ORIGINAL ARTICLE

Impact of AI-powered virtual triage and care referral on patient care seeking behavior in a Middle Eastern health plan

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ABSTRACT

Objective: To assess whether automated AI-based virtual triage and care referral (VTCR) improves appropriate acuity-based care by aligning patient healthcare seeking intent and potential care seeking behavior with triage output in a leading multinational healthcare plan based in the Middle East.

Methods: Data were derived from an AI-based symptom checker application and analyzed the pre- and post-VTCR care intentions of eligible health plan patients (N = 4,985) to examine how VTCR influenced potential care seeking behavior across five levels of care acuity. Pre- and post-triage care intentions were compared, and changes as a result of triage, including acuity level escalation and de-escalation, were assessed for statistical significance using Z-tests.

Results: Overall alignment with VTCR clinical guidance was 37.6% following virtual triage, improved from a 22.2% level of acuity alignment prior to VTCR. VTCR significantly decreased the number of patients with uncertain healthcare intention (62.9% or - 22.1 PP; p = .05), the largest group of whom decided to engage self-care after VTCR (13.9% of all patients). The largest changes in care intent occurred where patients altered their care plan to engage self-care (an increase of 128.2% or +18.8 PP; p = .05), reducing avoidable use of higher acuity services. Post-triage intent to access emergency care increased 138.8% (+ 1.9 PP; p = .05). The largest de-escalation of care acuity was observed among patients who before VTCR intended to engage a non-urgent outpatient consultation, but instead chose self-care after VTCR (9.3% of patients; p = .05).

Conclusions: Virtual triage reduced potential clinically inappropriate utilization of both higher and lower acuity care services by patients, and post-VTCR care seeking was better aligned with patients' actual clinical needs. VTCR improved early detection of and care referral for emergent conditions, and simultaneously reduced inappropriate ED and outpatient care utilization for symptoms that could be managed by patients through self-care. VTCR was able to reduce care acuity-level misalignment and potentially unnecessary and avoidable healthcare utilization.

Key Words: Virtual triage and care referral, Digital clinical triage, Artificial intelligence, Care acuity level, Symptom checker

1. INTRODUCTION

Timely access to appropriate healthcare is essential for achieving positive patient outcomes.[1,2] Nonetheless, care delays present a significant and ongoing challenge across healthcare systems. Most recently, the COVID-19 pandemic acted as a large barrier to healthcare access on a global scale, resulting in significant care delays.[3,4] The causes and consequences of delayed care are myriad and can arise from vari-

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ous factors in different population segments and differing processes of disease detection and healthcare delivery.[5–8] Care delays can lead to increased avoidable morbidity, poor patient outcomes, increased and unnecessary healthcare costs, and negative impacts on patient and clinician satisfaction.[9,10] Furthermore, care delays can exacerbate existing socioeconomic, racial, ethnic and gender inequities among vulnerable populations, who already face substantial barriers in accessing timely healthcare.[11–14]

A critical aspect in addressing the issue of care delay is care acuity alignment. Efforts to improve care acuity alignment seek to ensure that all patients receive the appropriate kind and urgency levels of care warranted by their clinical conditions. When the level of care delivered to the patient – be it emergent, outpatient clinic or office-based, telemedical, or self-care – is poorly aligned or misaligned with the patient's clinical urgency and clinical need, patients can be misdiagnosed, and under- or over-treated with excessive care complexity and cost. This acuity misalignment can occur when primary care problems are treated in an emergency department (ED), for example, or when patients with an emergent and serious condition present to an outpatient or telemedical setting not staffed nor equipped to complete a diagnosis or render appropriate treatment. Contributing to care acuity misalignment is the experience of patient indecision or indifference due to lack of awareness of serious potential illness or about what level of care to pursue, which can in turn produce avoidable care delay.[1,15] In addition to concerns about clinical appropriateness and effectiveness of care, acuity misalignment undermines efforts to improve the value, efficiency and cost-effectiveness of care, and to reduce avoidable care as a driver of escalating healthcare delivery costs that convey little or no clinical value in terms of patient impact.

