Original Article

The effect of diagnostic assessment programs on the diagnosis and treatment of patients with lung cancer in Ontario, Canada

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Abstract:

INTRODUCTION: Diagnostic assessment programs (DAPs) were implemented in Ontario, Canada, to improve the efficiency of the lung cancer care continuum. We compared the efficiency and effectiveness of care provided to patients in DAPs relative to usual care (non-DAPs).

METHODS: Lung cancer patients diagnosed between 2014 and 2016 were identified from the Ontario Cancer Registry. Using administrative databases, we identified various health-care encounters 6 months before diagnosis until the start of treatment and compared utilization patterns, timing, and overall survival between DAP and non-DAP patients.

RESULTS: DAP patients were younger ($P < 0.0001$), had fewer comorbidities ($P = 0.0006$), and were more likely to have early-stage disease (36% vs. 25%) than non-DAP patients. Although DAP patients had a similar time until diagnosis as non-DAP patients, the time until treatment was 8.5 days shorter for DAP patients. DAP patients were more likely to receive diagnostic tests and specialist consultations and less likely to have duplicate chest imaging. DAP patients were more likely to receive brain imaging. Among early-stage lung cancers, brain imaging was high (74% for DAP and 67% for non-DAP), exceeding guideline recommendations. After adjustment for clinical and demographic factors, DAP patients had better overall survival than non-DAP patients (hazard ratio [HR]: 0.79 [0.76–0.82]), but this benefit was lost after adjusting for emergency presentation (HR: 0.96 [0.92–1.00]). A longer time until treatment was associated with better overall survival.

CONCLUSION: DAPs provided earlier treatment and better access to care, potentially improving survival. Quality improvement opportunities include reducing unnecessary or duplicate testing and characterizing patients who are diagnosed emergently.

Keywords:

Diagnostic assessment program, efficiency, guideline concordance, imaging, lung cancer, wait times

For patients with lung cancer, prolonged diagnostic work-up or treatment planning can delay the start of treatment, rendering some patients inoperable and adversely affecting prognosis.[1-3] In light of this, some guidelines recommend a time from suspicion of lung cancer until diagnosis of 28 days and a time from diagnosis until treatment of 4–6 weeks.[4-6]

Given the importance of starting treatment as early as possible, a recent scoping review was conducted to better understand the variation in wait times across the lung cancer care continuum.[7] The authors identified 27 studies reporting median wait times from symptom onset until diagnosis ranging from 41 to 143 days and from diagnosis until the start of treatment ranging from 6 to 45 days. Another scoping review examined the effect of various interventions aimed at reducing

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these wait times, but most of the studies found focused on the time period leading up to diagnosis and many patients did not meet the recommended timeliness targets.[8-11]

Since 2010, lung diagnostic assessment programs (DAPs) were established across Ontario, Canada, to provide efficient and accessible diagnostic evaluation and treatment planning for patients with suspected lung cancer.[12,13] Services provided by DAPs include patient navigation, specialist consultations, and psychosocial support according to the standards outlined in Cancer Care Ontario's Lung Cancer Diagnostic Pathway Map.[12] In the current study, we report the effect of lung DAPs on health-care utilization, wait times, and overall survival.

Methods

Cohort selection

Patients with primary lung carcinomas were identified from the Ontario Cancer Registry (OCR) using the ICD-O-3 codes C340–349 restricted to the AJCC version 7 ICD-O-3 histology codes 8000–8576, 8940–8950, and 8980–8981. Patients were categorized as having small-cell lung cancer (histology codes 8041–8045) or non-small-cell lung cancer (all remaining histologies). Only malignant cases (ICD-O-3 behavior code 3) diagnosed between 2014 and 2016 were included.

Patients were excluded if they were <18 or >105 years of age at diagnosis, were diagnosed at the time of death or at autopsy, had an invalid health insurance number (a number unique to each Ontario resident used to access health-care services), were missing age or sex, or had multiple cancer diagnoses in their lifetime. To enable accurate capture of diagnostic and treatment interventions, we excluded patients who had a missing or non-Ontario postal code of residence at the time of diagnosis or had no record in the Ontario Health Insurance Program (OHIP) database within 1 year plus/minus diagnosis.

Data sources

Patients' death dates were obtained from the OCR and supplemented with the Registered Persons Database (RPDB), which contains information on vital statistics for all Ontarians. We obtained sex from the RPDB and neighborhood-level income quintile, immigrant density, urban/rural status, and region of residence from the 2006 Canadian Census using postal codes of residence at the time of diagnosis (linked using the Postal Code Conversion File Plus version 6a). Staging data were obtained from the Collaborative Staging database maintained by Ontario Health . The weighted Charlson Comorbidity Index was calculated (excluding cancer) based on hospital data up to 3 years before the OCR diagnosis date.[14]

Health-care encounters were identified using physician billing codes from OHIP or procedural codes from the Discharge Abstract Database (DAD; inpatient procedures) or the National Ambulatory Care Reporting System (NACRS; outpatient procedures) [Appendix 1]. The date of resective lung surgery was identified using OHIP, DAD, or NACRS [Appendix 2]. Systemic therapy information was obtained from the Activity Level Reporting database, Ontario Drug Benefit Program, New Drug Funding Program, DAD, and NACRS. We included any agent with antineoplastic activity, including chemotherapy, immunotherapy, hormonal therapy, or targeted therapy. Information about radiation was obtained from the Activity Level Reporting database, restricted to radiation applied to the chest.

We classified patients as having had an emergency visit if they had any record in NACRS with an emergency department indicator = 1 or a hospital admission record from DAD with entry code "E" within 7 days before the OCR diagnosis date (inclusive). We also classified patients as having been an inpatient on the diagnosis date if the OCR diagnosis date occurred between DAD admission and discharge dates (inclusive).

During the study period, each DAP in Ontario submitted data using the Diagnostic Data Upload Tool (DDUT). Patient-level data from lung DAPs in the DDUT database were used to identify whether a patient was diagnosed through a DAP.

Definitions

The date of diagnosis was obtained from the OCR, which preferentially uses the specimen retrieval date from the pathology report where evidence of cancer was confirmed. A patient was considered a "DAP patient" if they had a diagnosis date in the DDUT database ± 30 of the OCR diagnosis date. This 60-day window allowed for differences in how diagnosis is ascertained from the two data sources. All other patients were considered "non-DAP patients."

We defined the diagnostic interval as the time until the lung cancer diagnosis. To identify the starting point of the diagnostic interval, we searched for the first health-care encounter occurring within 6 months before diagnosis, restricting to a general practitioner visit, chest X-ray, chest computed tomography (CT) scan, abdominal CT scan, bronchoscopy, endobronchial ultrasound, chest fluoroscopy, or consultation with a respirologist, general surgeon, general thoracic surgeon, internal medicine specialist, or cardiologist. In sensitivity analysis, we omitted the visit to the general practitioner to provide estimates

of the diagnostic interval that were more comparable to published studies that also excluded this date.

We defined the pretreatment interval as the time from diagnosis until the start of treatment within 6 months after diagnosis. We also report the time from the first health-care encounter until treatment initiation as a measure of the duration of the entire diagnostic and treatment planning interval.

We reported the number of health-care encounters for each patient as the number of unique dates on which a patient had one or more health-care encounters.

Statistical methods

We used logistic regression to compare DAP and non-DAP patients' characteristics, linear regression to explore factors associated with continuous outcomes (e.g., wait times), and Cox proportional hazards regression for time-to-event analysis (e.g., overall survival). We also presented unadjusted overall survival analyses using Kaplan–Meier plots. We adjusted analyses for all covariates considered clinically relevant. Unless otherwise indicated, covariates included age, sex, urban/rural residence, neighborhood income quintile, neighborhood immigrant density, region of residence at the level of Local Health Integration Network (LHIN), Euclidean distance to the nearest DAP, Charlson Comorbidity Index, stage, histology, emergency visit within 7 days of diagnosis, and hospital admission on the diagnosis date. We reported odds ratios (OR), beta coefficients, and hazard ratios (HR) with 95% confidence intervals (CI), where appropriate. We used SAS v9.4 for all analyses (Cary, North Carolina: SAS Institute Inc.).

Privacy

All analyses were conducted at Ontario Health for system monitoring and identifying areas for quality improvement. Cells with counts <6 were suppressed.

Results

Cohort characteristics

A total of 22,049 incident lung cancer patients were identified. The mean age at diagnosis was 71 (standard deviation [SD]: 10.4) years, and most patients lived in an urban area (84%) [Table 1]. After adjustment, patients were more likely to be diagnosed in a DAP if they were younger (OR: 0.89 [0.86–0.92] per 10 years), lived in a rural neighborhood (OR: 1.21 [1.08–1.35]), lived in a less immigrant-dense neighborhood (OR: 0.50 [0.43–0.58] for the most versus the least dense), and lived closer to a DAP (OR: 0.88 [0.84–0.93] per 50 km). There was significant regional variability ($P < 0.0001$). DAP patients had fewer comorbidities (68% vs. 63% had no comorbidities, $P = 0.0008$), were less likely to have stage IV disease or unknown stage ($P < 0.0001$), and were 60% less likely to have had an emergency visit (OR: 0.41 [0.36–0.45]) or hospital admission (OR: 0.38 [0.34–0.42]) at the time of diagnosis.

Health-care utilization for diagnosis and treatment

DAP patients had three fewer health-care encounters than non-DAP patients (median: 23 (18, 31) unique dates for DAP patients versus median: 26 (19, 36) unique for non-DAP patients, $P < 0.0001$), but there was no difference after restricting encounter types to diagnostic tests and consultations specific to diagnosing lung cancer (median: 8 for both DAP and non-DAP patients) [Appendix 3].

Diagnostic tests

DAP patients were more likely to have received a positron emission tomography (PET)-CT scan (70% vs. 36%), a bronchoscopy (48% vs. 37%), an endobronchial ultrasound (18% vs. 9%), and a biopsy (91% vs. 80%) but less likely to have had an abdominal CT scan (55% vs. 68%) [Figure 1 and Appendix 3]. Regardless of stage, DAP patients were more likely to have received a brain magnetic resonance imaging or CT scan (86% vs. 77% for stage IV and 69% vs. 64% for stage I). DAP patients were less likely to have received a second or a third chest CT than non-DAP patients (16% vs. 24% received >1 chest CT scans), even though the initial scan was frequently a non-contrast scan (74% for DAP and 75% of non-DAP). If second chest CTs did occur, they were performed a median of 3–4 weeks after the first scan for DAP patients and after a median of 4–5 weeks for non-DAP patients [Appendix 4].

Consultations

Among stage III/IV patients, DAP patients were more likely to have a consultation with a radiation oncologist and a medical oncologist. DAP patients were more likely to have a consultation with a general surgeon or general thoracic surgeon, regardless of stage.

Treatment

DAP patients were also more likely to receive treatment [Figure 1 and Appendix 3]: 67% versus 57% of stage I and 64% versus 42% of stage II patients received surgery; 66% versus 56% of stage III and 43% versus 30% of stage IV patients received radiation; and 58% versus 45% of stage III and 49% versus 34% of stage IV patients received systemic therapy. Overall, 1,329 (15%) of DAP patients and 4,130 (32%) of non-DAP patients had no evidence of surgery, radiation, or chemotherapy within 6 months of diagnosis.

