



# Identifying Opportunities for Workflow Automation in Health Care: Lessons Learned from Other Industries

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## Abstract

**Background** Workflow automation, which involves identifying sequences of tasks that can be streamlined by using technology and modern computing, offers opportunities to address the United States health care system's challenges with quality, safety, and efficiency. Other industries have successfully implemented workflow automation to address these concerns, and lessons learned from those experiences may inform its application in health care.

**Objective** Our aim was to identify and synthesize (1) current approaches in workflow automation across industries, (2) opportunities for applying workflow automation in health care, and (3) considerations for designing and implementing workflow automation that may be relevant to health care.

**Methods** We conducted a targeted review of peer-reviewed and gray literature on automation approaches. We identified relevant databases and terms to conduct the searches across sources and reviewed abstracts to identify 123 relevant articles across 11 disciplines.

**Results** Workflow automation is used across industries such as finance, manufacturing, and travel to increase efficiency, productivity, and quality. We found automation ranged from low to full automation, and this variation was associated with task and technology characteristics. The level of automation is linked to how well a task is defined, whether a task is repetitive, the degree of human intervention and decision-making required, and the sophistication of available technology. We found that identifying automation goals and assessing whether those goals were reached was critical, and ongoing monitoring and improvement would help to ensure successful automation.

**Conclusion** Use of workflow automation in other industries can inform automating health care workflows by considering the critical role of people, process, and technology in design, testing, implementation, use, and ongoing monitoring of automated workflows. Insights gained from other industries will inform an interdisciplinary effort by the Office of the National Coordinator for Health Information Technology to outline priorities for advancing health care workflow automation.

## Keywords

- ▶ automation
- ▶ clinical care
- ▶ clinical information systems
- ▶ computing
- ▶ health care delivery
- ▶ health information technology
- ▶ informatics
- ▶ policy
- ▶ systems analysis
- ▶ workflow

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## Background and Significance

Twenty years ago, the National Academy of Medicine published two landmark reports<sup>1,2</sup> highlighting systemic quality and safety deficiencies in United States health care and outlining strategies to address them. Despite investments and innovations, challenges with inefficient workflows,<sup>3</sup> variable quality,<sup>4</sup> patient safety,<sup>5</sup> and poor outcomes remain.<sup>4</sup> Although different care delivery models and technological solutions offer great promise, the use of automation may also offer opportunities to address some of these challenges. Automation, defined as “the creation and application of technology to monitor and control the delivery of products and services,”<sup>6</sup> has been successfully implemented in other industries to improve quality, productivity, efficiency, timeliness, effectiveness, and operational safety, as well as to reduce costs and deliver better value to customers.

In health care, there is an opportunity to employ relevant techniques to better automate workflows (i.e., “the sequence of physical and mental tasks performed by various people within and between work environments”)<sup>7</sup> to reduce burden on providers and staff, improve quality and efficiency, and deliver better value to patients and caregivers.<sup>8,9</sup> Investments have been made to automate administrative and operational workflows in health care, for example, reducing time spent scheduling appointments<sup>10</sup> and minimizing manual medical record abstraction for automated calculation of quality metrics.<sup>11</sup> However, there are opportunities to improve the initiatives underway and leverage automation for treatment and care delivery, population health, patient safety surveillance and reporting, and analytics to benefit stakeholders across the health care continuum.

Recent advances in modern computing, including the advent of the internet of things, increased computing power, and access to information, have created opportunities for automation across industries.<sup>12–21</sup> Information access and sharing and computational advances facilitate faster processing times and have made automation innovations, such as ride sharing or food ordering applications, possible. Aviation has invested in automation for decades, using it across operations in everything from scheduling and managing flights and crews to flying an aircraft. Automation has facilitated manufacturing advances in production scheduling, assembly line,<sup>22</sup> robotics,<sup>23–25</sup> and quality control.<sup>22,26</sup> In finance, many banking processes are automated to benefit institutions and customers.<sup>27</sup> Several of these industries have had automation in place longer and gone through more advancement, as compared with health care.<sup>9</sup> Health care generally has similar workflows to these industries, including preparing for appointments and procedures, sharing financial and health data across institutions, organizing and assigning the human and supply resources necessary to deliver care, and reorganizing and reassigning those resources for expected and unexpected occurrences. Nonhealth care industries may offer useful examples and lessons learned to inform and advance implementation of automation in health care. In addition, now that the United States health care system has a more extensive health information

technology (IT) infrastructure and increased availability of electronic health data,<sup>28,29</sup> the opportunity to advance workflow automation in health care is far greater than it was 10 years ago.

