

Annemarie Jutel\* and Deborah Lupton

# Digitizing diagnosis: a review of mobile applications in the diagnostic process

**Abstract:** An increasing number of smartphone and software applications (“apps”) have been developed and marketed to assist in the process of diagnosis, yet little attention has been paid to their content, claims, potential risks, limitations or benefits of their use. This study sought to describe and catalogue available diagnosis apps and explore their impact on the diagnostic process. We undertook a content analysis of the app descriptions and developers’ websites using the descriptions provided for 131 medical diagnosis smartphone apps that were available in the Google Play and Apple App stores. Each app was reviewed for its content and approach, and its claims to medical authority. Four major categories of apps were identified: 1. apps for diagnosing; 2. diagnosis coding apps; 3. books, journals, or other publications in app format; 4. apps for medical education. Our analysis found that while these apps provide access to medical information previously widely not available to lay users and offered a convenient diagnostic tool for practitioners, many failed to describe the evidence base underpinning, or any other credential supporting, their design and use. These apps potentially shift how diagnosis operates, reconfiguring disease concepts and lay-professional relations. However they also raise the risk of conflict of interest and presenting inaccurate information. Further research is required into how these apps are used, the implications for medical practice and the impact on doctor-patient relationship.

**Keywords:** apps; diagnosis; doctor-patient; mobile software; smart phones.

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**\*Corresponding author: Annemarie Jutel**, Graduate School of Nursing, Midwifery and Health, Victoria University of Wellington, PO Box 6140, Wellington, New Zealand, E-mail: annemarie.jutel@vuw.ac.nz

**Deborah Lupton:** News & Media Research Centre, Faculty of Arts & Design, University of Canberra, Bldg 9, Room 9C9, Bruce, Australia. <http://orcid.org/0000-0003-2658-4430>

## Introduction

The right to diagnose is a powerful tool which has contributed to the authority of the medical profession for many decades. However, the diagnostic process has been confronted by recent changes in the practice of medicine. Doctors are no longer the only professionals who have authority to diagnose, and access to information has led to changes in the diagnostic relationship [1]. From the 1970s, patient consumerist movements have called for lay people to be provided with greater access to medical information. The ideal of the ‘engaged patient’ has recently emerged, charging lay people with the responsibility for taking greater control of their health states and medical care [2, 3]. With these changes, there has also been movement towards self-diagnosis.

Technologies have also played an integral role in shaping and altering diagnostic practices. The very latest of those to enter the field of medical diagnosis are those using digital technologies as part of the move towards digital health provision. These include mobile software applications (‘apps’) designed for smartphones and tablet computers. It is on these devices that this article focuses. Little scholarly attention has been paid to the place of apps in the diagnostic process and what their role has been in changing the social dynamic around, as well as the nature of, diagnosis. Yet apps designed to assist both health care practitioners and members of the lay public have proliferated in recent years. The implications of these new technologies for health care, public health, and health promotion are profound. These devices, their apps and related software, and the online platforms to which they connect, including social media sites, offer not only ready access to medical and health information on the internet but also new ways of monitoring, measuring, visualizing, and experiencing the human body.

Given the novelty of contemporary digital health technologies such as apps, the apparent benefits they promise and their unintended consequences have not been sufficiently investigated [4–7]. We argue that apps

should be viewed as sociocultural artefacts and worthy of social analysis [6]. The study here reported seeks to critically analyze apps designed for the medical diagnosis. Following an overview of the role played by technology in medical diagnosis, we describe the number and nature of available apps designed to streamline or putatively improve diagnosis. We then move on to an analysis of their ethical, social and cultural implications. In our focus on digitized diagnosis, we bring together the sociology of medical diagnosis [1, 8, 9] with a critical perspective on digital health technologies [3, 6, 7]. To our knowledge, no other research has been published that has attempted to adopt this approach to analyzing medical apps.

Much has been written about the ways in which medical technologies have transformed, and indeed created, new diagnostic categories [1, 10–12]. Many diseases are now diagnosed by technology rather than by symptom. Today, institutions and individuals commonly use digital tools. Diagnosticians will search for articles on Medline and entries in Google; they may use specialized search engines, electronic journal article summaries, diagnostic software or online calculators.

