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
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.\cite{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.\cite{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.\cite{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.\cite{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...
| Non-DAP (n=12,913) | DAP (n=9136) | DAP versus non-DAP |
|-------------------|--------------|-------------------|
| (n=12,913), n (%) | n (%)        | Crude OR (95% CI) | P | Adjusted OR (95% CI) | P |
| Age, years<sup>a</sup> | 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<sup>c</sup> | | | | | | |
| 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<sup>d</sup> | | | | | | |
| 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<sup>e</sup> | | | | | | |
| 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<sup>f</sup> | | | | | | |
| 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<sup>e</sup> | | | | | | |
| 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<sup>c</sup> | | | | | | |
| No | 7237 (56) | 7829 (86) | 1.0 (reference) | <0.0001 | 1.0 (reference) | <0.0001 |

* Contd...
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...
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.\textsuperscript{[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.\textsuperscript{[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.\textsuperscript{[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.\textsuperscript{[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)*, in days                   | P                                        | β (95% CI)*, in days                     | P                                        | β (95% CI)*, in days | P                                        |
| Overall                  | Mean 77.4 (59.2)                       | –                                        | Mean 45.5 (34.7)                         | –                                        | Mean 125.3 (66.9)   | –                                        |
|                          | Median 66 (25–131)                     |                                          | Median 40 (21–63)                        |                                          | 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)                       | <0.0001                                  | −8.5 (−9.7–−7.3)                        | −10.4 (−12.8–−8.0)                     | 3.3 (2.2–4.4)       | <0.0001                                 |
| 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)                    | <0.0001                                  | 3.6 (2.1–5.2)                           | <0.0001                                 | −18.2 (−21.3—15.1) | <0.0001                                 |
| 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)                       | <0.0001                                  | 1.6 (−0.5–3.7)                          |                                          | −9.1 (−13.3–−4.9)  | <0.0001                                 |
| Stage III                | −16.8 (−19.5—14.1)                    | <0.0001                                  | −1.6 (−3.2–0.1)                         |                                          | −19.2 (−22.4–15.9) | <0.0001                                 |
| Stage IV                 | −22.7 (−25—20.4)                      | <0.0001                                  | −10.3 (−11.8–−8.9)                      |                                          | −32.7 (−35.6–29.8) | <0.0001                                 |
| 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                                     | 0.0 (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)   |                                          |
| Urbanб                   |                                        |                                          |                                          |                                          |                                          |                                          |
| 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)     |                                          |
| Incomeб                  |                                        |                                          |                                          |                                          |                                          |                                          |
| 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)     |                                          |
| Immigrantб              |                                        |                                          |                                          |                                          |                                          |                                          |
| 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 Networkб| |                                   |                                          |                                          |                                          |                                          |                                          |
| 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 (1−10–9.3)      |                                          |
| 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 |
|--------------------------------------|-------------------------------------------|--------------------------------------------|
| **Habbous, et al.** Efficiency of lung diagnostic assessment program | **Annals of Thoracic Medicine** - Volume 16, Issue 1, January-March 2021 | **Table 2: Contd...** |
| **Bet** (95% CI), in days | **Bet** (95% CI), in days | **Bet** (95% CI), in days |
| **Waterloo Wellington** | **Distance to closest DAP (x50 km)**
| β (95% CI), a, in days | P | β (95% CI), a, in days | P | β (95% CI), a, in days | P |
| Table 2: Contd... | | | | | | |
| 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) | <0.0001 | | |
| 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) | <0.0001 | | |
| **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,** 
| **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) | P | Adjusted HR (95% CI) | P |
|-------------------|---|----------------------|---|----------------------|---|
| **DAP patient status** | **DAP patient status** | **DAP patient status** | **DAP patient status** | **DAP patient status** | **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) | 1.20 (1.18–1.22) | 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** | **Charlson Comorbidity Index** | **Charlson Comorbidity Index** | **Charlson Comorbidity Index** | **Charlson Comorbidity Index** | **Charlson Comorbidity Index** |
| Missing | 1.07 (1.03–1.13) | 0.96 (0.91–1.01) | 0.97 (0.92–1.02) | 0.0001 |
| 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) | 0.0001 |
| 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** | **Stage** | **Stage** | **Stage** | **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) | 0.0001 |
| Stage III | 5.05 (4.69–5.44) | 5.07 (4.70–5.46) | 4.90 (4.54–5.28) | 0.0001 |
| Stage IV | 11.7 (11.0–12.6) | 11.9 (11.1–12.7) | 10.6 (9.83–11.3) | 0.0001 |
| Unknown | 5.23 (4.15–6.60) | 4.60 (3.65–5.81) | 4.42 (3.50–5.58) | 0.0001 |
| **Histology** | **Histology** | **Histology** | **Histology** | **Histology** | **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) | 0.0001 |
| **Urban** | **Urban** | **Urban** | **Urban** | **Urban** | **Urban** |
| 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) | 0.0001 |
| **Income** | **Income** | **Income** | **Income** | **Income** | **Income** |
| Highest | 1.0 (reference) | <0.0001 | 1.0 (reference) | <0.0001 | 1.0 (reference) | 0.0001 |
| Mid-high | 1.03 (1.00–1.09) | 1.07 (1.02–1.14) | 1.06 (1.00–1.12) | 0.0001 |
| Middle | 1.08 (1.03–1.14) | 1.09 (1.03–1.16) | 1.07 (1.01–1.14) | 0.0001 |
| Mid-low | 1.12 (1.07–1.19) | 1.13 (1.06–1.20) | 1.13 (1.06–1.19) | 0.0001 |
| Lowest | 1.17 (1.11–1.23) | 1.21 (1.14–1.29) | 1.19 (1.12–1.26) | 0.0001 |
| **Immigrant** | **Immigrant** | **Immigrant** | **Immigrant** | **Immigrant** | **Immigrant** |
| 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) | 0.0001 |
| Most dense | 0.92 (0.87–0.97) | 0.85 (0.79–0.91) | 0.85 (0.79–0.91) | 0.0001 |
| **Local Health Integration Network** | **Local Health Integration Network** | **Local Health Integration Network** | **Local Health Integration Network** | **Local Health Integration Network** | **Local Health Integration Network** |
| 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)  | 0.0001 | 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 | Crude HR (95% CI) | P    | Adjusted HR (95% CI) | P    | Adjusted HR (95% CI) | P   |
|--------------------------------------|-------------------|------|----------------------|------|----------------------|-----|
| 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)     |      | 1.16 (1.07–1.25)     |     |
| 8–14 days                            | 1.87 (1.74–2.01)  |      | 1.16 (1.07–1.26)     |      | 1.22 (1.03–1.22)     |     |
| 15–21 days                           | 1.56 (1.45–1.69)  |      | 1.16 (1.07–1.26)     |      | 1.12 (1.03–1.22)     |     |
| 22–28 days                           | 1.39 (1.29–1.50)  |      | 1.12 (1.03–1.22)     |      | 1.05 (0.96–1.14)     |     |
| 29–35 days                           | 1.26 (1.17–1.36)  |      | 1.05 (0.96–1.14)     |      | 1.05 (0.96–1.14)     |     |
| 36–63 days                           | 1.09 (1.04–1.14)  |      | 1.05 (0.96–1.14)     |      | 1.05 (0.96–1.11)     |     |
| >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**

