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Characterising melanoma diagnostic pathways for patients in routine practice using administrative health data in Ontario, Canada: a population-based study

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ABSTRACT

Objective To characterise diagnostic pathways for patients with melanoma in routine practice and compare patient, disease and diagnostic interval (DI) characteristics across pathways.

Design Descriptive cross-sectional study using administrative health data.

Setting Population-based study in Ontario, Canada.

Participants Patients with melanoma diagnosed from 2007 to 2019.

Main outcome measures We used latent class cluster analysis to create clusters of patients with similar diagnostic experiences to characterise diagnostic pathways in routine practice. Indicator variables characterised the patient's keratinocyte carcinoma and dermatologist history, presentation pattern, procedure types, number of visits and procedures, and the activity on the diagnosis date. χ^2 tests and Pearson residuals were used. We characterised clusters by the lengths of their DI, primary care subinterval and specialist care subinterval.

Results There were 33 371 patients diagnosed with melanoma from 2007 to 2019. We identified four diagnostic pathways: 'primary care only' (n=6107), 'referred to specialist with immediate action' (n=8987), 'multiple visits and procedures in specialist care' (n=11 893) and 'specialist care only' (n=6384). Patient, disease and DI characteristics varied across pathways. Pathway types varied regionally. A higher proportion in the 'primary care only' pathway lived in rural areas whereas a higher proportion in the 'referred to specialist for immediate action' and the 'specialist care only' pathways lived in major urban centres. Across pathways, the median DI varied from 1 to 67 days, the median primary care subinterval varied from 1 to 30 days and the median specialist care subinterval varied from 1 to 25 days. Patients in the 'primary care only' pathway experienced the shortest DIs, and patients in the 'multiple visits and procedures in specialist care' pathway experienced the longest DIs.

Conclusions and relevance We identified four melanoma diagnostic pathways. The shortest DI, the 'primary care only' pathway, highlights the important role of primary care and the need to reduce the wait for specialists. Diagnostic processes varied across geographical locations. Future research should address reasons for these differences, including whether they are associated with inefficient or inappropriate care.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ There are very few population-based studies examining the various diagnostic pathways that patients with melanoma undergo and the factors that affect them, such as patient, disease and system-level factors.
⇒ An empirical approach was used to identify the diagnostic pathways, allowing us to objectively examine the routes to diagnosis for all patients with melanoma in Ontario.
⇒ Using the administrative health data limited the ability to comprehensively describe the diagnostic pathways and fully understand why a patient may have undergone several investigations prior to their definitive diagnosis.
⇒ Misclassification of visits labelled melanoma-related is possible, although using control charts to assign look-back periods for encounter inclusion minimises this possibility.

INTRODUCTION

Protracted and inefficient diagnostic pathways are associated with increased patient anxiety,[1–3] and they likely consume unnecessary healthcare resources.[4] Evidence is mixed on whether protracted pathways are associated with melanoma stage progression.[5–9] Administrative health data allow us to characterise system-related diagnostic intervals (DIs), which is the time and activity from patient presentation to a physician to the melanoma diagnosis.[10] This phase is important to study to potentially identify modifiable system factors for quality improvement. Few studies have examined the melanoma diagnostic

process, and they have been limited by their small sample size and use of selective samples.[11 12] One exception is a population-based study by Baade and colleagues that described the diagnostic process in Queensland, Australia.[13] They found that most patients first saw their primary care provider (PCP), though the diagnostic route varied by demographics and area of residence.[13]

Given the limited evidence on population-level characteristics of melanoma diagnostic pathways required to inform quality improvement, and how patient, disease, and system characteristics vary across the different pathways, we set out to investigate melanoma diagnostic pathways in routine practice in a large population-based sample. We investigated and characterised melanoma diagnostic pathways in routine practice in a large population-based cohort in the Canadian province of Ontario, where there is near-complete population coverage of its health administrative data. This allows a comprehensive overview of routine patient management in Ontario, and our findings provide insights into potentially vulnerable subgroups and circumstances in other health systems.

METHODS

Study design

This was a descriptive population-based cross-sectional study that used linked health administrative databases held at ICES, formerly known as the Institute for Clinical Evaluative Sciences. ICES is an independent, non-profit research institute whose legal status under Ontario's health information privacy law allows it to collect and analyse healthcare and demographic data, without consent, for health system evaluation and improvement. Ontario has a publicly funded universal health system that allows nearly all residents to access medically necessary hospital and physician services. This project was approved by the Health Sciences Research Ethics Board at Queen's University. Participant consent was waived as the research falls under Article 5.5A of the Tri-Council Policy Statement 2 (TCPS 2). Patients were not involved in creating the research question or the outcome measures nor were they involved in the design and implementation of the study. Study results and implications were presented at meetings and conferences.

