Connecting artificial intelligence and primary care challenges: findings from a multi stakeholder collaborative consultation

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ABSTRACT
Despite widespread advancements in and envisioned uses for artificial intelligence (AI), few examples of successfully implemented AI innovations exist in primary care (PC) settings.

Objectives To identify priority areas for AI and PC in Ontario, Canada.

Methods A collaborative consultation event engaged multiple stakeholders in a nominal group technique process to generate, discuss and rank ideas for how AI can support Ontario PC.

Results The consultation process produced nine ranked priorities: (1) preventative care and risk profiling, (2) patient self-management of condition(s), (3) management and synthesis of information, (4) improved communication between PC and AI stakeholders, (5) data sharing and interoperability, (6-10) clinical decision support, administrative staff support, (8) practitioner clinical and routine task support and (9) increased mental healthcare capacity and support. Themes emerging from small group discussions about barriers, implementation issues and resources needed to support the priorities included: equity and the digital divide; system capacity and culture; data availability and quality; legal and ethical issues; user-centred design; patient-centredness; and proper evaluation of AI-driven tool implementation.

Discussion Findings provide guidance for future work on AI and PC. There are immediate opportunities to use existing resources to develop and test AI for priority areas at the patient, provider and system level. For larger scale, sustainable innovations, there is a need for longer-term projects that lay foundations around data and interdisciplinary work.

Conclusion Study findings can be used to inform future research and development of AI for PC, and to guide resource planning and allocation.

INTRODUCTION
Advancements in artificial intelligence (AI) are leading to innovation in virtually every industry, including healthcare. In 2018, the WHO-UNICEF Global Primary Healthcare Conference emphasised a need to effectively use current data and technology for innovations that will achieve better healthcare for individuals and populations.1 Despite rich data sources and envisioned uses, the number of existing AI applications in primary care (PC) is smaller compared with other sectors.2,3,4,5,6,7,8 To direct efforts and support more concrete progress towards development and use of AI for PC, interdisciplinary work that engages PC and AI stakeholders is needed to better understand how current and near-term AI capabilities align with existing PC challenges.

For study purposes, PC is defined as first contact and continuing care provided primarily by family physicians and nurse practitioners and excluding services provided solely by specialist care providers.9,10 Ontario, Canada has a publicly funded healthcare system whereby PC is the entry point to the rest of the system and may be structured in
various ways, ranging from solo physician-based practices to large interdisciplinary teams.\textsuperscript{11} Increasing amounts of data, especially through adoption of electronic health records, coupled with advancements in computing infrastructure provide novel opportunities to use AI within PC.\textsuperscript{12} The field of AI began in the 1950s with a goal for computers to achieve human-like intelligence, for example, making inferences or learning patterns from data, and has since expanded in the types of problems addressed and disciplines involved, such as psychology, philosophy and linguistics.\textsuperscript{13} In PC, AI may be added to existing infrastructure, such as electronic health records, or be implemented through stand-alone devices.

The objectives of this study were to identify current PC challenges that may be amenable to support using AI, discuss barriers and needs for successful development and implementation of AI to support these challenges, and identify priority areas for AI and PC in Ontario, Canada. We addressed these objectives by holding a multi-stakeholder collaborative consultation session in early 2021.

**METHODS**

**Background: environmental scans**

As a preparation step for the stakeholder session, two brief environmental scans were conducted to better understand the landscape of PC needs and existing AI-driven tools. Environmental scans include identifying and summarising information on a topic, often to support decision making.\textsuperscript{14}

The first scan explored PC challenges discussed in literature for high-income countries from 2010 to 2020, including those specific to the COVID-19 pandemic. Challenges were organised using a framework that divides PC into a structural domain for system-level considerations including practice context and organisation, and a performance domain for service delivery and technical quality of clinical care.\textsuperscript{15} Example challenges are presented in table 1; detailed methods and results are available in a preprint.\textsuperscript{16}

The second scan identified through literature and web-based searches 110 AI-driven tools with potential uses in PC. An estimated 87% (n=96) were in use at the time of identification, based on web searching for purchase options and reviews without geographical restriction. Table 2 presents tool characteristics and figure 1 categorises the tools by PC-related tasks they are intended to support; categories are based on a framework by European Institute of Innovation & Technology Health and McKinsey & Company for assessing impact of AI on healthcare.\textsuperscript{17} Of note, these results focus on ‘ready-to-use’