| Time from diagnosis until first treatment (/30 days) | Crude HR (95% CI) | P    | Adjusted HR (95% CI) | P    | Adjusted HR (95% CI) | P   |
|----------------------------------------------------|-------------------|------|----------------------|------|----------------------|-----|
| 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)     |      | 2.31 (2.10–2.54)     |     |
| 8–14 days                                          | 3.10 (2.86–3.37)  |      | 2.31 (2.10–2.54)     |      | 1.95 (1.79–2.13)     |     |
| 15–21 days                                         | 2.41 (2.24–2.60)  |      | 1.95 (1.79–2.13)     |      | 1.81 (1.66–1.97)     |     |
| 22–28 days                                         | 2.05 (1.91–2.21)  |      | 1.81 (1.66–1.97)     |      | 1.65 (1.51–1.79)     |     |
| 29–35 days                                         | 1.70 (1.58–1.83)  |      | 1.65 (1.51–1.79)     |      | 1.28 (1.20–1.37)     |     |
| 36–63 days                                         | 1.27 (1.21–1.35)  |      | 1.28 (1.20–1.37)     |      | 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 |

*Adjusted for DAP, age, sex, comorbidity score, stage, histology, urban, income quintile, immigrant density, and LHIN of residence. bAdjusted 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. bSource: (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. It used a clinical pathway that included checklists, patient navigators, and dedicated booking times for CT scanning or bronchoscopy. 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. 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. 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.\textsuperscript{[13]}