Study population

The study included individuals diagnosed with cutaneous melanoma in Ontario between 1 January 2007 and 31 October 2019. Patients were excluded if they had less than 60 months of continuous Ontario Health Insurance Plan (OHIP) coverage preceding diagnosis and less than 6 months of continuous OHIP coverage postdiagnosis, were missing age or sex data, were under 20 years of age, were non-Ontario residents, or had concurrent cancer. We further excluded those for whom we were unable to assign a DI.

Determination of diagnostic pathways

Determination of the DI and its subintervals

This study was part of a larger study that included the creation of a linked dataset containing the DI for patients with melanoma in Ontario.[14 15] Determining the DI involved the use of OHIP physician claims data and Canadian Institute for Health Information (CIHI) hospital and outpatient data. The DI spans from the first cancer-related encounter with the healthcare system (the index date) to the cancer diagnosis date.[10] The method of identifying cancer-related healthcare encounters employed a control chart statistical methodology with category-specific look-back periods to maximise the identification of melanoma-specific encounters. Briefly, healthcare encounters were identified as melanoma-related if the frequency of occurrence increased in the 0–3 months prior to melanoma diagnosis compared with a 12–15 month background or control period. Control charts were used to identify the point in time prior to diagnosis when the weekly encounter rate exceeded the rate that would be expected based on the background rate of the encounter. This method has been described in more detail elsewhere.[14–17] There were 16 groupings of probable melanoma-related healthcare encounters, and all instances of these encounters were collected for all patients (although 16 categories were used to determine the start of the melanoma DI, 18 categories were used to describe the activities occurring within the DI (online supplemental appendix A)). These encounters were used to characterise the DI.[15] The first melanoma-related encounter was assigned as the index date.[10]

The primary care subinterval was defined as the time from the first visit with a non-melanoma-related specialist to either the first visit with a melanoma-related specialist or the diagnosis date, if no melanoma-related specialist was seen. The specialist care subinterval was the time from the first melanoma-related specialist visit to the diagnosis date (figure 1).

Determination of pathway variables

Pathway variables were derived from the encounters used to define the DI (see online supplemental appendix A for a list of categories). Pathway variables were guided by provincial melanoma pathway guidelines,[18 19] expert clinical knowledge (TPH, YA, HL, NJLH, FCW), our previous work in colorectal cancer[4] and data availability. Pathway variables included characteristics of the index visit of the subintervals, the number of visits and procedures within the subintervals, the activity on the diagnosis date, and patient history, including history of keratinocyte carcinoma (KC) and history with a dermatologist (figure 1). See online supplemental appendix B for more information.

Patient and disease characteristics

All patient variables were assigned as of the patient's index date. Age and sex were available from the Registered Persons Database. Comorbidity was assigned using the Johns Hopkins ACG System V.10.0.1 (build 879) Aggregated Diagnosis Groups.[20] Socioeconomic status was assigned at the dissemination area level using the material deprivation index quintile from the Ontario