Medical and health apps have emerged as important contributors to the digital health ecology. The first smartphones able to install third-party apps were released in 2008, followed in 2010 by the development of tablet computers also capable of downloading these apps. Millions of apps have now been published [13] including over 100,000 medical and health apps [14]. These apps include those directed specifically at medical professionals, providing detailed anatomical information and visuals, digital versions of medical textbooks and dictionaries, training videos and diagrams and drug prescribing information. Apps have been designed for this market that can monitor and measure many physical functions and symptoms (such as testing glucose, blood pressure, heart, kidney and lung function and so on), sometimes using hardware add-ons to smartphones that transform them into medical devices. Many more apps are marketed to lay people to provide medical and health information or assist them in self-monitoring their bodily functions and activities. This includes devices that can measure body weight, blood pressure, energy expended, steps taken, sleep patterns and brain activity. Others are directed at assisting patients to store and access their medical records and treatment regimens and track medical appointments, access medical trials, seek appropriate medical care, engage in patient support networks, share information on their condition with friends and family, monitor and self-manage chronic conditions such as diabetes and high blood pressure and to record their symptoms and manage

post-treatment care after treatment for acute conditions such as cancer.

Medical practitioners have begun to use apps and other digital technologies as part of their practice [5, 15]. At least one American medical school is requiring its students to use iPads using a variety of apps [16]. Medical and health apps are used by growing numbers of lay people in a world in which smartphone ownership is becoming increasingly common. In late 2012 a Pew Research Center survey found that 85% of adults in the US owned a mobile phone. Fifty-three per cent of these were smartphones, and one fifth of smartphone users had used their phone to download a health-related app. The most popular of these apps were related to monitoring exercise, diet and weight [17]. Another Pew survey found that one in three of the American adults surveyed had reported using online resources to self-diagnose or diagnose another individual [18]. Online diagnostic and risk calculator tools have been available to lay people for some years now, but such tools as smartphone apps are ever-more accessible and ready-to-hand.

These affordances, however, also offer potential risks concerning data privacy and security and the accuracy of the information that apps contain. Apps can offer many benefits for medical professionals and patients and lay people alike. Several writers and researchers in medicine and public health have drawn attention to such benefits [19–23]. However, other commentators have noted that there are numerous significant potential harms that are posed by the use of apps for medical and health-related purposes, including conflict of interest and transparency, ethical, and privacy issues, as well as those relating to accuracy of content, healthcare delivery and the doctor-patient relationship [5, 16, 24–26]. Despite the progressive and rapidly expanding entry of digital health technologies such as apps into healthcare service provision [3, 7, 27], researchers in the health services literature have yet to fully investigate these topics. No social research has yet been published on medical diagnosis apps. A broader view of the range of apps available and their possible role in either the support or hindrance of the diagnostic process is germane to the current growing culture of digital technology in diagnosis.

## Methods

To determine what kinds of medical diagnosis apps for smartphones are being offered to health professionals and the public, we undertook a content analysis of such apps that were available in the Google and Apple apps stores

in mid-December 2013. We focused on these stores alone, because they are by far the largest providers of apps, well above any other app stores. We searched for all apps using the phrase “medical diagnosis” in their titles or descriptions. To obtain a sample, we reviewed all of the smartphone apps listed under that search term in the Apple App Store ( $n=88$ ), and then matched the sample by reviewing the same number of apps from Google Play that were listed under this search term (the first 88 listed). This resulted in a total of 176 apps from both stores. We then reviewed each app and excluded those which were not in the English language or focused on veterinary diagnosis, diagnosis based on alternative medicine, or nursing diagnosis (see Table 1). (While the expression “nursing diagnosis” uses the same terminology as medical diagnosis, it is a different process. According to the American Nursing Association, “The nursing diagnosis is the nurse’s clinical judgment about the client’s response to actual or potential health conditions or needs”) [28]. Following this, from an original pool of 176, a total of 131 were retained for analysis. Sixty-four came from the Apple App Store, 59 from Google Play, and eight were found in both. One third of these apps were free to download, with the others available for purchase at prices starting at <1 and going as high as 80 US dollars or more.