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.\textsuperscript{[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.\textsuperscript{[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.\textsuperscript{[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.\textsuperscript{[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.\textsuperscript{[24–27]}

Despite longer wait times for lung cancer diagnosis in Ontario, 1- and 5-year survival rates were higher in international comparisons.\textsuperscript{[17,28]} There is little evidence that shorter diagnostic or pretreatment intervals improve survival.\textsuperscript{[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.\textsuperscript{[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).\textsuperscript{[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.
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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 |
| 1GT99 | 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-lobectomy-complete |
| M145 | Lungs & pleura-lobectomy-wedge resection |
| M144 | Lungs & pleura-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 |

Contd...
### Appendix 1: Contd...

| Code         | Description                                                                 |
|--------------|-----------------------------------------------------------------------------|
| 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 |

Contd...
### Appendix 1: Contd...

| Code     | Description                                                                 |
|----------|-----------------------------------------------------------------------------|
| 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**

| Code     | Description                                                                 |
|----------|-----------------------------------------------------------------------------|
| 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           |

**Brain/head MRI**

| Code     | Description                                                                 |
|----------|-----------------------------------------------------------------------------|
| 3AN40    | MRI, brain                                                                  |
| 3ER40    | MRI, head                                                                   |
| X421     | MRI, head (multi-slice sequence)                                            |
| X425     | MRI, head (multi-slice sequence), repeat                                     |

**Brain/head CT**

| Code     | Description                                                                 |
|----------|-----------------------------------------------------------------------------|
| 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**

| Code     | Description                                                                 |
|----------|-----------------------------------------------------------------------------|
| Z329     | Chest wall and mediastinum-endoscopy-mediastinoscopy                        |
| Z328     | Chest wall and mediastinum-endoscopy-with mediastinoscopy                   |

**Chest CT**

| Code     | Description                                                                 |
|----------|-----------------------------------------------------------------------------|
| 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**

| Code     | Description                                                                 |
|----------|-----------------------------------------------------------------------------|
| 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**

| Code     | Description                                                                 |
|----------|-----------------------------------------------------------------------------|
| X195     | Fluoroscopy, chest                                                          |
| X197     | Fluoroscopy, abdomen                                                        |
| X189     | Fluoroscopic control of clinical procedures done by another physician       |
| 3GT12    | Fluoroscopy, lung                                                           |

**Chest X-ray**

| Code     | Description                                                                 |
|----------|-----------------------------------------------------------------------------|
| X090     | Diagnostic radiology – chest – single view                                  |
| X091     | Diagnostic radiology – chest – two views                                    |

Contd...
### Appendix 1: Contd...

| Code    | Description                                                                                   |
|---------|-----------------------------------------------------------------------------------------------|
| X092    | Diagnostic radiology – chest – three or more views                                           |
| 3GY10** | X-ray, thoracic cavity                                                                       |

#### Consultations

| Code    | Description                                                                                   |
|---------|-----------------------------------------------------------------------------------------------|
| A645, A935, A646, A643, A644, C645, C935, C646, C643, C644 | General thoracic surgery***                                                                |
| A345, A765, A745, A346, A343, A340, A341, A348, 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, A485, A446, A443, A444, A441, A448, C445, C446, C443, C444, C441, W445, W765, W845, W446 | Medical oncology                                                                           |
| A465, A575, A476, A473, A474, A471, A478, C475, C575, C476, C473, C474, C471 | Respirology***                                                                             |
| 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

| Code    | Description                                                                                   |
|---------|-----------------------------------------------------------------------------------------------|
| Z327    | Bronchoscopy – with removal of foreign body, to Z327                                          |
| E632    | 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.                     |

Contd...
Appendix 1: Contd...