Duration of intervals between investigations or consultations and diagnosis

For both DAP and non-DAP patients, the chest X-ray

Table 1: Patient characteristics by diagnosis in a diagnostic assessment program

	Non-DAP (*n*=12,913), *n* (%)	DAP (*n*=9136), *n* (%)	DAP versus non-DAP			
			Crude OR (95% CI)	*P*	Adjusted OR (95% CI)[a]	*P*
Age, years[b]	71.0 (10.6)	69.8 (10.0)	0.89 (0.87–0.91)	<0.0001	0.89 (0.86–0.92)	<0.0001
Sex						
Male	6589 (51)	4489 (49)	1.0 (reference)	0.006	1.0 (reference)	0.83
Female	6324 (49)	4647 (51)	1.08 (1.02–1.14)		1.01 (0.94–1.08)	
Urban residence[c]						
Urban	11251 (87)	7299 (80)	1.0 (reference)	<0.0001	1.0 (reference)	0.0007
Rural	1662 (13)	1837 (20)	1.70 (1.58–1.83)		1.21 (1.08–1.35)	
Income quintile[c]						
Highest	2062 (16)	1573 (17)	1.0 (reference)	0.0007	1.0 (reference)	0.11
Mid-high	2379 (18)	1826 (20)	1.01 (0.92–1.10)		1.11 (0.99–1.25)	
Middle	2564 (20)	1765 (19)	0.90 (0.83–0.99)		0.98 (0.87–1.10)	
Mid-low	2810 (22)	1913 (21)	0.89 (0.82–0.97)		0.97 (0.87–1.09)	
Lowest	3055 (24)	2028 (22)	0.87 (0.79–0.95)		1.04 (0.93–1.17)	
Immigrant density[c]						
Least dense	7724 (60)	6830 (75)	1.0 (reference)	<0.0001	1.0 (reference)	<0.0001
Mid-dense	2944 (23)	1659 (18)	0.64 (0.60–0.68)		0.77 (0.70–0.86)	
Most dense	2120 (17)	564 (6)	0.30 (0.27–0.33)		0.50 (0.43–0.58)	
Local Health Integration Network[c, e]						
Central	1573 (74)	556 (26)	1.0 (reference)	<0.0001	1.0 (reference)	<0.0001
Central East	1900 (70)	811 (30)	1.20 (1.06–1.36)		0.87 (0.73–1.04)	
Central West	635 (77)	189 (23)	0.84 (0.70–1.02)		0.70 (0.55–0.89)	
Champlain	729 (30)	1735 (70)	6.63 (5.83–7.54)		5.72 (4.77–6.85)	
Erie St. Clair	842 (61)	546 (39)	1.82 (1.57–2.10)		1.43 (1.18–1.74)	
Hamilton Niagara	1548 (55)	1274 (45)	2.29 (2.03–2.59)		1.71 (1.44–2.03)	
Mississauga Halton	882 (76)	273 (24)	0.90 (0.77–1.07)		0.80 (0.64–1.00)	
North East	902 (62)	558 (38)	1.74 (1.51–2.00)		1.47 (1.18–1.83)	
North Simcoe Muskoka	486 (46)	569 (54)	3.27 (2.80–3.81)		2.56 (2.07–3.17)	
North West	233 (50)	231 (50)	2.82 (2.30–3.46)		2.24 (1.69–2.99)	
South East	641 (51)	605 (49)	2.65 (2.29–3.07)		1.80 (1.46–2.22)	
South West	865 (49)	896 (51)	2.89 (2.53–3.30)		2.10 (1.74–2.53)	
Toronto Central	1050 (70)	452 (30)	1.22 (1.05–1.40)		1.05 (0.86–1.28)	
Waterloo Wellington	627 (59)	441 (41)	2.02 (1.74–2.36)		1.45 (1.18–1.79)	
Euclidean distance to closest DAP[b, c]						
Median (IQR)	11.9 (5.4, 30.5)	15.8 (5.6, 44.2)	–	–	–	-
Mean (SD)	30.5 (50.9)	34.1 (48.7)	1.05 (1.05–1.11)	<0.0001	0.88 (0.84–0.93)	<0.0001
Charlson Comorbidity Index						
Missing	2099 (16)	1485 (16)	0.92 (0.85–0.99)	<0.0001	0.91 (0.83–1.01)	
0	6125 (47)	4721 (52)	1.0 (reference)	<0.0001	1.0 (reference)	0.0008
1	2533 (20)	1658 (18)	0.85 (0.79–0.91)		0.83 (0.75–0.91)	
2	1071 (8)	661 (7)	0.80 (0.72–0.89)		0.85 (0.75–0.98)	
3+	1085 (9)	611 (7)	0.73 (0.66–0.81)		0.87 (0.76–1.00)	
Stage						
Stage I	1925 (19)	1843 (27)	1.0 (reference)	<0.0001	1.0 (reference)	<0.0001
Stage II	612 (6)	632 (9)	1.08 (0.95–1.23)		1.03 (0.90–1.18)	
Stage III	1573 (16)	1577 (23)	1.05 (0.95–1.15)		1.09 (0.98–1.22)	
Stage IV	5953 (59)	2829 (41)	0.50 (0.46–0.54)		0.75 (0.68–0.82)	
Unknown	72 (1)	32 (0)	0.46 (0.31–0.71)		0.57 (0.36–0.89)	
Histology						
Small cell	1616 (13)	1016 (11)	1.0 (reference)	0.002	1.0 (reference)	0.98
Non-small cell	11297 (87)	8120 (89)	1.14 (1.05–1.24)		1.00 (0.90–1.11)	
Emergency visit within 7 days of diagnosis[d,e]						
No	7237 (56)	7829 (86)	1.0 (reference)	<0.0001	1.0 (reference)	<0.0001

Contd...

Table 1: Contd...

	Non-DAP (*n*=12,913), *n* (%)	DAP (*n*=9136), *n* (%)	DAP versus non-DAP			
			Crude OR (95% CI)	*P*	Adjusted OR (95% CI)[a]	*P*
Yes	5676 (44)	1307 (14)	0.21 (0.20–0.23)		0.38 (0.34–0.42)	
Admission on diagnosis[f]						
No	6684 (52)	7494 (82)	1.0 (reference)	<0.0001	1.0 (reference)	<0.0001
Yes	6229 (48)	1642 (18)	0.23 (0.22–0.25)		0.38 (0.35–0.42)	

[a]Adjusted for all variables in the table, [b]Odds ratio reflects the odds of being diagnosed in a DAP for every 10-year increase in age or 50-kilometer increase in distance from patients' neighborhoods to the closest DAP, [c]Source (or adapted from): Statistics Canada Postal Code Conversion File and Postal Code Conversion File Plus (June 2017) which is based on data licensed from Canada Post Corporation. The patients' postal code at diagnosis was used.
[d]Row percentages shown, [e]Evidence of an inpatient record in the Discharge Abstract Database including the date of diagnosis, [f]Evidence of an emergency department visit on the date of diagnosis or within 7 days earlier. DAP=Diagnostic assessment program, IQR=Interquartile range (25th–75th percentile), SD=Standard deviation, OR=Odds ratio, CI=Confidence interval

was typically the earliest imaging procedure, occurring a median of 18 (0, 68) days before diagnosis for DAP patients and a median of 39 (15, 74) days before diagnosis for non-DAP patients [Appendix 4]. The time from diagnosis until PET scan was 3 weeks for non-DAP patients (median: 22 [−5, 38] days) but 5 days for DAP patients (median: 5 [−8, 20]). Both DAP and non-DAP patients waited 3 weeks after diagnosis to receive a consultation with a medical oncologist or a radiation oncologist. DAP patients received a consultation with a general thoracic surgeon a median of 8 days before diagnosis, yet non-DAP patients received these consultations a median of 2 days after diagnosis. The median wait time for a general thoracic surgeon consultation between DAP and non-DAP patients was similar for stage I patients (12–14 days) but shorter for DAP patients among stage II patients (median: −1 day vs. +10 days).

Wait time – diagnostic interval

The time from first health-care encounter until diagnosis was a median 61 (13, 130) days (mean: 73 [SD: 62] days) for non-DAP patients and a median 64 (33, 123) days (mean: 78 [SD: 54] days) for DAP patients. After adjustment, DAP patients had a similar time until diagnosis as non-DAP patients (beta: −0.8 [−2.7, 1.1] days) [Table 2]. The diagnostic interval was longer for patients with more comorbidities (beta: 11.5 [9.3, 13.7] days longer for patients with Charlson score 1 vs. 0); shorter for patients with more advanced disease (beta: −16.8 [−19.5, −14.1] days for patients with stage III disease vs. stage I); 1 month shorter for patients who visited the emergency department within 1 week before diagnosis (beta: −28.5 [−31.1, −26.0] days); and 10 days longer for patients who were admitted at the time of diagnosis (beta: 9.8 [7.5, 12.1] days). Geographically, the maximum difference was <10 days between the regions with the longest and shortest diagnostic intervals.

Wait time – pretreatment interval

The time from diagnosis until the start of treatment was similar between DAP (median: 41 [19, 69] days) and non-DAP patients (median: 39 [22, 58] days) [wait times by stage in Appendix 5]. After adjustment, DAP patients had a significantly shorter pretreatment interval (beta: −8.5 [−9.7, −7.3] days) [Table 2]. The pretreatment interval was longer for patients with non-small-cell lung cancer (beta: 20.5 [18.9, 22.2] days) and for patients who had an emergency department visit within 1 week of diagnosis (beta: 19.4 [17.8, 21.1] days) but shorter for patients who were admitted at the time of diagnosis (beta: −30.4 [−31.9, −28.9] days).

Overall survival

In unadjusted analysis, DAP patients had significantly better overall survival than non-DAP patients (HR: 0.69 [0.66–0.71]). After adjustment for age, sex, rurality, neighborhood residence, comorbidity, stage, and histology, this effect was attenuated but still statistically significant (HR: 0.79 [0.76–0.82], $P < 0.0001$) [Table 3]. After additionally adjusting for emergency department visit within 7 days of diagnosis and hospital admission at the time of diagnosis, the prognostic effect of DAPs was further reduced (HR: 0.96 [0.92–1.00], $P = 0.05$).

We explored the relationship between wait times and overall survival [Table 3, bottom]. In the unadjusted analysis, a longer time until diagnosis was associated with better overall survival, exhibiting a linear trend ($P < 0.0001$) that was lost after adjustment ($P = 0.18$). A longer pretreatment interval was also associated with better overall survival, except for patients receiving treatment on the day of diagnosis [Figure 2]. This relationship persisted after adjustment ($P < 0.0001$). A similar trend was observed across stages [Appendix 6], but patients who received treatment on the diagnosis date had qualitatively different survival patterns according to stage. Treatment on the diagnosis date was associated with better overall survival for stage I patients (HR: 0.35 [0.24–0.50]) but worse survival for stage IV patients (HR: 2.29 [1.94–2.69]) [Appendix 6].