We then reviewed the online descriptions provided on the app stores for each of these apps. We sought to summarize the content and approach of each app, but also to iteratively identify common themes or assumptions and thematic orientations of the apps as these became apparent in the sample as a whole. Each app was analyzed for such features as its claims to medical authority and the ways in which medical knowledge, lay people and medical practitioners were represented. We also reviewed material provided by the app developers on their websites (if provided), examining this content in relationship to further claims of medical authority or information about evidence base. Following agreement about how the apps should be analyzed, both authors conducted separate reviews and

conferred about their findings. Any disagreements concerning interpretation of the apps content were reconciled by discussion between the authors.

## Results and discussion

We began our analysis by identifying topic categories for the medical diagnosis apps among our sample of 131 apps. They are as follows:

1. Effecting diagnoses: 57 apps
2. Medical books, journals, or other publications about diagnosis in app format: 24 apps
3. Diagnosis coding aids: 20 apps
4. Textbook and teaching tools for medical education in diagnosis in app format: 15 apps.

Fifteen apps either did not fit into any of these categories or did not provide enough details to determine their content, and were coded as “Other” (see Table 2).

Of the total sample of apps we analyzed, 36 targeted lay people, 93 targeted professionals, and two targeted both. We determined the target by the narrative provided by the developers, who generally specified the intended audience by using such terms as “helps physicians” or “make a differential diagnosis of your patient” if directed at medical professionals, or “helps you analyze your symptoms” if designed for lay people.

It was evident from reviewing the app descriptions provided on Google Play (Apple App Store does not provide exact download figures) that the popularity of the apps ranged widely. Several of the apps in our sample had been downloaded hundreds of thousands or even millions of times, while others had attracted only few downloads. One mobile health journalist estimated that there could be as many as ten thousand health-related apps specifically targeting medical professionals [29]. While we cannot know from these figures how or even whether downloaded apps are used once placed on users’ smartphones or mobile devices, these suggest that users are attracted to at least some diagnosis apps in high numbers.

**Table 1** Excluded apps.

Reason for exclusion	Number of excluded apps
Not in English or non-standard English	17
Not about process of diagnosis	14
Veterinary diagnosis	4
Nursing diagnosis	3
Pre-test study guide	3
Not for medical diagnosticians	2
Not Western medical diagnosis	2
Total excluded	45

**Table 2** App categories.

Category	# Apps
Text book or teaching tool	15
Book, journal or other publication in app format	24
Diagnosis app	57
Coding app	20
Other	15
Total	131

## Apps for helping diagnose

We identified 57 apps that focused specifically on the process of clinical diagnosis. By this we mean that they provided explicit direction for arriving at a diagnosis in the presence of particular symptoms.

A total of 33 of these apps were directed at medical professional users. Some of the apps were designed to provide information about specific illnesses to generalists. For example, the *MS Diagnosis* app “uses an interactive decision tree to lead the physician through the McDonald criteria for MS [multiple sclerosis]”. Each one of these applications delivered guidance about specialist diagnosis to general practitioners. However some of the apps were more general, and were designed to support the expertise of the individual doctor, rather than bringing in specialist expertise.

The principle of easy retrieval of general knowledge for medical practitioners was underlined in a number of apps. The affordances of ubiquitous digital technologies, including ready access to large databases and algorithmic calculations offered by software, were heavily promoted in many of these apps. The description for *Diagnostic Radiology* notes: “Get your hands on a revolutionary new way to master abdominal imaging and access the knowledge of today’s experts on tomorrow’s technology”. Similarly, *Visual DX* provides images that would otherwise be difficult to access in the diagnostic setting. These are designed to both “aid diagnostic accuracy” and “[p]rovide on the spot patient education with real medical images”. *Caracal Diagnosis* has as its tagline “Smart Diagnosis”. The developers describe it as a clinical decision support system that can be “of great help when it comes to determining diseases or medical conditions”. Users input medical terms and the tool’s algorithms suggest the most likely diagnosis by matching the terms with the information stored in its database.

Twenty-four of the apps that we identified as helping to make a diagnosis were directed specifically at lay users. These apps commonly represented themselves as allowing lay people to self-diagnose, contending that they will save lay people’s time and money (by potentially allowing them to avoid a visit to the doctor), allay their anxieties, improve their health by allowing them to diagnose a medical condition and then seek treatment, educate them by enhancing their medical knowledge and support patient empowerment by conferring information about diagnoses”. As claimed by the developers of the *Common Illnesses & Diagnosis* app, it helps users to “Be your own physician now!” These apps typically used images of doctors in their logos, screenshots and even titles (e.g.,

“Doctor Diagnose”, “Virtual Doctor”, “Dr Android MD Diagnosis” and “Pocket Doctor”).

