ORIGINAL ARTICLE

Using AI-based virtual triage to improve acuity-level alignment of patient care seeking in an ambulatory care setting

George A. Gellert*[1], Lawrence Garber[2], Aleksandra Kabat-Karabon[1], Kacper Kuszczyński[1], Tim Price[1], Eric J. McLean[1], Katarzyna Trybucka[1], Matthew W. Nichols[3], Jennifer M. Pike[3], Michael J. Powers[2], Piotr M. Orzechowski[1]

[1] *Infermedica, USA, Poland and UK*
[2] *Reliant Medical Group, USA*
[3] *OptumHealth Enterprise Clinical Technology, USA*

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ABSTRACT

Objective: Evaluate how an AI-based virtual triage (VT) and care referral technology impacted live triage and care referral in an outpatient/ambulatory care network.
Methods: Analysis of a dataset of 8,088 outpatient online encounters assessed how VT influenced patient care seeking action/behavior.
Results: There were modest decreases in patients seeking outpatient care, including in-person or video face-to-face encounters (-12.5%), or engaging self-care (-8.2%). Patient engagement of virtual care through e-visits and telephone calls increased moderately (19.1%). One-third (35.0%) of patients changed care seeking likely as a result of VT care referral. Another third (32.3%) reported a pre-VT care intent aligned with the VT care recommendation, and a third (32.7%) did not change care sought when their pre-VT intent was not aligned. A total of 12.0% de-escalated acuity of care seeking as recommended by VT, most frequently from outpatient care to virtual care (6.5%) or self-care (4.3%). When VT recommended care de-escalation, 53.5% de-escalated care. In 21.2% care acuity was escalated, of whom 10.6% pursued virtual care and 7.5% pursued outpatient care instead of self-care, while 3.1% whose care intent was virtual care instead pursued outpatient care. When VT recommended care escalation, 96.2% escalated care. Overall, 26.7% of patients required no further action or involvement of clinical staff.
Conclusions: Virtual triage impacted patient care seeking action/behavior among almost half of patients whose pre-VT intent differed from the VT recommendation, with patients nearly twice as likely to follow recommendations to seek higher rather than lower levels of care acuity, while modestly reducing the number of face-to-face visits and increasing virtual care. Overall, a quarter of patients using VT were able to perform self-care without interacting with the healthcare team. Virtual triage has the potential to efficiently and effectively redirect patients to more appropriate levels of care.

Key Words: Virtual triage, Digital clinical triage, Artificial intelligence, Care acuity level, Nurse triage, Ambulatory care

1. INTRODUCTION

Virtual triage (VT), or symptom checkers, are a digital technology accessible by patient-users 24/7/365 on the internet, which help them assess their symptoms to decide what setting and acuity of care is warranted. VT functionality or engines complete a medical triage interview where the patient-user

*Correspondence: George A. Gellert; Email: ggellert33@gmail.com; Address: Infermedica, 703 Sentry Hill, San Antonio, TX 78260, USA.

provides information about symptoms experienced, medical history, demographic and risk factors. The encounter process poses questions relevant to the patient's presentation, including about symptom intensity, and certain VT applications deploy a statistical probabilistic algorithm to further assess symptoms using an integrated medical knowledge base, and an inference algorithm based on prior information conveyed.

VT classification algorithms that deploy artificial intelligence (AI) consider illness or condition severity and urgency or acuity. The VT engine infers probable conditions, and automatically determines the next question for the patient-user. The VT encounter path is not pre-structured, and when conveyed new evidence, VT can switch hypotheses (as live physicians do). Patient-user responses are analyzed on a current basis as the VT engine conveys a symptom analysis and explanation of potential causes, illness severity, and a suggested referral to a care setting with an appropriate level of medical care urgency or acuity. The encounter is completed with the presentation of the symptom analysis and referral to the needed level of care, such as suggesting transport to an emergency department (ED), consult an outpatient physician in a medical office or clinic, or engaging self-care.