### Table 1 Example primary care challenges discussed in literature from 2010 to 2020

<table>
<thead>
<tr>
<th>Structural domain</th>
<th>Performance domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>General primary care challenges</td>
<td>Physician burnout</td>
</tr>
<tr>
<td>► Provider shortage</td>
<td>► Need for improved coordination</td>
</tr>
<tr>
<td>► Resource allocation does not meet current demands</td>
<td>► Difficulty of applying guidelines for patients with multimorbidity</td>
</tr>
<tr>
<td>► Nurse practitioners not able to practice full scope of skills</td>
<td>► Need for improved relational continuity</td>
</tr>
<tr>
<td>► Inequitable access</td>
<td></td>
</tr>
<tr>
<td>COVID-19-specific challenges</td>
<td>Decreased use of primary care services</td>
</tr>
<tr>
<td>► Lack of personal protective equipment</td>
<td>► Virtual care reduced human connection</td>
</tr>
<tr>
<td>► Provider payment delays</td>
<td>► Care continuum challenges</td>
</tr>
<tr>
<td>► Nurse shortages in northern communities</td>
<td>► Patient backlogs</td>
</tr>
<tr>
<td>► Need for early diagnosis and follow-up of high-risk patients</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2 AI-driven tool characteristics identified by environmental scan

<table>
<thead>
<tr>
<th>AI-driven tool characteristics</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intended end users</td>
<td></td>
</tr>
<tr>
<td>Primary care providers</td>
<td>73 (66)</td>
</tr>
<tr>
<td>Patients</td>
<td>31 (28)</td>
</tr>
<tr>
<td>Primary and specialty care service interactions</td>
<td>6 (5)</td>
</tr>
<tr>
<td>Geographical distribution of marketing</td>
<td></td>
</tr>
<tr>
<td>Solely in Canada</td>
<td>14 (13)</td>
</tr>
<tr>
<td>Canada and internationally</td>
<td>36 (33)</td>
</tr>
<tr>
<td>No mention of Canada</td>
<td>60 (55)</td>
</tr>
<tr>
<td>Vendor mention of AI involvement</td>
<td></td>
</tr>
<tr>
<td>Direct mention of AI on website</td>
<td>80 (73)</td>
</tr>
<tr>
<td>Additional web-searching needed to verify AI use</td>
<td>22 (20)</td>
</tr>
<tr>
<td>Suggested but no confirmed AI use</td>
<td>8 (7)</td>
</tr>
</tbody>
</table>

AI, artificial intelligence.
tools, but 36 active patents were also identified and a previous scoping review looked at the state of AI and PC research specifically. Detailed methods and results are in online supplemental material A.

Participants

We invited patient (includes caregiver), provider (physician or nurse), research (AI and/or PC focused), digital health (involved in the creation or implementation of digital health infrastructure in Ontario) and decision-maker (health system planners or managers at provincial, regional and local levels) stakeholders with expertise or interest in AI and Ontario PC. Participants were recruited by e-mail individually using the study investigators’ networks, with identification based on existing relationships and searches of relevant organisational websites and publications. Patients and caregivers were recruited by the patient advisor coinvestigator.

Overview of agenda

The 4.5-hour multi stakeholder consultation session was held on 26 March 2021 through Zoom. Primers introducing core AI and PC concepts were created and provided to participants in advance of the event. The morning agenda included a welcome and orientation, brief presentation on the environmental scans, and a keynote address by Dr Winston Liaw on ‘The experience of using AI in primary healthcare’. The afternoon included small and large group (all participants present) discussions, described below, with ranking activities according to a modified version of the nominal group technique. Participants remained in the same small group throughout the event. Each group had a designated moderator, AI-knowledge resource person and note taker; these roles could be fulfilled by one or more people. The AI-knowledge person was present to answer any technical questions and to ensure discussions did not stray from realistic current or near-term AI capabilities. Real-time, independent and anonymous ranking was done using Mentimeter. Moderators and AI-knowledge people did not participate in ranking activities.

Nominal group technique

The nominal group technique was developed to facilitate idea generation and discussion in a group setting for the purpose of arriving at a list of priorities. It can be done within a day and allows for equal voting weights by all participants. Steps included:

First small group discussion: ideating PC challenges

In each small group, participants were asked to independently write down answers to the question, ‘Thinking about PC, what issues do you think may be amenable to AI solutions?’. Participants were invited to share ideas in a roundtable format, each offering an idea with a brief discussion about why it is an issue for them, until no new unique ideas were generated. The group then worked together to collapse and clarify issues, if needed, to enter them into a Mentimeter poll. Finally, each participant was asked to ‘Rank based on what you feel are the top priorities for implementation in PC of issues that have a potential AI solution’. Each group ended step 1 with up to 12 ranked issues.

First big group report back

In turn, each small group selected a member to share their Mentimeter chart and briefly describe the group’s top ranked challenges to the large group.