## Medical publications in app format

App platforms also enabled the re-presentation of traditional medical publications about diagnosis in a different format. Twenty-four of the apps were simply app forms of previously-published books, journals or other publications such as dictionaries or guidebooks, but many offered capabilities beyond the standard print formats. These were the most expensive apps, and the prices paralleled those of the products in their standard published formats. Several app descriptions highlighted the digital indexing capacity of the app to provide access to information. The query potential was embedded in the name of one app – *Iddx: Infectious Disease Queries* – where “users can find lists of matching infectious diseases by using the disease search criteria (99 signs & symptoms, 39 epidemiological factors, and 16 regions of the world)”. *The Ferri: Practical Guide to the Care of the Medical Patient 8th Edition* advertised the benefit of app version of paper publications’ “unique navigation elements” allowing the user to “find topics across all indexes”. One app was used as a kind of meta-crawler of previously-published material. *Elsevier App Shelf* allowed the user to search across a number of Elsevier published books.

## Diagnosis coding apps

Twenty apps were promoted as a cost-effective and practical way to undertake diagnostic coding. Diagnostic coding is an administrative activity which is at the base of both medical billing, and public health monitoring. After clinical diagnosis, codes from approved diagnostic nosologies are applied, usually by a coding specialist as opposed to a diagnostician. It is the first step in medical billing, as insurance companies have a list of codes they will reimburse, and treatments associated with particular codes. It is also a surveillance mechanism, helping to track disease prevalence for the World Health Organization. And finally, it plays an important role in hospital administration as an audit tool of health problems and medical performance. In the US, some practices hire specialized coders to ensure that they are getting the best reimbursement for the services provided via the coding strategies.

The apps that were designed to assist with coding purported to help translate the clinical diagnosis into acceptable codes for insurance or epidemiological purposes.

The *IMO Terminology Browser*, for example, touts that it will “provide clinical users a way to capture and code diagnoses or procedures without altering the language they would normally use. It speeds up the coding process, reduces unnecessary physician-coder communication, and results in fewer rejected claims”. The description for the *MarginMaker ICD-9* app reminds potential purchasers that “Hospital margins are dependent on provider documentation”. *Sat ICD-9 Coder* developers ask: “how much are you paying someone to do your diagnosis coding? How much do you lose when codes are not specific enough?” The description for the *ICD-9* encourages healthcare professionals to “try our app, you’ll never have to flip through a heavy book or go hunting for other coding reference again”. Here again the apparent benefits of app over paper formats are emphasized as part of the sales pitch.

## Textbook and teaching tools for medical education

Fourteen of the apps were app-formatted tools for teaching diagnosis to medical students and other healthcare professionals. These included standard textbooks like *Non-Hodgkin Lymphoma – A Living Medical eTextbook* and *Non-Small Cell Lung Cancer – A Living Medical eTextbook* as well as the *Current Diagnosis and Treatment* series, diagnosis-learning tools for a variety of sub-specialties including pediatrics, psychiatry and others. These took the standard teaching text book and transformed them into apps, with the additional functionality offered by the digital format.

Several such apps, as well as those designed for more experienced medical practitioners, used gaming strategies in an attempt to render learning diagnosis protocols fun. *Prognosis: Your Diagnosis* is claimed to have a “fun, interactive cartoon-style narrative”. It also provides the opportunity to engage with other users and discuss the diagnosis on a social media platform. There were a range of apps in the *Prognosis* range, including also *Prognosis: Questions* and *Prognosis: Neurology*. “Quiz” apps (for example: *Radiology 4 Med Students Lite*, *Flash Cards*) and games were designed to deliver diagnostic teaching experiences, either through a traditional question-answer flash card, or more novel means. *Ward Round* for example, is described as an “exciting new medical learning experience where you are placed in the role of the doctor to solve clinical medical mysteries against the clock”. Social networking study apps like *Prognosis: Questions* were directed at students, providing a platform where they could “make queries and get their doubts clarified”.