VT directs patients to acuity-appropriate care settings available within a care network, potentially accelerating delivery of care and reducing care delays, and visits/utilization of services of higher than medically needed acuity and cost. This study evaluates whether VT and care referral can impact patient care seeking behavior and actions when integrated with a nurse triage function and virtual care delivery capabilities in an outpatient ambulatory care delivery system.

AI-based algorithms can accurately triage patients and predict the need for critical care.[1] Morse et al. evaluated a symptom checker chatbot within an integrated US health system and found VT recommendations comparable to those provided by telephonic nurse triage lines.[2] When integrated into clinical workflows, VT can potentially help manage the volume of messages in clinician inboxes. Akbar et al. found that primary care practitioners spent a mean of 52 minutes managing their inboxes, 37% of which occurred outside work hours, with 28% spent on patient-initiated messages and 29% on test results.[3] Strategies to assist in efficiently managing patient-initiated messages were recommended to alleviate inbox workload.[3]

A qualitative analysis examined strategies that primary care physicians and group practices use in managing electronic inboxes and found numerous inbox volume management strategies.[4] Message volume and patients' expectations for a rapid reply were sources of physician stress. However, investments in virtual technologies that enabled patients to have 24/7 access to digital-first primary care incurred significantly lower acute hospital costs using such platforms.[5] Studies indicate the promise of virtual triage in improving clinical workflows, efficiency, and reduction of unnecessary testing and imaging.[6]

2. METHODS

2.1 Research objective

Our objective was to evaluate how VT integration into the triage and care referral operation of a large outpatient/ambulatory care network influenced patient care engagement and use of different acuity levels of care in relation to VT recommendations.

2.2 Setting

Reliant Medical Group is an outpatient multispecialty group practice based in Massachusetts, USA. It operates 20 medical facilities throughout the state that provide a wide range of healthcare services to the community. With over 500 providers caring for over 320,000 patients, Reliant Medical Group (RMG) delivers a full range of primary care and over 30 different areas of specialty care, including same-day medical care for urgent needs. RMG operates an online and telephonic nurse triage service to evaluate, advise and refer patients to the appropriate care based on their clinical presentation. In 2021, Reliant implemented and integrated an AI-driven virtual triage capability from Infermedica within its clinical triage and care referral functions. Reliant is part of Optum, a leading health solution and care delivery organization.

2.3 VT technology platform, configuration and data source

The Infermedica VT engine completes evidence-driven analyses focusing on 800 illnesses, 1,500 symptoms, and 200 risk factors. Utilizing artificial intelligence, including machine learning and natural language processing, the triage engine assesses patient-user reported symptoms, queries for more information, examines numerous clinical hypotheses and possibilities, and suggests the most likely conditions based on the medical history and current clinical presentation. VT then suggests to the patient-user to the safest and most clinically suitable care setting. In light of new data/information reported, the VT engine examines numerous clinical hypotheses and possibilities just as a physician does. At the start of the virtual triage encounter, patient-users are queried regarding what their healthcare intent is.

Infermedica's virtual triage platform, Symptomate, which is free for public use in 24 different languages, since 2012 has had over 17 million VT encounters have been completed

by members of the public, the data of which is used in the de-identified aggregate to refine the AI within Infermedica's virtual triage and care referral engine.

2.4 VT engine clinical validity

AI-based VT engines require rigorous validation to ensure safety and minimize mistriage. VT focuses on common diseases by design, with AI built to err on the side of over-triage to higher acuity care rather than possibly missing and misguiding a patient with acute care needs. VT accuracy varies across clinical specialties and settings, as determined by the depth of disease-specific data used to train the triage AI. VT validity has been evaluated using clinical vignettes prepared by physicians of various patient symptomatic presentations in different clinical settings.[7–10] In one study, Infermedica's virtual triage engine provided safe recommendations in 97.8% of instances.[8] Published studies, while providing a point in time comparison, become quickly outdated due to the rapid evolution of AI-based VT. For example, since the 2019 Gilbert et al. analysis[8] there have been 29 releases of the Infermedica medical content model and 17 updates to core functionality, including new epidemiological models and triage algorithms, each designed to improve accuracy and safety. Prior to deploying VT, RMG completed an independent clinical validation of Infermedica VT diagnostic accuracy involving 407 test cases or vignettes for patients age 12 years and older.[11] The diagnostic accuracy was reported at 92%.

