1%)**	
2020	230	92 (40.0%)	47 (20.4%)	137 (59.6%)	**44 (19.1%)****	
Diff	−22.8% (68 patients)	−32.4% (44 patients)	−21.7% (13 patients)	−25.5% (47 patients)	+22.2% (8 patients)	
Oesophageal						
2018–2019	165	82 (49.7%)	88 (53.3%)	37 (22.4%)	26 (15.8%)	
2020	130	71 (54.6%)	64 (49.2%)	29 (22.3%)	22 (16.9%)	
Diff	−21.2% (35 patients)	−13.4% (11 patients)	−27.3% (24 patients)	−21.6% (8 patients)	−15.4% (4 patients)	
Colorectal						
2018–2019	906	650 (71.7%)	310 (34.2%)	120 (13.2%)	172 (19.0%)	
2020	797	552 (69.3%)	291 (36.5%)	117 (14.7%)	164 (20.6%)	
Diff	−12.0% (109 patients)	−15.1% (98 patients)	−6.1% (19 patients)	−2.5% (3 patients)	−4.7% (8 patients)	
Liver						
2018–2019	120 (1.6%)	34 (28.3%)	9 (7.5%)	9 (7.5%)	**76 (63.3%)**	
2020	97 (1.4%)	35 (36.1%)	11 (11.3%)	7 (7.2%)	**50 (51.5%)***	
Diff	−19.2% (23 patients)	+2.9% (1 patients)	+22.2% (2 patients)	−22.2% (2 patients)	−34.2% (26 patients)	
Lung						
2018–2019	1029 (13.3%)	**129 (12.5%)**	242 (23.5%)	**346 (33.6%)**	**476 (46.3%)**	
2020	952 (14.1%)	**77 (8.1%)***	224 (23.5%)	**254 (26.7%)***	**516 (54.2%)***	
Diff	−7.5% (77 patients)	−40.3% (52 patients)	−7.4% (18 patients)	−26.6% (92 patients)	+8.4% (40 patients)	
Melanoma						
2018–2019	334 (4.3%)	**250 (74.9%)**	7 (2.1%)		**82 (24.6%)**	
2020	205 (3.0%)	**117 (57.1%)***	9 (4.4%)		**81 (39.5%)***	
Diff	−38.6% (129 patients)	−53.2% (133 patients)	+28.6% (2 patients)		−1.2% (1 patient)	
Female breast						
2018–2019	1118 (14.5%)	859 (76.8%)	393 (35.2%)	**509 (45.5%)**	**28 (2.5%)**	725 (64.8%)
2020	995 (14.7%)	738 (74.2%)	343 (34.5%)	**381 (38.3%)***	**37 (3.7%)***	658 (66.1%)
Diff	−11.0% (123 patients)	−14.1% (121 patients)	−12.7% (50 patients)	−25.1% (128 patients)	+32.1% (9 patients)	−9.2% (67 patients)

TABLE 3 (Continued)

	Total cases	Surgery	Chemotherapy	Radiotherapy	None of these treatments	Hormone therapy
Uterine						
2018–2019	213 (2.8%)	**169 (79.3%)**	36 (16.9%)	**47 (22.1%)**	**23 (10.8%)**	17 (8.0%)
2020	176 (2.6%)	**121 (68.8%)***	30 (17.0%)	**59 (33.5%)***	**32 (18.2%)***	13 (7.4%)
Diff	−17.4% (37 patients)	−28.4% (48 patients)	−16.7% (6 patients)	+25.5% (12 patients)	+39.1% (9 patients)	−23.5% (4 patients)
Prostate						
2018–2019	1035 (13.4%)	**96 (9.3%)**	**73 (7.1%)**	283 (27.3%)	**273 (26.4%)**	**657 (63.5%)**
2020	885 (13.1%)	**57 (6.4%)***	**83 (9.4%)***	249 (28.1%)	**315 (35.6%)***	**488 (55.1%)***
Diff	−14.5% (150 patients)	−40.6% (39 patients)	+13.7% (10 patients)	−12.0% (34 patients)	+15.4% (42 patients)	−25.7% (169 patients)
Kidney						
2018–2019	237 (3.1%)	130 (54.9%)	**13 (5.5%)**	13 (5.5%)	93 (39.2%)	
2020	161 (2.4%)	80 (49.7%)	**17 (10.6%)***	12 (7.5%)	71 (44.1%)	
Diff	−32.1% (76 patients)	−38.5% (50 patients)	+30.8% (4 patients)	−7.7% (1 patients)	−23.7% (22 patients)	

Note: The values in bold are shown for the number and proportion of treatment types which were significantly different between the 2 time periods, by tumour site.