Second small group discussion: in-depth exploration of priorities

Small groups reconvened for in-depth discussions of their top 2–3 ranked issues. Lower ranked items could be discussed with group consensus. Facilitated discussions encouraged participants to think about barriers, implementation issues or feasibility and resources that would be needed to develop and/or implement AI to address the issues. Although discussions were facilitated on an item-by-item basis, there was overlap between groups and
between items such that common themes applicable to all or most items emerged. Common themes that emerged are separated from item-specific points in the presentation of results.

Second big group report back
In turn, each small group had 6 min to report on their previous discussion and priorities to the large group.

Full group ranking activity
The priorities selected for discussion and reported on by each small group were merged into one list with similar items combined. Each participant ranked the entire list of items based on the criteria of, ‘Practicality, feasibility and achievability within the next year or two’. Participants were shown ranking results in real-time and thanked for their participation.

After the stakeholder event, the research team reviewed the list of ranked priorities in combination with the small group discussion notes to construct a final list of priority areas. Words or descriptions were refined to increase clarity of presentation, maintaining the core content behind each ranked priority.

RESULTS

Participants
There were 35 participants: 8 providers, 8 patient advisors, 4 decision-makers, 3 digital health stakeholders and 12 researchers. Participants were divided into four prespecified small groups, each with a range of stakeholder types.

First small group discussion: ideating PC challenges
Complete lists of identified issues and rankings generated by each small group are in online supplemental material B. A summary with similar items across groups collapsed includes:

- Managing and/or consolidating information from different sources to facilitate identification of problems.
- Clinical decision support.
- Administrative staff support.
- Patient self-management.
- Data sharing and interoperability between providers.
- Risk profiling and reminders for screening and preventive care.
- System coordination and referral centralisation.
- Documentation and clerical duties.
- Patient triage in autumn (expected pandemic recovery phase) and help to manage and identify high-risk patients.
- Mental healthcare.
- Communication and adoption between AI and PC practitioners.

Second small group discussion: in-depth exploration of priorities
In discussing feasibility and necessary resources for successful development or implementation of AI to meet identified priorities, groups considered areas spanning from technical underpinnings of AI-driven tools to human and system-level factors. A synthesis of these discussions is below.

Groups emphasised data availability and quality as a foundation for successful AI development and application. Participants noted several different types and sources of potentially valuable data that exist, such as patient portals, text-based clinical notes, and structured electronic medical record (EMR) entries. Participants also noted challenges with the current state of EMR databases, and how it would be beneficial to work towards standardisation and interoperability. They expressed concerns about learning from biased data, reconciling data from different sources (eg, allergy reported in one database but not another), and the need for digital infrastructure and storage. While participants emphasised the need for long-term projects to develop high-quality PC databases, they also suggested small-scale AI projects with available data as a useful starting point.

Data considerations also emerged in conversations about legal and ethical issues. Challenges to be addressed included data ownership, including EMR vendors who can sell data, and data sharing with informed patient consent. Participants debated pros and cons of data sharing vs non-sharing as a standard setting, considering potential group benefit and personal privacy and control. Another unresolved barrier towards deployment of AI in PC settings is clarity around AI-driven tool certification to allow use in clinical settings.

In discussing the development of AI-driven tools, participants emphasised the need for user-centred and ethical design that includes input from patient, provider and AI stakeholders, noting there may be heterogeneous preferences even within these stakeholder groups. Workflow considerations for tool design were also mentioned. In addition to design-oriented comments, participants discussed care-oriented needs, such as patient-centredness and fostering trust between patients, providers and technology. Participants expressed that they did not want AI to block patient-provider relationships or to act as an independent authority.

Once developed, there is a need for proper evaluation of AI-driven tool implementation. Participants envisioned starting with small-scale projects that take advantage of available data and working with ‘early adopters’ or care teams at high-quality test sites to develop and test AI for PC settings. Participants encouraged thinking carefully about what meaningful evaluation will look like and what indicates success according to different stakeholders. Participants also mentioned a need for more research funding to conduct this type of research.

Conversations also considered the role of system capacity and culture and how organisational change will be at least as big a barrier to innovation as technical challenges are. Participants noted the need for intersectoral collaboration and for more integration and alignment between jurisdictions, especially for data regulations...
and linkage. The capacity to share information through communities, for example, with patient social networks and social media, was also raised as a useful resource.

Finally, a central theme of caution around equity and the digital divide emerged throughout all discussions. Example concerns included access to required technology and consideration of populations who may have unique experiences or needs, such as older adults or those experiencing homelessness.

**Full group ranking activity: final prioritised list**

After combining similar items across small groups, there were nine AI and PC priorities to rank. Table 3 presents the final ranked list with extended descriptions based on notes taken in the second small group discussions. At a high level, there are four areas that the priorities are intended to support: practitioners in a clinical setting (Priorities 1,6A,8); patients (priorities 2,9); system-level activities (priorities 6B,3) and foundational areas that would support the quality and efficiency of other priorities (priorities 4,5).