Discussion

Our study demonstrates that DAP patients receive more treatment and have better overall survival than

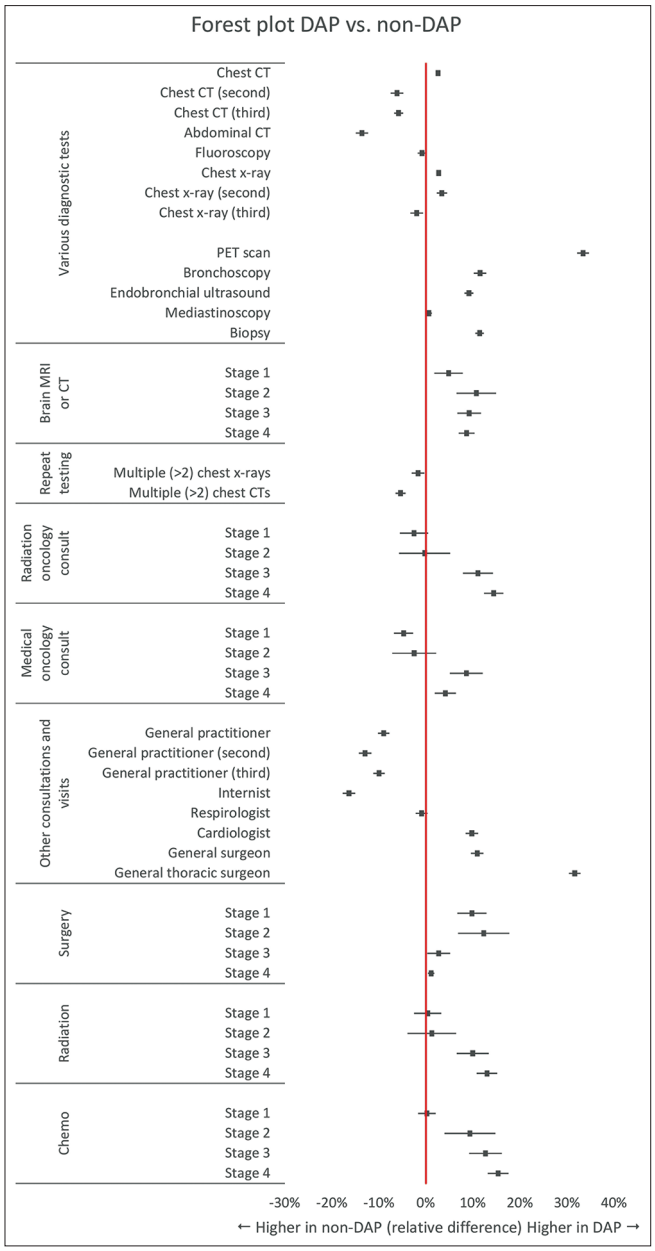

Figure 1: Receipt of diagnostic tests or consultations from 6 months before diagnosis until either the date of first treatment or 2 months after diagnosis (if no treatment). Absolute difference in frequency of testing between DAP and non-DAP patients is shown on the x-axis, which was calculated as % DAP-% non-DAP so that positive values indicate higher utilization in DAPs. Corresponding percentages are reported in Appendix 3. The dot corresponds to the mean difference in proportions, and the horizontal lines represent the 95% confidence interval. DAP = Diagnostic assessment program, CT = Computed tomography, PET = Positron emission tomography, MRI = Magnetic resonance imaging

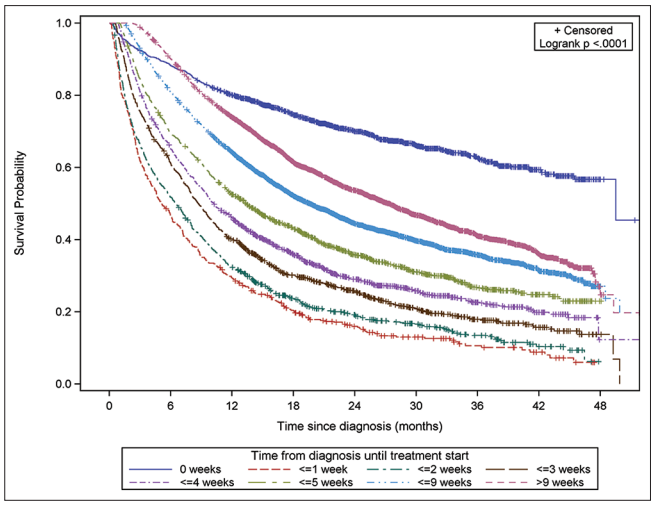

Figure 2: Kaplan–Meier plot for overall survival stratified by the time from diagnosis until treatment. Log-rank P < 0.0001

non-DAP patients, despite comparable wait times for diagnosis. This is consistent with data published by the International Cancer Benchmarking Partnership showing that among Canadian provinces, Ontario had the highest survival rates but the longest wait-times.[17] Taken together, these results imply that organized diagnostic assessment and treatment for lung cancer offers benefits that are clinically important beyond shorter wait times.

Furthermore, we have previously reported that patient navigation associated with DAPs successfully mitigates the negative effects of longer wait times on patient experience.[16] Compared with non-DAP patients, DAP patients were more likely to receive diagnostic tests and consultations with specialists. By providing more streamlined access to specialist assessment, DAP patients had increased opportunity for treatment. DAP patients had a shorter pre-treatment interval, but there was no evidence that the reduced interval improved survival.

Although overall survival for DAP patients was better than non-DAP patients, the mechanism is unknown. We found that the prognosis for DAP patients was better than for non-DAP patients after adjusting for most clinical and demographic characteristics. However, this effect was largely explained by patients who presented to emergency or required hospital admission. One explanation is that urgent presentation is usually a reflection of symptoms which in turn are often related to advanced disease and thus is a strong confounder for the effect of DAPs on survival. Another explanation is that DAPs reduce the likelihood of such urgent cases from arising through early referrals and fast-tracking, thereby serving as a mediator. Since patients diagnosed emergently comprise almost half of all lung cancers, these patients should be further characterized in future work.[15,17,18]

In international comparisons including nine jurisdictions, wait times for lung cancer diagnosis in Ontario were longer than Wales, Denmark Sweden, England, and Scotland.[17] To improve the efficiency of lung cancer diagnosis and treatment, many cancer programs in Canada implemented programmatic changes that focused on reducing the duration of the diagnostic interval. The "Time to Treat" program launched at a single hospital in Toronto in 2005

Table 2: Factors associated with wait times

	Time from first visit until diagnosis		Time from diagnosis until first treatment		Time from first visit until first treatment	
	β (95% CI)[a], in days	*P*	β (95% CI)[a], in days	*P*	β (95% CI)[a], in days	*P*
Overall	Mean 77.4 (59.2) Median 66 (25–131)	–	Mean 45.5 (34.7) Median 40 (21–63)	–	Mean 125.3 (66.9) Median 118 (71–175)	–
DAP patient status						
Non-DAP patient	0.0 (reference)	0.42	0.0 (reference)	<0.0001	0.0 (reference)	<0.0001
DAP patient	−0.8 (−2.7–1.1)		−8.5 (−9.7–−7.3)		−10.4 (−12.8–−8.0)	
Age, years (×10)	2.2 (1.4–3.0)	<0.0001	2.2 (1.7–2.8)	<0.0001	3.3 (2.2–4.4)	<0.0001
Sex						
Male	0.0 (reference)	0.06	0.0 (reference)	0.03	0.0 (reference)	0.06
Female	1.6 (−0.1–3.3)		1.2 (0.1–2.3)		2.9 (0.7–5.1)	
Charlson Comorbidity Index						
Missing	−22.6 (−24.9–−20.2)		3.6 (2.1–5.2)		−18.2 (−21.3–−15.1)	
0	0.0 (reference)	<0.0001	0.0 (reference)	<0.0001	0.0 (reference)	<0.0001
1	11.5 (9.2–13.7)		2.7 (1.2–4.2)		14.5 (11.6–17.4)	
2	19.9 (16.7–23.1)		3.0 (0.8–5.1)		21.5 (17.2–25.8)	
3+	34.3 (31.1–37.5)		5.1 (2.9–7.3)		38.8 (34.4–43.3)	
Stage						
Stage I	0.0 (reference)	<0.0001	0.0 (reference)	<0.0001	0.0 (reference)	<0.0001
Stage II	−10.5 (−14.1–−7)		1.6 (−0.5–3.7)		−9.1 (−13.3–−4.9)	
Stage III	−16.8 (−19.5–−14.1)		−1.6 (−3.2–0.1)		−19.2 (−22.4–−15.9)	
Stage IV	−22.7 (−25–−20.4)		−10.3 (−11.8–−8.9)		−32.7 (−35.6–−29.8)	
Unknown	−9.8 (−20.4–0.9)		3.4 (−5.9–12.7)		1.3 (−17.1–19.8)	
Histology						
Small-cell lung cancer	0.0 (reference)	0.13	0 (reference)	<0.0001	0.0 (reference)	<0.0001
Non-small-cell lung cancer	1.9 (−0.6–4.5)		20.5 (18.9–22.2)		21.9 (18.6–25.2)	
Urban[b]						
Urban	0.0 (reference)	0.41	0.0 (reference)	0.26	0.0 (reference)	0.49
Rural	−1.1 (−3.8–1.6)		−1.0 (−2.7–0.7)		−2.0 (−5.5–1.4)	
Income[b]						
Highest	0.0 (reference)	0.52	0.0 (reference)	0.31	0.0 (reference)	0.78
Mid-high	0.9 (−1.9–3.6)		−1.5 (−3.3–0.3)		0.7 (−2.9–4.2)	
Middle	−1.0 (−3.8–1.8)		−0.5 (−2.3–1.3)		−0.7 (−4.3–2.9)	
Mid-low	−0.6 (−3.3–2.2)		−0.6 (−2.4–1.1)		−0.9 (−4.5–2.6)	
Lowest	−1.3 (−4.1–1.5)		0.2 (−1.6–2.1)		−0.7 (−4.3–2.9)	
Immigrant[b]						
Least dense	0.0 (reference)	<0.0001	0.0 (reference)	0.20	0.0 (reference)	0.006
Mid-dense	5.3 (2.9–7.7)		0.7 (−0.9–2.2)		5.6 (2.5–8.7)	
Most dense	6.8 (3.4–10.2)		2.0 (−0.2–4.3)		8.5 (4.0–12.9)	
Local Health Integration Network[b]						
Central	0.0 (reference)	0.0003	0.0 (reference)	<0.0001	0.0 (reference)	0.007
Central East	−6.9 (−10.8–−3.1)		10.1 (7.6–12.6)		2.9 (−2.1–8.0)	
Central West	−1.6 (−6.7–3.6)		−0.8 (−4.1–2.5)		−2.7 (−9.4–3.9)	
Champlain	−2.6 (−6.7–1.5)		4.3 (1.6–6.9)		1.8 (−3.5–7.1)	
Erie St. Clair	−0.1 (−4.6–4.4)		3.1 (0.1–6.0)		3.1 (−2.7–9.0)	
Hamilton Niagara	−0.6 (−4.5–3.4)		3.4 (0.8–6.0)		4.1 (−1.0–9.3)	
Mississauga Halton	−3.2 (−7.9–1.6)		−0.4 (−3.6–2.7)		−0.8 (−7.0–5.4)	
North East	−0.3 (−5.4–4.9)		−5.0 (−8.3–−1.6)		−5.2 (−11.8–1.5)	
North Simcoe Muskoka	−2.3 (−7.4–2.7)		1.0 (−2.3–4.3)		−1.6 (−8.2–4.9)	
North West	−2.0 (−9.0–4.9)		1.2 (−3.3–5.7)		−2.2 (−11.1–6.7)	
South East	−3.5 (−8.5–1.4)		3.9 (0.7–7.1)		2.1 (−4.3–8.5)	
South West	0.0 (−4.4–4.4)		3.9 (1.0–6.8)		5.4 (−0.4–11.1)	
Toronto Central	0.2 (−4.1–4.6)		0.1 (−2.7–3.0)		2.1 (−3.7–7.8)	

Contd...

Table 2: Contd...