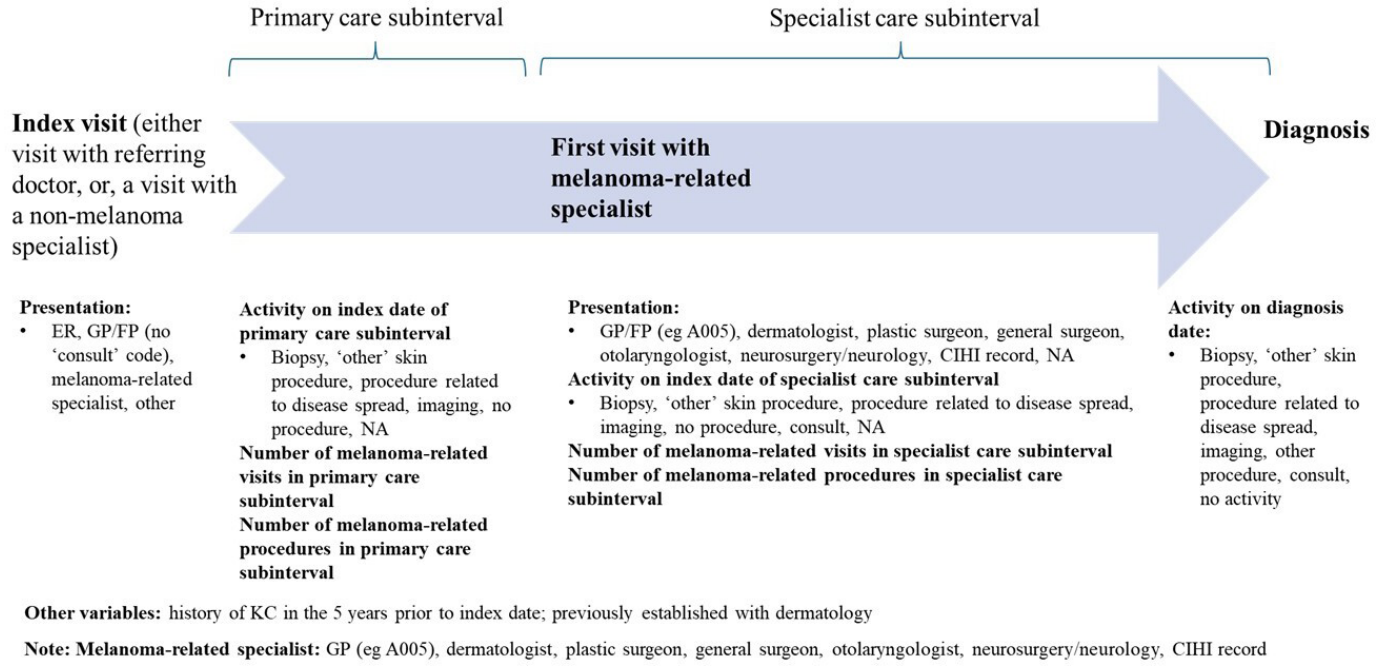

Figure 1 Pathway variables for latent class cluster analysis. CIHI, Canadian Institute for Health Information; ER, emergency room; GP/FP, general practitioner/family physician; KC, keratinocyte carcinoma; NA, not applicable.

Marginalisation Index.[21 22] Rurality was assigned at the census subdivision level using the rurality index of Ontario, a measure of relative rurality based on geographical factors related to access to health services.[23 24] The history of KC in the 5 years prior to the index date was assigned based on an algorithm developed by Chan *et al*, which was shown to have 82.3% sensitivity and 92.9% specificity.[25]

Ontario Cancer Registry provided melanoma case information, including histology, anatomical location, diagnosis date and stage; previously abstracted pathology reports for a subset of patients were also used to assign stage.

System characteristics

At the time of this study, Ontario was divided into 14 local health integration networks (LHINs), which were responsible for funding, coordinating and providing healthcare services for their region. LHIN number was anonymised. 'Established with dermatology' was defined as three or more dermatologist visits (OHIP) in the 5 years prior to the index contact date. Census data were used to calculate dermatologist density per 100 000 population.

Statistical analyses

We used latent class cluster analysis (LCCA) of the pathway variables to identify clusters of patients with similar diagnostic experiences. These clusters are our diagnostic pathways. LCCA is a model-based clustering approach which identifies K unobserved latent classes based on response patterns of clustering variables.[26 27] Each patient is assigned a posterior probability of cluster membership based on the distribution of pathway variables and is assigned to the cluster with the maximum probability of membership.[26 27]

To determine the number of clusters, we examined 2–11 cluster solutions to identify the optimal classification scheme and plotted the resulting Bayesian Information Criterion (BIC). The cluster number was chosen by considering the BIC value (smaller values are better), the relative change in BIC per additional cluster,[28–30] as well as model usefulness.

We described the clusters according to the distribution of pathway variables and described demographic and disease characteristics, as well as the distribution of the DI and its subintervals. We evaluated the association between pathway, demographic, and disease variables and cluster membership using χ^2 tests. To determine which cells most strongly contributed to a significant χ^2 statistic, we calculated Pearson residuals for each cell[31] and highlighted those cells with a Pearson residual ≤–15 or ≥15 for pathway variables and ≤–4 or ≥4 for patient and disease characteristics. A larger Pearson residual was chosen for pathway variables since, by definition, the distribution of these variables should be significantly different between clusters.

LCCA was conducted using the poLCA package in RStudio, and clustering variables were entered into the model as categorical variables, as presented in table 2. Once cluster membership was assigned, further analyses were conducted using SAS Enterprise Guide V.7.1 (SAS Institute, Cary, North Carolina, USA).

RESULTS

Study population

The final cohort consisted of 33 371 patients (figure 2). Table 1 presents patient and disease characteristics. The average age was 63.6 (SD 15.7) years and 54.6% were

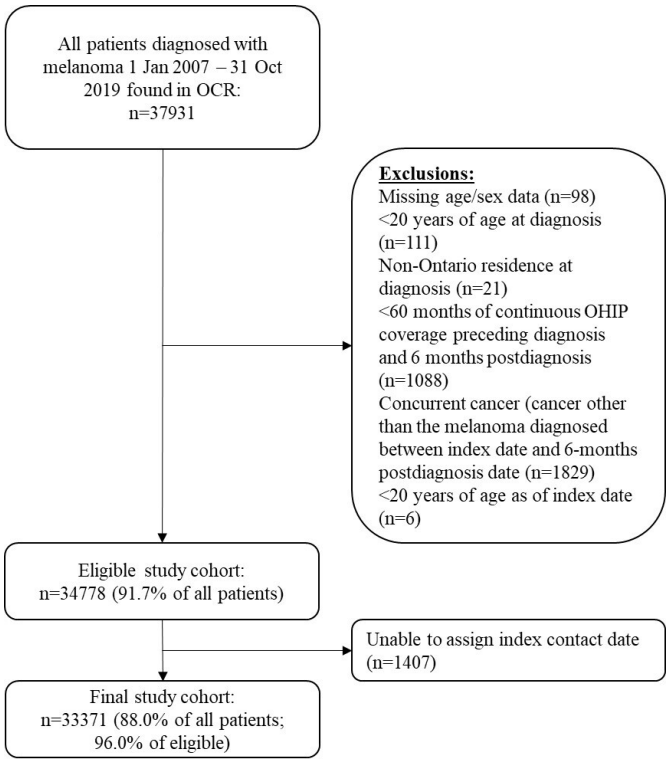

Figure 2 Cohort creation flowchart. OCR, Ontario Cancer Registry; OHIP, Ontario Health Insurance Plan.