## Credibility of apps

We examined the app descriptions and the developers’ websites (if provided) for their evidence base, or their claims to authority and expertise. As noted earlier, medical authority to diagnose is longstanding but is currently subject to challenges from various quarters, including from digital devices. As such, we were interested in identifying the ways in which the apps we reviewed made reference to the authority to diagnose and what credentials were enunciated for each app as underpinning its authority.

While many of the apps’ developers make no reference to their authors, others make vague references to the apps being developed by a “real doctor”, “written specifically for mobile by a UK doctor,” or developed by a “valid medical team”. The *Your Rapid Diagnosis* apps, which are directed at both lay and professional users, claims to have been “developed by one of Australia’s leading private hospital companies”. *Pocket Doctor Lite* similarly advertises that it is “written specifically for mobile by a UK doctor”. The developers of *Caracal Diagnosis* make much of its database that stores “1600 diseases and medical conditions” to contribute to the algorithmic diagnosis it provides. However no details are given of how this database was constructed and from where the developers drew their information. None of the apps referred to a review process equivalent to that imposed on traditional medical publications.

Apps designed for lay users generally featured even fewer details about their authorship or evidence base beyond referring to a “doctor” in the title or app description. A check of the developers’ websites often revealed that the developers were involved in producing a range of apps completely unrelated to medicine. The *Common Illnesses & Diagnosis* app, for example, is part of a stable of apps including logic puzzles, scary stories and the history of Ancient Rome.

Other apps directed at a healthcare professional user can be traced back to books and publishers who name the authors and review the material even though no reference is made to them in the app descriptions. On the other hand, some of the apps name their authors and editors and their credentials directly on the app store site (*sMMSE for iPad*, *Quick Medical Diagnosis & Treatment*, *Diagnosaurus*, *5-Min Emergency Medicine Consult*, *Current Diagnosis and Treatment in Psychiatry*). The developers of *On Call Principles and Protocols* name its authors, but do not provide any information about their credentials. Some apps were linked with associations or institutional credentials. *The MS Diagnosis and Management* app is produced by the National MS Society, while the similarly

named *MS Diagnosis* lists a Dutch clinical professor of neuro-epidemiology and neurologist as the creator of the protocol used in the app. *Emergency Medicine* was developed by the Vancouver Coastal Health Authority for its employees, but also for wider distribution.

We detected a certain ambivalence in many of the apps' descriptions directed at lay people for self-diagnosis. Even while focused on diagnosis, and directed at lay users, the wording in many of these apps expressed caution about suggesting that a lay person should use them as the only method of diagnosis or even for self-diagnosis at all. For example they prefaced the use of the word diagnosis in the app descriptions with adjectives such as "possible", "probable", and "likely" in relation to the diagnoses to which these apps might lead. The developers of *Doctor Diagnose Symptom Check*, for example, hasten to explain: "The application doesn't intend to replace a doctor but rather to inform the patients and make them more aware". The developers of *Doctor Online* emphasize that users should "[n]ever ignore professional medical advice in seeking treatment because of something you have read on this tool". Several developers represent the information they presented on their apps as a means by which lay people could select the right type of medical help rather than diagnosing themselves definitively. The *Dignity Health* app, for example, offers a symptom checker that is directed at "Help[ing] you decide if you should seek emergency care, seek care that day, or make an appointment".

Such caveats were also evident on some of the apps directed at healthcare professionals. *The Prognosis: Your Diagnosis* popular series of apps, for example, lists numerous members of their "international board of editors" on the developer's website, but no details are given of their qualifications or workplace.

The "terms of use" statement on the website is very clear that users of the apps should not rely upon their accuracy: "The information this application contains is strictly for academic use only, and is in no way a substitute for the clinical acumen and expertise of a medical professional". It is further noted that the developers "do not guarantee the accuracy, completeness or the reliability of information provided".

## Conclusions

Diagnosis apps can bring tremendous benefit to a diagnostician. Particularly in high pressure or in field settings, they enable the clinician to access information that otherwise would stay on the shelves. Furthermore, with the benefit of digital indexing, they make information easier

to look up and source. In the case of less common disorders, the app and its indexing potential provide access to diagnostic definitions which might otherwise be hidden in old medical school memories. These affordances can appeal to healthcare professionals as offering a very appealing diagnostic adjunct.