	Time from first visit until diagnosis		Time from diagnosis until first treatment		Time from first visit until first treatment	
	β (95% CI)[a], in days	*P*	β (95% CI)[a], in days	*P*	β (95% CI)[a], in days	*P*
Waterloo Wellington	−8.3 (−13.2–−3.4)		5.5 (2.2–8.8)		−3.9 (−10.5–2.6)	
Distance to closest DAP (×50 km)[b]	−0.3 (−1.4–0.9)	0.62	2.0 (1.2–2.7)	<0.0001	1.6 (0.1–3.0)	0.05
Emergency visit within 7 days of diagnosis						
No	0.0 (reference)	<0.0001	0.0 (reference)	<0.0001	0.0 (reference)	<0.0001
Yes	−28.5 (−31.1–−26.0)		19.4 (17.8–21.1)		−12.1 (−15.4–−8.8)	
Admission on diagnosis						
No	0.0 (reference)	<0.0001	0.0 (reference)	<0.0001	0.0 (reference)	<0.0001
Yes	9.8 (7.5–12.1)		−30.4 (−31.9–−28.9)		−18.6 (−21.5–−15.6)	

[a]Adjusted for all variables in the table. Beta is the point estimate from a linear regression, corresponding to the change in the time until first treatment (in days) for every 1-unit increment in the predictor. For example, DAP patients had a 0.8-day shorter time from first visit until diagnosis and 8.5-day shorter time from diagnosis until first treatment, [b]Source or adapted from Statistics Canada Postal Code Conversion File and Postal Code Conversion File Plus (June 2017) which is based on data licensed from Canada Post Corporation. The patients' postal code at diagnosis was used. DAP=Diagnostic assessment program, CI=Confidence interval

Table 3: Factors associated with overall survival

	Crude HR (95% CI)	*P*	Adjusted HR (95% CI)[a]	*P*	Adjusted HR (95% CI)[b]	*P*
DAP patient status						
Non-DAP patient	1.0 (reference)	<0.0001	1.0 (reference)	<0.0001	1.0 (reference)	0.05
DAP patient	0.69 (0.66–0.71)		0.79 (0.76–0.82)		0.96 (0.92–1.00)	
Age, years (×10)	1.18 (0.16–1.20)	<0.0001	1.20 (1.18–1.22)	<0.0001	1.20 (1.18–1.22)	<0.0001
Sex						
Male	1.0 (reference)	<0.0001	1.0 (reference)	<0.0001	1.0 (reference)	<0.0001
Female	0.75 (0.73–0.77)		0.92 (0.79–0.85)		0.80 (0.77–0.83)	
Charlson Comorbidity Index						
Missing	1.07 (1.03–1.13)		0.96 (0.91–1.01)		0.97 (0.92–1.02)	
0	1.0 (reference)	<0.0001	1.0 (reference)	<0.0001	1.0 (reference)	<0.0001
1	1.09 (1.05–1.14)		1.06 (1.01–1.11)		1.05 (1.00–1.10)	
2	1.24 (1.17–1.32)		1.21 (1.14–1.29)		1.18 (1.11–1.26)	
3+	1.39 (1.31–1.48)		1.36 (1.28–1.46)		1.28 (1.20–2.37)	
Stage						
Stage I	1.0 (reference)	<0.0001	1.0 (reference)	<0.0001	1.0 (reference)	<0.0001
Stage II	2.24 (2.03–2.48)		2.27 (2.05–2.51)		2.26 (2.04–2.50)	
Stage III	5.05 (4.69–5.44)		5.07 (4.70–5.46)		4.90 (4.54–5.28)	
Stage IV	11.7 (11.0–12.6)		11.9 (11.1–12.7)		10.6 (9.83–11.3)	
Unknown	5.23 (4.15–6.60)		4.60 (3.65–5.81)		4.42 (3.50–5.58)	
Histology						
Small-cell lung cancer	1.0 (reference)	<0.0001	1.0 (reference)	<0.0001	1.0 (reference)	0.01
Non-small-cell lung cancer	0.54 (0.52–0.57)		0.90 (0.86–0.95)		0.94 (0.89–0.99)	
Urban[b]						
Urban	1.0 (reference)	0.57	1.0 (reference)	0.27	1.0 (reference)	0.61
Rural	1.01 (0.97–1.06)		0.97 (0.92–1.02)		0.99 (0.93–1.04)	
Income[b]						
Highest	1.0 (reference)	<0.0001	1.0 (reference)	<0.0001	1.0 (reference)	<0.0001
Mid-high	1.03 (0.98–1.09)		1.07 (1.02–1.14)		1.06 (1.00–1.12)	
Middle	1.08 (1.03–1.14)		1.09 (1.03–1.16)		1.07 (1.01–1.14)	
Mid-low	1.12 (1.07–1.19)		1.13 (1.06–1.20)		1.13 (1.06–1.19)	
Lowest	1.17 (1.11–1.23)		1.21 (1.14–1.29)		1.19 (1.12–1.26)	
Immigrant[b]						
Least dense	1.0 (reference)	0.0009	1.0 (reference)	<0.0001	1.0 (reference)	<0.0001
Mid-dense	0.95 (0.91–0.99)		0.94 (0.89–0.99)		0.94 (0.89–0.98)	
Most dense	0.92 (0.87–0.97)		0.85 (0.79–0.91)		0.85 (0.79–0.91)	
Local Health Integration Network[b]						

Contd...

Table 3:Contd...

	Crude HR (95% CI)	*P*	Adjusted HR (95% CI)	*P*	Adjusted HR (95% CI)	*P*
Central	1.0 (reference)	<0.0001	1.0 (reference)	<0.0001	1.0 (reference)	0.0001
Central East	1.08 (1.00–1.16)		1.09 (1.00–1.18)		1.13 (1.04–1.23)	
Central West	1.02 (0.92–1.13)		1.05 (0.94–1.17)		1.05 (0.94–1.18)	
Champlain	1.07 (1.00–1.16)		1.25 (1.15–1.37)		1.21 (1.11–1.32)	
Erie St. Clair	1.30 (1.20–1.42)		1.09 (0.99–1.20)		1.12 (1.02–1.23)	
Hamilton Niagara	1.18 (1.10–1.26)		1.15 (1.06–1.25)		1.18 (1.08–1.28)	
Mississauga Halton	1.12 (1.03–1.23)		1.23 (1.12–1.36)		1.27 (1.15–1.41)	
North East	1.28 (1.18–1.38)		1.18 (1.06–1.30)		1.21 (1.08–1.35)	
North Simcoe Muskoka	1.11 (1.01–1.21)		1.20 (1.07–1.33)		1.16 (1.04–1.30)	
North West	1.08 (0.94–1.22)		1.10 (0.95–1.27)		1.11 (0.96–1.29)	
South East	1.27 (1.17–1.39)		1.17 (1.05–1.30)		1.21 (1.09–1.34)	
South West	1.25 (1.15–1.35)		1.13 (1.03–1.25)		1.15 (1.04–1.26)	
Toronto Central	1.05 (0.97–1.14)		1.13 (1.02–1.24)		1.12 (1.01–1.23)	
Waterloo Wellington	1.29 (1.18–1.42)		1.23 (1.11–1.36)		1.26 (1.14–1.40)	
Distance to closest DAP (×50 km)[b]	1.01 (1.00–1.03)	0.12	–	–	1.00 (0.98–1.02)	0.92
Emergency department visit within 7 days of diagnosis						
No	1.0 (reference)	<0.0001	–	–	1.0 (reference)	<0.0001
Yes	2.92 (2.82–3.02)				1.54 (1.46–1.62)	
Admission on diagnosis						
No	1.0 (reference)	<0.0001	–	–	1.0 (reference)	<0.0001
Yes	1.79 (1.74–1.85)				1.26 (1.19–1.32)	
Wait times: Diagnostic interval						
Time from first visit until diagnosis						
0 days (on the diagnosis date)	1.92 (1.81–2.03)	<0.0001	–	–	0.96 (0.90–1.03)	<0.0001
1–7 days	2.09 (1.97–2.23)				0.93 (0.87–1.00)	
8–14 days	1.87 (1.74–2.01)				1.16 (1.07–1.25)	
15–21 days	1.56 (1.45–1.69)				1.16 (1.07–1.26)	
22–28 days	1.39 (1.29–1.50)				1.12 (1.03–1.22)	
29–35 days	1.26 (1.17–1.36)				1.05 (0.96–1.14)	
36–63 days	1.09 (1.04–1.14)				1.05 (1.00–1.11)	
>63 days	1.0 (reference)				1.0 (reference)	
Time from first visit until diagnosis (per 30 days)	0.90 (0.89–0.91)	<0.0001	–	–	0.99 (0.98–1.00)	0.18
Wait times: Pretreatment interval						
0 days (on the diagnosis date)	0.60 (0.54–0.66)	<0.0001	–	–	1.14 (1.01–1.28)	<0.0001
1–7 days	3.52 (3.17–3.90)				2.95 (2.62–3.31)	
8–14 days	3.10 (2.86–3.37)				2.31 (2.10–2.54)	
15–21 days	2.41 (2.24–2.60)				1.95 (1.79–2.13)	
22–28 days	2.05 (1.91–2.21)				1.81 (1.66–1.97)	
29–35 days	1.70 (1.58–1.83)				1.65 (1.51–1.79)	
36–63 days	1.27 (1.21–1.35)				1.28 (1.20–1.37)	
>63 days	1.0 (reference)				1.0 (reference)	
Time from diagnosis until first treatment (/30 days)	0.87 (0.85–0.88)	<0.0001	–	–	0.81 (0.79–0.83)	<0.0001

[a]Adjusted for DAP, age, sex, comorbidity score, stage, histology, urban, income quintile, immigrant density, and LHIN of residence. [b]Adjusted for DAP, age, sex, comorbidity score, stage, histology, urban, income quintile, immigrant density, LHIN of residence, distance to closest DAP, emergency department visit within 7 days of diagnosis, and admission on diagnosis . [b]Source: (or adapted from) Statistics Canada Postal Code Conversion File and Postal Code Conversion File Plus (June 2017) which is based on data licensed from Canada Post Corporation. Patients' postal codes of residence at diagnosis were used. HR=Hazard ratio, CI=Confidence interval, DAP=Diagnostic assessment program, LHIN=Local Health Integration Network

used a clinical pathway that included checklists, patient navigators, and dedicated booking times for CT scanning or bronchoscopy.[9] Program implementation was associated with a reduction in the median time from suspicious chest radiograph until diagnosis from 128 to 20 days, but referral patterns were markedly different pre- and postimplementation, making comparisons difficult.[9] One program in Newfoundland, Canada, hired additional CT technologists and extended CT operating hours, which reduced the time from initial imaging to confirmatory CT from 19 days to 7.5 days and first abnormal image until biopsy from 81 days until 48 days.[1] We observed a similar

reduction from the time of the first chest X-ray until the first chest CT scan (12 days for non-DAP patients and 7 days for DAP patients), but an earlier chest CT did not reduce the diagnostic interval in Ontario. In many lung DAPs, patients' diagnostic and staging evaluations are directed by the same thoracic surgeon who ultimately assumes responsibility for treating that patient. This eliminates the need for surgical referral following diagnosis, which may explain the shorter pretreatment interval for DAP patients who had general thoracic surgeon consultations sooner than non-DAP patients. DAPs may also enable better access to health-care services for patients who do not have a general practitioner.[15]

In addition to wait times, the effectiveness of a DAP can be explored by assessing the alignment of care with various guidelines. First, the timely use of PET among DAP patients (median: 5 days after diagnosis) is consistent with evidence, suggesting that PET should be performed quickly following biopsy.[19] DAPs likely accomplished this by requesting PET scanning earlier in the process of determining disease extent than non-DAPs, potentially even before a biopsy was performed. Second, the shorter time until treatment observed among DAP patients may partly be explained by fewer repeated CTs, suggesting better access to original images and better coordination of care as more tests are performed in the same place and within the same medical record system.[20] The earlier use of chest CT in DAPs (25 versus 3 days before diagnosis) could reduce the use of less sensitive diagnostic imaging (e.g., repeat chest X-ray or sputum cytology) that has been linked to duplicate testing and delay.[21] However, repeated CTs were still frequently observed. Third, although DAP patients were less likely to receive an abdominal CT scan, more than half of all patients received this scan. Abdominal CTs are not broadly recommended for lung cancer patients because chest CTs include the liver and PET scans are more accurate for the diagnosis of intra-abdominal metastases.[22,23] Fourth, the use of brain imaging was higher among DAP patients, but utilization was high even among stage I–II patients. This finding is consistent with prior reports, where the perceived risk of brain metastasis and subsequent impact to patient management is felt to be high enough to justify imaging despite guidelines.[24-27]

Despite longer wait times for lung cancer diagnosis in Ontario, 1- and 5-year survival rates were higher in international comparisons.[17,28] There is little evidence that shorter diagnostic or pretreatment intervals improve survival.[7] Wait times for lung cancer diagnosis and treatment in Ontario are similar to those reported elsewhere in Canada and internationally, but 1 and 5 year survival rates were higher in Ontario.[19,28] Confounding of the relationship between wait times and survival may persist even after adjustment for the best-known and available prognostic factors (e.g., stage, comorbidity, histology, and age), as demonstrated by the often inverse relationship between survival and wait times (e.g., due to appropriate triaging).[29] Thus, quality improvement initiatives should strive to improve outcomes such as efficiency, quality of life, concordance with evidence-based care, patient experience, and value-for-money rather than the more readily measured wait times.