*$P < .05$.

with reduced proportion with pathological diagnoses (67.7%–61.4%), and increased proportion with clinical diagnoses (31.9%–37.6%). There were increased proportions diagnosed by death certificate for uterine cancer (1.4%–4.5%) and leukaemia (2.9%–4.9%) (Table S5).

3.3 | Stage

There was a significant change in case distribution by stage at diagnosis for all cancers overall, with a reduction in proportion with Stage 1 (29.3%–25.1%) and increase in proportion with Stage IV tumours (20.5%–23.2%) ($P < .001$) (Table 1). There were significant shifts in stage at diagnosis for certain cancers, with the proportion of lung cancer cases diagnosed with most advanced disease (Stage IV) rising from 42.7% to 47.9%, while the proportion with earlier stage (I or II) disease reduced from 28.9% to 23.0% (Table 2). For prostate cancers patients, with reduced proportions with Stage I (43.7%–41.2%) and Stage III (22.8%–19.0%) and increased proportions with Stage II (5.8%–9.9%) and Stage IV (17.2%–20.1%). Kidney cancer patients had significantly reduced proportions of Stage I (55.7%–43.5%) and increased proportions with Stage III (16.9%–24.8%) and Stage IV (15.6%–21.7%) (Table 2).

In other sites the change in case distribution was not found to be significant, for example, the proportion of breast cancer patients diagnosed with Stage I disease reduced from 41.4% to 36.9% while the proportion diagnosed with Stage III and IV increased from 15.8% to 18.7%, though this change in case distribution by stage was not significant. Similarly for colorectal cancer patients, there was a small reduction in the proportion diagnosed with Stage I (15.3%–14.3%) and a moderate increase in those diagnosed with Stage III and IV (49.5%–53.0%). For melanoma patients there was a reduction in the proportion diagnosed with Stage I disease (63.5%–57.1%) and an increase in those diagnosed with Stage II (14.7%–19.5%), but the change in overall case distribution by stage was not significant (Table 2). For all other tumour sites, including stomach, pancreatic, liver, gallbladder, uterine, ovarian, cervical, bladder, testicular and thyroid the change in overall case distribution by stage was not significant (Table S6).

3.4 | Treatment

There were significant changes in treatments received by cancer patients in the initial pandemic period. There was a significant reduction in the proportion of patients undergoing surgery, from 41.3% to 38.2% ($P < .001$) and a significant reduction in the proportion receiving radiotherapy, from 24.1% to 22.3% ($P = .005$). There was an increase in the proportion receiving chemotherapy (25.7%–26.8%), although this difference was not significant, and no significant difference in the proportion receiving hormone therapy (18.9%–18.0%). The largest change was found in those receiving no treatment, which increased from 29.1% in 2018–2019 to 33.4% in 2020 ($P < .001$) (Table 1).

TABLE 4 Observed and net survival for patients with cancer diagnosed in April–December of 2018–2020 by period of diagnosis—comparing between April–December of 2020 and April–December 2018–2019.

