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eVisits in the digital era of Swedish primary care

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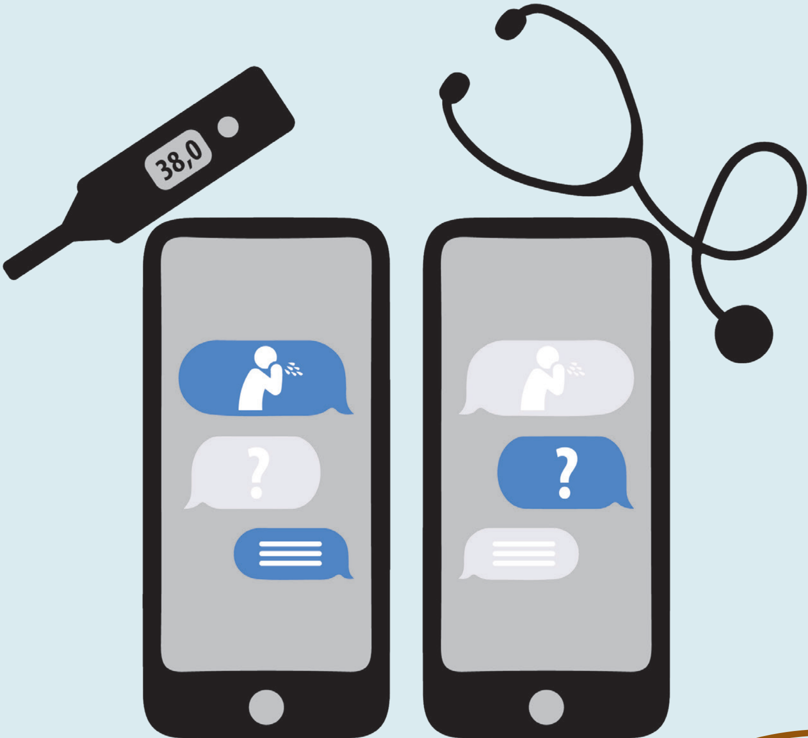

eVisits in the digital era of Swedish primary care

Artin Entezarjou, M.D.

DOCTORAL DISSERTATION

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Title and subtitle
eVisits in the digital era of Swedish primary care

Abstract
Objective: To evaluate asynchronous digital visits (eVisits) with regard to digital communication, clinical decision-making, and subsequent care utilization in the digital era of primary care in Sweden.

Methods: A mixed-methods approach was adopted across the various papers in the thesis, with all studies evaluating the eVisit platform Flow in various clinical contexts.

- Paper I was a comparative study of digital triage decisions when presented with automated patient history reports generated by the platform. Inter-rater reliability of triage decisions by majority vote in a panel of five physicians was compared to triage decisions by a machine learning model trained using data labelled by an expert primary care physician.
- Paper II was a qualitative focus group study of nurse and physician experiences of digital communication at three primary health care centers using the platform. Themes were generated using qualitative content analysis as described by Graneheim and Lundman.
- Papers III and IV were observational studies comparing office visits in the Skåne Region from Capio, a large private health care provider, to eVisit patients from Capio Go, a national eVisit service. Adult patients with a chief complaint of sore throat, dysuria, or cough/common cold/influenza were recruited. eVisit patients were recruited prospectively digitally prior to their eVisit, while the office visit control group was recruited retrospectively using letters. Paper III primarily compared antibiotic prescription rates per sore throat visit, while paper IV primarily compared subsequent physical health care utilization within two weeks for patients in the Skåne Region.

Results: Interrater reliability was low (Cohen κ 0.17) between the panel majority vote and the machine learning model. Physicians and nurses experienced *digitally filtered primary care, adjusting to a novel medium of communication* highlighting challenges in interpreting symptoms through text as well as alterations in practice workflow using asynchronous communication. Antibiotics prescription rate within three days was not higher after eVisits compared to office visits (169/798 (21.2%) vs. 124/312 (39.7%) for sore throat, respectively; $P<.001$). No significant differences in subsequent physical visits within two weeks (excluding the first 48 h of expected "digit-physical" care) were noted following eVisits compared to office visits (179 (18.0%) vs. 102 (17.6%); $P = .854$).