men. The stage was missing for 45.1%, but for those with stage information, 58% had stage I. 17% had a history of KC, and 20% were established with a dermatologist prior to their index date. Almost 20% of the cohort lived in counties with no dermatologists.

Characteristics of the clusters

Based on the largest difference in BIC values for successive clusters, a four-cluster solution was optimal for this dataset (figure 3). The distribution of pathway variables according to the cluster can be found in table 2. Influential cells are indicated in bold. The proportion of patients in clusters 1–4 was 18.3%, 26.9%, 35.6% and 19.1%, respectively.

Cluster 1 was comprised of all patients without a specialist care subinterval, and we have called this the 'primary care only' pathway. Compared with other clusters, patients in cluster 1 were less likely to be established with a dermatologist, more likely to have a biopsy at the start of their primary care subinterval, more likely to have multiple visits and procedures in the primary care subinterval, and more likely to have a procedure related to disease spread on their diagnosis date. They had an average of 1.8 visits in their DI and underwent an average of 1.2 procedures.

Cluster 2 contained patients with both primary care and specialist care subintervals, and we have called this cluster the 'referred to specialist with immediate action' pathway. Compared with other clusters, patients in cluster 2 were more likely to initially see a general practitioner/family physician (GP/FP) and more likely to have only one visit and no procedures in their primary care subinterval. These patients were more likely to see a dermatologist at the start of their specialist care subinterval and have a biopsy on the first day of their specialist care subinterval. All patients in cluster 2 had one visit and one procedure in their specialist care subinterval. Patients in cluster 2 had an average of 2.2 visits in their DI and underwent an average of 1.1 procedures.

Cluster 3 contained patients with both primary care and specialist care subintervals, and we refer to this cluster as the 'multiple visits and procedures in specialist care' pathway. Like cluster 2, patients in cluster 3 were more likely to see a GP/FP at the start of their primary care subinterval and more likely to have one visit and no procedures in their primary care subinterval. They were more likely to see a plastic surgeon or general surgeon at the start of their specialist care subinterval, more likely to have a consult only at the start of this subinterval and were more likely to have multiple visits and procedures in their specialist care subinterval. Patients in cluster 3 had an average of 4.4 visits within the DI and underwent an average of 1.8 procedures.

Cluster 4 contained all patients who did not have a primary care subinterval, and we have called this cluster the 'specialist care only' pathway. Compared with other clusters, patients in cluster 4 were more likely to have a history of KC and more likely to be previously established with dermatology. These patients were more likely to see a dermatologist at the start of their specialist care subinterval, have an 'other' skin procedure on the first visit in the specialist care subinterval, and have multiple visits and procedures in their specialist care subinterval. Patients in cluster 4 had an average of three visits in their DI and underwent an average of 1.7 procedures.

Patient, disease, and DI characteristics across diagnostic pathways

Patient characteristics according to the cluster can be found in table 1. Influential cells are bolded. Compared with other clusters, patients in cluster 1 had a lower comorbidity burden, were more likely to live in rural and non-major urban areas with no dermatologists, and more likely to live in LHINs E and M. These patients were more likely to be diagnosed with melanoma not otherwise specified with an unknown location and more likely to be diagnosed with stage IV disease. Cluster 1 patients had the shortest DI, with a median of 1 day.

Compared with other clusters, patients in cluster 2 were younger with a lower comorbidity burden and more likely to have melanomas on the extremities. These patients were more likely to live in major urban areas, high dermatology-dense counties and LHINs B and F. Patients in this cluster had the second longest DI, with a median of 31 days, the longest primary care subinterval, and the shortest specialist care subinterval.