In order to ensure prompt and accurate alignment of care acuity, healthcare plans and providers can implement more responsive and efficient clinical triage, which will drive better overall patient health outcomes and improved organizational financial performance.[15,16] New technology solutions to improve care acuity alignment have emerged in recent years, including virtual triage and care referral (VTCR) that utilizes artificial intelligence (AI), which can be integrated within current healthcare system workflows to provide a more accessible and efficient mode of determining accurate care acuity alignment, and reduce care delays and associated costs, human and material, of acuity misalignment.[17,18] This study examines the impact of the integration of virtual triage within the existing clinical assessment process and triage workflow of a leading health plan in the Middle East region, and in particular the impact on improving care acuity alignment and influencing patient-user care seeking actions.

2. METHODS

2.1 Research objectives

Assess whether VTCR that deploys AI improves care acuity alignment by appropriately re-aligning patient post-VTCR healthcare intent and care pursuit in the Middle Eastern service population of a leading multinational health plan.

2.2 Study design and setting

The United Arab Emirates has passed legislation to require universal healthcare, but coverage has not yet been implemented by all seven emirates. Employers must provide health insurance for expatriate workers. The Emirati healthcare system combines services in both the government-funded public sector for citizens and a fast growing private sector. UAE nationals benefit from universal healthcare in Abu Dhabi and Dubai, the two largest of the seven emirates. The UAE has an advanced healthcare system and a highly developed infrastructure where the standard of care is high. The UAE mandated international accreditation in public and private facilities to attract patients, and has a total of 36 government and 79 private hospitals.[19] Abu Dhabi and Dubai emirates have an advanced health information ecosystem including state of the art electronic health records.

The UAE has a unique demographic structure, with most of its population comprised of expatriates who have migrated to the country to pursue work opportunities (82% of Dubai's population are expatriates).[18] Government facilities provide free care for UAE nationals and a low-cost option for non-nationals. Foreign expatriates and non-nationals purchase (or have purchased on their behalf) private insurance to cover medical expenses. Many expatriates prefer private care because it offers more language options and they have familiarity with foreign-trained medical staff. The UAE has 62 registered and regulated health insurance companies. Of these, 35 are national entities and 27 are branches of foreign health insurance companies.

The health plan implementing VTCR and the focus of this study is a global, multinational third-party administrator based in the Middle East and Gulf Region. The health plan works with insurers and healthcare providers to support its patients. By using technology to create a digital ecosystem, the health plan bridges the gap between different stakeholders and enables more seamless healthcare processes. A digital application allows patients to submit and review claims, view insurance information, find a healthcare provider, contact a healthcare provider via video call or use their digital insurance card. In addition, the application includes an AI-based symptom checker or virtual triage engine from Infermedica,

which assists patients in finding the right level of needed care and connecting with appropriate care options.

Data for this analysis were collected from the VTCR AI platform from Infermedica as implemented by a leading health plan in the Middle East over a one year period from the June 2023 to May 2024. Assessing care intent before VTCR involved identifying patient healthcare intentions regarding five levels of acute care, plus a sixth category for patients who were uncertain about or could not identify their healthcare intent, which were then evaluated relative to the care recommendation generated from virtual triage. The five care categories included: (1) self-care not requiring clinical attention; (2) non-urgent outpatient consultation not requiring medical evaluation; (3) urgent outpatient care within 24 hours but not emergent; (4) emergency care where the patient self-transports to an ED; and (5) call an ambulance for immediate transfer to an ED if unable to self-transport. Pre- and post-triage intended care were evaluated for changes after VTCR.