| Code  | Description                                                                 |
|-------|-----------------------------------------------------------------------------|
| 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

| Code  | Description                                                                 |
|-------|-----------------------------------------------------------------------------|
| 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  | Hilary 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             | 5537 (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

| Various diagnostic tests                      | Non-DAP ($n=12,913$), $n$ (%) | DAP ($n=9136$), $n$ (%) |
|-----------------------------------------------|---------------------------------|-------------------------|
| 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$^a$                                      | Non-DAP ($n=5953$), $n$ (%) | DAP ($n=2829$), $n$ (%) |
|--------------------------------------------------|------------------------------|-------------------------|
| Median (IQR), 90th percentile                     | 26 (19, 36), 49              | 23 (18, 31), 40         |
| Mean (SD)                                        | 30 (17)                      | 26 (13)                 |
| Relevant visits$^b$                               |                              |                         |
| Median (IQR), 90th percentile                     | 8 (5, 10), 13                | 8 (6, 10), 12           |
| Mean (SD)                                        | 8 (4)                        | 8 (3)                   |
| Stage IV ($n=8782$)                              |                              |                         |
| 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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*Contd...*
### 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, b, c

| Chest CT (OHIP only) | | |
|---------------------|---------------------|
| 0 | 937 (3) | 58 (1) |
| 1 | 4826 (37) | 4080 (44) |
| 2 | 4736 (37) | 3399 (37) |
| 3 | 2131 (17) | 1201 (13) |
### Appendix 3: Contd...

| All patients (n=22,049) | Non-DAP (n=12,913), n (%) | DAP (n=9,136), n (%) |
|-------------------------|---------------------------|----------------------|
| 4                       | 607 (5)                   | 313 (3)              |
| 5+                      | 222 (2)                   | 85 (1)               |

#### Chest X-ray (OHIP only)

|                           | Non-DAP (n=12,913)       | DAP (n=9,136)        |
|---------------------------|--------------------------|----------------------|
|                          |                          | n (%)                |
|                          |                          | Mean days (SD)       |
|                          |                          | Median days (IQR), p90|
| 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

|                           | Non-DAP (n=12,913)       | DAP (n=9,136)        |
|---------------------------|--------------------------|----------------------|
|                          |                          | n (%)                |
|                          |                          | Mean days (SD)       |
|                          |                          | Median days (IQR), p90|
| 0                        | 938 (73)                 | 4253 (47)            |
| 1                        | 3512 (27)                | 4859 (53)            |
| 2                        | 13 (<1)                  | 24 (<1)              |

#### Biopsy (OHIP only)

|                           | Non-DAP (n=12,913)       | DAP (n=9,136)        |
|---------------------------|--------------------------|----------------------|
|                          |                          | n (%)                |
|                          |                          | Mean days (SD)       |
|                          |                          | Median days (IQR), p90|
| 0                        | 5047 (39)                | 2542 (28)            |
| 1                        | 6234 (48)                | 5338 (58)            |
| 2                        | 1357 (11)                | 1086 (12)            |
| 3+                       | 275 (2)                  | 170 (2)              |

*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), *Also adjusted for having received 1–2 prior exams, *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, *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=9,136) |
|------------------------------|------------------------|
| n (%)                        | Mean days (SD)         | Median days (IQR), p90 |
| First visit until diagnosis (no GP)* | 12,913 (100) | 60 (60) | 40 (4, 110), 158 |
| First visit until diagnosis (+GP)* | 12,913 (100) | 73 (62) | 61 (13, 130), 166 |
| General practitioner consultation #1 until diagnosis | 9912 (77) | 50 (63) | 26 (0, 99), 152 |
| General practitioner consultation #2 until diagnosis | 6893 (53) | 19 (51) | 1 (-6, 36), 103 |
| General practitioner consultation #3 until diagnosis | 4330 (34) | 5 (45) | 0 (-19, 15), 68 |
| Chest x-ray #1 until diagnosis | 12,250 (95) | 40 (54) | 18 (0, 69), 132 |
| Chest x-ray #2 until diagnosis | 10,006 (77) | 10 (45) | 0 (-5, 17), 71 |
| Chest x-ray #3 until diagnosis | 7224 (56) | -3 (42) | -2 (-19, 0), 41 |
| Chest CT until diagnosis | 12,499 (97) | 25 (44) | 3 (0, 35), 93 |
| Chest x-ray #1 until chest CT #1 | 12,007 (93) | 15 (54) | 7 (0 30), 85 |
| Chest CT #2 until diagnosis | 6789 (53) | -3 (36) | -1 (-15, 0), 36 |
| Chest CT #1 until chest CT #2 | 6789 (53) | 38 (39) | 26 (5, 56), 96 |
| Chest CT #3 until diagnosis | 2355 (18) | -21 (39) | -12 (-40, 0), 5 |
| Chest CT #2 until chest CT #3 | 2355 (18) | 32 (31) | 22 (6, 47), 77 |
| Abdominal CT until diagnosis | 8798 (68) | 12 (44) | 0 (-2, 15), 68 |
| Stage I | 893 | 35 (61) | 21 (0, 72), 129 |
| Stage II | 337 | 22 (57) | 8 (-1, 41), 108 |
| Bronchoscopy (no endobronchial ultrasound) | 4746 (37) | -2 (38) | -2 (-13, 0), 32 |
| Biopsy until diagnosis | 10,317 (80) | 2 (33) | 0 (-2, 0), 23 |
**Appendix 4: Contd...**