Compared with other clusters, patients in cluster 3 were more likely to live in LHINs C, G, H and I. They were also

Table 1 Demographic, disease and DI characteristics for whole cohort and by cluster

Characteristic	Overall cohort (n=33 371)	Cluster 1 (primary care only) (n=6107) 18.3%	Cluster 2 (referred to specialist with immediate action) (n=8987) 26.9%	Cluster 3 (multiple visits and procedures in specialist care) (n=11 893) 35.6%	Cluster 4 (specialist care only) (n=6384) 19.1%
Patient factors					
Sex					
Male	54.6	54.2	52.2	54.7	**58.3**
Female	45.4	45.8	47.8	45.3	**41.7**
Age					
Mean (SD)	63.6 (15.7)	62.1 (15.4)	62.4 (15.9)	64.2 (15.8)	65.6 (15.2)
20–45	13.5	15.2	**15.2**	12.8	**10.9**
46–55	16.1	17.2	**17.9**	15.7	**13.6**
56–65	22.2	23.8	22.8	21.7	21.0
66–75	22.9	23.0	21.2	23.1	24.9
76–85	18.2	16.1	**16.3**	18.7	**21.9**
>85	7.0	**4.7**	6.7	8.0	7.8
Comorbidity					
Minor ADG					
0–1	10.2	11.2	11.2	9.8	**8.5**
2	10.0	11.2	10.4	10.0	**8.0**
3	11.7	13.0	13.0	11.6	**8.7**
4	13.1	14.5	13.1	13.1	11.7
5	12.7	12.3	13.0	12.9	12.5
6	11.4	11.2	11.5	11.1	11.7
7	9.7	9.3	8.9	9.7	11.2
8	7.7	6.9	7.3	7.4	**9.5**
9+	13.7	**10.5**	**11.5**	14.4	**18.3**
Major ADG					
0	38.0	**41.7**	**41.4**	37.9	**29.7**
1	30.6	31.4	31.3	29.8	30.2
2	17.5	16.2	15.8	17.1	**21.6**
3+	14.0	**10.7**	**11.5**	15.2	**18.5**
Deprivation quintile					
1 (least deprived)	26.2	25.6	26.0	24.7	**29.6**
2	22.9	22.5	23.3	22.6	23.0
3	20.2	21.1	20.2	20.7	18.5
4	16.8	17.2	16.4	17.4	16.0
5 (most deprived)	13.2	12.8	13.4	13.9	12.1
Missing	0.7	0.8	0.6	0.7	0.8
Rurality					
Rural	11.6	**17.2**	**9.6**	11.0	10.0
Non-major urban	28.1	**36.2**	**24.7**	28.4	**24.5**
Major urban	60.4	**46.6**	**65.7**	60.7	**65.5**
Disease factors					
Histology					

Continued

Table 1 Continued

Characteristic	Overall cohort (n=33 371)	Cluster 1 (primary care only) (n=6107) 18.3%	Cluster 2 (referred to specialist with immediate action) (n=8987) 26.9%	Cluster 3 (multiple visits and procedures in specialist care) (n=11 893) 35.6%	Cluster 4 (specialist care only) (n=6384) 19.1%
Superficial spreading melanoma	34.9	33.8	36.7	36.1	**31.5**
Nodular melanoma	11.5	10.1	11.6	**13.3**	**9.7**
Lentigo maligna melanoma	8.4	**3.9**	8.0	9.2	**11.7**
Acral lentiginous melanoma	0.9	0.7	0.8	0.9	1.3
Other	3.6	2.9	3.4	4.0	3.8
NOS	40.6	**48.7**	39.6	**36.6**	42.0
Location					
Extremities	44.4	44.9	**48.4**	42.6	41.7
Trunk	32.1	34.6	32.2	31.6	30.7
Face	12.1	**6.9**	11.8	**13.6**	**14.5**
Scalp and neck	6.7	**4.6**	6.1	7.3	**8.3**
NOS	4.7	**9.0**	**1.5**	4.9	4.8
Stage					
I	32.2	33.1	33.5	31.0	31.8
II	13.0	11.8	13.5	14.1	11.6
III	7.1	7.1	7.4	7.5	5.8
IV	2.6	**4.3**	**1.1**	2.8	2.5
Missing	45.1	43.7	44.4	44.6	48.3
System factors					
County-level dermatologist density, per 100 000 population					
0	18.9	**28.5**	**15.3**	18.5	**15.7**
>0, ≤1	13.9	15.0	12.4	15.2	12.7
>1, ≤2	32.2	31.2	31.3	**35.0**	29.4
>2	34.9	**25.2**	**41.1**	**31.3**	**42.3**
LHIN*					
A	7.1	**3.1**	8.0	6.3	**11.2**
B	9.6	10.0	**11.8**	**7.2**	10.3
C	8.8	**4.0**	9.0	**10.5**	10.2
D	5.3	**6.6**	4.6	5.2	5.2
E	10.2	**17.9**	9.0	**8.7**	**7.2**
F	6.5	**4.7**	**7.8**	6.1	7.1
G	5.5	5.8	**3.3**	**7.4**	4.6
H	11.7	**8.4**	12.6	**13.3**	10.8
I	6.8	6.3	**5.5**	**8.2**	6.5
J	1.7	**2.4**	**0.6**	2.0	1.7
K	3.3	2.8	3.8	3.6	2.6
L	13.3	12.3	14.3	13.1	13.3
M	5.7	**9.9**	5.9	**3.8**	4.8
N	4.6	5.6	3.8	4.6	4.5