**DISCUSSION**

This study engaged patients and caregivers, providers, decision-makers, digital health and research participants in a nominal group technique process to identify priority areas for AI and PC. Small group discussions identified barriers, implementation issues, and necessary resources for progress. The final list of nine priority areas included physician, patient and system-level supports; and foundational areas that are necessary for the success of AI in other priority areas.

The consultation session revealed foundations that need to be improved to support progress in AI development and application, such as communication between PC and AI stakeholders, intersectoral collaboration, data standards and interoperability, and legal issues. In addition to longer-term foundational work, participants encouraged the initiation of AI projects that align with priorities and offered suggestions about conducting these projects in settings where the data and culture are in place to support the continuum of AI development through to careful evaluation and implementation. Core values to maintain throughout these processes included collaboration between diverse participants to maintain suitability of a candidate tool for practice settings, and to attend to equity concerns and patient-centredness.

Most of the ranked priorities from the consultation session include areas wherein AI may support PC by performing relevant functions or tasks, such as using AI to predict patients at high risk of poor health where early intervention is useful. It is noteworthy that despite this consultation session happening during the COVID-19 pandemic, with instructions that the pandemic should be considered in responses, only two COVID-19 specific priorities were identified in the first small group discussion and none remained in the final ranked list. It is also interesting that the environmental scan found 110 AI-driven tools that may be relevant to PC, yet among our participants selected for their engagement in AI and PC, few examples of AI-driven tools implemented in Ontario PC settings were discussed. Appraising specific tools to see if they are available in Ontario and whether they are suitable to meet priority areas as delineated in this study could be an avenue for future research.

The two ‘foundation-related’ priorities (4 and 5) will support progress of AI for all areas of PC. Many AI applications for PC will rely on data generated by PC, which was the topic of priority 5 and in small group discussions about data access, quality and consent. Initiatives supporting use of Ontario PC data for research include Institute for Clinical Evaluative Sciences (ICES) and the emerging PC Ontario Practice-Based Learning and Research Network, as well as national databases such as those housed by the Canadian PC Sentinel Surveillance Network and the Canadian Institute for Health Information. Paprica et al explored views of Ontario general public regarding the use of linked administrative health data held by ICES, finding that people are generally in favour of using these data for public benefit, assuming privacy and security; however, positive attitudes towards data use are more mixed or negative when there is private sector involvement. These findings are congruent with our findings regarding the importance of data ownership and oversight for AI-driven tool development, which has substantial private sector involvement.

Data sharing and communication also was a priority in a study by Shaw et al that used the nominal group technique to elicit priorities for virtual care-related policy planning for Ontario PC. Similar to AI, at the time of their consultation (before the COVID-19 pandemic) virtual care was considered a novel technology with potential benefit. Their recommendations included the need for a patient-centred focus and system- or social-level changes. One suggestion for engaging patients was in outcome measure selection, which is relevant for AI applications as well which ties together the themes emerging from our study around patient centredness and the need for rigorous evaluation. Another relevant suggestion regarding virtual care implementation was the use of a sociotechnical model of care, which is also cited as important for AI to contribute to a learning health system framework whereby data are used in feedback loops to improve care. The idea of a sociotechnical model aligns with themes from our small group discussions about the importance of system culture and communication between stakeholders. Previous work towards improving multidisciplinary collaborations includes guidelines produced by Saleh et al for AI-clinical collaborations, codesign of a documentation assistant for PC consultations by Kocaballi et al in Australia, and a ‘code to bedside’ framework for quality improvement methods by Smith et al in the USA.

Given the breadth and complexity of PC, there are many perceived opportunities for AI to be useful-focused efforts on tangible projects are needed for the field to...
Our consultation session identified priority PC challenges, which AI is well suited to support given the current or near-term capabilities of AI and the Ontario PC context. Although the consultation sessions focused on Ontario, the environmental scans suggest there may be similarities in terms of AI-driven tools and PC needs in other jurisdictions. Other sectors may use our list of priorities as a starting point to refine based on their context.
Together, the findings from our study can be used to guide future research and evaluation efforts, as well as to guide organisations and decision-makers in guiding the allocation of resources towards advancing AI for PC.

**Strengths and limitations**

Strengths of the study, which is the first to identify priorities for AI and PC in Ontario, included bringing together multiple types of stakeholders and designing small group sessions to facilitate equal participation. The study prework to both appraise the present context based on environmental scans and to provide primer documents provided foundational knowledge that supported strong engagement by all participants, regardless of prior AI knowledge. Limitations include representation mainly from academic communities as opposed to industry and private practice. The environmental scans were not limited in this way; therefore, help to balance these findings.