2.5 Responsible use of AI

As part of Optum's Responsible Use of AI/ML Program all AI used by Reliant, including third party AI such as Infermedica's VT AI solution, is reviewed by a board of cross-functional leaders including technologists, clinicians, medical ethicists, data scientists, security experts, and privacy and legal professionals prior to implementation. The board evaluates the potential impact of AI on individuals (including patients and providers), and confirms that appropriate performance and bias testing has been completed for any AI that is proposed for use by the organization. Infermedica's AI-based VT solution satisfied the requirements of Optum's Responsible Use of AI/ML Program.

2.6 VT implementation and integration

VT implementation at RMG was intended to address the organizational need to enhance patient experience and care through an application that triages patients age 12 and older. VT provides triage summaries to physicians and nurses, and guides patients toward self-care or virtual care/telemedicine, when appropriate, improving clinical workflows and productivity while reducing in-person visit costs. Component technologies deployed in the implementation included: the Infermedica API as the VT engine; RMG's electronic health record (EHR) from Epic Systems Corporation for patient data, clinical order management and electronic documentation; an Optum developed Check My Symptoms application as the patient-facing front end, embedded within Epic's MyChart patient portal; and RMG EHR integration to extract and transmit patient demographics and clinical risk factors to the VT tool, and push VT summaries back to the patient care team. VT went live in August 2021.

2.7 Sample selection and eligibility criteria

Encounters were selected from among all Reliant patient VT encounters using the following criteria: (1) Reliant VT encounters completed over an 18-month period between January 1, 2022 and end June 2023; (2) VT encounters where the patient's pre-virtual triage care intent was recorded. A total of 9,325 VT encounters occurred during the study period, and application of these criteria resulted in the selection of a dataset of 8088 Reliant VT patient encounters.

2.8 Data captured and analyses completed

Data for this analysis was extracted and de-identified from VT encounters engaged by patient-users of the Infermedica AI-driven VT engine deployed within the Reliant Medical Group healthcare delivery system. Analyses were performed on this Health Insurance Portability and Accountability Act (HIPAA) Safe Harbor de-identified dataset of 8088 Reliant VT patient encounters to assess if and how the use of virtual triage influenced patient care seeking action/behavior. Data management and analyses were completed using Microsoft Excel and Google Sheets (Online Spreadsheet Editor). The data collected and used in the analyses included the following information: patient pre-VT care intention; VT care acuity level recommended to the patient; after VT care engagement action by patients; and duration of nurse triage encounter per patient encounter.

Just prior to a VT encounter, all study patient-users completed a one question pre-VT patient care intention survey to determine the type of care they intended to pursue before evaluation of their symptoms and history by the virtual triage engine. The patient survey provided the following response categories: self-care, virtual care, face-to-face outpatient care or visit to an emergency department. The VT clinical care referral acuity and the post-VT care actions of patients were grouped into the same categories. Grouping the values of pre-VT care intent, VT generated level of care acuity recommendation, and post-VT patient care action to the same categories enabled comparisons of care seeking intent before the VT encounter and care acuity level engaged by patients

after the VT encounter. It also enabled examination to determine if the VT recommended level of care acuity impacted patients actual care acuity choices and care seeking action.