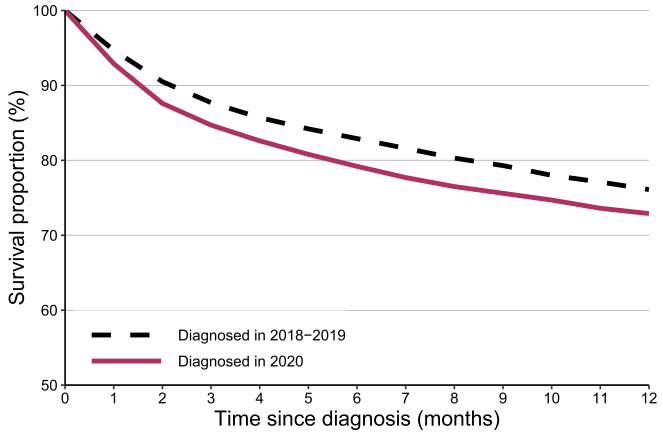
	Observed survival		Log-rank test between survival functions	Net survival	
	2018–2019	2020		2018–2019	2020
All cancers (excl NMSC)					
3 months	86.7% (86.1%–87.3%)	**83.3% (82.3%–84.2%)***		87.7% (87.2%–88.2%)	**84.7% (83.7%–85.7%)***
6 months	81.3% (80.7%–82.0%)	**77.0% (75.9%–78.1%)***		82.9% (82.3%–83.6%)	**79.2% (78.1%–80.3%)***
One-year	73.7% (72.9%–74.4%)	**69.8% (68.6%–70.9%)***	***P* < .001**	76.1% (75.4%–76.8%)	**72.9% (71.6%–74.2%)***
Head and neck					
3 months	94.4% (92.2%–96.0%)	90.6% (85.8%–93.8%)		93.7% (91.3%–96.1%)	90.0% (85.5%–94.7%)
6 months	88.3% (85.3%–90.6%)	82.1% (76.3%–86.7%)		88.0% (84.9%–91.2%)	81.9% (76.0%–88.2%)
One-year	77.4% (73.7%–80.6%)	68.4% (61.7%–74.2%)	***P* = .001**	76.8% (72.8%–81.0%)	68.5% (61.6%–76.1%)
Oesophageal					
3 months	81.8% (77.1%–85.5%)	73.8% (65.4%–80.5%)		83.8% (79.9%–87.8%)	73.7% (65.7%–82.7%)
6 months	69.9% (64.6%–74.6%)	60.0% (51.1%–67.8%)		73.1% (68.3%–78.3%)	62.7% (54.2%–72.5%)
One-year	53.5% (48.0%–58.7%)	42.3% (33.7%–50.6%)	***P* = .039**	57.5% (52.0%–63.5%)	43.4% (34.4%–54.8%)
Stomach					
3 months	75.4% (69.8%–80.0%)	71.4% (62.7%–78.3%)		76.8% (71.7%–82.3%)	76.0% (68.9%–83.8%)
6 months	65.2% (59.3%–70.5%)	55.1% (46.1%–63.2%)		67.7% (62.0%–73.9%)	61.9% (53.6%–71.4%)
One-year	44.5% (38.5%–50.2%)	39.6% (31.1%–47.9%)	*P* = .497	46.9% (41.0%–53.6%)	46.2% (37.6%–56.8%)
Colorectal					
3 months	88.3% (86.7%–89.7%)	87.1% (84.4%–89.2%)		90.5% (89.1%–91.9%)	89.8% (87.7%–91.9%)
6 months	82.7% (80.8%–84.4%)	82.3% (79.4%–84.8%)		85.9% (84.2%–87.6%)	85.9% (83.4%–88.5%)
One-year	75.2% (73.2%–77.2%)	77.0% (73.8%–79.8%)	*P* = .957	80.1% (78.1%–82.2%)	82.2% (79.4%–85.2%)
Liver					
3 months	60.9% (54.3%–66.8%)	64.2% (53.7%–72.9%)		61.8% (55.5%–68.8%)	66.5% (57.1%–77.5%)
6 months	48.1% (41.6%–54.3%)	55.8% (45.2%–65.1%)		50.2% (43.7%–57.7%)	57.1% (47.0%–69.3%)
One-year	34.9% (28.9%–41.0%)	38.9% (29.2%–48.6%)	*P* = .576	37.6% (31.5%–44.9%)	41.7% (31.4%–55.4%)
Pancreas					
3 months	55.7% (50.7%–60.4%)	49.0% (42.3%–55.3%)		62.3% (57.5%–67.5%)	52.7% (45.8%–60.7%)
6 months	40.9% (36.1%–45.8%)	35.7% (29.5%–41.9%)		48.2% (42.9%–54.1%)	38.2% (31.5%–46.3%)
One-year	27.7% (23.4%–32.2%)	23.8% (18.5%–29.5%)	*P* = .224	34.5% (29.5%–40.4%)	27.6% (21.8%–35.0%)
Lung					
3 months	69.7% (67.6%–71.6%)	**62.6% (59.4%–65.7%)***		71.7% (69.5%–74.0%)	**64.9% (61.6%–68.4%)***
6 months	56.7% (54.5%–58.9%)	**48.9% (45.7%–52.1%)***		60.1% (57.8%–62.5%)	**52.4% (49.0%–56.0%)***
One-year	40.3% (38.1%–42.4%)	35.0% (32.0%–38.1%)	***P* = .002**	43.3% (40.9%–45.8%)	39.0% (35.6%–42.7%)
Melanoma					
3 months	99.5% (98.6%–99.9%)	99.0% (96.1%–99.7%)		99.8% (99.4%–100.0%)	99.3% (98.1%–100.0%)
6 months	98.8% (97.6%–99.4%)	98.5% (95.4%–99.5%)		99.3% (98.5%–100.0%)	99.2% (97.8%–100.0%)
One-year	95.1% (93.1%–96.5%)	96.5% (92.8%–98.3%)	*P* = .345	97.5% (96.0%–99.0%)	98.6% (96.5%–100.0%)
Female breast					
3 months	98.7% (98.1%–99.1%)	97.7% (96.5%–98.5%)		98.9% (98.3%–99.5%)	97.8% (96.7%–99.0%)
6 months	97.4% (96.6%–98.0%)	96.6% (95.2%–97.6%)		98.0% (97.0%–99.0%)	96.9% (95.4%–98.4%)
One-year	95.0% (94.0%–95.9%)	94.6% (92.9%–95.9%)	*P* = .449	96.4% (95.1%–97.7%)	95.7% (93.8%–97.6%)