Although this is a large population-based study, there are some limitations. First, delayed referral to a DAP may result in misclassification of DAP status, as some patients may have had some of their diagnostic assessment performed in usual care. This will underestimate the effect of DAPs. Second, administrative data do not include indications for tests, so we cannot speak to the appropriateness of duplicate imaging (e.g., for progression of symptoms). Third, we did not estimate the effect of DAPs on patients who are ultimately determined to be cancer free. We anticipate that they would have had a similar experience in the diagnostic interval to those with a cancer diagnosis. Fourth, implementation of evidence-based pathways in DAPs may have also influenced care pathways outside of DAPs. This blending of exposure may result in an underestimation of the true effect of DAPs. Finally, we did not examine the impact of DAPs on patient experience and quality of life, but prior studies have reported better patient experience associated with DAPs.

Conclusion

Lung cancer patients diagnosed through a DAP were more likely to receive testing and consultation with specialists during the diagnostic and pretreatment intervals and subsequently, to receive treatment. Although DAPs reduced the time from diagnosis until treatment, this duration still exceeds recommended targets and the frequency of duplicate imaging was higher than expected. To optimize health care utilization and outcomes, further work is required to assess apparent inefficiencies such as repeated chest CT scans, abdominal CT scans despite PET-CT, and brain imaging for stage I patients.

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Conflicts of interest
There are no conflicts of interest.

References

1. Byrne SC, Barrett B, Bhatia R. The impact of diagnostic imaging wait times on the prognosis of lung cancer. Can Assoc Radiol J 2015;66:53-7.
2. Kuroda H, Sugita Y, Ohya Y, Yoshida T, Arimura T, Sakakura N, *et al*. Importance of avoiding surgery delays after initial discovery of suspected non-small-cell lung cancer in clinical stage IA patients. Cancer Manag Res 2019;11:107-15.
3. Frelinghuysen M, Fest J, Van der Voort Van Zyp NC, Van der Holt B, Hoogeman M, Nuyttens J. Consequences of referral time and volume doubling time in inoperable Patients With Early Stage Lung Cancer. Clin Lung Cancer 2017;18:e403-9.
4. Kasymjanova G, Small D, Cohen V, Jagoe RT, Batist G, Sateren W, *et al*. Lung cancer care trajectory at a Canadian centre: An evaluation of how wait times affect clinical outcomes. Curr Oncol 2017;24:302-9.
5. Olsson JK, Schultz EM, Gould MK. Timeliness of care in patients with lung cancer: A systematic review. Thorax 2009;64:749-56.
6. Di Girolamo C, Walters S, Gildea C, Benitez Majano S, Rachet B, Morris M. Can we assess Cancer Waiting Time targets with cancer survival? A population-based study of individually linked data from the National Cancer Waiting Times monitoring dataset in England, 2009-2013. PLoS One 2018;13:e0201288.
7. Jacobsen MM, Silverstein SC, Quinn M, Waterston LB, Thomas CA, Benneyan JC, *et al*. Timeliness of access to lung cancer diagnosis and treatment: A scoping literature review. Lung Cancer 2017;112:156-64.
8. Malalasekera A, Nahm S, Blinman PL, Kao SC, Dhillon HM, Vardy JL. How long is too long? A scoping review of health system delays in lung cancer. Eur Respir Rev 2018;27:180045.
9. Lo DS, Zeldin RA, Skrastins R, Fraser IM, Newman H, Monavvari A, *et al*. Time to treat: A system redesign focusing on decreasing the time from suspicion of lung cancer to diagnosis. J Thorac Oncol 2007;2:1001-6.
10. Malmström M, Rasmussen BH, Bernhardson BM, Hajdarevic S, Eriksson LE, Andersen RS, *et al*. It is important that the process goes quickly, isn't it?" A qualitative multi-country study of colorectal or lung cancer patients' narratives of the timeliness of diagnosis and quality of care. Eur J Oncol Nurs 2018;34:82-8.
11. Largey G, Ristevski E, Chambers H, Davis H, Briggs P. Lung cancer interval times from point of referral to the acute health sector to the start of first treatment. Aust Health Rev 2016;40:649-54.
12. Evans WK, Ung YC, Assouad N, Chyjek A, Sawka C. Improving the quality of lung cancer care in ontario: The lung cancer disease pathway initiative. J Thorac Oncol 2013;8:876-82.
13. Honein-AbouHaidar GN, Stuart-McEwan T, Waddell T, Salvarrey A, Smylie J, Dobrow MJ, et al. How do organisational characteristics influence teamwork and service delivery in lung cancer diagnostic assessment programmes? A mixed-methods study. BMJ Open 2017;7:e013965. doi: 10.1136/bmjopen-2016-013965.
14. Quan H, Sundararajan V, Halfon P, et al. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. Med Care 2005;43:1130-9.
15. Elliss-Brookes L, McPhail S, Ives A, Greenslade M, Shelton J, Hiom S, et al. Routes to diagnosis for cancer Determining the patient journey using multiple routine data sets. Br J Cancer 2012;107:1220-6.
16. Wheeler S, Gilbert J, Kaan M, Klonikowski E, Holloway C. The patient: The importance of knowing your navigator. Patient Exp J 2015;2;Article 12 . [Doi: 10.35680/2372-0247.1058].
17. Menon U, Vedsted P, Zalounina Falborg A, Jensen H, Harrison S, Reguilon I, et al. Time intervals and routes to diagnosis for lung cancer in 10 jurisdictions: Cross-sectional study findings from the International Cancer Benchmarking Partnership (ICBP). BMJ Open 2019;9:e025895.
18. Suhail A, Crocker CE, Das B, Payne JI, Manos D. Initial presentation of lung cancer in the emergency department: A descriptive analysis. CMAJ Open 2019;7:E117-23.
19. Yeung CS, Musaddaq B, Hare S, Wagner T. 18F-FDG-PET/CT study after lung biopsy in suspected lung cancer patients: Time is of the essence. Nucl Med Commun 2017;38:99-100.
20. Moore HB, Loomis SB, Destigter KK, Mann-Gow T, Dorf L, Streeter MH, et al. Airway, breathing, computed tomographic scanning: Duplicate computed tomographic imaging after transfer to trauma center. J Trauma Acute Care Surg 2013;74:813-7.
21. Verma A, Lim AY, Tai DY, Goh SK, Kor AC, Dokeu AA, et al. Timeliness of diagnosing lung cancer: Number of procedures and time needed to establish diagnosis: Being right the first time. Medicine (Baltimore) 2015;94:e1216.
22. Verschakelen JA, Bogaert J, De Wever W. Computed tomography in staging for lung cancer. Eur Respir J Suppl 2002;35:40s-8s.
23. Maziak DE, Darling GE, Inculet RI, Gulenchyn KY, Driedger AA, Ung YC, et al. Positron emission tomography in staging early lung cancer: A randomized trial. Ann Intern Med 2009;151:221-8, W-48.
24. Schoenmaekers JJ, Dingemans AC, Hendriks LE. Brain imaging in early stage non-small cell lung cancer: Still a controversial topic? J Thorac Dis 2018;10:S2168-71.
25. Diaz ME, Debowski M, Hukins C, Fielding D, Fong KM, Bettington CS. Non-small cell lung cancer brain metastasis screening in the era of positron emission tomography-CT staging: Current practice and outcomes. J Med Imaging Radiat Oncol 2018;62:383-8.
26. Ando T, Kage H, Saito M, Amano Y, Goto Y, Nakajima J, et al. Early stage non-small cell lung cancer patients need brain imaging regardless of symptoms. Int J Clin Oncol 2018;23:641-6.
27. Balekian AA, Fisher JM, Gould MK. Brain imaging for staging of patients with clinical stage IA non-small cell lung cancer in the national lung screening trial: Adherence with recommendations from the choosing wisely campaign. Chest 2016;149:943-50.
28. Coleman MP, Forman D, Bryant H, Butler J, Rachet B, Maringe C, et al. Cancer survival in Australia, Canada, Denmark, Norway, Sweden, and the UK, 1995-2007 (the International Cancer Benchmarking Partnership): An analysis of population-based cancer registry data. Lancet 2011;377:127-38.
29. Brookhart MA, Stürmer T, Glynn RJ, Rassen J, Schneeweiss S. Confounding control in healthcare database research: Challenges and potential approaches. Med Care 2010;48:S114-20.

Appendix 1: List of codes

Chemotherapy (CIHI – DAD/NACRS)	
ZZ.35.$A-#	Pharmacotherapy, total body
$=CA	Approach="per orifice (oral) approach"
$=HA	Approach="percutaneous approach (intramuscular, intravenous, subcutaneous, intradermal)
$=YA	Approach="route not elsewhere classified (e.g., transdermal, etc.)"
#=M0	Using antineoplastic agent, NOS
#=M1	Using alkylating agent
#=M2	Using antimetabolite
#=M3	Using plant alkaloid and other natural product
#=M4	Using cytotoxic antibiotic and related substance
#=M5	Using other antineoplastic
#=M6	Using endocrine therapy
#=M7	Using immunostimulant
#=M8	Using immunosuppressive agent
#=M9	Using combination (multiple) antineoplastic agents
Surgery/excision (CIHI)	
1GR89	Excision total, lobe of lung
1GR87	Excision partial, lobe of lung
1GT87	Excision partial, lung NEC
1GT89	Excision total, lung NEC
1GR91	Excision radical, lobe of lung
1GT91	Excision radical, lung NEC
1GM87	Excision partial, bronchus NEC
Surgery (OHIP)	
M143	Lungs & pleura-exc.-lobectomy-complete
M145	Lungs & pleura-exc.-lobectomy-wedge resection
M144	Lungs & pleura-exc.-lobectomy-segmental resection
M135	Lungs & pleura-inc-major decorticatn of lung for empye/tumor
M142	Lungs & pleura-exc.-pneumonectomy-complete
M137	Lungs & pleura-thoracotomy-with or without biopsy.
Radiofrequency ablation (RFA)	
1GM59	Destruction, bronchus NEC
1GT59	Destruction, lung NEC
1GV59	Destruction, pleura
J069	Radiofrequency ablation
Transarterial chemoembolization (TACE)	
J021	Diag. rad. Clinic proc.– thoracic/abdom. angio. nonselective
J022	Diag. rad. Clinic proc.– thoracic/abdom. angio. selective
J040	Diag. radiol.-clinic proc.-embolization – first vessel
J047	Diag. radiol.-clinic proc.-embolization – each additional vessel catheterized and occluded per vessel
R776	Cannulation for infusion chemotherapy – hepatic artery
X181	Abdominal, thoracic, cervical or cranial angiogram by catheterization - Using film changer, cine, or multiformat camera - Non-selective
X182	Abdominal, thoracic, cervical or cranial angiogram by catheterization - Using film changer, cine, or multiformat camera - Selective
Z597	Intracavitary/intratumoral injection
Surgery/excision (quality-based procedures)*	
1GJ87LA	Excision partial, trachea open approach (e.g., transcervical, collar incision) with simple apposition (anastomosis)
1GJ87LANR	Excision partial, trachea open approach with stent implant with simple apposition (anastomosis)
1GJ87LANRA	Excision partial, trachea open approach with stent implant using autograft
1GJ87LANRE	Excision partial, trachea open approach and stent implant using local flap (e.g., omental wrap, pericardial patch)
1GJ87LAXXA	Excision partial, trachea open approach (e.g., transcervical, collar incision) using autograft

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Appendix 1: Contd...