As the federal agency that coordinates health IT policy and leverages modern computing to advance health information exchange across the United States, the Office of the National Coordinator for Health Information Technology (ONC)<sup>30</sup> is leading a collaborative and interdisciplinary effort to outline priorities for health care workflow automation. To inform this effort, we reviewed the literature to understand how automation is used across industries and disciplines and to identify lessons learned that could be applied in health care.<sup>31,32</sup> This article describes findings from the literature review and implications for the use of automation approaches in health care, and it presents considerations to identify workflows and to implement relevant automation approaches.

## Objectives

The literature review has two main objectives. First, to identify current approaches in workflow automation across industries. Second, to synthesize evidence across literature to identify (1) opportunities from nonhealth care industries that could be employed or applied in health care to advance workflow automation; and (2) considerations for designing and implementing workflow automation across industries and disciplines that may be relevant to health care.

## Methods

To better understand workflow automation in other industries and identify lessons learned applicable to health care, we conducted a targeted review focused on key, relevant work. Sources included peer-reviewed journals and such gray literature as issue briefs, government reports, and conference proceedings and presentations that were published in English. We developed a targeted list of search terms most relevant to addressing the topic to stay focused on the overall objectives, given the breadth of the area being investigated, as shown in **Table 1**. The gray literature search included web searches for colloquial terms related to the search terms. We identified relevant databases to search the peer-reviewed literature, some of which include gray literature and appear in both sections of **Table 1**. We searched literature from 2014 to 2019. A Master of Library Science-trained librarian provided input into the keywords and conducted searches.

The search yielded 139 articles. Two health informatics experts screened articles to ensure that they met the overall objectives by review of abstracts, and 123 were deemed relevant for inclusion based on the focus of this effort. The excluded articles did not have workflow as a central focus or were primarily focused on technology. Results from web searches were screened in a similar manner.

Resources reviewed spanned a variety of industries and disciplines. Two health informatics experts used the Higher

**Table 1** Databases and keywords for literature review (2014–2019)

Sources searched	Search terms
Peer-reviewed literature	
<ul style="list-style-type: none"> <li>• Business Source Corporate</li> <li>• Cumulative Index to Nursing and Allied Health Literature</li> <li>• Cochrane Central Library</li> <li>• Google Scholar</li> <li>• Library, Information Science and Technology Abstracts</li> <li>• PsycINFO</li> <li>• PubMed</li> <li>• Web of Science</li> </ul>	(workflow* OR “work flow*” OR process OR processes OR (work* AND flow*)) AND automat* AND (“health IT” OR “health information technology*” OR health care OR “health care” OR “information system*” OR agriculture* OR “food production” OR transportation OR hospitality OR industry* OR business* OR “operations research” OR “industrial engineer*” OR “human factor*” OR ergonomic*) AND success* OR solution* OR “case study” OR “case studies” OR evaluate OR review*
Gray literature	
Searches in the Cochrane Central library and Web of Science	Web searches based on the search terms and colloquial terms for the search terms

Education Statistics Agency (HESA) Joint Academic Coding System (JACS) 3.0 principal subject codes (highest level) to characterize the literature that was reviewed and to organize and count representation across disciplines.<sup>33</sup> The HESA JACS codes represent an open source classification of higher education information for data users. Each resource was reviewed by at least one health informatics expert. Review included extracting key points from each resource related to people, process, or technology;<sup>34</sup> factors that have been identified in the literature as relevant to the design, implementation, and use of technology in work places. Themes across resources were identified related to approaches to automation, opportunities for applying workflow automation in health care, and implementation considerations. The experts met weekly during the literature review to identify key points and themes, resolve any differences in perspectives, and refine key points.