TABLE 4 (Continued)

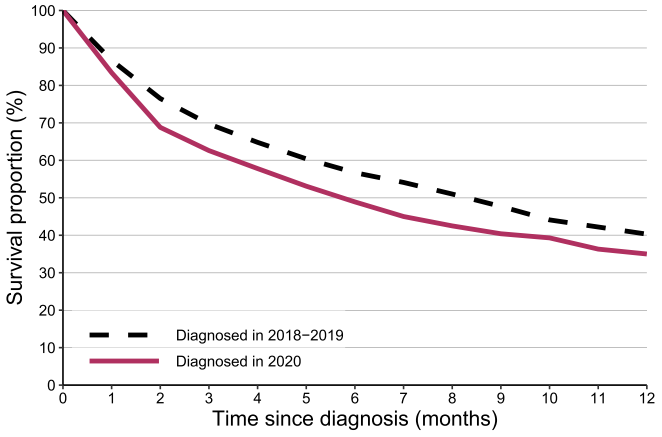
	Observed survival		Log-rank test between survival functions	Net survival	
	2018–2019	2020		2018–2019	2020
Cervical					
3 months	99.3% (95.0%–99.9%)	100%		99.6% (98.8%–100.0%)	100%
6 months	97.8% (93.5%–99.3%)	98.1% (87.4%–99.7%)		98.3% (96.2%–100.0%)	99.0% (97.1%–100.0%)
One-year	92.8% (87.0%–96.1%)	92.5% (81.1%–97.1%)	$P = .385$	92.3% (86.9%–98.1%)	85.3% (70.8%–100.0%)
Uterine					
3 months	94.3% (91.6%–96.1%)	91.7% (86.3%–95.0%)		94.7% (92.5%–97.0%)	92.2% (88.1%–96.5%)
6 months	91.2% (88.1%–93.6%)	86.9% (80.8%–91.2%)		91.8% (89.0%–94.7%)	87.9% (82.9%–93.2%)
One-year	87.4% (83.8%–90.2%)	80.4% (73.5%–85.6%)	**$P = .009$**	88.6% (85.4%–92.0%)	82.2% (76.4%–88.4%)
Ovarian					
3 months	85.2% (80.8%–88.6%)	81.3% (73.2%–87.2%)		84.8% (80.6%–89.2%)	80.3% (72.1%–89.4%)
6 months	80.2% (75.5%–84.2%)	77.2% (68.8%–83.7%)		80.2% (75.5%–85.2%)	76.0% (67.3%–85.8%)
One-year	71.2% (66.0%–75.8%)	72.4% (63.5%–79.4%)	$P = .626$	70.9% (65.3%–77.0%)	71.3% (62.3%–81.6%)
Prostate					
3 months	98.3% (97.6%–98.8%)	96.7% (95.3%–97.7%)		99.2% (98.6%–99.8%)	97.8% (96.8%–98.8%)
6 months	97.0% (96.2%–97.7%)	**94.8% (93.2%–96.1%)***		98.6% (97.8%–99.4%)	96.7% (95.4%–98.0%)
One-year	93.7% (92.5%–94.7%)	92.8% (90.9%–94.3%)	$P = .293$	96.9% (95.8%–98.0%)	96.2% (94.7%–97.7%)
Kidney					
3 months	90.1% (87.0%–92.5%)	86.0% (79.5%–90.5%)		90.8% (88.2%–93.5%)	87.1% (82.0%–92.6%)
6 months	86.1% (82.6%–88.9%)	77.7% (70.4%–83.4%)		87.2% (84.0%–90.5%)	78.7% (72.2%–85.8%)
One-year	80.0% (76.1%–83.4%)	73.2% (65.6%–79.5%)	$P = .075$	82.1% (78.5%–85.9%)	74.6% (67.6%–82.3%)
Bladder					
3 months	89.1% (85.4%–91.9%)	85.9% (79.7%–90.3%)		91.3% (87.8%–95.0%)	90.8% (86.8%–95.0%)
6 months	81.6% (77.2%–85.3%)	76.5% (69.3%–82.2%)		83.5% (78.7%–88.6%)	84.0% (78.7%–89.6%)