Continued

Table 1 Continued

Characteristic	Overall cohort (n=33 371)	Cluster 1 (primary care only) (n=6107) 18.3%	Cluster 2 (referred to specialist with immediate action) (n=8987) 26.9%	Cluster 3 (multiple visits and procedures in specialist care) (n=11 893) 35.6%	Cluster 4 (specialist care only) (n=6384) 19.1%
Interval characteristics (days)					
DI length	(n=33 371)				
25th percentile	8.0	1.0	14.0	35.0	1.0
50th percentile	36.0	1.0	31.0	67.0	23.0
75th percentile	85.0	21.0	67.0	112.0	91.0
90th percentile	142.0	68.0	115.0	175.0	146.0
Primary care subinterval length	(n=26 987)				
25th percentile	6.0	1.0	13.0	10.0	–
50th percentile	22.0	1.0	30.0	27.0	–
75th percentile	54.0	21.0	66.0	56.0	–
90th percentile	100.0	68.0	113.0	99.0	–
Specialist care subinterval length	(n=27 264)				
25th percentile	1.0	–	1.0	9.0	1.0
50th percentile	6.0	–	1.0	25.0	23.0
75th percentile	42.0	–	1.0	57.0	91.0
90th percentile	97.0	–	1.0	100.0	147.0

The bolded cells denote Pearson residuals >|4|.
n is the number of observations.
*LHINs have been anonymised.
ADG, adjusted diagnostic groups; LHIN, local health integration network; NOS, not otherwise specified.

more likely to have nodular melanomas and melanomas diagnosed on the face. Patients in this cluster experienced the longest DI, with a median of 67 days, and the longest specialist care subinterval.

Finally, compared with other clusters, patients in cluster 4 were older and had a higher comorbidity burden. These patients were more likely to live in the least deprived neighbourhoods, major urban areas

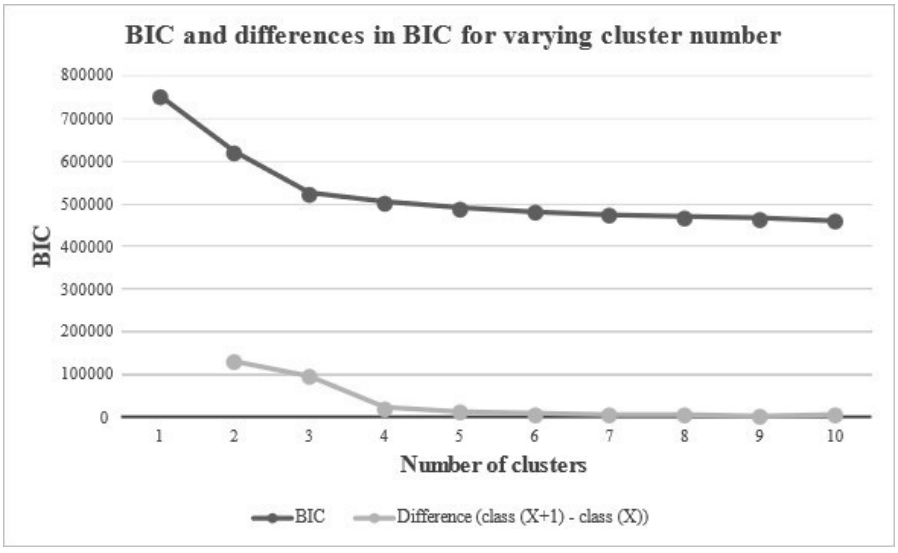

Figure 3 Value of Bayesian Information Criterion according to number of clusters and difference in BIC values across successive clusters.