## Workflow Automation Approaches across Industries

Our review sought examples of automation that could apply to health care. We identified key examples of the use of automation in other industries, a continuum for automation, the role of technology across that continuum, factors that guide workflow selection for automation, and considerations in designing and implementing automation. JACS areas represented in the reviewed literature are in **–Table 2. –Supplementary Table S1** (available in the online version) includes a detailed mapping of all the reviewed articles to the JACS areas. There were several JACS areas representing a broad range of disciplines, with the majority of articles from computer science and subjects allied to medicine, engineering, and technology.

Analysis of the 123 articles yielded six themes: use of workflow automation in other industries, importance of establishing goals for automation, strategies for identifying and selecting workflows to automate, the automation continuum, consideration for designing and implementing workflow automation, and ongoing monitoring and continuous improvement. A discussion of each of the themes follows.

## Workflow Automation in Other Industries

Automation was used for several workflows across a range of industries. Some industries, such as manufacturing and banking and finance, have long-standing histories of using automation.<sup>27,35</sup> Other industries are newer to automation, including legal consultation,<sup>36</sup> hospitality,<sup>37</sup> and transportation (e.g., ride sharing).<sup>38</sup> Across industries, a variety of workflows were automated, including accounting functions,<sup>27,39</sup> document routing,<sup>40</sup> work and resource allocation,<sup>41,42</sup> quality monitoring and control,<sup>43–48</sup> report generation,<sup>35,49</sup> and supply chain and logistics management.<sup>40–52</sup> In addition, automation has been used for physical and chemical processes,<sup>45,53</sup> and biologic and laboratory pre- and postanalytic activities.<sup>54–57</sup>

Examples of automation found in the literature focused primarily on automating workflow at a single organization

**Table 2** Mapping of included literature to Joint Academic Coding System area based on the Joint Academic Coding System 3.0 principal subject code

JACS areas	Articles by JACS area
Computer science	35
Subjects allied to medicine	21
Engineering and technology	20
Medicine and dentistry	19
Business and administrative studies	13
Biological sciences	7
Mass communications and documentation	3
Agriculture and related subjects	2
Architecture, building, and planning	1
Education	1
Social studies	1
<b>Total articles included</b>	<b>123</b>

Abbreviation: JACS, Joint Academic Coding System.  
Note: Reprinted with permission from the Office of the National Coordinator for Health Information Technology.<sup>32</sup>

(e.g., streamlining processes in manufacturing for aerospace<sup>58</sup> or streamlining response to citizen requests in a municipality)<sup>12</sup> or across an enterprise (e.g., allocating work and sharing associated documents in a credit union with multiple branches)<sup>27</sup> versus efforts focused on advancing automation for an industry as a whole. The literature was characterized by documentation of successful examples of automation, rather than failed attempts. The remaining themes denote ways to ameliorate potential problems that can be caused by automation, which can be applied to health care.<sup>59</sup>

**Establishing Goals for Workflow Automation**

Organizations pursue automation for several reasons, including saving time, improving productivity, and enhancing quality.<sup>21</sup> For example, one business office sought to reduce employee time when conducting tasks within a workflow, such as activity tracking and providing targeted employee guidance through automation.<sup>23</sup> Similarly, automation of workflows in dairy farming was pursued to improve milk output while reducing manual effort for milking.<sup>60</sup>

The importance of identifying clear goals for automation and gaining consensus about them among stakeholders cuts across industries and workflows.<sup>61</sup> For example, in aerospace engineering, end-users identified a workflow that was highly repetitive and manual as a candidate for automation to save time and improve efficiency.<sup>61</sup> This example highlights the importance of engaging stakeholders who will be impacted by workflow automation and aligning automation goals with workflows selected for automation.<sup>23</sup>