1GJ87LAXXE	Excision partial, trachea open approach (e.g., transcervical, collar incision) using local flap (e.g., omental wrap, pericardial patch)
1GJ87QB	Excision partial, trachea open thoracic approach (e.g., mediastinal, posterolateral thoracotomy) with simple apposition (anastomosis)
1GJ87QBNR	Excision partial, trachea open thoracic approach with stent implant with simple apposition (anastomosis)
1GJ87QBNRA	Excision partial, trachea open thoracic approach with stent implant using autograft
1GJ87QBNRE	Excision partial, trachea open thoracic approach with stent implant using local flap (e.g., omental wrap, pericardial patch)
1GJ87QBXXA	Excision partial, trachea open thoracic approach (e.g., mediastinal, posterolateral thoracotomy) using autograft
1GJ87QBXXE	Excision partial, trachea open thoracic approach (e.g., mediastinal, posterolateral thoracotomy) using local flap (e.g., omental wrap, pericardial patch)
1GM87DA	Excision partial, bronchus NEC using endoscopic (percutaneous) approach
1GM87LA	Excision partial, bronchus NEC using open approach
1GR87DA	Excision partial, lobe of lung using endoscopic approach (VATS)
1GR87NW	Excision partial, lobe of lung using intrapericardial (transpericardial) approach
1GR87QB	Excision partial, lobe of lung using open thoracic approach
1GT87DA	Excision partial, lung NEC using endoscopic approach (VATS)
1GT87NW	Excision partial, lung NEC using intrapericardial (transpericardial) approach
1GT87QB	Excision partial, lung NEC using open thoracic approach
1GV87DA	Excision partial, pleura using endoscopic approach (VATS)
1GV87LA	Excision partial, pleura using open approach
1ME87DA	Excision partial, lymph node (s), mediastinal using endoscopic approach
1ME87LA	Excision partial, lymph node (s), mediastinal using open approach
1MF87DA	Excision partial, lymph node (s), intrathoracic NEC using endoscopic approach
1MF87LA	Excision partial, lymph node (s), intrathoracic NEC using open approach
1MN87DA	Excision partial, lymphatic vessels of thoracic region no tissue used endoscopic approach
1GN92LA	Excision radical with reconstruction, carina using open approach
1GR91NW	Excision radical, lobe of lung open intrapericardial (transpericardial) approach with simple closure
1GR91NWXXA	Excision radical, lobe of lung open intrapericardial (transpericardial) approach using autograft (pericardium)
1GR91NWXXF	Excision radical, lobe of lung open intrapericardial (transpericardial) approach using free flap
1GR91NWXXG	Excision radical, lobe of lung open intrapericardial (transpericardial) approach using distant pedicled flap
1GR91NWXXL	Excision radical, lobe of lung open intrapericardial (transpericardial) approach using xenograft
1GR91NWXXN	Excision radical, lobe of lung open intrapericardial (transpericardial) approach using synthetic material
1GR91NWXXQ	Excision radical, lobe of lung open intrapericardial (transpericardial) approach using combined sources of tissue
1GR91QB	Excision radical, lobe of lung open thoracic approach with simple closure
1GR91QBXXA	Excision radical, lobe of lung open thoracic approach using autograft (pericardium)
1GR91QBXXF	Excision radical, lobe of lung open thoracic approach using free flap
1GR91QBXXG	Excision radical, lobe of lung open thoracic approach using distant pedicled flap
1GR91QBXXN	Excision radical, lobe of lung open thoracic approach using synthetic material
1GR91QBXXQ	Excision radical, lobe of lung open thoracic approach using combined sources of tissue
1GT91NW	Excision radical, lung NEC using simple closure open intrapericardial (transpericardial) approach
1GT91NWXXF	Excision radical, lung NEC using free flap open intrapericardial (transpericardial) approach
1GT91NWXXG	Excision radical, lung NEC using distant pedicled flap open intrapericardial (transpericardial) approach
1GT91NWXXN	Excision radical, lung NEC using synthetic material open intrapericardial (transpericardial) approach
1GT91NWXXQ	Excision radical, lung NEC using combined sources of tissue open intrapericardial (transpericardial) approach
1GT91QB	Excision radical, lung NEC with simple closure open thoracic approach
1GT91QBXXF	Excision radical, lung NEC using free flap open thoracic approach

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Appendix 1: Contd...

1GT91QBXXG	Excision radical, lung NEC using distant pedicled flap open thoracic approach
1GT91QBXXN	Excision radical, lung NEC using synthetic material open thoracic approach
1GT91QBXXQ	Excision radical, lung NEC using combined sources of tissue open thoracic approach
1GR89DA	Excision total, lobe of lung using endoscopic approach (VATS)
1GR89NW	Excision total, lobe of lung using intrapericardial (transpericardial) approach
1GR89QB	Excision total, lobe of lung using open thoracic approach
1GT89DA	Excision total, lung NEC using endoscopic approach (VATS)
1GT89NW	Excision total, lung NEC using intrapericardial (trans pericardial) approach
1GT89QB	Excision total, lung NEC using open thoracic approach
1GV89DA	Excision total, pleura using endoscopic approach (VATS)
1GV89LA	Excision total, pleura using open approach
1ME89DA	Excision total, lymph node (s), mediastinal using endoscopic approach
1ME89LA	Excision total, lymph node (s), mediastinal using open approach
	PET scan
J700	PET, single pulmonary nodule
J706	PET, non-small-cell lung cancer
J709	PET, limited disease small-cell lung cancer
J710	PET, esophageal carcinoma
J711	PET, metastatic squamous cell carcinoma, evaluation of neck nodes
Other	PET database (insured, access, or registry)
	Brain/head MRI
3AN40	MRI, brain
3ER40	MRI, head
X421	MRI, head (multi-slice sequence)
X425	MRI, head (multi-slice sequence), repeat
	Brain/head CT
3AN20	CT, brain
3ER20	CT, head
X400	CT, head without IV contrast
X401	CT, head with IV contrast
X188	CT, head with and without IV contrast
X402	CT, complex head without IV contrast
X405	CT, complex head with IV contrast
X408	CT, complex head with and without IV contrast
	Mediastinoscopy
Z329	Chest wall and mediastinum-endoscopy-mediastinoscopy
Z328	Chest wall and mediastinum-endoscopy-with mediastinoscopy
	Chest CT
X406	CT, thorax – without IV contrast
X407	CT, thorax – with IV contrast
X125	CT, thorax – with and without IV contrast
3GY20**	CT, thoracic cavity
	Abdominal CT
X409	CT, abdomen – without IV contrast
X410	CT, abdomen – with IV contrast
X126	CT, abdomen – with and without IV contrast
3OT20**	CT, abdominal cavity
	Fluoroscopy
X195	Fluoroscopy, chest
X197	Fluoroscopy, abdomen
X189	Fluoroscopic control of clinical procedures done by another physician
3GT12	Fluoroscopy, lung
	Chest X-ray
X090	Diagnostic radiology – chest – single view
X091	Diagnostic radiology – chest – two views

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Appendix 1: Contd...

X092	Diagnostic radiology – chest – three or more views
3GY10**	X-ray, thoracic cavity
	Consultations
A645, A935, A646, A643, A644, C645, C935, C646, C643, C644	General thoracic surgery***
A345, A765, A745, A346, A343, A340, A341, A348, C345, C765, C745, C346, C343, C344, C341	Radiation oncology
A335, A365, A330, A332, A331, A338, C335, C365, C330, C332	Diagnostic radiology (e.g., second opinions; not typically patient consultations)
A035, A935, A036, A033, A034, C035, C935, C036, C033, C034, W035, W036	General surgery***
A445, A845, A446, A443, A444, A441, A448, C445, C845, C446, C443, C444, C441, W445, W765, W845, W446	Medical oncology
A465, A575, A476, A473, A474, A471, A478, C475, C575, C476, C473, C474, C471	Respirology*** Internal medicine***
A005, A911, A912, A945, A905, A006, A003, A004, A888, A091, A900, A933, A100, A937, A967, C005, C911, C912, C945, C905, C006, C003, C004, C933, H065, H105, H102, H103, H101, H104, H132, H133, H131, H134, H152, H153, H151, H154, H122, H123, H121, H124, W105, W911, W912, W106	General practitioner
	Bronchoscopy
Z327	Flexible or rigid, with or without bronchial biopsy, suction or injection of contrast material
E632	Bronchoscopy – with removal of foreign body, to Z327
E633	Bronchoscopy – with dilatation of stricture, to Z327
E634	Bronchoscopy – with selective endobronchial blocker or catheter insertion, to Z327
E635	Bronchoscopy – with palliative endobronchial tumor resection including laser or cryotherapy, to Z327
E636	Bronchoscopy – with broncho-alveolar lavage for diagnosis of malignancy or diagnosis and/or treatment of infection and includes obtaining specimens suitable for differential cellular analysis, to Z327
E637	Bronchoscopy – with selective brushings of all 18 segmental bronchi for occult carcinoma *in situ*; specimens labeled as to site, to Z327
E638	Bronchoscopy – with transbronchial lung biopsy under image intensification only, to Z327
E622	Bronchoscopy – any bronchoscopic procedure for patients under 3 years of age, to Z327
E677	Bronchoscopy – transbronchial needle aspiration (TBNA) of mediastinal and/or hilar lymph nodes, to Z327
E678	Bronchoscopy – transbronchial needle aspiration (TBNA) of lung mass, to Z327
E838	Bronchoscopy in a high-risk patient with respiratory failure (i.e., severe hypoxemia or hypercapnia), to Z327
E846	Bronchoscopy – rigid bronchoscopy rendered immediately after flexible bronchoscopy, to Z327
Z360	Emergency rigid bronchoscopy for obstructed airway
Z330	Endoscopy – with bronchoscopy
Z333	Endoscopy – with transbronchial biopsy under image intensification (including bronchoscopy)
Z348	Endoscopy – with bronchoscopy and mediastinotomy
Z359	Repeat bronchoscopy for tracheobronchial toilet when performed within one week of another bronchoscopic procedure
Z342	Limited bronchoscopy with placement of endobronchial blocker and/or double-lumen tube
Z359	Repeat bronchoscopy for tracheobronchial toilet when performed within one week of another bronchoscopic procedure
G050	Endobronchial ultrasound (EBUS), for guided biopsy of hilar and/or mediastinal lymph nodes
E837	Additional biopsy (s) performed by EBUS, to a maximum of 3, to G050
Z334	Total unilateral lung lavage with or without bronchoscopy using double-lumen tube and single lung anesthesia
Z335	Thoracoscopy (pleuroscopy) with or without pleural biopsy, suction, etc.

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Appendix 1: Contd...