2.3 Virtual triage technology

Infermedica's VTCR technology uses clinical evidence to evaluate 800+ illnesses, 1500+ symptoms, and 300+ disease risks in 22 languages. Using AI, VTCR evaluates the symptoms presented by patients and identifies the probable illnesses based on clinical history and illness presentation. As a first step, patients are queried about their care intent. Utilizing machine learning and natural language processing, the VT engine solicits patient-user reported symptoms and medical history, seeks more information as needed, and assesses varied clinical hypotheses and possibilities like a human clinician does. After evaluating symptom presentation and medical history, the VTCR AI identifies conditions that most closely align with the patient presentation and input, and conveys to the patient information about the nature and potential consequences of each condition. VTCR then refers the patient to the safest and most clinically appropriate care acuity level, one of the five noted earlier. At this juncture in the patient workflow, the post-VTCR care intent survey asks the patient what care they intend to pursue. The study data, including patient demographics, VTCR output, and the pre- and post-VTCR intent survey, derive from VTCR patient encounters with Infermedica's VTCR technology. Arabic and English were the primary languages patients used during this implementation.

2.4 Respondent selection and characteristics

Data were evaluated from June 1^{st}, 2023-May 31^{st}, 2024 with eligibility including all VTCR encounters (28,185) where the patient reported their pre- and post-VTCR healthcare seeking intention (N = 4,985). Almost the entire study population was comprised of multinational expatriates living in the UAE for employment. These individuals and their employers are required to purchase health insurance while in country. The study group thus were comprised of employed individuals or their family dependents.

2.5 Analyses conducted

A dataset of eligible health plan patient interviews which captured pre-VTCR and post-VTCR patient care intentions (N = 4,985) was evaluated to determine how VTCR impacted patient intent to seek healthcare. We examined whether care seeking following VTCR matched that recommended by the technology, and assessed for any changes as a result of triage, including acuity escalation and de-escalation. Type of outpatient care selected by patients post-VTCR was also analyzed and grouped into three categories: primary care, specialist and urgent care. Leading risk factors for morbidity and mortality were also examined.

Google Sheets Online Spreadsheet Editor and Microsoft Excel were used for analysis of data that included patient healthcare intention prior to and after VTCR. VTCR recommendations were grouped into the five levels of acuity plus intent uncertain/unknown categories outlined earlier. To assess VTCR influence on patient choice, healthcare seeking intent before and after VTCR were compared using Z-tests for two proportions to evaluate whether differences were statistically significant. Given that the analysis involves comparing proportions of categorical outcomes, the Z-test for proportions was used as a standard and widely accepted statistical method designed for such comparative analysis. Although the raw data represents a categorical outcome (intent shifts), the analysis involves comparing the calculated proportions of these shifts. This approach is further justified by the large sample sizes in the dataset, which ensure that the sampling distribution of the sample proportions is well-approximated by a normal distribution, thereby making the Z-test a valid tool for assessing statistical significance.

3. RESULTS

Table 1 presents the demographic profile of patients with respect to age and gender. There was a slightly greater percentage of males than females in the study cohort. Among both genders, age was skewed to younger age strata of 18-44 years old. There were no clinically or statistically meaningful differences between the total patient population and patients who fully completed the care intent survey, with the exception of patients 45-59, which comprised less than 10% of those and all encounters.

Table 1. Patient age and gender profile

Gender	Age	Number of Encounters (%) (N = 28,185)	Number of Encounters (%) with Known Care Intent (N = 4,985)
Female	<18	209 (0.7%)	43 (0.9%)
	18-29	6,041 (21.4%)	973 (19.5%)
	30-44	5,373 (19.1%)	955 (19.2%)
	45-59	722 (2.6%)	155 (3.1%)
	60-74	37 (0.1%)	6 (0.1%)
	>75	1 (0.0%)	0 (0.0%)
Total Females		**12,383 (43.9%)**	**2,132 (42.8%)**
Male	<18	250 (0.9%)	61 (1.2%)
	18-29	6,648 (23.6%)	1,174 (23.6%)
	30-44	7,715 (27.4%)	1,364 (27.4%)
	45-59	1,087 (3.9%)	228 (4.6%)
	60-74	97 (0.3%)	24 (0.5%)
	>75	5 (0.0%)	2 (0.0%)
Total Males		**15,802 (56.1%)**	**2,853 (57.2%)**
All Patient Totals		28,185 (100.0%)	4,985 (100.0%)

With respect to the languages in which patients completed the VTCR encounter, it was English in 61.7% of all encounters and in 62.1% of encounters with known care intent, and Arabic for 35.4% of all encounters and 35.8% of encounters with known care intent. The remaining encounters were completed in French.