Automation goals may not be met if a clear set of goals is not identified and stakeholders impacted by automation are not engaged. Reasons for not achieving those goals include selection of processes that are not suitable for automation, such as those listed in **Table 3**, selection of technology not suitable for the workflow, a lack of suitable available technology, or use of available technology that is improperly applied. In addition, insufficient understanding and response to organizational aspects of implementation can lead to unmet automation goals,<sup>9</sup> such as stakeholder concerns about losing the ability to interact with or access decision-making authority<sup>22,62-67</sup> and worries related to the impact on quality, safety, privacy, and security.<sup>48,68-74</sup>

**Strategies for Identifying and Selecting Workflows to Automate**

Several common characteristics of workflows were found in the literature that can be used to identify and select suitable

workflows to automate. In particular, the decision to automate a particular workflow and to what degree is based on several factors, summarized in **Table 3**.<sup>63,75,76</sup> In contrast, the literature revealed characteristics associated with workflows that are more difficult to automate, summarized in **Table 3**.<sup>8,12,18,27,39,54,62,77-79</sup> Careful selection with these characteristics in mind can help to prevent some of the documented problems that automation can cause<sup>59</sup> across industries, including health care.

Identifying workflows and determining suitability for and degree of automation are typically based on analysis of three aspects.<sup>63,75,80</sup> The first relates to people and the degree of human intervention required. The second aspect relates to process—the characteristics of the tasks within a workflow and repetition of workflows with clear roles and responsibilities. The third aspect relates to technology and the availability of tools to support a range of workflows for full or partial automation.

**Automation Continuum**

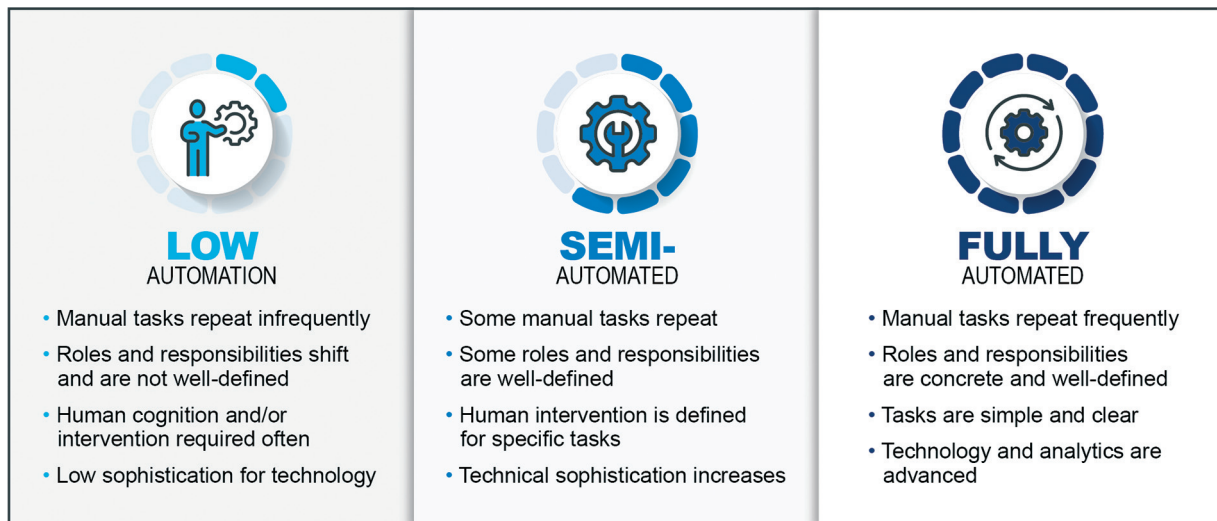
As summarized in **Fig. 1**, we found automation implementations ranging from workflows, where humans continued to be significantly involved, to semi- and fully automated workflows with little or no human involvement. Semi-automated workflows included content management of library workflows to highlight actions that should be taken manually;<sup>81</sup> client profile development in banking to identify which might need personalized attention;<sup>82</sup> and quality assurance processes in the automotive industry to identify outlier assembled parts that need human review.<sup>43</sup> Some examples of fully automated workflows included production scheduling and workload management in a manufacturing plant<sup>58</sup> and optimizing production cycles in biomanufacturing.<sup>44,47</sup>