The nature and acuity of care delivered were analyzed based on EHR and health information exchange data using four groupings or strata: self-care not requiring engagement with a clinician; virtual care, here defined as an e-visit or telephone call; outpatient care, including in-person and video face-to-face visits (which are increasingly undifferentiated in practical and operational terms); and emergency department care. E-visits are asynchronous secure messaging between patients and their healthcare team using Reliant's patient portal. These strata are used in the presentation of all tabulated data.

The dataset was evaluated for statistically significant differences in patient post-VT healthcare seeking action by age and gender using Z-test for two proportions (level of significance of 0.01 with Bonferroni correction was used). Language was not statistically tested, as virtually all (99%) of encounters were completed by English-speaking users.

3. Results

3.1 Impact of virtual triage on patient care seeking action/behavior

Compared to pre-VT intent during the study period, overall there were modest decreases in patients seeking outpatient care including in-person and video face-to-face visits (-12.5% percentage points or PP), or engaging self-care (-8.2 PP) (see Table 1). However, patient engagement of virtual care (an e-visit or telephone call) increased moderately (19.1 PP), while there was only a slight increase in ED use (1.6 PP). In absolute terms, with only 59 patients of 8,088 (0.7%) having a pre-VT care intent of seeking ED care, it is clear that in general terms, in this ambulatory care setting and patient population, few patients who perceive a need for emergency care utilize VT for validation or guidance. All differences between pre-VT care intent and post-VT care seeking action/behavior were statistically significant ($p < .01$). Overall, a quarter (26.7%) of patients using VT were able to perform self-care without further interacting with the healthcare team (i.e., no further messaging, calls, or visits).

Table 1. Change in patient pre-virtual triage care intent versus post-triage care seeking by acuity level

Level of Care Acuity	Pre-VT* Patient Care Intent (Percent)	Care Seeking Action Post-VT (Percent)	Absolute# (Relative) Magnitude of Change from Care Intent to Care Seeking Action	Change Statistical Difference
Self-care	2,818 (34.8%)	2,157 (26.7%)	- 8.2 PP (- 23.5%)	$p < .01$
Virtual care (e-visits and telephone calls)	1,392 (17.2%)	2,935 (36.3%)	+ 19.1 PP (+ 110.8%)	$p < .01$
Outpatient care (in-person and video face-to-face visits)	3,819 (47.2%)	2,804 (34.7%)	- 12.5 PP (- 26.6%)	$p < .01$
Emergency department care	59 (0.7%)	192 (2.4%)	+ 1.6 PP (+ 225.4%)	$p < .01$
Total	8,088 (100%)	8,088 (100%)	--	--

Note. * VT – virtual triage; # PP – percentage points

3.2 Specific impact of VT on patient care seeking action/behavior

Virtual triage had a substantial impact on patient care seeking actions among the 8088 VT encounters analyzed (see Table 2). Over one-third (35%) of patients changed their care seeking from their initial pre-VT care intent in alignment with the care referral and acuity recommendation of virtual triage. Another third of patients (32.3%) reported a pre-VT care intent that aligned with the care recommendation from virtual triage (although confirmation of this may have nonetheless influenced patient care seeking actions). Another third (32.7%) did not change their care seeking action as a result of the VT care recommendation when their pre-VT intent was not aligned with the VT engine care recommendation. No statistically significant differences were found in patient post-VT healthcare seeking action by age and gender.

3.3 Impact of VT on patient care acuity de-escalation

A total of 12.0% of patients de-escalated the acuity level of their care seeking as recommended by VT. Table 3 presents triage encounters where the care acuity level decreased (i.e., de-escalated). The most frequent de-escalation of care acuity occurred among patients having an initial outpatient face-to-face care intent who instead pursued a virtual care visit (e-visit or telephone call) as recommended by VT (528 out of 1,509, or 35.0% of such patients). This represented 6.5% of all VT encounters. The next most frequent care acuity de-escalation was among patients having an outpatient pre-VT care intent (in-person or video face-to-face visit), who instead pursued self-care as recommended by VT (349 out of

1,509, or 23.1% of such patients). This occurred in 4.3% of all VT encounters. An additional 91 out of 302 or 30.1% of such patients with an initial pre-VT intent to pursue virtual care (e-visit or telephone call) instead pursued self-care as recommended by VT (comprising 1.1% of all VT encounters). Overall, 968 of the 1,811 patients (53.5%) sought lower care acuity when VT recommended it.