Table 2 Distribution of pathway variables

	Overall cohort (n=33 371)	Cluster 1 (Primary care only) (n=6107) 18.3%	Cluster 2 (Referred to specialist with immediate action) (n=8987) 26.9%	Cluster 3 (Multiple visits and procedures in specialist care) (n=11 893) 35.6%	Cluster 4 (Specialist care only) (n=6384) 19.1%
History of KC in 5 years prior to index date					
Yes	17.3	11.2	11.2	15.7	**34.7**
No	82.7	88.9	88.8	84.3	**65.3**
Established with dermatology prior to index date (3+ visits in 5 years)					
Yes	19.7	6.7	13.0	14.3	**51.7**
No	80.3	**93.3**	87.0	85.7	**48.3**
Initial presentation					
ER	1.2	2.3	1.0	1.3	0.0
GP/FP	74.8	90.3	**94.2**	**92.3**	**0.0**
Melanoma-related specialist	19.1	**0.0**	**0.0**	**0.0**	**100.0**
Other	4.9	7.4	4.8	6.3	**0.0**
Primary care subinterval					
Activity on index date					
Biopsy	12.7	**53.2**	**3.1**	**5.6**	**0.0**
'Other' skin procedure	2.5	5.4	2.4	2.5	0.0
Procedure related to disease spread	0.3	0.9	0.1	0.2	0.0
Head imaging	0.2	0.4	0.1	0.3	0.0
No procedure	65.2	**40.2**	**94.4**	**91.1**	**0.0**
Not applicable	19.1	**0.0**	**0.0**	**0.0**	**100.0**
Number of melanoma-related visits					
1	65.0	59.8	**90.3**	**93.4**	**0.0**
2	10.5	**27.3**	6.3	10.6	**0.0**
3+	5.4	**12.8**	3.4	6.0	0.0
Not applicable	19.1	**0.0**	**0.0**	**0.0**	**100.0**
Number of melanoma-related procedures					
0	56.6	**9.4**	**91.5**	**84.9**	**0.0**
1	19.3	**71.9**	**6.9**	**12.0**	**0.0**
2	3.8	**14.6**	1.1	2.3	**0.0**
3+	1.2	**4.1**	0.5	0.8	0.0
Not applicable	19.1	**0.0**	**0.0**	**0.0**	**100.0**
Specialist care subinterval					
Initial presentation					
GP/FP consult	4.7	**0.0**	7.7	6.3	2.0
Dermatologist	47.0	**0.0**	**65.5**	45.4	**68.8**
Plastic surgeon	12.9	0.0	11.0	**21.7**	11.5
General surgeon	12.0	**0.0**	13.6	**18.6**	9.2
Otolaryngologist	1.9	0.0	1.9	2.2	2.9
Neurosurgery/Neurology	0.7	0.0	0.0	1.1	1.3
CIHI record	2.6	0.0	0.4	4.7	4.4
Not applicable	18.3	**100.0**	**0.0**	**0.0**	**0.0**

Continued

Table 2 Continued

	Overall cohort (n=33 371)	Cluster 1 (Primary care only) (n=6107) 18.3%	Cluster 2 (Referred to specialist with immediate action) (n=8987) 26.9%	Cluster 3 (Multiple visits and procedures in specialist care) (n=11 893) 35.6%	Cluster 4 (Specialist care only) (n=6384) 19.1%
Activity on index date					
Biopsy	41.4	**0.0**	**91.7**	**21.5**	47.2
'Other' skin procedure	9.0	**0.0**	8.3	9.3	**18.2**
Procedure related to disease spread	0.7	0.0	0.0	1.3	1.2
Head imaging	0.5	0.0	0.0	0.9	1.0
No procedure	2.1	0.0	0.0	3.3	4.6
Consult	28.0	**0.0**	**0.0**	**59.6**	27.9
Not applicable	18.3	**100.0**	**0.0**	**0.0**	**0.0**
Number of melanoma-related visits					
1	35.6	**0.0**	**100.0**	**5.3**	35.7
2	23.1	**0.0**	**0.0**	**51.7**	24.4
3	10.0	**0.0**	**0.0**	**20.1**	15.1
4	4.8	**0.0**	**0.0**	**9.3**	7.9
5	3.0	0.0	**0.0**	5.3	5.7
6	1.6	0.0	0.0	2.8	3.2
7+	3.5	0.0	**0.0**	5.6	**7.9**
Not applicable	18.3	**100.0**	**0.0**	**0.0**	**0.0**
Number of melanoma-related procedures					
0	3.2	0.0	**0.0**	**6.9**	3.8
1	55.0	**0.0**	**100.0**	49.4	54.9
2	15.2	**0.0**	**0.0**	**29.8**	**23.9**
3	4.6	**0.0**	**0.0**	**8.0**	**9.0**
4+	3.8	**0.0**	**0.0**	**6.0**	**8.4**
Not applicable	18.3	**100.0**	**0.0**	**0.0**	**0.0**
Diagnosis					
Activity on diagnosis date					
Biopsy	85.0	76.6	91.6	85.5	82.7
'Other' skin procedure	2.3	2.2	**5.3**	**0.1**	2.1
Procedure related to disease spread	1.5	**6.6**	0.0	0.7	0.4
Head imaging	0.3	1.1	0.0	0.2	0.2
Other procedure	0.9	3.8	0.0	0.4	0.2
Consult	0.8	0.1	0.0	1.6	0.8
No activity on OCR diagnosis date	9.3	9.7	**3.1**	11.6	13.7

The bolded cells denote Pearson residuals >|15|.
CIHI, Canadian Institute for Health Information; ER, emergency room; GP/FP, general practitioner/family physician; KC, keratinocyte carcinoma; OCR, Ontario Cancer Registry.

and LHIN A. These patients were also more likely to have lentigo maligna melanoma and live in counties with the highest dermatologist density. Cluster 4 had the second shortest DI, with a median of 23 days, and had a similar specialist care subinterval as cluster 3.