Tables 2 and 3 present the impact of VTCR on initial patient care intent. There was a substantial and statistically significant decrease (-62.9% or -22.1 percentage points or PP, $p < .05$) in the proportion of patients who remained uncertain about and could not state their care intent, as well as a significant increase in those indicating a self-care intent (+128.2% or 18.8 PP, $p < .05$) relative to their pre-VTCR stated intent. Emergency care intent increased by +138.8% or +1.9 PP for self-transport emergency care and by 115.4% or +0.3 PP for emergency department transport by ambulance (both $p < .05$).

Table 2. Impact of virtual triage and care referral on initial patient care intent

	Pre-VTCR* Patient Care Intent (%) (N = 4,985)	Post-VTCR Patient Care Intent (%) (N = 4,985)	Absolute (Relative) Magnitude of Change in Care Intent (PP)#	Statistical Significance
Unknown/uncertain of care intent	1,750 (35.1%)	649 (13.0%)	- 62.9% (-22.1 PP)	$p < .05$
Self-care	731 (14.7%)	1,668 (33.5%)	+ 128.2% (+18.8 PP)	$p < .05$
Non-urgent outpatient care	2,332 (46.8%)	2,403 (48.2%)	+ 3.0% (+1.4 PP)	$p = .15$
Urgent outpatient care (within 24 hours)	92 (1.8%)	77 (1.5%)	- 16.3% (-0.3 PP)	$p = .20$
Emergency care, self-transport	67 (1.3%)	160 (3.2%)	+ 138.8% (+1.9 PP)	$p < .05$
Emergency care, with ambulance transport	13 (0.3%)	28 (0.6%)	+ 115.4% (+0.3 PP)	$p < .05$
Total	4,985 (100.0%)	4,985 (100.0%)		

Note. *VTCR – virtual triage and care referral; # PP – percentage points

The increase in the number of patients stating a post-VTCR intention to engage in self-care demonstrates that VTCR reduced inappropriate potential utilization of higher acuity care services. Thus, post-VTCR patient care seeking was better aligned with patients' actual clinical needs. There was an increase in the number of patients intending to access emergency care that was care acuity level appropriate, and which warranted escalation of acuity level based on VTCR output (see Tables 2 and 3). While relatively infrequent in terms of overall care acuity level matching across the entire cohort, VTCR facilitated potential early detection and care referral of severe conditions that warrant immediate, urgent care. The magnitude of the percentage change is large because of the small denominator of patients in this category, thus a minor change in numerator causes large percentage differences. There was no significant change in the number of patients having an intent to access outpatient care or outpatient care within 24 hours.

The largest changes in care intent involved a de-escalation of care acuity among patients who planned to seek a non-urgent outpatient consultation and instead chose self-care after VTCR (9.3% of patients, $p = .05$), as seen in Table 3. Care acuity escalation occurred among patients who intended initially to engage in self-care but who, following VTCR, instead chose to obtain non-urgent outpatient care (2.3% of all patients). Among patients who were uncertain and did not know which level of care to pursue, the largest group decided to engage in self-care following VTCR (13.9% of all patients, $p = .05$).

A significant decrease of 13.5% (- 5.0 PP) was observed in patients with a primary care intention, driven largely by an increase of 9.6% (+ 5.7 PP, $p = .05$) in those intending to seek specialty care (see Table 4).

Among patients who changed healthcare seeking intention, 23.5% (or 3.6% of all patients, $p = .05$) de-escalated to care of lower acuity, compared with 17.7% (or 2.7% of all patients, $p = .05$) who escalated their intent to higher acuity care (see Table 5). Over one half of patients (58.8%) changing care seeking intention (or 9.1% of all patients) changed their intent from uncertain to a specific level of care delivery recommended by VTCR. The overall level of compliance with VTCR care referral recommendations was 37.6%, a substantial decrease from the 77.8% of patients whose pre-VTCR care intent did not align with the care referral recommendations of VTCR.