Table 2. Impact of virtual triage on patient care seeking

Post-VT* Change in Care Seeking Action and Acuity	VT Impact on Care Seeking (Percent)
Care seeking changed from pre-VT care intent aligned with VT recommendation#	2,830 (35.0%)
Pre-VT care intent and VT care recommendation aligned	2,613 (32.3%)
No change in patient care seeking action when not aligned&	2,645 (32.7%)
Total	8,088 (100%)

Note. *VT – virtual triage; #Reports only individuals whose changes in care seeking were aligned with the care referral recommendation of virtual triage, excluding other changes in healthcare seeking that patients may have engaged; &Includes individuals recommended a higher level of care but who changed to a lower level of care, and individuals recommended a lower level of care but who changed to a higher level of care.

Table 3. Changes in patient care seeking where care acuity was de-escalated and aligned with virtual triage recommendation

Care Acuity De-Escalation Following VT*	Patients Complied with VT Care Recommendation Despite Different Pre-VT Care Intent (Percent) [Compared to All VT Encounters]
From outpatient care intent# to virtual care& per VT	528 of 1,509 (35.0%) [528 of all 8,088 encounters (6.5%)]
From outpatient care intent to self-care per VT	349 of 1,509 (23.1%) [349 of all 8,088 encounters (4.3%)]
From virtual care intent to self-care per VT	91 of 302 (30.1%) [91 of all 8,088 encounters (1.1%)]
From ED† care intent to outpatient care, virtual care, or self-care per VT	24 of 30 (80.0%) [24 of all 8,088 encounters (0.3%)]
Total seeking lower acuity care in alignment with VT recommendation	992 of 1,841 (53.9%) [992 of all 8,088 encounters (12.3%)]

Note. *VT – virtual triage; #Outpatient care includes in-person and video face-to-face visit; &Virtual care includes e-visits and telephone calls; †ED – emergency department

Table 4. Changes in patient care seeking where care acuity was escalated and aligned with virtual triage recommendation

Care Acuity Escalation Following VT*	Patients Complied with VT Care Recommendation Despite Different Pre-VT Care Intent (Percent) [Compared to All VT Encounters]
From virtual care# intent to outpatient care& per VT	253 of 274 (92.3%) [253 of all 8,088 encounters (3.1%)]
From self-care intent to outpatient care VT	607 of 1,511 (40.2%) [607 of all 8,088 encounters (7.5%)]
From self-care intent to virtual care per VT	857 of 1,511 (56.7%) [857 of all 8,088 encounters (10.6%)]
From outpatient care, virtual care, or self-care intent to ED† care per VT	98 of 121 (80.9%) [98 of all 8,088 encounters (1.2%)]
Total seeking higher acuity care per VT	1,815 of 1,906 (95.3%) [1,815 of all 8,088 encounters (22.4%)]

Note. *VT – virtual triage; #Virtual care includes e-visit or telephone call; &Outpatient care includes in-person or video face-to-face visit; †ED – emergency department

3.4 Impact of VT of patient care acuity escalation

Table 4 presents the actions of patients who were recommended a higher level of care acuity by VT. In 21.2% of all VT encounters, care acuity was escalated in alignment with VT recommendations. The most frequent escalation of care acuity occurred among patients having a pre-VT intent of

self-care who instead sought virtual care as recommended by VT (857 out of 1,511, or 56.7% of such patients, or 10.6% of all VT encounters). The next most frequent care acuity escalation was among patients having a pre-VT intent of self-care who instead pursued outpatient care as recommended by VT (607 out of 1,511, or 40.2% of such patients), which comprised 7.5% of all VT encounters. An additional 253 out of 274, or 92.3% of such patients having a pre-VT intent of virtual care instead pursued outpatient care (in-person or video face-to-face visit) as recommended by VT, comprising 3.1% of all VT encounters. Overall, 1,717 of the 1,785 patients (96.2%) where VT recommended a higher acuity level actually sought such care.