One-year	68.0% (62.9%–72.5%)	60.6% (52.8%–67.5%)	$P = .111$	73.0% (67.8%–78.6%)	72.0% (65.4%–79.3%)
Brain and CNS					
3 months	68.3% (61.8%–74.0%)	74.8% (65.4%–81.9%)		78.9% (73.7%–84.5%)	80.4% (73.3%–88.2%)
6 months	52.7% (45.9%–59.0%)	53.3% (43.4%–62.2%)		66.9% (60.3%–74.2%)	66.4% (56.4%–78.1%)
One-year	36.2% (29.9%–42.4%)	32.7% (24.0%–41.6%)	$P = .847$	53.5% (44.8%–63.8%)	45.8% (33.8%–62.1%)
Lymphoma					
3 months	90.7% (88.1%–92.7%)	85.6% (80.8%–89.2%)		91.1% (88.8%–93.5%)	87.1% (83.1%–91.3%)
6 months	87.5% (84.6%–89.8%)	80.7% (75.5%–85.0%)		88.3% (85.6%–91.1%)	83.2% (78.6%–88.1%)
One-year	81.1% (77.8%–83.9%)	75.2% (69.6%–79.9%)	**$P = .035$**	82.8% (79.6%–86.1%)	78.4% (73.3%–83.8%)
Myeloma					
3 months	92.9% (89.2%–95.3%)	94.1% (88.0%–97.1%)		94.5% (91.9%–97.1%)	94.9% (91.1%–98.9%)
6 months	89.3% (85.1%–92.4%)	88.1% (80.8%–92.8%)		92.1% (88.9%–95.4%)	91.0% (86.0%–96.3%)
One-year	83.6% (78.8%–87.5%)	78.8% (70.3%–85.2%)	$P = .144$	88.8% (85.1%–92.7%)	83.3% (76.6%–90.6%)
Leukaemia					
3 months	88.6% (84.9%–91.4%)	86.1% (79.9%–90.6%)		90.4% (87.4%–93.5%)	88.3% (83.6%–93.3%)
6 months	83.0% (78.8%–86.5%)	79.5% (72.5%–84.9%)		85.4% (81.6%–89.3%)	82.4% (76.5%–88.8%)
One-year	75.1% (70.4%–79.1%)	70.5% (62.9%–76.8%)	$P = .453$	78.6% (74.3%–83.2%)	74.7% (67.9%–82.2%)

Note: The values in bold show where observed or net survival (3month, 6 month or 1 year) was significantly different between the 2 time periods, by tumour site.

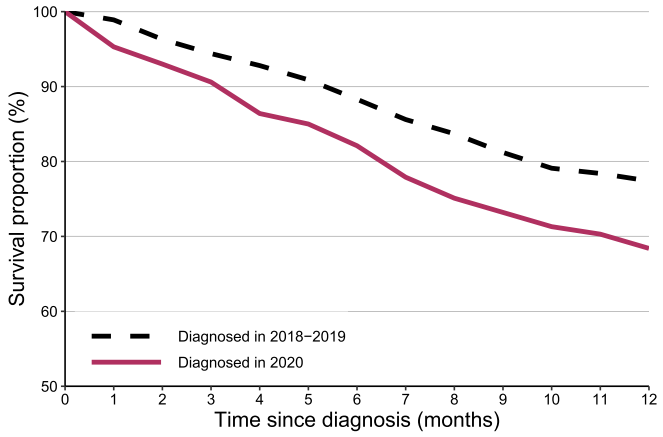
These findings were mirrored for certain tumour sites, with significant reduction in the proportion of lung cancer patients receiving surgery (12.5%–8.1%, $P < .001$) and radiotherapy (33.6%–26.7%, $P < .001$), no change in the proportion receiving chemotherapy, and a large, significant increase in the proportion not receiving any treatment (46.3%–54.2%, $P < .001$) (Table 3). There was a significant