Conclusions: eVisits do not seem to be associated with over-prescription of antibiotics, or over-utilization of physical health care when assessing common infectious symptoms. Given staff experiencing uncertainties in interpretation of symptoms and triage decisions being inconsistent, eVisits may be best used as one of many modalities to access primary care, with focus placed on facilitating patient-centered professional judgement by staff, rather than automation of complex decisions.

Keywords: telemedicine, eVisit, primary care, artificial intelligence, decision support, machine learning, triage, virtual visit, organization of health services, biotechnology & bioinformatics, information technology, antibiotics, cystitis, respiratory tract infection, streptococcal tonsillitis,

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MADE IN SWEDEN

To my parents

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Original papers

I. Entezarjou A, Bonamy AE, Benjaminsson S, Herman P, Midlöv P. Human- Versus Machine Learning-Based Triage Using Digitalized Patient Histories in Primary Care: Comparative Study. JMIR Med Inform. 2020 Sep 3;8(9):e18930. doi: 10.2196/18930. PMID: 32880578; PMCID: PMC7499160.

II. Entezarjou A, Bolmsjö BB, Calling S, Midlöv P, Milos Nymberg V. Experiences of digital communication with automated patient interviews and asynchronous chat in Swedish primary care: a qualitative study. BMJ Open. 2020 Jul 23;10(7):e036585. doi: 10.1136/bmjopen-2019-036585. PMID: 32709650; PMCID: PMC7380727.

III. Entezarjou A, Calling S, Bhattacharyya T, Milos Nymberg V, Vigren L, Labaf A, Jakobsson U, Midlöv P. Antibiotic Prescription Rates After eVisits Versus Office Visits in Primary Care: Observational Study. JMIR Med Inform. 2021 Mar 15;9(3):e25473. doi: 10.2196/25473. PMID: 33720032.

IV. Entezarjou A, Sjöbeck M, Midlöv P, Nymberg VM, Vigren L, Labaf A, Jakobsson U, Calling S. Health care utilization following "digi-physical" assessment compared to physical assessment for infectious symptoms in primary care. BMC Prim Care. 2022 Jan 12;23:4. doi: 10.1186/s12875-021-01618-2. PMID: 35036998; PMCID: PMC8753946.

Abbreviations

AI	Artificial intelligence
CRP	C-reactive protein
DTC	Direct-to-consumer
EHR	Electronic health record
EMR	Electronic medical record
eVisit	Asynchronous chat-based visit
GP	General practitioner
IT	Information technology
ICE	Ideas, concerns, and expectations
ICT	Information communication technologies
NLP	Natural language processing
PCP	Primary care physician
PHCC	Primary healthcare center
RST	Rapid streptococcal antigen testing
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology

Definitions

The following list includes terms as used in this thesis. As telemedicine is a relatively novel field of medicine, the terminology is rapidly evolving, and many terms are used inconsistently in the literature. Definitions below may thus become less relevant as the field progresses further.

Algorithm	A set of rules that must be followed when solving a particular problem. In the context of information technology, this may involve a set of rules for when certain questions are presented to a user, or when a certain answer triggers a computer system to respond in a pre-defined way (1). Within the field of machine learning, algorithms are procedures, able to be described in math or pseudocode, run on data to create a machine learning "model" including (2): • Linear Regression • Logistic Regression • Decision Tree • Artificial Neural Network • Naive Bayes • k-Nearest Neighbors • k-Means
Asynchronous communication	Asynchronous is defined as not existing or happening at the same time (1). Asynchronous communication thus involves two parties not required to be present simultaneously, so that information exchange can occur with delay with consideration to when the opposing party receives information.
Artificial intelligence (AI)	Umbrella term for the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages (3). Computer systems mimicking human behavior patterns, but do not necessarily involve machine learning and may instead involve simpler software algorithms.
Automated patient history	Using digital questionnaires to acquire a patient medical histroy prior to interacting with health care staff. Varies in complexity from a standard set of questions, to a pre-defined algorithm with certain questions asked when certain conditions are fullfilled, to a complex adaptive system with advanced natural language processing. The term is used inconsistently in the literature, with some variations including: • Automated medical history • Automated patient interview • Automated medical interview