3.5 Impact of VT on triage nurse clinical workflow

Table 5 shows the total duration of triage nurse engagement with patients using virtual triage. Almost half of these patients (45%) required no further action or involvement of the triage nurse. Nurses spent one minute or less working on encounters with 61.6% of patients using VT. Cumulatively, 77.3% of patient encounters post-VT deployment required five or less minutes of nurse engagement, and in 86.1% encounters were 10 minutes or less. The median nurse triage engagement with patients post-VT was under two minutes.

Table 5. Duration of triage nurse patient engagement following virtual triage integration

Nurse Triage Duration	Number of Encounters (Percent)	Encounter Duration Cumulative Percent
No further action required	3,636 (45.0%)	45.0%
≤ 1 minute	1,346 (16.6%)	61.6%
2-5 minutes	1,268 (15.7%)	77.3%
6-10 minutes	713 (8.8%)	86.1%
11-20 minutes	617 (7.6%)	93.7%
> 20 minutes	508 (6.3%)	100%
Total VT encounters	8,088 (100%)	100%
Median nurse triage duration	1.9 minutes	--
Mean nurse triage duration	7.7 minutes	--

4. Discussion

With one in three patients realigning their post-VT care seeking action/behavior when not initially aligned with the VT care referral, this analysis suggests that VT substantially influenced patient care seeking and final level of care acuity selected (see Table 2). That pre-VT patient care intent and VT care recommendation aligned in only one-third of patients is remarkable, with important implications for healthcare providers and payers. Improved care acuity alignment through automated triage and accelerated care referral can reduce care delays, a contributor to preventable morbidity/mortality and unnecessary care utilization.[12–23] It could also potentially enable a reduction of avoidable care utilization at higher than necessary levels of care acuity, which can help reduce avoidable healthcare over-utilization, and associated avoidable care expenditure or costs. However, an almost equal percentage of patients did not change their care seeking when pre-VT intent was not aligned with the care recommendation generated by VT AI, indicating that AI-based VT must continue its evolution and continuous improvement in how it influences patient-user perception, and how effectively it compels changes in patient care seeking behavior.

With a total of 12.0% of all VT patient-users de-escalating and 21.2% escalating care acuity in alignment with VT recommendations, provider clinical effectiveness, patient safety, and plan or system operational and financial performance will likely be affected. The fact that roughly two-thirds of patients who changed their healthcare seeking behavior did so to escalate the acuity of care sought suggests that VT may also have value in earlier detecting and referring conditions which can reduce care delays, and favorably impact patient outcomes and system financial performance.[12–23] While it is clinically intuitive that only a handful of patients using VT with a pre-VT intent to visit an ED changed their care seeking to lower acuity care, it is noteworthy that 1.3% of all patients using VT with a non-ED pre-VT intent followed the advice of VT to seek ED care. It appears from this data that few patients with emergency conditions use VT in an ambulatory care setting. Nonetheless, evidence suggests that VT can detect early prodromal symptoms of common, life-threatening conditions among those accessing the Symptomate functionality available on the internet from home or work.[23] Thus, VT may have a role in early detection/referral of life-threatening symptoms.

When VT appropriately diverts patients to seek lower acuity care, including virtual care and self-care, it reduces use of unnecessary face-to-face primary care services. When it diverts patients from unnecessary ED visits, it reduces the avoidable high cost of ED care while improving the clinical effectiveness and impact of the ED. This reduces avoidable patient and system financial expense while recovering ED clinical capacity to provide care to higher acuity, sicker patients that truly need an ED level of care. Aligning patient care seeking to ensure appropriate acuity of care services contributes to improved clinical effectiveness, reduced cost to patients, and likely improved financial performance of care delivery organizations.