Table 3. Patient healthcare seeking intention pre- vs. post-virtual triage and care referral

		Self-care	Outpatient Care Not Urgent	Urgent Outpatient Care (Within 24 Hours)	Emergency Care via Self-transport	Emergency Care via Ambulance	Unknown/ Uncertain Care Intent	Total
		Healthcare Seeking Intention Following Virtual Triage and Care Referral (%)						
Pre-Triage Healthcare Seeking Intent	Self-care	490 (9.8%)	115 (2.3%)	7 (0.1%)	9 (0.2%)	3 (0.1%)	107 (2.1%)	731 (14.7%)
	Non-urgent outpatient care	462 (9.3%)	1,690 (33.9%)	18 (0.4%)	39 (0.8%)	5 (0.1%)	118 (2.4%)	2,332 (46.8%)
	Urgent outpatient care (within 24 hours)	17 (0.3%)	28 (0.6%)	32 (0.6%)	8 (0.2%)	2 (0.0%)	5 (0.1%)	92 (1.8%)
	Emergency care self-transport	6 (0.1%)	16 (0.3%)	5 (0.1%)	38 (0.8%)	0 (0.0%)	2 (0.0%)	67 (1.3%)
	Emergency care with ambulance	0 (0.0%)	1 (0.0%)	0 (0.0%)	3 (0.1%)	8 (0.2%)	1 (0.0%)	13 (0.3%)
	Patient did not know/was uncertain of care intent	693 (13.9%)	553 (11.1%)	15 (0.3%)	63 (1.3%)	10 (0.2%)	416 (8.3%)	1,750 (35.1%)
	Total	1,668 (33.5%)	2,403 (48.2%)	77 (1.5%)	160 (3.2%)	28 (0.6%)	649 (13.0%)	4,985 (100.0%)

Table 4. Outpatient healthcare seeking intention pre- vs. post-VTCR by provider type

	Healthcare Seeking Intention Before VTCR* (%)	Healthcare Seeking Intention Following VTCR (%)	Absolute (and Relative) Change in Magnitude of Healthcare Seeking Intent (PP)#	Change in Healthcare Intent per 1,000 VTCR Encounters
Primary care provider	892 (36.8%)	789 (31.8%)	- 13.5% (- 5.0 PP)	- 50
Specialist care provider	1,440 (59.4%)	1,614 (65.1%)	+ 9.6% (+ 5.7 PP)	+ 57
Urgent care provider	92 (3.8%)	77 (3.1%)	- 18.2% (- 0.7 PP)	- 7
Total	2,424 (100.0%)	2,480 (100.0%)		

Note. Urgent care differs from inpatient emergency care in that it indicates a need for near term outpatient care. * VTCR – virtual triage and care referral; # PP - percentage points

Virtual triage has been examined as a new and additive potential vehicle for the surveillance and early detection of serious conditions requiring urgent care and for identifying and engaging individuals with chronic disease risk factors in efforts to reduce risk.[19] As shown in Table 6, 15,760 patients (or 55.9% of completed encounters) reported one or more of the following leading chronic disease risk factors: overweight or obese (31.2% of VTCR encounters), smoking tobacco (23.8%), diagnosed hypertension (11.1%), high serum cholesterol (8.9%), and diagnosed diabetes (2.6%).