(A) Age–standardised net survival for all patients with cancer (ex NMSC) diagnosed in April–December of 2018–2020 by period of diagnosis



(B) Observed survival for patients with lung cancer diagnosed in April–December of 2018–2020 by period of diagnosis



(C) Observed survival for patients with head and neck cancer diagnosed in April–December of 2018–2020 by period of diagnosis

FIGURE 1 (A) Age-standardised net survival for all patients with cancer (ex NMSC) diagnosed in April–December of 2018–2020 by period of diagnosis. (B) Observed survival for patients with lung cancer diagnosed in April–December of 2018–2020 by period of diagnosis. (C) Observed survival for patients with head and neck cancer diagnosed in April–December of 2018–2020 by period of diagnosis.

reduction in the proportion of prostate cancer patients receiving surgery (9.3%–6.4%, $P = .012$) or hormone therapy (63.5%–55.1%, $P < .001$), with a significantly increased proportion receiving chemotherapy (7.1%–9.4%, $P = .030$) and a large, significant increase in the proportion not receiving any treatment (26.4%–35.6%, $P < .001$). For breast cancer, there was a significant reduction in the proportion of patients receiving radiotherapy (45.5%–38.3%, $P < .001$), but no significant difference in the proportions receiving surgery, chemotherapy or hormone therapy (Table S8), and a small but significant increase in the proportion not receiving any treatment (2.5%–3.7%, $P = .047$). For colorectal patients there was no significant difference in the proportions receiving surgery, chemotherapy or radiotherapy or in those not receiving any treatment (Table 3).

The most common finding across tumour sites was an increased proportion of patients not receiving any treatment (melanoma [24.6%–39.5%], HAN [12.1%–19.1%]). Conversely for liver cancer there was a significant increase in patients received any treatment compared to previous years (63.3%–51.5%, $P = .046$).

For some tumour sites, it appears a modal shift occurred; for example for uterine cancer patients a reduced proportion received surgery (79.3%–68.8%, $P = .007$) while an increased proportion received radiotherapy (from 22.1% to 33.5%, $P = .003$). A significantly increased proportion of kidney cancer patients received chemotherapy (5.5%–10.6%, $P = .027$) (Table S8). Other tumour sites such as pancreatic, gallbladder, oesophageal, ovarian, stomach, testicular, bladder and cervical cancer also found no significant difference in the proportions receiving different treatment modalities (Table S8).

3.5 | Survival

Significant reductions in short-term survival were found, with 6-month observed survival decreasing from 81.3% for those diagnosed in April–December 2018–2019, to 77.0% for those diagnosed in April–December 2020 (Table 4). One-year survival was significantly reduced from 73.7% to 69.8% between the same two diagnosis

periods (Log-rank test of equality found a statistically significant difference between survival functions for 2018–2019 and 2020 [$P < .001$] [Table 4, Figure 1A]). Age-standardised net survival (ASNS) was also significantly reduced with 1-year ASNS decreased from 76.1% (patients diagnosed April–December 2018–2019) to 72.9% (patients diagnosed April–December 2020) and 6-month ASNS reduced from 82.9% to 79.2% between the same two time periods. ASNS takes account of deaths from other causes, including COVID-19.

Significant differences between 1-year observed survival functions (SF) for 2018–2019 and 2020 were found for five tumour sites, namely, Lung (40.3%–35.0% [1-year timepoint (1yrTP), $P = .002$ (SF)]), Head and Neck (77.4%–68.4% [1yrTP], $P = .001$ [SF]), Oesophageal (53.5%–42.3% [1yrTP], $P = .039$ [SF]), Lymphoma (81.1%–75.2% [1yrTP], $P = .035$ [SF]) and Uterine cancer (87.4%–80.4% [1yrTP], $P = .009$ [SF]) (Table 4, Figure 1B,C, S5, S6, S23, S24, S35 and S36).