DISCUSSION

We identified four diagnostic pathways experienced by patients with melanoma in Ontario, which varied by each of our pathway variables. The patterns of use of primary and specialist care differentiated the clusters. Patients in

cluster 1 had their melanomas excised in primary care without prior consultation with a specialist, patients in cluster 2 were immediately referred to a specialist for excision, whereas those in cluster 3 had multiple visits and procedures in their specialist care subinterval prior to the diagnosis of melanoma. We did not find evidence of a primary care subinterval for patients in cluster 4, and these patients most often initially saw a dermatologist.

There were differences in patient, disease and health system characteristics, as well as the length of the DI and its subintervals, across the four diagnostic pathways. Notably, patients in the 'primary care only' (cluster 1) pathway had the shortest median DI, while patients in the 'multiple visits and procedures in specialist care' (cluster 3) had the longest median DI. We also saw variations in pathway membership by LHIN. This may be partly explained by the differences in the degree of rurality and dermatologist supply across LHINs, but may also suggest variation in care received across the province.

CCO's (Cancer Care Ontario) melanoma pathway map recommends that PCPs biopsy suspected melanomas when possible and refer patients otherwise.[19] However, only 18.3% of our cohort were diagnosed in primary care, prior to seeing a specialist (cluster 1). Patients diagnosed within primary care were more likely to live in rural areas, suggesting that physicians practising in rural areas are more likely to perform biopsies and other specialist services, possibly due to the scarce supply of specialists. This is consistent with previous research in Northern Scotland and Queensland, Australia which found that patients living in rural areas were more likely to have melanomas excised in primary care and less likely to see a dermatologist.[13 32]

The melanoma DI length varied across pathways. During the period of this study, the Canadian Task Force on Preventive Healthcare suggested that physicians in Canada could follow guidelines set out by Australia and New Zealand (due to the unavailability of Canadian-specific guidelines), which state that biopsy should be completed within 2 weeks of initial GP consult and referral to a specialist should occur within 2 weeks where management by primary care is inappropriate.[33] Patients in clusters 1 and 4 (37% of our cohort) experienced care that most strongly adhered to this wait time guidance whereas patients in clusters 2 and 3 had care that diverged. Potential reasons for delay include accessibility of specialists, misdiagnoses, incorrect referrals or procedures or complexity of diagnostic procedures. A limited number of rapid-access skin clinics have recently been introduced in Ontario to expedite the DI and reduce the number of unnecessary procedures. These rapid-access skin clinics have the potential to greatly reduce the wait time between a PCP visit and a specialist visit for a biopsy, as well as reduce the number of unnecessary visits and procedures in the primary care and specialist care subintervals.

Our study has several strengths. First, this is a large population-based study, which was able to objectively examine routes to diagnosis for all patients with melanoma in Ontario, Canada. We were able to use health administrative data to create and analyse our diagnostic pathways. Second, we used LCCA to create the clusters of patients. This method ensured that clusters were created based on important differences in the pathway-variable distributions, rather than relying on subjective groupings.

Our study has some limitations. Our study variables do not comprehensively describe the diagnostic pathway. Finer detail on disease presentation and urgency of referral may have identified more pathways, and the inclusion of histology and imaging results would have allowed us to better capture the relevance of the procedures to the melanoma diagnostic pathway. Many patients had multiple procedures prior to their definitive diagnosis. These procedures may have been necessary if the patient presented with multiple lesions, and do not necessarily represent inappropriate care. Patient chart review was not used to validate diagnostic pathway assignment, as this was not feasible in the context of the current work. We were unable to determine if a patient presented with multiple lesions. Patients in cluster 4 were more likely to have a history of KC (34.7% of patients) and be previously established with dermatology (51.7% of patients). It is possible that some procedures we captured were not related to the melanoma, but rather, related to their previous dermatological concerns. Future research should separately examine the diagnostic pathways for patients with a history of KC and those previously established with dermatology, as methods for index date derivation may need to be adapted for these populations. Race-based data was not available, due to government privacy legislation. Finally, there may have been misclassification introduced, in that some of the encounters that were deemed melanoma-related may have occurred for reasons other than the melanoma. Our approach using control charts and signal strengths to assign category-specific look-back periods[14 16] enhanced by clinical review is designed to maximise the chance that the encounter recorded in administrative records was related to the melanoma diagnosis.

Conclusion

In this population-based study, we found important opportunities for quality improvement in melanoma diagnosis. Thirty-six per cent of patients with melanoma in Ontario followed the most guideline-divergent diagnostic pathway (cluster 3), with 80% in that cluster exceeding current provincial waiting standards.[18] There were often multiple procedures leading to diagnosis for patients in clusters 1, 3 and 4. We found large differences in the diagnostic process according to dermatologist supply, rurality and LHIN of residence. Notably, the 'primary care only' pathway had the shortest time to diagnosis, suggesting the importance of supporting primary care biopsy, where appropriate, consistent with current provincial guidelines. A means to provide more timely and efficient melanoma

diagnosis must be developed to ensure the highest quality diagnostic care for those with suspicious skin lesions.

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