Table 5. Virtual triage and care referral impact on change in patient healthcare seeking intent

Healthcare Seeking Intent and VTCR* Recommendation Alignment	Impact of VTCR Recommendation on Patient Healthcare Seeking Intent (%)	Magnitude of Change in Care Acuity Level (%)
Healthcare seeking change in intent after VTCR	769 (15.4%)	–
Lower acuity healthcare intent as a result of VTCR recommendation (de-escalated acuity)	–	181 (23.5% of patients changing healthcare intent; 3.6% of total patients)
Higher acuity healthcare as a result of VTCR recommendation (escalated acuity)	–	136 (17.7% of patients changing healthcare intent; 2.7% of total patients)
Post-VTCR healthcare intent changed from uncertain to that recommended by VTCR	–	452 (58.8% of patients changing healthcare intent; 9.1% of total patients)
Pre-triage healthcare intent and VTCR recommendation were aligned/identical	1,105 (22.2%)	–
Patient did not change healthcare intent to that recommended by VTCR when not aligned	3,111 (62.4%)	–
Total	4,985 (100.0%)	769 (15.4%)

Note. * VTCR – virtual triage and care referral

Table 6. Chronic disease risk factors reported to virtual triage

Risk Factor	Number of Patients (%)
Overweight and obesity	8,806 (31.2%)
Smoking cigarettes	6,706 (23.8%)
Diagnosed hypertension	3,141 (11.1%)
High cholesterol	2,515 (8.9%)
Diagnosed diabetes	746 (2.6%)

4. Discussion

4.1 Implications of key study findings

VTCR significantly decreased the number of patients with uncertain healthcare intention (62.9% or - 22.1 PP; p = .05), the largest group of whom decided to engage self-care after VTCR (13.9% of all patients, an increase of 128.2% or +18.8 PP; p = .05), and potentially reducing avoidable use of higher acuity services. Post-triage intent to access emergency care increased 138.8% (+ 1.9 PP; p = .05). A large de-escalation of care acuity was observed among patients who prior to VTCR intended to engage an outpatient non-urgent consultation, but instead chose self-care after VTCR (9.3% of patients; p = .05).

With 77.8% of patient's pre-VTCR care intent not aligning with VTCR recommendations, the fact that over one in five individuals in this group changed their healthcare intent because of the VTCR encounter is compelling. These findings demonstrate that VTCR delivers substantial potential clinical, operational and financial value to the health plan by reducing avoidable/unnecessary high acuity care and associated care costs, and in expediting care for patients with serious illness by reducing harmful care delays. Strategies to increase patient compliance with VTCR care recommendations should be explored, including financial incentives that reduce co-payments, contribute to health promotion programs such as reduced cost of fitness center membership, or home-based diagnostic technology including blood pressure cuffs, oximeters, etc. Ability to rapidly and easily schedule telemedicine or virtual care appointments can be integrated seamlessly with VTCR to incent early detection and expedited care of more serious clinical issues and compliance with VTCR care recommendations.[20]

A relatively small number of patients de-escalated their intent to lower acuity care compared to other studies in similar settings.[15,16] Only 3.6% of all patients opted for lower acuity healthcare based on the VTCR recommendation, in

contrast to 12.0% of patients in the Reliant study in the United States (US)[15] and 14% in the Médis study in Portugal.[16] This difference may be attributable to this study's lower overall compliance rate with the VTCR care recommendation; however other factors likely contributed, such as differences in cultural, health and internet/digital literacy, or health insurance benefits coverage between the US, Portugal and the UAE. Similarly, the rate of escalation of care driven by VTCR recommendations was lower in the present analysis (2.7% of all patients) compared to the US (21.2%)[1] and the Médis (8.6%) studies.[15,16] These differences may also reflect setting-specific influences not influenced by the technology itself, including patient demographics, and caution is warranted in extrapolating these results to other healthcare systems.

This analysis demonstrated a large increase of 128.2% in the intent of patients to engage self-care following use of VTCR. Similar, albeit less pronounced results were observed in the Médis study, where self-care engagement increased by 39.5%.[16] Conversely, the US study reported an 8.2% decrease in the number of patients engaging in self-care.[15]