4 | DISCUSSION

The impact of COVID-19 on elements of the cancer pathway and for specific tumour sites have been reported, but this is the first to study reveal the stark, adverse impact of COVID-19 on the entire cancer patient journey, from initial presentation and diagnosis through to treatment and survival, at a population level and for all tumour sites.[9–13,30–32] Overall, there was a 13% (almost 1000) reduction in new (incident) cancer cases with variations by tumour type, ranging from reductions of 39% for melanoma to 3.6% for stomach cancer and reductions of 7.5% for lung, 11% for female breast, 12% for colorectal and 14.5% for prostate cancer, respectively. In the pre-pandemic period cancer cases had risen steadily in NI and were projected to continue increasing, so the reduction in cancer cases was unprecedented and shows the profound impact of COVID on cancer diagnoses.[33] However, this was less than the 23% reduction in pathologically diagnosed (PD) cancers previously reported for Northern Ireland in 2020 and also less than the 27% reduction in cancer diagnoses during the COVID-19 pandemic reported in a recent meta-analysis of population-based studies.[17,34] However, these studies often relied exclusively on cancers identified from pathological samples, which highlights the importance of assessing finalised, complete population-based cancer registrations to obtain a completer and more accurate picture, as in the current study.

Some cancers, namely pancreatic and gallbladder, did not experience a reduction in cases, which may be due to their severity of symptoms, but which also suggest that Hepato-Pancreato-Biliary (HPB) pathways may have maintained during the initial stages of the pandemic. A study in the Netherlands also reported pancreatic cancer incidence in the second quarter of 2020 to be similar to 2017–2019, and indeed reported increased incidence in the fourth quarter of 2020.[35]

There were significant differences across age cohorts and deprivation quintiles, with reductions greatest for younger people (<55 years;19% decrease) and those residing in least deprived areas (22% decrease). Younger women were impacted by the pause on population-based breast and cervical cancer screening programs, which are available to women under 55 years in Northern Ireland. Younger patients may also have had less severe disease symptoms, which may have been easier to ignore during initial periods of draconian COVID restrictions. Furthermore, those of working age experienced huge, sudden lifestyle disruptions, including working from home (WFH) and managing childcare and home-schooling, which may have led to symptoms being ignored and avoidance of healthcare settings. Those from less deprived areas may have strictly followed, and even over-interpreted, stay-at-home advice and avoided attending healthcare settings even when symptoms developed.

The significantly higher proportion with an emergency admission before diagnosis (16% compared to 20%) may have been due to severe restrictions in access to GP and non-emergency HC settings at early stages of pandemic and sudden alterations to how primary care services were delivered with moves to online bookings and phone and video consultations.[36] The significantly lower proportions diagnosed pathologically (85%-to-83%) may have been due to restricted access to diagnostics in early stages of the pandemic. Reductions in small biopsy diagnostic procedures and cancer resections were reported in the early pandemic period in an Irish region, suggesting a COVID-19 impact on both diagnostic and therapeutic services.[37]

There was significant stage shift to more advanced disease, with lower proportions of cases diagnosed at an early stage (29% compared to 25%) and higher proportions diagnosed at a late-stage (21% compared to 23%). Pauses, interruptions and reduced capacity with breast, bowel and cervical cancer screening programs, which identify early-stage cancers, have been highlighted as a potential factor in delayed diagnosis and reduced detection of early-stage cancers.[30,38] Lower proportions of early-stage breast cancers, and higher proportions of later stage, have been associated with pandemic-related reduced breast screening volumes.[30] In Northern Ireland the Department of Health (DOH) paused routine cancer screening services on April 7, 2020, with breast cancer screening temporarily paused for 4 months.[39,40] The increase in later-stage diagnosis may be associated with delays in presentation of people with symptoms due to COVID-related healthcare and societal restrictions. Delays in presentation associated with COVID have been reported in a hospital-based study from Barcelona, which suggested their findings of significantly longer intervals between symptoms onset and cancer diagnosis in the early COVID period (median 39 days) compared to the pre-pandemic period (20 days), were a possible factor associated with the shift to later disease stage. An English study which found a reduction of one-third in prostate cancer cases also reported a higher proportion with advanced stage disease (Stage IV: 21.2% vs 17.4%) in 2020 compared to 2019.[41]