Big data	Extremely large data sets that may be analyzed computationally to reveal patterns, trends, and associations, especially relating to human behavior and interactions (3).
Clinical decision support systems	A variety of tools to enhance decision-making in the clinical workflow. These tools include computerized alerts and reminders to care providers and patients; clinical guidelines; condition-specific order sets; focused patient data reports and summaries; documentation templates; diagnostic support, and contextually relevant reference information, among other tools (4).
Deep learning	A subset of machine learning that uses neural networks for applications, such as image recognition, text generation, playing Go, or self-driving cars (5).
Digi-physical care	A novel academic term used in this thesis, a combination of digital visits and physical visits to assess a patient, usually by first assessing digitally and scheduling a physical follow-up if deemed necessary (context of paper III and IV). Digi-physical care may also involve an initial physical assessment with digital follow-up (context of paper II), distinguishing the term from "digital-first" consultations as described in the literature (6).
Digitalization	Definition remains contested in the literature, but in this thesis defined as organizational and cultural changes to include and maintain technologies in the process of service delivery to meet established public health goals (7). Formally synonymous with digitization, i.e. the process of changing data into a digital form that can be easily read and processed by a computer (1).
Digitization	Definition remains contested in the literature but in this thesis defined as the technical process of converting existing analog records to digital data (7). Formally synonymous to digitalization, i.e. the process of changing data into a digital form that can be easily read and processed by a computer (1).
Digital encounters	A subset of telemedicine, and one of many terms undefined in the literature used to describe a two-way, free-form, digital communication between patients and their health care providers, using text, audio, or video, synchronously or asynchronously. May thus include eVisits, virtual visits, and direct-to-consumer telemedicine. Uses information communication technology software, meaning the term excludes traditional telephone communication. Does not include one-way communication or isolated transfer of single parameters such as vital signs, electrocardiograms, lab results, i.e. telemonitoring, distinguishing the term from the broader term "telemedicine". *In this thesis, the preferred umbrella term used for this purpose is "digital visits".*
Digital visits	A subset of telemedicine, and one of many terms undefined in the literature used to describe a two-way, free-form, digital communication between patients and their health care providers, using text, audio, or video, synchronously or asynchronously. May thus include eVisits, virtual visits, and direct-to-consumer telemedicine. Uses information communication technology software, meaning the term excludes traditional telephone communication. Does not include one-way communication or isolated transfer of single parameters such as vital signs, electrocardiograms, lab results, i.e. telemonitoring, distinguishing the term from the broader term "telemedicine". *The chosen umbrella term used consistently throughout this thesis.*
Digital tools	Involving or relating to the use of computer technology (3).

Direct-to-consumer (DTC) telemedicine	Telemedicine services where provider consumers (patients) access to care for common non-emergent conditions through telephone and live video via personal computers and mobile phone apps (8). May include audio exchange without video, distinguishing the term from “virtual visits”. Does not involve primary communication via text, distinguishing the term from “eVisits”.
Doctor	A person who has been trained in medical science, whose job is to treat people who are ill or injured (1). Does not necessarily indicate that specialty training is complete. The term is synonymous with the term “physician” in this thesis.
eConsultation	“Electronic consultation”. Inconsistent definition in the literature. In this thesis used to describe using information communication technology software provider-to-provider, using text, audio, or video, synchronously or asynchronously, as also used in the literature (9). Some literature also use the term eConsultation as a subset of telemedicine, and one of many terms undefined in the literature used to describe a two-way, free-form, digital communication between patients and their health care providers, using text, audio, or video, synchronously or asynchronously. May thus include eVisits, virtual visits, and direct-to-consumer telemedicine. Uses information communication technology software, meaning the term excludes traditional telephone communication. Does not include one-way communication or isolated transfer of single parameters such as vital signs, electrocardiograms, lab results, i.e. telemonitoring, distinguishing the term from the broader term “telemedicine” (10). *In this thesis, the preferred umbrella term used for this purpose is “digital visits”.*
eHealth	“Electronic health”. Umbrella term referring to the cost-effective and secure use of information communication technologies in support of health and health related fields, including health-care services, health surveillance, health literature, and health education, knowledge, and research (11). According to some definitions synonymous with “digital health and care”, which includes tools and services that use information and communication technologies to improve prevention, diagnosis, treatment, monitoring and management of health-related issues and to monitor and manage lifestyle-habits that impact health (12).
eLearning	“Electronic learning”. Use of information communication technologies for education; one of the key strategies for health workforce training (11).
Electronic health record (EHR)	Real-time, patient-centered records that contain a patient’s medical history, diagnoses and treatment, medications, allergies, immunizations, as well as radiology images and laboratory results (13).
Electronic medical record (EMR)	Real-time, patient-centered records that contain a patient’s medical history, diagnoses and treatment, medications, allergies, immunizations, as well as radiology images and laboratory results.
eVisits	“Electronic visits”. Asynchronous digital visits where patient and health care provider primarily communicate via two-way text-based communication. May also, depending on the platform, allow for other forms of data exchange asynchronously, such as images or voice messages (14).