**CONCLUSION**

A multi stakeholder event was held to identify priority areas for AI and PC in Ontario, Canada, with additional findings related to barriers and resources that would be needed to fully realise the benefits of these technologies. Findings provide both specific topic areas to pursue as needed to fully realise the benefits of these technologies. Findings related to barriers and resources that would be needed to realise the benefits of these technologies. Findings provide both specific topic areas to pursue as needed to realise the benefits of these technologies. Findings related to barriers and resources that would be needed to realise the benefits of these technologies. Findings provide both specific topic areas to pursue as needed to realise the benefits of these technologies. Findings related to barriers and resources that would be needed to realise the benefits of these technologies. Findings provide both specific topic areas to pursue as needed to realise the benefits of these technologies.

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**Acknowledgements**

We would like to acknowledge and thank all participants of the stakeholder consultation session for their time and energy, with a special thanks to the patient and caregiver advisors for sharing their perspectives on artificial intelligence and primary care.

**Contributors**

All authors were involved in the planning of the study. RB conducted the environmental scans under the supervision of JKK, AT and DJL. JKK, AT, DJL, LM and JBB conducted the stakeholder event with additional support from BD, MP, WL and RHV (not authors). JKK, AT, DJL and LM developed the study outputs into the paper. JKK drafted the manuscript. All authors critically reviewed and approved the content. JKK is the guarantor.

**Funding**

This work was supported by an INSPIRE-PHC Applied Health Research Question grant funded through the Ontario Ministry of Health and Long-Term Care.

**Competing interests**

The INSPIRE-PHC program provided funds to Western University to support this research project, including staff contracts. Some authors receive salary support from Western University or the University of Toronto and used time from within their roles at those institutions to engage in the research project.

**Patient consent for publication** Not applicable.

**Ethics approval** The project was approved by the Western Health Sciences REB (Project ID 116208).

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** Data sharing not applicable as no datasets generated and/or analysed for this study. All data relevant to the study are included in the article or uploaded as online supplemental information. Not applicable.

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Supplementary Material A: Artificial Intelligence Tool Environmental Scan

Ravninder Bahniwal

An environmental scan was conducted to identify existing artificial intelligence (AI) driven tools that might be relevant to primary care (PC). This scan included a systematic search of peer-reviewed and grey literature, websites of key organizations, registered patents, and a web-based search.

Methods

Scope of Search
For this report, PC will include all first-contact services by providers, while excluding any services provided solely by specialist care providers. AI-driven tools targeted for a) use by PC providers, b) use by patients in PC, and c) use for mediating the interactions between PC and other parts of the health care system were included. The tools themselves had to be a) described as AI, b) portrayed characteristics of AI, c) developed using AI subtypes, or d) existing tools that incorporate AI specific technology. Searches were initially conducted in Summer 2020 and update searches were performed in early 2021.

Search Strategy
The search strategy is presented in Table A-1. Once key organizations and databases were identified, their websites were hand-searched using the established search terms to identify potential AI-driven tools. Once potential tools were identified, a Google search was used to locate vendor websites and secondary websites describing the tool in more detail. If the tool used AI and was deemed appropriate for use in PC, details regarding the AI-driven tool such as description, location, and target users were inputted into an Excel spreadsheet. This process was followed for grey literature, published literature, and web searches. The number of published literature papers identified are in Table A-2. Patents were searched using Espacenet, an international patent database (European Patent Office, 2020) and the Canadian Intellectual Property Office (Government of Canada, 2020).

Table A-1: Development of the Search Strategy

<table>
<thead>
<tr>
<th>Steps</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1: Develop key terms</td>
<td><strong>Primary Search Terms:</strong> Artificial Intelligence (Tools), Primary (Health) Care</td>
</tr>
<tr>
<td></td>
<td><strong>Additional Key Words:</strong> Family Medicine, Family Physicians, Machine Learning, Virtual Health Care, Electronic Medical Record, Healthcare, Intelligent Medicine</td>
</tr>
<tr>
<td>Step 2: Key Organizations</td>
<td>Hand search the following websites with primary search terms: Ontario MD, Athenahealth, Canada Health Infoway, Vector Institute for Artificial Intelligence,</td>
</tr>
</tbody>
</table>
Kaiser Permanente, Institute of Electrical and Electronics Engineers (IEEE), Qianhai Institute of Innovative Research (QIIR), EPIC, eClinicalWorks, CERNER, AMS Healthcare, Nuance, MEDETECH, Allscripts, Binah.ai, Cloud DX, Big White Wall, JUNO, Sensely