The degree of automation was generally linked to the complexity of tasks within a workflow, types of decision rules involved for the workflow, sophistication of technology needed, technology availability, and human intervention needed.<sup>64,83-85</sup> Determining the degree of automation requires reviewing workflows and their context. For example, in a semi-conductor manufacturing plant, workflows across the production line were reviewed to determine which could be fully automated, semi-automated, or should remain manual.<sup>22</sup> Workflows that were fully automated were typically simple parts assembly; workflows that were partially automated involved initial assembly with human finishing and initial quality assurance; and workflows that remained manual involved review of items

**Table 3** Workflow characteristics that promote or challenge automation

Characteristics that promote automation	Characteristics that challenge automation
<ul style="list-style-type: none"> <li>• Manual data entry</li> <li>• High frequency and/or repetition</li> <li>• Clearly defined independent and dependent variables for modeling</li> <li>• Clear roles and responsibilities</li> </ul>	<ul style="list-style-type: none"> <li>• Complex decision rules that are tacit and inconsistently followed</li> <li>• Inconsistent data requirements</li> <li>• Independent and dependent variables that influence decision-making</li> <li>• Inconsistent or unclear roles and responsibilities</li> <li>• Deviation from “ideal” workflows in practice</li> </ul>





**Fig. 1** Automation spectrum and workflow and technology characteristics. Adapted with permission from the Office of the National Coordinator for Health Information Technology.<sup>32</sup>

identified as having possible defects from a quality assurance review. Similarly, additional examples of fully automated workflows in other industries found in the literature include labor allocation in a distribution center based on volumes,<sup>50</sup> robotic process automation to address routine workflows in an office with repetitive business tasks,<sup>35</sup> and water treatments that were automatically tracked and adjusted based on changes in salination level.<sup>65</sup>

Several technology capabilities and characteristics noted in the literature that support the continuum of automation are listed in **Table 4**. These characteristics occur across industries and are relevant to health care. Characteristics and capabilities to consider when selecting technology to support workflow automation range from attending to data systems and how they interoperate and are integrated, technical infrastructure and its ability to support automation activities or processes, the ability to effectively present knowledge and information visually, design and needs of decision rules, and security needs.

**Table 4** Workflow automation technology considerations

1. Number and type of systems housing relevant data to support workflows<sup>86,87</sup>
2. Interoperability between systems in which relevant data are stored across types and formats<sup>86–88</sup>
3. Technical infrastructure, including cloud-based capabilities, analytics, and computing power<sup>45,46,69,79,89</sup>
4. Data visualization capabilities available for dashboards and other visual representations of data<sup>42,57,88</sup>
5. Complexity of decision rules required<sup>41,79,90</sup>
6. Communication and networking considerations, such as bandwidth<sup>13</sup>
7. Integration of automated workflow with other organizational information systems<sup>45,46,82,91</sup>
8. Security considerations within and across systems<sup>91</sup>

### Considerations for Designing and Implementing Workflow Automation

When designing and implementing workflow automation, aspects of people, process, and technology found in the literature may offer important lessons to apply workflow automation in health care.

People aspects include attaining leadership support and ensuring that staff throughout the organization is aware of the institutional commitment to automation.<sup>39,92</sup> Another key implementation consideration is identifying those who are participants in or impacted by workflows being considered for automation or being automated, and engaging their support and participation as these workflows are identified and redesigned and automation is implemented.<sup>27</sup> Engaging stakeholders includes obtaining their input as roles and responsibilities are documented, training them, eliciting their feedback during implementation of automated workflows, and proactively addressing concerns.<sup>61,70,93–95</sup>

Aspects of this process include documenting, analyzing, and redesigning workflows.<sup>96</sup> Engaging stakeholders throughout workflow redesign can help to support the desired automated end state.<sup>97</sup> Documenting workflows involves identifying activities, intersections with other workflows, constraints, dependencies, and resources.<sup>72,96</sup> Analyzing workflows involves reviewing the documented workflow to support redesign.<sup>97</sup> Redesigned workflows include changes to documentation to support the desired automated end state.<sup>58,98</sup> The redesigned workflows can be used as a basis for training and launch of the automated workflows.<sup>99,100</sup> After launch, keeping stakeholders engaged and making relevant changes was noted across industries.<sup>47,101</sup>