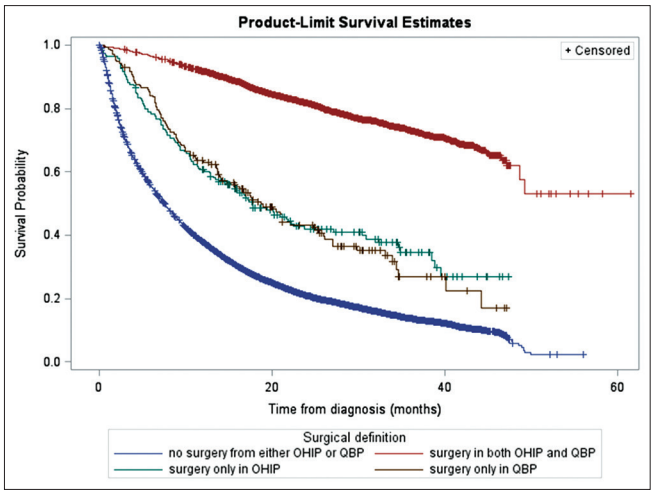
Z355	Quadroscopy or panendoscopy – with or without biopsy (nasopharyngoscopy, laryngoscopy, bronchoscopy, esophagoscopy with or without gastro-duodenoscopy) using separate instruments in search of malignant disease
	Biopsy
Z340	Incision – biopsy of lung, needle
Z336	Incision – biopsy of pleura, needle – including diagnostic aspiration
J149	Ultrasonic guidance of biopsy, aspiration, amniocentesis or drainage procedures (one physician only)
G050	EBUS, for guided biopsy of hilar and/or mediastinal lymph nodes
E837	Additional biopsy (s) performed by EBUS, to a maximum of 3, to G050
E638	Bronchoscopy – with transbronchial lung biopsy under image intensification only, to Z327
Z405	Biopsy, anterior cervical lymph node (s), unilateral
M138	Hilar lymph node or lung biopsy with full thoracotomy
Z338	Excision – biopsy of pleura or lung – with limited thoracotomy
Z353	Incision – incisional biopsy of chest wall for tumor
Z354	Incision – excisional biopsy of rib for tumor
Z355	Quadroscopy or panendoscopy – with or without biopsy (nasopharyngoscopy, laryngoscopy, bronchoscopy, esophagoscopy with or without gastro-duodenoscopy) using separate instruments in search of malignant disease
L705	Lab. Med. – anatomic pathology – cytology and histology – aspiration biopsy (e.g., lung, breast, thyroid, prostate)
L805	Lab. Med. – anatomic pathology – cytopathology – aspiration biopsy (e.g., lung, breast, thyroid, prostate)
Z578	Biopsy – multiple para-aortic lymph nodes
Z333	Endoscopy – with transbronchial biopsy under image intensification (including bronchoscopy)
Z328	Endoscopy – with mediastinotomy
2GM71	Biopsy, bronchus
2ME71	Biopsy, mediastinal lymph nodes
2GT71	Biopsy, lung
2MF71	Biopsy, intrathoracic lymph nodes
2GV71	Biopsy, pleura
2GW71	Biopsy, mediastinum
2SZ71	Biopsy, soft tissue of the chest and abdomen
2OT71	Biopsy, abdominal cavity
2MD71	Biopsy, axillary lymph nodes
2SL71	Biopsy, ribs
2MG71	Biopsy, intra-abdominal lymph nodes

*With the following ICD-10 diagnostic codes: D038, D039, D048, D049, D097, D099, D197, D199, D367, D369, D487, D489, D022, D023, D024, D143, D144, D150, D152, D157, D159, D190, D380, D381, D382, D383, D384, D385, D386, D001, D130, D142, D167, **For counts of procedures, these codes were omitted (may be double-counted since the date of service may not be identical in CIHI as it is in OHIP), ***For surgical oncology, these codes were restricted to health service provider specialty codes 03 (general surgery), 09 (cardiovascular and thoracic surgery), 47 (respiratory diseases), and 64 (thoracic surgery). For internal medicine, these codes were restricted to health service provider specialty code 13 (internal medicine). RFA=Radiofrequency ablation, TACE=Transarterial chemoembolization, EBUS=Endobronchial ultrasound, CT=Computed tomography, MRI=Magnetic resonance imaging

Appendix 2: Definition of surgery date

Algorithm	Time frame for codes	*n* (%)	Median (IQR)
OHIP	Any time	5258 (23%)	43 (0, 71)
OHIP (without M137)	Any time	5182 (23%)	43 (0, 71)
CIHI surgical codes	Any time	5059 (23%)	43 (0, 71)
QBP	Any time	5159 (23%)	42 (0, 70)
OHIP	After diagnosis	3997 (18%)	56 (37, 84)
CIHI	After diagnosis	3755 (17%)	57 (39, 84)
Either OHIP or CIHI	Any time	5307 (24%)	43 (0, 71)
First CIHI, then OHIP (identical results if order reversed)	Any time	5337 (24%)	43 (0, 71)
Either OHIP or CIHI, including TACE or RFA	Any time	5958 (27%)	42 (0, 70)

Using OHIP alone, 23% of patients were identified who had surgery (as defined in Appendix 1) a median of 43 (0, 71) days after diagnosis. Sensitivity analysis to omit code M137 (Lungs & pleura thoracotomy with or without biopsy) did not change this estimate (algorithm 2 vs. 1). Using the 5-digit CIHI surgical codes yielded very similar estimates as OHIP (algorithm 3 vs. 1). Similarly, using the Quality-Based Procedure methodology produced similar estimates (algorithm 4 vs. 3). Given the extent of agreement between OHIP and CIHI, we used the Quality-Based Procedure methodology as our gold standard because the codes are highly specific and have been vetted by clinical experts. It remains unclear whether the patients identified as having received surgery only from a single source are in fact surgical patients



Appendix 3: Indicators of health-care utilization and treatment for DAP versus non-DAP patients

All patients (*n*=22,049)	Non-DAP (*n*=12,913), *n* (%)	DAP (*n*=9136), *n* (%)
Various diagnostic tests		
Chest CT 1	12,499 (97)	9076 (99)
Chest CT 2b	6789 (53)	4240 (46)
Chest CT 3b	2355 (18)	1134 (12)
Abdominal CT	8798 (68)	4982 (55)
Fluoroscopy	1972 (15)	1320 (14)
Chest X-ray 1	12,250 (95)	8913 (98)
Chest X-ray 2b	10,006 (77)	7387 (81)
Chest X-ray 3b	7224 (56)	4932 (54)
Bronchoscopy	4746 (37)	4408 (48)
PET scan	4696 (36)	6372 (70)
Endobronchial ultrasound	1146 (9)	1645 (18)
Mediastinoscopy	674 (5)	534 (6)
Biopsy	10,317 (80)	8342 (91)
Consultations and visits		
General practitioner consultation 1	9912 (77)	6191 (68)
General practitioner consultation 2b	6893 (53)	3694 (40)
General practitioner consultation 3b	4330 (34)	2151 (24)
Respirology consultation	4224 (33)	2904 (32)
Cardiology consultation	4607 (36)	4150 (45)
Internal medicine consultation	7600 (59)	3881 (42)
Diagnostic radiology consultation	1087 (8)	1576 (17)
General surgeon consultation	4768 (37)	4369 (48)
General thoracic surgeon consultation	5263 (41)	6613 (72)
Medical oncology consultation	9691 (75)	6169 (68)
Radiation oncology consultation	6936 (54)	5502 (60)
Number of health-care encounters		
Any visit[c]		
Median (IQR), 90th percentile	26 (19, 36), 49	23 (18, 31), 40
Mean (SD)	30 (17)	26 (13)
Relevant visits[c]		
Median (IQR), 90th percentile	8 (5, 10), 13	8 (6, 10), 12
Mean (SD)	8 (4)	8 (3)
Stage IV (*n*=8782)	**Non-DAP (*n*=5953), *n* (%)**	**DAP (*n*=2829), *n* (%)**
Medical oncology consultation	2783 (47)	1430 (51)
Radiation oncology consultation	3551 (60)	2095 (74)
General surgeon consultation	1658 (28)	1078 (38)

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Appendix 3: Contd...

All patients (*n*=22,049)	Non-DAP (*n*=12,913), *n* (%)	DAP (*n*=9136), *n* (%)
General thoracic surgeon consultation	1443 (24)	1672 (59)
PET scan	709 (12)	1223 (43)
Brain/head MRI	1882 (32)	1403 (50)
Brain CT	3925 (66)	1430 (51)
Brain MRI or CT	4582 (77)	2422 (86)
Biopsy	4549 (76)	2505 (89)
Surgery	94 (2)	76 (3)
Chemotherapy	2033 (34)	1400 (49)
Radiation (chest)	1797 (30)	1221 (43)
Stage III (*n*=3150)	**Non-DAP (*n*=1573), *n* (%)**	**DAP (*n*=1577), *n* (%)**
Medical oncology consultation	699 (44)	836 (53)
Radiation oncology consultation	1011 (64)	1188 (75)
General surgeon consultation	602 (38)	745 (47)
General thoracic surgeon consultation	767 (49)	1124 (71)
PET	828 (53)	1219 (77)
Brain MRI	548 (35)	790 (50)
Brain CT	917 (58)	798 (51)
Brain MRI or CT	1260 (80)	1408 (89)
Biopsy	1398 (89)	1508 (96)
Surgery	199 (13)	242 (15)
Chemotherapy	708 (45)	909 (58)
Radiation (chest)	883 (56)	1042 (66)
Stage II (*n*=1244)	**Non-DAP (*n*=612), *n* (%)**	**DAP (*n*=632), *n* (%)**
Medical oncology consultation	149 (24)	138 (22)
Radiation oncology consultation	238 (39)	244 (39)
General surgeon consultation	300 (49)	335 (53)
General thoracic surgeon consultation	417 (68)	533 (84)
PET scan	426 (70)	560 (89)
Brain MRI	243 (40)	308 (49)
Brain CT	291 (48)	296 (47)
Brain MRI or CT	471 (77)	554 (88)
Biopsy	548 (90)	588 (93)
Surgery	319 (42)	407 (64)
Chemotherapy	209 (34)	275 (44)
Radiation (chest)	189 (31)	203 (32)
Stage I (*n*=3768)	**Non-DAP (*n*=1925), *n* (%)**	**DAP (*n*=1843), *n* (%)**
Medical oncology consultation	267 (14)	168 (9)
Radiation oncology consultation	664 (34)	589 (32)
General surgeon consultation	1000 (51)	1073 (58)
General thoracic surgeon consultation	1318 (68)	1545 (84)
PET scan	1432 (74)	1614 (88)
Brain MRI	586 (30)	749 (41)
Brain CT	769 (40)	655 (36)
Brain MRI or CT	1234 (64)	1270 (69)
Biopsy	1586 (82)	1679 (91)
Surgery	1105 (57)	1238 (67)
Chemotherapy	178 (9)	174 (9)
Radiation (chest)	532 (28)	516 (28)
Repeated tests[a, d]		
Chest CT (OHIP only)		
0	937 (3)	58 (1)
1	4826 (37)	4080 (44)
2	4736 (37)	3399 (37)
3	2131 (17)	1201 (13)

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Appendix 3: Contd...

All patients (*n*=22,049)	Non-DAP (*n*=12,913), *n* (%)	DAP (*n*=9136), *n* (%)
4	607 (5)	313 (3)
5+	222 (2)	85 (1)
Chest X-ray (OHIP only)		
0	687 (5)	224 (2)
1	2302 (18)	1557 (17)
2	2859 (22)	2511 (27)
3	2305 (18)	2078 (23)
4	1554 (12)	1175 (13)
5	954 (7)	611 (7)
6	583 (5)	353 (4)
7+	1669 (13)	627 (5)
PET		
0	938 (73)	4253 (47)
1	3512 (27)	4859 (53)
2	13 (<1)	24 (<1)
Biopsy (OHIP only)		
0	5047 (39)	2542 (28)
1	6234 (48)	5338 (58)
2	1357 (11)	1086 (12)
3+	275 (2)	170 (2)

[a]Receipt of diagnostic tests or consultations from 6 months before diagnosis until either the date of first treatment or 2 months after diagnosis (if no treatment), [b]Also adjusted for having received 1–2 prior exams, [c]Any visit corresponded to any unique billing date from the OHIP database. No restriction was applied to the specific billing codes used. In contrast, relevant visits only included chest CT, abdominal CT, chest X-ray, biopsy, bronchoscopy, fluoroscopy, or consultation with a medical oncologist, surgeon, radiation oncologist, or internal medicine specialist, [d]To count repeated tests, only billing codes from the OHIP were considered. If a procedure date differed between OHIP and other databases, there would be a risk of counting the encounter twice. Thus, the number of tests will be lower than reported earlier in the table. CT=Computed tomography, PET=Positron emission tomography, MRI=Magnetic resonance imaging, OHIP=Ontario Health Insurance Program, MRI=Magnetic resonance imaging