4.2 Study limitations

A study limitation is the reliance on patient self-reporting of care intent prior to and following VTCR to assess the impact of the technology on patient healthcare choices and care seeking behavior. The accuracy of this relies centrally on an assumption that patients are truthful and accurate in stating their care intentions during the VTCR encounter. It is possible that actual patient care seeking behavior following VTCR might not reflect utilization intent as declared during VTCR. Lacking post-VTCR validation of actual care sought, it is possible that reported patient intent did not translate into real world care behavior, impacting the internal validity and generalizability of the reported results. The final care acuity decision of patients may be influenced by their current plan coverage, access to resources for self-care, availability of non-urgent outpatient care, and other potential confounders. Patient sampling may also introduce potential selection bias, as patients who engage digital health tools may be different in key characteristics from the general population in terms of internet access, digital and health literacy, or care seeking behavior as noted above. This is particularly the case among VTCR users, who tend to be younger and female.[21]

The relatively low VTCR compliance rate observed in this study (37.6%) further constrains generalizability and may reflect unique characteristics of the healthcare setting, digital environment or patient population. In contrast, the US study reported a VTCR compliance rate exceeding 60%, with 35% of patients altering their care intent following virtual triage and 32.3% aligned with VTCR guidance.[15] Even higher compliance (83.9%) was reported in the Médis study in Portugal, where VTCR was supported by direct nurse involvement, which may increase patient trust of the technology.[16] The absence of live personal reinforcement in this UAE setting may have impacted patient confidence in the AI-driven recommendations of virtual triage, underscoring the context-dependent nature of VTCR adoption. Another contributor to low adoption could be a general distrust of AI applications in healthcare stemming from concerns related to technical, ethical or regulatory issues.[22]

4.3 Future research imperatives

To increase confidence in the impact of VTCR, data on actual care seeking behavior of patients, including care received, should be collected in the future to ensure that stated post-VTCR care intent by patients aligns with actual care seeking action. Subsequent studies should incorporate objective data sources, such as claims or medical records, to validate whether stated care intent matches actual utilization. Utilization data such as claims or care records should be collected to validate patient self-reported changes in care intent. Capture of such data was not possible in the current study design. Prospective evaluation of how changes in care intent impact actual care utilization and health outcomes should constitute the next phase of research on the integration of VTCR into existing triage and care referral workflows.

Patient compliance with AI-based VTCR care referral warrants further study to better understand key drivers behind post-triage patient decision-making and care engagement. The US study reported a higher compliance rate (60.0%), and a third of patients altered their initial healthcare intent based on the recommendation of VTCR, while another third (32.3%) had initial care intent aligned with VTCR.[15] In the Portuguese health plan, Médis, where AI-based VTCR was integrated with and supported by nurse care recommendations, a higher compliance rate of 83.9% was observed.[16] Increased patient trust of VTCR in those settings may be due to the direct involvement and diagnostic confirmation of a nurse.

Future research should endeavor to understand drivers of patient compliance with automated AI-based VTCR care recommendations in order to enable user interface and other design enhancements that drive greater VTCR impact. Analysis of varying contributors to different levels of VTCR engagement and impact on care intent and utilization should be evaluated. Future studies should explore drivers of patient compliance with VTCR recommendations, including digital health literacy, trust in automated technology, and various contextual factors. While patients report a generally

positive attitude toward AI-assisted care, hesitancy remains, particularly among older individuals, those with religious or politically conservative beliefs and attitudes, and among certain racial groups.[22–24] These findings underscore the importance of understanding how psychological, psychosocial and sociodemographic factors shape patients' openness to AI-based VTCR.

Comparing VTCR implementations with and without live clinician support may clarify the role of human reinforcement in improving VTCR compliance. Stratified analyses across demographic and clinical groups may reveal which populations benefit most from VTCR, and can help guide tailored VTCR deployment strategies. Prospective randomized controlled trials of VTCR will be critical to evaluating improvements delivered in provider clinical and patient-user workflows and resource optimization. VTCR impact on the financial performance of health plans and healthcare delivery organizations should be a focus of future investigation, where logistic regression or multivariate analyses to control for potential confounders, and to better identify predictors of higher VTCR intent alignment and change may be useful.