Workflow automation involves aspects of technology such as selection and usability. Technology capabilities and characteristics identified from the literature that support the continuum of automation across industries that may be relevant to health care are listed in **Table 4**. These represent characteristics and capabilities to consider when selecting

technology to support workflow automation. One step is identifying available technologies to ensure that technology aligns with stakeholder needs and the redesigned workflow.<sup>45,48</sup> This involves ensuring that information can be shared across systems.<sup>83,87</sup> If information is not interoperable, that may influence automation due to manual intervention being required.<sup>87</sup> Another aspect is reviewing metrics to determine whether the expected improvements occurred<sup>44,56,102</sup> and, if they did not, to explore why and make changes accordingly.<sup>103</sup> Changes that may be needed might include retraining, workflow changes, changes in decision- rules, or technology changes.<sup>39,44,57,85,104</sup>

### Ongoing Monitoring and Continuous Improvement

As workflow automation is implemented and used, ongoing monitoring and analysis are needed. This involves an understanding of how best to deploy technology to manage workflow and examination of how automation is used to make any needed adjustments in design or implementation.<sup>49</sup> User satisfaction with the system and the overall design and implementation process are important to consider when evaluating the alignment of technologies and workflows.<sup>60,105</sup> Ensuring user satisfaction involves assessing usability of systems.<sup>67</sup> Ongoing analysis involves assessing the physical structure and the intersection of technology, workflow automation, and physical layout.<sup>86</sup> It is important to continue to refine the boundaries of automation in practice and make changes to accommodate where human interaction might be needed.<sup>52,101</sup> Human interaction may involve reviewing error reports, duplicate records, or exceptions that require manual intervention for further analysis.<sup>39,57,106</sup> Outcomes may involve changes in the degree of automation, changes in technology, or changes in decision support to inform automation.<sup>54</sup>

One common theme found in the literature was the need to continue monitoring and reviewing automated workflows.<sup>96</sup> This involves returning to the original automation goals and reviewing progress. One way to do this is to continually engage with stakeholders and end-users to obtain their perspectives.<sup>101</sup> Another is to identify metrics related to the original goals and regularly review progress.<sup>96,106</sup> Ongoing measurement and stakeholder engagement were noted across industries and types of workflows to identify changes to optimize automation.<sup>56,107,108</sup>

### Opportunities and Considerations for Health Care Delivery

The findings from the literature point to several considerations for automation of health care workflows. Industry-wide gains from automation may require broad collaboration in a manner that other industries have undertaken.<sup>61,102,109</sup> The types of workflows selected for automation vary based on goals,<sup>41,50</sup> organizational factors,<sup>9,15</sup> the level of human intervention,<sup>39</sup> and characteristics of the workflow and technology being considered.<sup>61,110</sup> Although health care tasks may differ from tasks performed in other industries, and thus, the automation approaches from other industries

may not be directly applicable; there are lessons learned regarding how to approach automation that may be important to consider in the application of automation approaches in health care. Although health care has made use of automation, it is generally employed in administrative and operational processes such as billing,<sup>98</sup> compound preparation,<sup>45,111</sup> or delivery of medications, meals, or linens<sup>112</sup> with the purpose of reducing “no-show” rates for scheduled appointments, increasing patient throughput, and reducing the burden of operational workflows. There are examples of automation of clinical care tasks such as screening processes,<sup>113</sup> transmitting results and other communications,<sup>114</sup> and application of clinical guidelines<sup>115,116</sup> that use health IT. There is an opportunity to explore different degrees of automation for workflows that have experienced less automation. Automating clinical data review by using technology to identify—(1) gaps and locate missing information or data housed in third-party systems or (2) identify and resolve duplicate data from multiple sources—could support the cognitive tasks involved in treatment and care delivery workflows, such as setting follow-up reminders, communicating with consulting clinicians, checking the status of immunizations administered, reviewing data for an upcoming encounter at a clinic or hospital, and ensuring critical items are addressed prior to discharge. Continuous, automated data monitoring, and alerting across disease registries, as well as nonclinical datasets related to social determinants of health, could streamline population health interventions and communications. The use of standards and machine learning approaches could reduce the burden of surveillance workflows, such as medical record abstraction, as well as reporting and transmission workflows for quality, safety, and public health data. These technologies can use carefully crafted and tested algorithms that collect, organize, analyze, and present data to automate analytics workflows. In addition, there may be opportunities to employ automation to expand, refine, and streamline other administrative and operational workflows regarding care logistics, supply chain, preauthorization, and payment.