The greatest level of diversion of cases in absolute terms occurred among patients having an initial pre-VT self-care intent who instead pursued virtual care (e-visit or telephonic), where in 10.6% of all VT encounters patients complied with a VT care recommendation different than their pre-VT care intent (see Table 4). Similarly, 6.5% of patients having an initial pre-VT outpatient care (in-person or video face-to-face) intent, complied with a VT recommendation for virtual care (see Table 3). Systems seeking to expand their virtual care delivery volume and associated revenue could potentially benefit from VT implementation because VT may increase new revenue generating virtual/telemedical clinical encounters. VT directed patients with an initial self-care intent to appropriately use virtual care as well as outpatient care. Improved care acuity alignment is thus not only a clinical best practice standard, but also improves health plan and system operational and financial performance, evidencing the reality of the cliché that delivering good medicine is good business for health systems and payers.

It is notable that over a quarter (26.7%) of patient-users were able to take care of their needs without further involving the healthcare system. For the week following the VT session, there were no visits, calls, or significant messaging for these patients. Given the conservative nature of this metric, it's likely that the true number of self-care patients was even higher because some self-care patients likely had visits, calls, or messages entirely unrelated to the problem that they used VT for. This is an important benefit to patients, who were able to get needed medical information 24/7/365. For healthcare providers, instead of responding to online messages or calls from these patients, they were able to redirect resources to other patients in need, likely reducing response times and improving patient satisfaction.

Several limitations to the generalizability of the study findings are notable. The Reliant Medical Group is a multispecialty medical group caring for patients throughout Central and MetroWest Massachusetts, with an urban hub in Worcester. Worcester is a city of 205,000 people, with over 35,000 college students, a quintessential "college town." Thus, the RMG patient population may be more highly educated and health literate than other parts of the US, with somewhat higher socioeconomic status, and possibly better health insurance coverage. These characteristics would tend to increase or favor a greater impact of AI-based virtual triage and care referral than might occur in other US communities. Presumably, the ability to revise patient care acuity misperception and misalignment, and to educate and favorably change patient care seeking behavior, would be increased in a more affluent, educated subject population. On the other hand, the Worcester area has a higher rate of Medicaid beneficiaries and is more blue-collar compared to nearby Boston. Demographically, it is comprised of 53.6% White (Non-Hispanic), with the balance of the population being Black or African American (Non-Hispanic) (11.6%), White (Hispanic) (11.1%), Asian (Non-Hispanic) (6.8%), and Two+ (Hispanic) (6.5%). This racial breakdown of the population is more representative of the general US population in its diversity and socioeconomic spectrum, increasing the generalizability of the reported findings.

Our analyses did not specifically evaluate the appropriateness of the VT recommendations or whether triage nurses reviewing the VT outcomes may have influenced the level of care sought by the patient, both of which would have required extensive chart reviews. Prior studies showed a high performance for VT in terms of finding conditions that likely explain the symptoms, as well as recommended triage level.[8, 11] Plus, Reliant nurses are credentialed and registered professionals who would recognize and alter an inappropriate clinical triage or care referral. It is thus reasonable to assume that in the vast majority of cases, the patient received appropriate guidance from VT and the need for nurses to alter the recommendation was minimal. But this study did not evaluate whether nurses contacted patients post-VT to alter the care recommendation.

Future research on the impact and potential value of VT integrated into nurse triage should focus firstly on replicating and validating these findings. This should include in-person clinical validation of actual patient acuity and diagnosis, at least among those patient-users who engage any form of in-person clinical care. Chart review and patient surveys could also help determine whether nurse reinforcement of VT recommendations impacted patient compliance or outcomes.