4.4 Study implications for practice

These data indicate that VTCR was clinically effective and potentially cost-effective in re-aligning care intentions among patients who had an initial care intent not supported by their actual clinical acuity, and in potentially reducing avoidable care utilization. VTCR greatly reduced patient uncertainty about what acuity or kind of care to engage, and can facilitate early detection and care referral of severe conditions warranting immediate care.[20] Reducing care delays in acute, serious illnesses can reduce morbidity, prevent avoidable hospital or ICU admissions and shorten hospital length of stay.[2–8, 10–12] These VTCR-induced changes in care seeking intent may reduce inappropriate care utilization, and also increase capacity to provide faster, clinically appropriate access for patients with higher acuity care needs, likely improving clinical outcomes.[20]

The substantial volume of patients whose pre-VTCR intent was to engage self-care, but who escalated to non-urgent outpatient care intent, might have presented with more serious clinical concerns if their care had been delayed by self-care. By steering patients toward appropriate care pathways, VTCR may ease the burden on busy emergency services and allow health systems to better manage resource allocation. The increase in specialty care seeking observed in this study suggests that VTCR may help patients navigate directly to the care they need, lessening the number of visits required for patients to complete a care episode, reducing delays and improving care timeliness that potentially also improves patient outcomes and experience/satisfaction.[20, 21]

The impact of VTCR on patient decision-making is particularly notable in the substantial (over 50%) reduction in patients who were uncertain about their care need before VTCR and who selected a specific care pathway after triage. This speaks to the ability of VTCR to empower patients and reduce patient decision inertia and care anxiety, and to drive earlier intervention. Over half of patients altered their healthcare intention from uncertainty to a specific level of care delivery after VTCR, illustrating that VTCR helped patients who did not know what level of care acuity to engage so as to move forward.

Advances in generative and conversational AI, including large language models, will dramatically evolve VTCR capabilities by enabling a voice automated patient workflow. This technological advancement may yield substantial reductions in inefficient resource use and live and automated call center costs, while increasing provider capacity by diverting more routine, non-urgent clinical care demand away from busy clinicians so they can better meet demand for higher acuity level care.

Chronic diseases contribute significantly to preventable morbidity and mortality across the globe. Substantial percentages of patients reported chronic disease risk factors during their VTCR encounter. Early identification of chronic disease risk factors enables health plans, insurers and care systems to proactively engage patients in risk reduction efforts and preventive care to reduce morbidity or to slow disease progress. Addressing risk factors for costly endemic chronic diseases, early in the course or etiology of illness, can enhance quality of life for patients, improve long term population health outcomes, and reduce avoidable healthcare costs associated with unmanaged chronic conditions.

5. Conclusions

Virtual triage and care referral significantly decreased the number of patients with uncertain healthcare intention and who did not know what kind or level of healthcare acuity to pursue, the largest group of whom decided to engage self-care after VTCR. Patient compliance with the care recommendations of AI-based virtual care was high, with one in three patients altering their pre-triage care intent to align with the recommendation of VTCR. The largest change in care intent occurred where patients altered their care plan to engage self-care, reducing avoidable use of higher acuity services. Post-triage intent to access emergency healthcare increased, which potentially facilitates early detection and care referral and reduces care delays that negatively impact patient outcomes. The largest de-escalation of care acuity in-

tent was observed among patients who intended to engage an outpatient consultation on a non-urgent basis prior to VTCR, and instead chose self-care following the VTCR encounter. These findings demonstrate that VTCR may potentially reduce clinically inappropriate utilization of both higher and lower acuity care services by patients, and that post-VTCR patient care seeking intent was better aligned with patients' actual clinical needs within the health plan studied.

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AUTHORS CONTRIBUTIONS
GAG, AKK, TP and AAN designed the study methodology and interpreted the data; GAG wrote the first draft of the manuscript; GAG, TP, AKK, AAN and GLG edited all subsequent drafts of the manuscript; TP, AKK, GAG, and AAN reviewed and organized the data, validated the data analyses, and co-authored the results interpretation and the discussion sections; GLG assisted with project management, literature search, reference integration, and completing journal submission.

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GAG, TP, AAN, and GLG are advisors to Infermedica; AKK is an employee of Infermedica.

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