Step 3: Grey Literature  
Hand search the following websites with primary search terms: Health Quality Ontario, Canadian Agency for Drugs and Technologies in Health, Canadian Institute for Health Information (CIHI), Turning Research into Practice (TRIP), Open Grey, Canadian Medical Association Infobase, Canadian Institute for Advanced Research, The College of Family Physicians of Canada

Step 4: Web-based search  
Google search with “Artificial Intelligence” AND “Primary Care”, scan titles of results on pages 1 through 10 to identify tools

Step 5: Peer reviewed literature  
Keyword Search Query of “Artificial Intelligence” AND “Primary Care” for Cochrane Library, PubMed, EMBASE, Cinahl, Web of Science, Scopus, IEEE Xplore, ACM Digital Library

Step 6: Patents  
Search Espacenet and Canadian Intellectual Property Office with “Artificial Intelligence” AND “Primary Care”, include only active patents with descriptions showing potential use in PC

Table A-2: Peer Reviewed Literature Search Part of the AI-driven Tool Environmental Scan

<table>
<thead>
<tr>
<th>Database</th>
<th>Total Number of Results</th>
<th>Final Number of Tools Included</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cochrane Library</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pub Med</td>
<td>154</td>
<td>5</td>
</tr>
<tr>
<td>EMBASE</td>
<td>104</td>
<td>0</td>
</tr>
<tr>
<td>Cinahl</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>Web of Science</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>SCOPUS</td>
<td>108</td>
<td>0</td>
</tr>
<tr>
<td>IEEE Xplore</td>
<td>41</td>
<td>0</td>
</tr>
<tr>
<td>ACM Digital Library</td>
<td>118</td>
<td>2</td>
</tr>
</tbody>
</table>

Data Extraction and Organization  
An Excel spreadsheet was used to keep a record of the findings throughout the search, including details of the company, description of the AI-driven tool, whether it explicitly mentioned
relevance to PC or if this was referred, whether AI was mentioned alongside the tool, geographical location where the tool was being marketed, target end user, and category of usage. The use categories were taken based on a framework developed by EIT Health and McKinsey & Company (EIT Health, 2020). Descriptions of the categories are in Table A-3. For patents believed to have applications in PC, the title and description of the patent, applicant name and location was noted in the spreadsheet.

Table A-3: Descriptions of Categories Assigned to Identified Tools

<table>
<thead>
<tr>
<th>Category</th>
<th>Description of Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient Level</strong></td>
<td></td>
</tr>
<tr>
<td>Self-care, prevention and wellness</td>
<td>Aimed at supporting people to live healthier lives, monitoring and tracking devices (ex. vital signs), provide personalized guidance to individuals</td>
</tr>
<tr>
<td>Triage and early diagnosis</td>
<td>Symptom checkers that help triage patients and provide guidance if additional healthcare resources are required, helpful when there are long waiting times</td>
</tr>
<tr>
<td>Diagnostics</td>
<td>Help with diagnosis, such as when further clinical work is needed to determine underlying reasons for symptoms, often focus on specific, well-defined tasks</td>
</tr>
<tr>
<td>Clinical Decision Support</td>
<td>Retrieve relevant medical information for each patient and present it in a structured way, help physicians decide on best treatment option, determine patients at high risk of deterioration and complications, provide guidance for early intervention</td>
</tr>
<tr>
<td>Care Delivery</td>
<td>Often Natural Language Processing-based solutions that support practitioners during their direct interaction with patients, able to take notes, retrieve information from medical records, includes monitoring and treatment devices used in delivery of care</td>
</tr>
<tr>
<td>Chronic Care Management</td>
<td>Help patients manage their chronic diseases and continue care without needing hospitalization</td>
</tr>
<tr>
<td><strong>System Level</strong></td>
<td></td>
</tr>
<tr>
<td>Improving population health management</td>
<td>Analyze large datasets that may uncover correlations between factors or identify early risk factors that can trigger early intervention and prevention at a system level, helps determine what to prioritize</td>
</tr>
<tr>
<td>Improving healthcare operations</td>
<td>Decrease time spent on routine, low-value administrative tasks to increase direct time with patients, helps with tasks occurring in the background of patient care such as scheduling and capacity management</td>
</tr>
</tbody>
</table>


**Results**
A total of 127 existing AI-driven tools with potential relevance to PC and an additional 36 active patents were identified. A complete list of identified tools is available upon request. Given the challenging nature of the search, this may not be an exhaustive list, but it does give an indication of the range of tools that are either currently influencing PC or showing promise with their development. A minority of tools stated a direct use in PC while most tools were targeted towards a variety of health care settings of which PC may be one. Example tools that specify a direct interest in PC are in Table A-4.