Reviewed literature emphasized the importance of establishing agreed-upon goals for automation.<sup>12,61</sup> Given the state of automation in health care, two potential goals could be to (1) expand and enhance administrative and operational workflows (e.g., improving efficiency or reducing manual processes) while focusing on training the workforce into new roles; and (2) identify opportunities to automate the workflows that have not experienced a great deal of automation in health care. Obtaining interdisciplinary input and perspective across the health care industry to refine and implement automation around these goals are essential as illustrated by the reviewed literature.<sup>117,118</sup>

Use of automation in health care requires attention to several considerations of paramount importance when deciding to automate a workflow and selecting its level of automation. First, the degree to which a human is needed “in the loop” to review, make decisions, and apply judgement at critical workflow decision points will inform whether a workflow should have low, semi-, or full automation. The

literature showed that a poorly automated workflow can affect quality and trust<sup>45,50,55,60,61</sup> and, in contrast to other industries, such as manufacturing, health care providers, staff, and patients contribute to a co-produced service involving coordination, communication, and commitment to an intended health goal or status.<sup>3,19,84</sup> The foundational role of the provider–patient relationship in the human experience of care delivery underscores the importance of selecting workflows to automate that create and maintain trust in the humans and technology involved. Moreover, patient privacy and data security are important considerations in health care delivery,<sup>1</sup> which calls for a critical need for careful planning and protection in highly automated workflows. Lastly, with the opportunity to apply advanced computational techniques to health care, attention must be paid to ensure such techniques do not perpetuate existing biases in health and health care nor create new ones.

We found that priorities, goals, and outcomes were driving forces for automation across industries.<sup>27,44,60,110</sup> With a multitude of stakeholders within health care, there may be conflicting automation needs and goals. There are opportunities for automation to support needs of many stakeholders, including administration and administrative staff, many types of clinicians, allied health professionals, patients and caregivers, and public health experts. It will be important to balance conflicting needs and goals when multiple stakeholders are part of the same workflow. In addition, incentives to encourage automation may propel its adoption, particularly for specific workflows, such as population health, where the benefits and value are derived by stakeholders who have not financed automation.

In addition, workflows being automated may require redesign as part of the implementation process. Any redesign should build on the established automation goals and desired outcomes, with a focus on the effectiveness and efficiency of current workflows and how automation would support and work as part of redesigned workflows. Similar to recommended best practices in health IT design and implementation,<sup>119,120</sup> this will require analyzing current workflows and mapping proposed workflows, while considering the roles, needs, and responsibilities of multiple stakeholders that may be involved.

Successful design and implementation of automation in workflow will require a robust technical infrastructure that can support desired automation activities. This may require health care organizations to analyze current infrastructure and its capabilities to sustain or support automation solutions or technologies being considered or designed.

Many examples from the literature focused on automated workflows at a single organization or across an enterprise, but not across an entire industry.<sup>18,20,22,58,86,97,121</sup> For widespread gains within the health care delivery system, it is important that automation efforts can scale across health care, and lessons learned from the development of health information exchanges may offer some insights on what may and may not work in trying to make industrywide gains on automation in health care.<sup>122</sup> Some industries, such as manufacturing and finance, have experienced widespread

gains through automation, following collective efforts to address common needs.<sup>24,27,123</sup> In health care, there is an opportunity to make gains across organizations or stakeholders to have an impact; it will be important to identify and understand what opportunities exist across the industry.