|                | Non-DAP patients (n=12,913) | DAP patients (n=9,136) |
|----------------|----------------------------|------------------------|
|                | n (%)                      | Mean days (SD)         | Median days (IQR, p90) |
| Fluoroscopy until diagnosis | 1972 (15)                  | 2 (44)                 | -1 (-14, 0), 51       |
| Brain MRI to diagnosis | 4268 (33)                  | -5 (39)                | -2 (-25, 0), 30       |
| General surgery oncology consultation until diagnosis | 4768 (37)                  | 25 (60)                | 7 (-11, 53), 126     |
| Stage I        | 1000                       | 33 (61)                | 22 (-13, 70), 127    |
| Stage II       | 300                        | 21 (59)                | 7 (-14, 43), 117     |
| General thoracic surgery oncology consultation until diagnosis | 5263 (41)                  | 6 (49)                 | -2 (-21, 21), 72     |
| Stage I        | 1318                       | 19 (58)                | 12 (-22, 52), 105    |
| Stage II       | 417                        | 8 (54)                 | -1 (-25, 28), 93     |
| Internal medicine consultation until diagnosis | 7600 (59)                  | 26 (60)                | 0 (-1, 48), 132      |
| Respirology consultation until diagnosis | 4224 (33)                  | 21 (57)                | 0 (-9, 35), 124      |
| Cardiology consultation until diagnosis | 4607 (36)                  | 32 (64)                | 8 (-9, 71), 140      |
| Referral to DAP to diagnosis | -                            | -                      | -                    |
| Diagnosis until medical oncology consultation | 4999 (39)                  | 19 (40)                | 19 (8, 35), 56       |
| Stage I        | 6936 (54)                  | 22 (40)                | 20 (9, 36), 61       |
| Stage II       | 4696 (36)                  | 13 (43)                | 22 (-5, 38), 56      |
| PET until first treatment | 4251 (33)                  | 47 (35)                | 40 (23, 62), 90      |
| Diagnosis until first treatment | 8783 (68)                  | 47 (38)                | 41 (19, 69), 100     |
| First visit until first treatment (no GP)* | 8783 (68)                  | 107 (67)               | 96 (54, 153), 201    |
| First visit until first treatment (+GP)* | 8783 (68)                  | 120 (69)               | 113 (65, 171), 214   |

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, p90=90th percentile.

**Appendix 5: Types of treatment and wait times by stage**

|                | All patients (n=22,049) | Stage I (n=3768) | Stage II (n=1244) | Stage III (n=3150) | Stage IV (n=8782) | Unknown (n=104) |
|----------------|-------------------------|------------------|------------------|-------------------|------------------|-----------------|
|                | n (%)                   | Stage I n (%)    | Stage II n (%)   | Stage III n (%)   | Stage IV n (%)   | Unknown n (%)   |
| 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 | 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 (16)                | 16 (<1)          | 46 (4)           | 417 (13)          | 63 (1)           | <6              |

wait times (days)^c

|                | Median (IQR, p90) |
|----------------|------------------|
| Diagnosis until treatment | 40 (21, 63), 92^a | 45 (13, 70), 99 | 48 (26, 70), 100 | 41 (25, 63), 91 | 31 (18, 52), 77 | 53 (11, 78), 94 |
| First visit until diagnosis^a | 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 (64, 181), 220 | 111 (70, 167), 211 | 84 (49, 148), 196 | 123 (85, 206), 274 |

^aExcluding radiofrequency ablation (RFA) and transarterial chemoembolization (TACE). ^bIncludes 10 patients who also started chemotherapy on the surgery date. ^cStratified 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. ^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)         | $P$                 | HR (95% CI)          | $P$                 | HR (95% CI)       | $P$                 |
| >63 days            | 1.0 (reference)     | <.0001               | 1.0 (reference)     | 0.01               | 1.0 (reference)    | <.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) |

*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