Comparative evaluation of the clinical and financial outcomes of patient-users who engage with VT compared to those who do not, as well as factors that drive patient-user

trust, engagement and adoption of VT solutions, are also important areas of future inquiry. Furthermore, RMG patient-users sorted roughly equally with respect to alignment of their pre-VT perception of needed care acuity and intent relative to the output of AI-based VT and care referral. One-third aligned with the VT engine output and two-thirds did not, with the latter group then segregating almost equally into those accepting and acting upon the VT care referral recommendation or not, half adopting it and half rejecting and retaining their incorrect pre-VT care intent and action. If the use of VT is to increase in magnitude and healthcare impact/value, it will be critical to examine and understand the patient characteristics and factors contributing to both accepting and rejecting the care acuity referral recommendation of VT. We need to understand why the one-third of all patient-users who accepted the VT output and changed their care seeking behavior did so, and of equal criticality, we must examine the reasoning of the one-third that rejected the VT care recommendation and chose instead to pursue an acuity of care misaligned with their actual clinical care needs.

Finally, future research efforts should be designed cognizant of the reality that AI-based virtual triage and care referral technology is only one element within the rich digital health ecosystem that will continue expanding for patients and their care. For example, in coming years VT patient-users may enter or input their personally measured digital blood pressure, pulse, respiratory rate, temperature, blood oxygen saturation, and serum glucose readings, as well as other key clinical metrics. The interoperability with and integration of such real time biometric and vitals data within the AI that drives VT and care referral will greatly deepen and enrich its clinical evaluation and validity, and enhance its resultant care acuity recommendations. Research on such synergistic integration of other virtual and digital diagnostic technologies could revolutionize the accuracy and power of AI-based VT to earlier identify patients at elevated risk of severe illness, and accelerate healthcare delivery for conditions where care delays can mean the difference between life and death.[23] It will also enable far greater accuracy in acuity assessment and appropriate care acuity patient guidance, reducing avoidable higher than necessary acuity care seeking and utilization, and expanding telemedical care opportunities. This will allow over-utilized EDs to function as EDs rather than as primary care clinics, reduce overall care system and out-of-pocket expenses for patients, and help health systems and payers achieve far greater efficiencies in managing all outpatient care delivery.

5. Conclusions

Virtual triage demonstrated the ability to identify and redirect the healthcare seeking behavior and action of over one-third of patients whose pre-VT care intent and perceived care need was not aligned with their actual symptom/condition acuity as determined by VT. VT increased patient engagement of presumably appropriate care acuity across all acuity levels, and enabled meaningful improvements in redirecting patients whose pre-triage intent was not aligned with the care recommendation generated by VT AI. Virtual triage impacted patient care seeking behavior and action, with patients nearly twice as likely to follow VT recommendations for higher than for lower levels of care acuity, while modestly reducing the number of face-to-face visits. VT increased diversion of patients from higher acuity outpatient care (in-person or video face-to-face visits) to virtual care involving an e-visit or telephone encounter, and from potentially inappropriate self-care to virtual care. Overall, a quarter of patients using VT were able to perform self-care without any further interaction with the healthcare team or payers.

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Authors contributions

GAG, LG, AKK, KK and TP were involved with the design of the study, completing and/or interpreting the analyses, reviewing manuscript drafts. GAG wrote the first and subsequent drafts of the manuscript. LG, EJM, MWN, JMP, and MJP were involved with the joint virtual and nurse triage program design and/or implementation. LG, KT, PMO, and TP were involved in reviewing drafts of the manuscript.

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Conflicts of Interest Disclosure

GAG, AKK, TP, KK, KT, and PMO are either employees of or medical advisors to Infermedica. LG and MJP are employees of Reliant Medical Group. MWN and JMP are employees of OptumHealth.

Informed consent

Not necessary for de-identified dataset.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

DATA SHARING STATEMENT

No additional data are available.

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