However our research suggests that they should be used with great caution by both lay people and practitioners in the context of evidence-based practice. The lack of verifiable information provided about the evidence or expertise used to develop these apps is of major concern. The apps are of very variable quality, ranging from those that appear to have the support and input of distinguished medical experts, specialty groups or medical societies to those that offer little or nothing to support their knowledge claims. While at one end of the spectrum we can see apps as a delivery system for information which has been subject to the conventional forms of academic review, at the other extreme, we see apps developed by entrepreneurs with interests in many topics outside medicine, with little input from medical sources, or with inadequate information to ascertain what the sources might be. The lack of information provided by many app developers also raises questions about how users can determine the presence of conflicts of interest and commercial interests that might determine content.

The sheer number and constant proliferation of medical apps in general pose difficulties for regulatory agencies to maintain oversight of their quality and accuracy. Such guidelines are important to protect patient safety and prevent psychological harm from erroneous diagnoses. An app developed by a pharmaceutical company or medical device manufacturer can suggest diagnoses which will result in the use of the company's products, and there is currently no control over or regulation thereof. App developers can promise benefits and outcomes with little possibility of being exposed if the information they provide is incorrect or misleading.

In the face of these issues, it has been contended that the content of all medical apps should be externally peer-reviewed by medical professionals to ensure quality and safety.<sup>5</sup> The relevant regulatory bodies in many countries have not yet established guidelines and regulations for overseeing medical apps, and are struggling with how to deal with the vast numbers of new apps flooding the market. At the time of writing, NHS England was working on a bilateral framework with the US Food and Drug Administration (FDA), which in September 2013 released a set of guidelines by which medical apps are to be regulated in that country. The guidelines note that many medical apps would not come under its jurisdiction because they are not defined as medical "devices" and

would not pose a risk to patients if they do not operate as intended. Under the FDA guidelines, however, medical diagnosis apps fit the definition of medical “devices”: “When the intended use of a mobile *app* is for the diagnosis of disease or other conditions [emphasis added], or the cure, mitigation, treatment, or prevention of disease, or is intended to affect the structure or any function of the body of a man [sic], the mobile app is a device” [30].

More broadly, medical apps such as those we examined pose challenges to traditional concepts of how medical education should be undertaken and diagnoses made; and for the doctor-patient relationship. The diagnosis is potentially a point of contention between patient and doctor because of the fact that it is so important to validating the patient’s complaint and allocating of resources (sick leave, treatment, and so forth). Alternatively, it can stigmatize, so whoever can name a disorder has power to shape the patient’s narrative, identity and future. The authority to diagnose resides traditionally with the professional. The diagnosis app, however, challenges this authority, by the pre-diagnostic work it supports. While the app developers, for the most part, are careful to postulate to lay users that their apps are not intended to replace the doctor, they nonetheless guide the patient to shape the diagnosis she will present to the clinician and thus potentially redistribute power in the doctor-patient relationship [31].

The diagnosis app raises not only the specter of shifting locus of authority in the doctor patient encounter, but also questions about agendas concealed behind the algorithmic applications; about quality control and credentials. They approach diagnosis from a necessarily binary system of information, effacing the fine detail of the individual case in the classificatory framework. Digital health technologies such as mobile apps have the potential, therefore, of configuring new domains of health, illness and medical practice. The decision-making pathways of diagnosis apps – their algorithmic authority – delimit the ways in which bodily signs, symptoms and sensations are reported, understood, interpreted and treated.

Apps also differ from previous diagnostic technologies in the open access of the lay public to their use. Many medical apps are designed for medical education as well as to assist qualified practitioners in their daily work routines. As such, they contain highly detailed and specialized medical information that previously was not available to lay people. This in itself is a major change in the ways in which medical information has been distributed. Medical apps designed for healthcare professionals can be downloaded and used by anyone. Some now include specialized sensors or attachments that facilitate monitoring of

the body and the identification of medical conditions that in past times were the preserve of members of the medical profession. This openness of access disturbs professional dominance and expertise. We would suggest, therefore, that digital technologies such as medical apps have the potential for challenging medical control over knowledge about health and illness further than any other technology from the past.

Our study suggests that much more research needs to be undertaken into the content of medical apps and how they are actually used (or for that matter, resisted). Further research that directs attention at how both healthcare practitioners and lay people are using these apps would elucidate how these issues are being experienced in the healthcare setting and the implications for healthcare services.

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