Table A-4: Descriptions of Companies and Their Tools That Stated a Direct Use in PC

<table>
<thead>
<tr>
<th>Company</th>
<th>AI-Driven Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaiser Permanente</td>
<td>HIV prediction tool uses machine learning algorithm to predict who would become infected with HIV during a three-year period. This tool can be incorporated into electronic health records to alert PC providers to speak with patients most likely to benefit from discussions about PrEP.</td>
</tr>
<tr>
<td>University of Nottingham</td>
<td>An AI based clinical decision support software that scans patients' routine medical data and predicts which of them would have heart attacks or strokes within 10 years. It is intended for use by PC doctors while the patient is in front of them during a routine appointment or in a systematic screen of the entire list.</td>
</tr>
<tr>
<td>Brain FX</td>
<td>Brain FX assessment tools create a brief brain health profile of strengths and weaknesses in 10 to 15 minutes with automated reporting and advanced real-time analytics for baseline comparison or cohort analysis to determine next steps.</td>
</tr>
<tr>
<td>Saykara</td>
<td>Kara is the first fully ambient intelligent virtual assistant. Kara interprets conversations with patients so you can enter the exam room, treat the patient and be done charting. Kara can create SOAP notes, place orders, write referrals, and complete pre-charting by reaching out to the patient ahead of time.</td>
</tr>
<tr>
<td>Suki</td>
<td>Suki is an AI-powered, voice-enabled digital assistant for doctors that generates accurate notes and gets smarter with each interaction. Doctors finish their notes an average of 76% faster with Suki.</td>
</tr>
<tr>
<td>Tyto Care</td>
<td>TytoHome is a remote examination tool and telehealth platform that connects consumers to clinicians to enable a comprehensive medical examination (ears, nose, throat, lungs, heart, temperature).</td>
</tr>
<tr>
<td>---------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>telehealth start-up</td>
<td></td>
</tr>
<tr>
<td>Cambridge Cognition</td>
<td>CANTAB Mobile is a digital memory assessment tool for PC that can triage memory complaints in clinic.</td>
</tr>
<tr>
<td>cognitive assessment software provider</td>
<td></td>
</tr>
<tr>
<td>Skin Analytics</td>
<td>DERM AI is a machine learning tool that identifies malignant skin lesions with high levels of sensitivity and specificity.</td>
</tr>
<tr>
<td>research led company committed to helping more people to survive skin cancer</td>
<td></td>
</tr>
<tr>
<td>Eyenuk Inc.</td>
<td>EyeArt AI Eye Screening System makes in-clinic, real-time diabetic retinopathy screening possible for PC practices, diabetes centres, and optometric offices by allowing physicians to quickly and accurately identify referable DR patients during a diabetic patient's regular exam.</td>
</tr>
<tr>
<td>global medical technology company</td>
<td></td>
</tr>
</tbody>
</table>

**AI documentation.** Before classifying a tool as having AI capabilities, vendor websites were hand-searched for indications of AI use. Use of AI was directly mentioned on the vendor websites for 96 (76%) tools, whereas 23 (18%) required an additional web-search to determine the use of AI technologies. For 8 (6%) tools, the use of AI was unclear both on vendor websites and with a web-based search. Instead, AI use was inferred based on a deeper examination of website content. It should be noted that websites were not consistent when discussing the technology used by their tools. A trend can be seen with AI and software technology companies offering the most detail on the intricacies of their technology, whereas larger companies known for their EMR systems did not include many technical details. It should be noted that it is difficult to find complete information on the tools such as use cases, settings in which they should be implemented and how they were developed. While websites often included a page to input contact information so the vendor could directly contact a potential customer regarding a demo or further details, key information about the tools was not always publicly available. This finding suggests that end users could experience difficulties finding comprehensive information about the AI tools that exist, leading to potential skepticism and lack of trust in implementing new technologies.

**Locations**
When seeking the locations for the AI-driven tools, 17 (13%) were found to exist solely in Canada, 40 (31%) were found both in Canada and internationally, and 70 (55%) did not mention any use in Canada. It was noted that overall, 24 (19%) of the vendor companies are based in the United States region known as “Silicon Valley”, a global centre for innovative technology companies. These companies were also observed to have the most comprehensive information on
their tools. Equally, four vendor companies based in Israel provided a similar level of information on their products as the Silicon Valley-based companies. This observation aligns with the Israeli government initiative to maximize usefulness for AI and encourage partnerships between foreign and domestic business, Israeli start-ups and health organizations (EIT Health, 2020). These findings align with technology sectors of countries such as US, UK, China and Israel building their health data repositories and investing in AI (Strome, 2020). Canada currently spends billions to purchase electronic health record systems from US vendors, and in the future will have to import costly AI technologies if it does not develop and scale AI applications within its borders (Strome, 2020).