Appendix 4: Time between events in the patient pathway

	Non-DAP patients (*n*=12,913)			DAP patients (*n*=9136)		
	n (%)	Mean days (SD)	Median days (IQR), p90	*n* (%)	Mean days (SD)	Median days (IQR), p90
First visit until diagnosis (no GP)*	12,913 (100)	60 (60)	40 (4, 110), 158	9136 (100)	67 (51)	51 (28, 103), 153
First visit until diagnosis (+GP)*	12,913 (100)	73 (62)	61 (13, 130), 166	9136 (100)	78 (54)	64 (33, 123), 162
General practitioner consultation #1 until diagnosis	9912 (77)	50 (63)	26 (0, 99), 152	6191 (68)	56 (61)	42 (8, 102), 154
General practitioner consultation #2 until diagnosis	6893 (53)	19 (51)	1 (−6, 36), 103	3694 (40)	26 (54)	13 (−4, 49), 109
General practitioner consultation #3 until diagnosis	4330 (34)	5 (45)	0 (−19, 15), 68	2151 (24)	10 (49)	0 (−19, 29), 78
Chest x-ray #1 until diagnosis	12,250 (95)	40 (54)	18 (0, 69), 132	8913 (98)	51 (48)	39 (15, 74), 127
Chest x-ray #2 until diagnosis	10,006 (77)	10 (45)	0 (−5, 17), 71	7387 (81)	13 (42)	0 (−1, 28), 68
Chest x-ray #3 until diagnosis	7224 (56)	−3 (42)	−2 (−19, 0), 41	4932 (54)	−6 (41)	−2 (−26, 0), 36
Chest CT until diagnosis	12,499 (97)	25 (44)	3 (0, 35), 93	9076 (99)	34 (35)	25 (13, 43), 77
Chest x-ray #1 until chest CT #1	12,007 (93)	15 (54)	7 (0 30), 85	8860 (97)	17 (48)	12 (1, 32), 75
Chest CT #2 until diagnosis	6789 (53)	−3 (36)	−1 (−15, 0), 36	4240 (46)	−2 (35)	0 (−16, 2), 36
Chest CT #1 until chest CT #2	6789 (53)	38 (39)	26 (5, 56), 96	4240 (46)	45 (35)	36 (21, 63), 96
Chest CT #3 until diagnosis	2355 (18)	−21 (39)	−12 (−40, 0), 5	1134 (12)	−23 (39)	−16 (−44, 0), 15
Chest CT #2 until chest CT #3	2355 (18)	32 (31)	22 (6, 47), 77	1134 (12)	37 (32)	30 (12, 53), 84
Abdominal CT until diagnosis	8798 (68)	12 (44)	0 (−2, 15), 68	4982 (55)	21 (44)	14 (0, 36), 75
Stage I	893	35 (61)	21 (0, 72), 129	707	43 (53)	34 (10, 68), 127
Stage II	337	22 (57)	8 (−1, 41), 108	330	32 (46)	27 (8, 49), 92
Bronchoscopy (no endobronchial ultrasound)	4746 (37)	−2 (38)	−2 (−13, 0), 32	4408 (48)	−3 (28)	0 (−9, 0), 21
Biopsy until diagnosis	10,317 (80)	2 (33)	0 (−2, 0), 23	8342 (91)	3 (22)	0 (0, 0), 15

Contd...

Appendix 4: Contd...

	Non-DAP patients (*n*=12,913)			DAP patients (*n*=9136)		
	n (%)	Mean days (SD)	Median days (IQR), p90	*n* (%)	Mean days (SD)	Median days (IQR), p90
Fluoroscopy until diagnosis	1972 (15)	2 (44)	−1 (−14, 0), 51	1320 (14)	0 (35)	0 (−6, 0), 20
Brain MRI to diagnosis	4268 (33)	−5 (39)	−2 (−25, 0), 30	4471 (49)	−2 (31)	−3 (−18, 8), 22
General surgery oncology consultation until diagnosis	4768 (37)	25 (60)	7 (−11, 53), 126	4369 (48)	19 (49)	8 (−10, 29), 92
Stage I	1000	33 (61)	22 (−13, 70), 127	1073	23 (53)	13 (−12, 41), 100
Stage II	300	21 (59)	7 (−14, 43), 117	335	16 (50)	7 (−14, 29), 80
General thoracic surgery oncology consultation until diagnosis	5263 (41)	6 (49)	−2 (−21, 21), 72	6613 (72)	9 (29)	8 (−7, 21), 37
Stage I	1318	19 (58)	12 (−22, 52), 105	1545	13 (35)	14 (−10, 28), 47
Stage II	417	8 (54)	−1 (−25, 28), 93	533	9 (30)	10 (−11, 23), 41
Internal medicine consultation until diagnosis	7600 (59)	26 (60)	0 (−1, 48), 132	3881 (42)	30 (65)	6 (−15, 70), 139
Respirology consultation until diagnosis	4224 (33)	21 (57)	0 (−9, 35), 124	2904 (32)	15 (46)	0 (−8, 20), 86
Cardiology consultation until diagnosis	4607 (36)	32 (64)	8 (−9, 71), 140	4150 (45)	23 (53)	10 (−9, 36), 113
Referral to DAP to diagnosis		–	–	9136 (100)	21 (41)	17 (6, 29), 47
Diagnosis until medical oncology consultation	4999 (39)	19 (40)	19 (8, 35), 56	3463 (38)	23 (29)	22 (14, 34), 49
Stage I						
Stage II						
Diagnosis until radiation consultation	6936 (54)	22 (40)	20 (9, 36), 61	5502 (60)	22 (30)	21 (12, 33), 49
Stage I						
Stage II						
Diagnosis until PET	4696 (36)	13 (43)	22 (−5, 38), 56	6372 (70)	5 (26)	5 (−8, 20), 33
PET until first treatment	4251 (33)	47 (35)	40 (23, 62), 90	5797 (63)	44 (29)	38 (23, 58), 81
Diagnosis until first treatment	8783 (68)	47 (38)	41 (19, 69), 100	7807 (85)	43 (30)	39 (22, 58), 83
First visit until first treatment (no GP)*	8783 (68)	107 (67)	96 (54, 153), 201	7807 (85)	108 (57)	97 (64, 145), 193
First visit until first treatment (+GP)*	8783 (68)	120 (69)	113 (65, 171), 214	7807 (85)	119 (61)	108 (70, 163), 206

Number of patients receiving each test within 6 months of diagnosis until the date of first treatment (or 2 months after diagnosis if no treatment). *Excludes or includes the general practitioner (GP) visit when establishing the first visit date. DAP=Diagnostic assessment program, PET=Positron emission tomography, SD=Standard deviation, IQR=Interquartile range (25th, 75th percentile); p90–90th percentile

Appendix 5: Types of treatment and wait times by stage

	All patients (*n*=22,049), *n* (%)	Stage I (*n*=3768), *n* (%)	Stage II (*n*=1244), *n* (%)	Stage III (*n*=3150), *n* (%)	Stage IV (*n*=8782), *n* (%)	Unknown (*n*=104), *n* (%)
Receipt of intervention between diagnosis and 1-year afterward						
Radiation	8399 (38)	1048 (28)	392 (32)	1925 (61)	3018 (34)	21 (20)
Chemotherapy	8484 (38)	352 (9)	484 (39)	1617 (51)	3433 (39)	13 (13)
Surgery	4965 (23)	2343 (62)	726 (58)	441 (14)	170 (2)	13 (13)
Transarterial chemoembolization	416 (2)	42 (1)	21 (2)	70 (2)	179 (2)	<6
Radiofrequency ablation	464 (2)	23 (1)	18 (1)	40 (1)	256 (3)	<6
First intervention[a]						
Radiation	5826 (26)	918 (24)	253 (20)	981 (31)	2439 (28)	18 (18)
No treatment	5459 (25)	367 (10)	147 (12)	638 (20)	3489 (40)	62 (60)
Chemotherapy	5184 (24)	182 (5)	101 (8)	738 (23)	2635 (30)	10 (10)
Surgery[b]	4713 (21)	2282 (61)	696 (56)	376 (12)	156 (2)	13 (13)
Chemoradiation	867 (4)	16 (<1)	46 (4)	417 (13)	63 (1)	<6
Wait times (days)[c]	**Median (IQR), p90**	**Median (IQR), p90**	**Median (IQR), p90**	**Median (IQR), p90**	**Median (IQR), p90**	**Median (IQR), p90**
Diagnosis until treatment	40 (21, 63), 92[d]	45 (13, 70), 99	48 (26, 70), 100	41 (25, 63), 91	31 (18, 52), 77	53 (11, 78), 94
First visit until diagnosis[d]	62 (23, 127), 165	98 (50, 147), 171	76 (36, 133), 166	61 (27, 122), 162	42 (11, 108), 158	79 (30, 143), 173
First visit until treatment	114 (70, 172), 214	141 (98, 185), 229	124 (84, 181), 220	111 (70, 167), 211	84 (49, 148), 196	123 (85, 206), 274

[a]Excluding radiofrequency ablation (RFA) and transarterial chemoembolization (TACE), [b]Includes 10 patients who also started chemotherapy on the surgery date, [c]Stratified by first treatment, the median time until treatment was 43 (26, 69) days for those who received radiation first, 39 (0, 64) days for those who received surgery first, 35 (20, 56) days for those who received chemotherapy first, and 52 (38, 73) days for those who received chemoradiation first, [d]First visit date includes visits with the general practitioner . IQR=Interquartile range (25th percentile, 75th percentile), p90–90th percentile

Appendix 6: Association of the pretreatment interval with overall survival by stage

	Stage I (*n*=3768)		Stage II (*n*=1244)		Stage III (*n*=3150)		Stage IV (*n*=8782)	
	HR (95% CI)[a]	*P*	HR (95% CI)[a]	*P*	HR (95% CI)[a]	*P*	HR (95% CI)[a]	*P*
>63 days	1.0 (reference)	<.0001	1.0 (reference)	0.01	1.0 (reference)	<.0001	1.0 (reference)	<0.0001
36–63 days	0.98 (0.82–1.18)		1.16 (0.93–1.45)		1.30 (1.14–1.47)		1.45 (1.32–1.58)	
29–35 days	1.08 (0.80–1.46)		0.99 (0.66–1.48)		1.49 (1.25–1.79)		1.97 (1.77–2.20)	
22–28 days	1.23 (0.87–1.73)		1.58 (1.12–2.23)		1.79 (1.50–2.14)		2.06 (1.85–2.29)	
15–21 days	1.29 (0.87–1.91)		1.09 (0.66–1.79)		2.09 (1.73–2.53)		2.30 (2.06–2.56)	
8–14 days	1.70 (1.08–2.70)		1.66 (0.92–2.98)		2.74 (2.17–3.45)		2.63 (2.34–2.96)	
1–7 days	2.35 (1.46–3.77)		2.00 (1.15–3.49)		3.81 (2.96–4.91)		3.31 (2.86–3.83)	
0 days (on the diagnosis date)	0.35 (0.24–0.50)		0.71 (0.45–1.14)		1.03 (0.79–1.35)		2.29 (1.94–2.69)	
>63 days	1.0 (reference)	0.03	1.0 (reference)	0.39	1.0 (reference)	0.18	1.0 (reference)	<0.0001
36–63 days	1.01 (0.84–1.23)		1.01 (0.81–1.26)		0.96 (0.86–1.08)		1.08 (1.01–1.15)	
29–35 days	0.76 (0.51–1.13)		0.85 (0.57–1.28)		1.14 (0.95–1.37)		1.04 (0.94–1.15)	
22–28 days	1.32 (0.91–1.90)		1.06 (0.70–1.59)		0.99 (0.83–1.18)		1.14 (1.03–1.26)	
15–21 days	0.91 (0.59–1.41)		1.05 (0.61–1.81)		1.11 (0.92–1.35)		1.16 (1.05–1.27)	
8–14 days	2.09 (1.28–3.40)		1.63 (1.09–2.44)		1.24 (0.92–1.35)		1.08 (1.00–1.20)	
1–7 days	1.19 (0.82–1.71)		0.82 (0.51–1.33)		0.91 (0.75–1.10)		0.93 (0.86–1.01)	
0 days (on the diagnosis date)	1.30 (0.95–1.79)		0.98 (0.66–1.45)		1.03 (0.86–1.23)		0.93 (0.86–1.01)	

[a]Adjusted for DAP, age, sex, comorbidity score, stage, histology, urban, income quintile, immigrant density, LHIN of residence, distance to closest DAP, emergency department visit within 7 days of diagnosis, and admission on diagnosis. HR=Hazard ratio, CI=Confidence interval