Reduced 1-year survival for all cancers overall was driven by five tumours; Lung Head and Neck, Oesophageal, Lymphoma and Uterine cancer. Regarding lung cancer, the similarity and overlap of symptoms with COVID-19 have created particular challenges, with individuals with a new cough and breathlessness advised to isolate and test for

COVID-19, which may have led to delayed or missed diagnoses.[42] Indeed, a study reported that people avoided healthcare services despite having concerning symptoms, or if they felt COVID-19 was the cause of their symptoms, while another reported reduction in people presenting with cough to primary care in 2020.[43,44] In Northern Ireland pathologically diagnosed lung cancer cases have been particularly slow in returning to pre-pandemic levels, while deficits in lung cancer referrals from GPs in the United Kingdom remain.[42,45]

Severe access restrictions and reduced attendance at dentists and dental services due to pandemic are likely contributory factors to both the later stage at diagnosis and poorer survival of HAN cancer patients found in our study. Indeed, the dramatic reduction in dental visits in Northern Ireland at the start of the pandemic has not recovered, which is concerning as regular dental visits have been shown to be associated with earlier stage of diagnosis for oral and pharyngeal cancers and dentists have been acknowledged as key to management of patients treated for head and neck cancer.[46–48]

For other tumours no survival differences were found, with survival functions very similar for pandemic and pre-pandemic periods for breast, bowel and cervical cancers, although longer term follow-up is required. Interestingly there were no short-term survival differences for cancers with established screening programs, namely breast, colorectal and cervical cancers, suggesting the impact of short-term screening delay may be limited. A previous study of breast cancer found that delays of 6–12 weeks had little impact on overall outcome.[49] Another study reported worse survival for delays over 12 weeks, but that within individual stages, longer delays had no adverse survival impact.[50] Differences in both observed and net survival were found our study suggesting that the pandemic impacted on both cancer-related and non-cancer related mortality for cancer patients in NI.

4.1 | Limitations

Although our study confirms the stark extent of COVID-19 impacts, due to the multiple factors at play, including societal and travel restrictions, reduced access to healthcare and the public's reluctance to attend healthcare settings, alongside unmeasured confounding, our study cannot isolate definitive causes. The adverse psychological impact of the COVID-19 pandemic on individual cancer patients has been reported, but our study had no access to patients reported outcome or experience measures (PROMs/PREMs). Survival data was only available to 1 year post-diagnosis, but medium to longer-term monitoring will be undertaken. Data on patient co-morbidities, which may have contributed to non-cancer related mortality, was not available. Although this is a population-based study, there is the potential that stage and survival differences in the less common tumours in Northern Ireland may not have been detectable due to the smaller baseline population.

5 | CONCLUSIONS

The COVID-19 pandemic had a profound impact on cancer patient pathways in Northern Ireland with almost 1000 fewer cases, greater proportions diagnosed by emergency admission and significant stage-shift away from early to more advanced stage disease. There was major treatment impact with lower rates of surgery and radiotherapy and, worryingly, significantly higher proportions receiving no treatment. There were significant reductions in 1-year observed (any cause) and net (cancer-specific) survival. Our study confirms the stark, adverse impact of COVID-19 on the entire cancer patient pathway at population level—from presentation, diagnosis, stage, treatment through to survival, which will need close monitoring for recovery. Our study will help target public health campaigns to identify and treat 'missing' patients as well as informing service recovery and assisting efforts to protect cancer services in future pandemics or systemic disruptions to healthcare system.

AUTHOR CONTRIBUTIONS

Damien Bennett: Concept design and research implementation; preparation of article; review and editing of article; supervision of project. **Inez Murray:** Concept design and research implementation; preparation of article; review and editing of article. **Helen Mitchell:** Concept design and research implementation; review and editing of article. **Anna Gavin:** Concept design and research implementation; review and editing of article. **David Donnelly:** Concept design and research implementation; original data collection and primary analysis; review and editing of article. The work reported in the article has been performed by the authors, unless clearly specified in the text.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The datasets generated and/or analysed during the current study can be requested to NICR. De-identified, non-patient level data and further information are available from the corresponding author on reasonable request.

ETHICS STATEMENT

NICR has ethical approval for collection of the data used in our study – Northern Ireland Research Ethics Committee (NIREC) Reference Number: 20/NI/0132.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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