**Target end user.** Of the total 127 identified tools, 81 (64%) were targeted towards PC providers, ranging from virtual assistants and risk assessment tools to devices aiding in diagnosis. There were 38 (30%) intended for patient use and can help with monitoring vital signs, checking symptoms, and managing chronic diseases. Of the tools intended for patient use, 12 (32%) are capable of remotely screening patients and directing them to appropriate healthcare services. If proven effective, these tools have the potential to reduce clinical workloads in PC while creating more time for providers to address patients with urgent needs. Another 8 (6%) tools were focused on the interaction between PC and specialist care services and can provide significant benefit in regions lacking specialty care access. For example, tools that detect diabetic retinopathy, malignant skin lesions and atrial fibrillation can be used when a referral is not possible or when long wait times create a delay before care can be provided by a specialist. The 36 active patents were not organized further as their target end-users in PC were often unclear and were used only to recognize the degree of innovation in progress.

**Categories of Tools**
As seen in Figure 1 of the manuscript, an overwhelming number of tools are targeted towards improving healthcare operations, aligning with current discussions on documentation practices contributing to increased physician burnout and reduced time spent with patients. Many tools in use focus on reducing time spent in administrative tasks such as record keeping and appointment scheduling. Speech recognition technologies and virtual assistants for notetaking are being utilized to enable PCP to focus exclusively on patient interactions. For patients accessing PC, there is an emphasis on empowering individuals to take control of their health through triage and diagnosis tools available on mobile applications. There are also several devices which track information such as vital signs and other wellness data to provide personalized guidance. Example tools for each category are in Figure A-1.
Figure A-1: Examples of AI-Driven Tool for Each Category

Based on the available data about the AI-driven tools, it is estimated that approximately 106 (83%) of the examined tools are currently in use somewhere in the world, with active patents confirming a future of further innovation. While scanning peer-reviewed literature, there were many articles focused on algorithms in development, along with discussion on the future of clinical decision support systems for specific diseases. Together with active patents, this observation may offer insight into the tools in development. Although many tools have EMR
integration capabilities, there are still several tools developed independently by start-ups and information technology companies. In order to maximize their use in PC, it is important to connect PC providers and patients with the tools capable of solving current challenges in PC.

References


Supplementary Material B: Small Group Discussion 1 Identified Areas

Items were generated during the first small group discussion. Bolded items were discussed in the second small group discussion and the presented wording is from the small group discussion notes; other items are worded according to group’s Mentimeter ranking chart from the first big group report back and thus may be more abbreviated.

Small Group 1

1. Consolidating information from different sources to facilitate identification of problems
2. Clinical decision support
3. Administrative staff support, e.g. decision making around what type of care (virtual/in person), triaging, scheduling
4. Patient self-management
5. Automated translation of language-literacy level
6. Portal medication view, visit/calendar view
7. Prescription renewal – patient driven synthesis of vast information – clinical decision support
8. Appropriate intervention as soon as possible – aggregate data
9. Bridge use of technology with patient comfort – equity concept
10. Vaccine alert, administrative function
11. Triage – link patient with right person

Small Group 2

1. Patient self-management of disease is challenging, especially with multimorbidity. Patients have challenges in self-management of multimorbidity
2. Manage the firehose of information – new medical knowledge is created, data is in charts, how can we use that newly created knowledge combined with what is in the chart to update care/suggest tests/develop or diagnose – expanding scope of practice and improving equity/access
3. Data sharing and interoperability between/among providers
4. AI could support changes to models of care – as a catalyst/lubricant that connects big data to people to improve the health care system
5. Primary care providers have to deal with many mundane workflow issues that could be made less painful
6. Information does not always flow effectively from providers to patient and caregiver

Small Group 3

1. Risk profiling and reminders for screening and preventative care – use AI to personalize and go beyond general guidelines
2. System coordination and referral centralization
3. Documentation and clerical duties
4. Patient level clinical decision making
5. Treatment plan prioritization
6. Population health management – identify unseen patterns and proactive reach out
7. Data collection
8. **Patient triage in the fall – identify high risk patients and how to manage**
9. Medical education resource amalgamation
11. New ways of communication
12. Flexibility and human contact

**Small Group 4**

1. **Preventative care**
2. **Mental health care**
3. **Communication and adoption between AI and PC practitioners**
4. Reducing paperwork / clinical overhead
5. Handling patient contributed data
6. Assisting prioritization of care
7. Bedside manner assistance
8. Improving accuracy
9. Reducing inefficiencies
10. Communication challenges
11. Solving abandoned patients