## Future Directions and Conclusion

The reviewed literature clearly points to a set of factors to consider when automating workflows. In particular, there are attributes that make certain workflows more apt for automation such as frequency, roles, and responsibilities being clearly defined, and being manual or characterized by high data entry. That said, we identified a continuum of automation examples that varied depending on task and technology characteristics. This included workflow automation that had “humans in the loop,” particularly in highly complex workflows. We found automation is applied for diverse purposes including reducing or eliminating redundant workflows, removing waste, identifying fraud and abuse, improving quality, improving efficiency, or increasing productivity among others.

However, advancing automation in health care will require careful consideration of which workflows to automate, what instrumentation may be required to do so, how automation solutions are developed and implemented, how to measure effectiveness, and who benefits from automation. Efforts to advance automation more broadly will require participation from different stakeholders across health care, including developers, informaticians, researchers, health care practitioners, and policymakers.

In particular, it will be important to evaluate workflows and identify areas of greatest need. Clearly defining automation goals will be critical to identify and develop relevant solutions, and implementation and evaluation processes. It will be important to thoughtfully advance technology needed to support automation of prioritized workflow. As with any new innovations or technology, advancing automation in health care will require the development of robust and transparent testing and evaluation approaches. Ideally, automation should be designed with closed feedback loops that allow for real-time performance monitoring. Furthermore, the development and implementation of workflow automation in health care will require creation of policies that both allow advancement of automation and include needed safeguards to protect data and assess and mitigate risks. Lastly, as the use of automation increases in health care, it will be important to identify and share relevant best practices broadly. These efforts will require health care stakeholders to invest and reinforce the necessary infrastructure and resources to support development, evaluation, and implementation of automation approaches.

With continued concerns regarding quality, effectiveness, efficiency, safety, and patient-centeredness of health care, automation of workflow that leverages modern computing capabilities offers an opportunity to address relevant concerns while benefiting from pertinent advancements from outside of health care. As part of its effort to advance

workflow automation in health care, ONC will use insights gained from other industries along with discussions with key informants and a multidisciplinary workshop to inform priorities for health care workflow automation.

### Clinical Relevance Statement

Advancements in modern computing have created new opportunities to leverage automation to improve the way care is delivered by providers, and the way health is managed by patients. Developing and implementing workflow automation in health care might benefit from leveraging lessons learned from other industries. This article summarizes the extent of workflow automation in other industries, characterizes how workflows are automated, and identifies design and implementation considerations to better support the implementation of workflow automation in health care.

### Multiple Choice Questions

1. What is the purpose of the effort ONC is leading to advance workflow automation in health care?
  - a. To develop an artificial intelligence engine to be implemented in electronic health record systems across the United States.
  - b. To establish priorities for workflow automation by using modern computing.
  - c. To advance standards that enable electronic health data sharing for clinical care and research.
  - d. To develop a clinical avatar that will support patients and caregivers in managing their health.

**Correct Answer:** The correct answer is option b. ONC is leading a project that will establish priorities to advance workflow automation in health care. The project will identify opportunities for automation in health care in both clinical and administrative areas; explore what would need to be instrumented to enable such automation; explore the need for new and/or updated workflows; and introduce perspectives from other industries such as finance, hospitality, and manufacturing.<sup>31</sup>

2. What are characteristics of tasks within a workflow that are best suited to full automation?
  - a. Manual tasks that repeat infrequently.
  - b. Tasks that have frequently shifting roles and responsibilities.
  - c. Tasks with complex decision rules.
  - d. Simple and clear tasks.

**Correct Answer:** The correct answer is option d. Manual tasks that repeat frequently, have concrete and well-defined roles, and responsibilities, and have simple decision rules are best suited for full automation. By contrast, tasks that repeat infrequently, have shifting responsibilities that are not well defined, and require a high degree of human cognition or intervention to navi-

gate complex decision-making are generally associated with low automation.<sup>31</sup>

### Protection of Human and Animal Subjects

There were no human and/or animal subjects included in this literature review.

### Authors' Contributions

T.Z.C., S.N.H., and N.K. led the conception of the article. All authors revised the article critically and provided intellectual content, and they also approved the final version for submission. The order of authors listed in the manuscript has been approved by all authors.

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### Conflict of Interest

None declared.

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