Family medicine	As defined by Swedish law, outpatient health care offered without delimitations with regards to diseases, age, or patient populations. Provides medical assessment, treatment, nursing, prevention, and rehabilitation when no particular medical, technical or other particular competence is required (15). In this thesis synonymous to “primary care”, “general medicine”, and “general practice”. Is also considered a medical specialty for physicians, which in Sweden requires 60 months of clinical training.
General medicine	As defined by Swedish law, outpatient health care offered without delimitations with regards to diseases, age, or patient populations. Provides medical assessment, treatment, nursing, prevention, and rehabilitation when no particular medical, technical or other particular competence is required (15). In this thesis synonymous with “primary care”, “family practice”, and “general practice”. Is also considered a medical specialty for physicians, which in Sweden requires 60 months of clinical training.
General practice	As defined by Swedish law, outpatient health care offered without delimitations with regards to diseases, age, or patient populations. Provides medical assessment, treatment, nursing, prevention, and rehabilitation when no particular medical, technical or other particular competence is required (15). In this thesis synonymous with “primary care”, “family medicine”, and “general practice”.Is also considered a medical specialty for physicians, which in Sweden requires 60 months of clinical training.
General practitioner (GP)	A doctor who is trained in general medicine and who treats patients in a local community rather than at a hospital (1). The term is more commonly used in the United Kingdom, where a minimum of three years of specialty training is required. In this thesis synonymous with “general medicine specialist” (the most commonly used term in Sweden, where a minimum of five years of post-graduate training is required), and “family physician” (the most commonly used term in the United States, where a minimum of three years of post-graduate training is required).
Hardware	The machines and electronic parts in a computer or other electronic system (1).
Health care	As defined by Swedish law, measures to medically prevent, investigate and treat diseases and injuries, health care transportation, and the disposal of deceased individuals (16).
Information communication technology (ICT)	Synonymous with information technology, i.e. systems, especially computers and telecommunications, for storing, retrieving, and sending information (3).
Information technology (IT)	Systems, especially computers and telecommunications, for storing, retrieving, and sending information (3).
Labelled data	Data that comes with a label, defined as the feature a machine learning model is trying to predict. If we are trying to predict the type of pet we have (for example cat or dog), based on information on that pet, then that is the label. If we are trying to predict if the pet is sick or healthy based on symptoms and other information, then that is the label. If we are trying to predict the age of the pet, then the age is the label (5).
Machine learning	A subset of artificial intelligence involving the process whereby a computer distills meaning by exposure to training data (17). May involve simpler modelling using regression, or more advanced modelling using deep learning with neural networks. Does not include pre-defined algorithms unless they self-modify with exposure to training data.

mHealth	"Mobile health". Umbrella term for the use of mobile devices – such as mobile phones, patient monitoring devices, personal digital assistants and wireless devices – for medical and public health practice (11). May include telemedicine services, telemonitoring, self-tracking, information provision websites, self-care apps and much more.
Model	Refers specifically to a machine learning model. The program saved after running a machine learning algorithm on training data. Represents the rules, numbers, and any other algorithm-specific data structures required to make predictions (2).
Natural language processing (NLP)	Subfield of artificial intelligence, the use of computers to process natural languages, for example for translating (1).
Neural networks	A computer system that is designed to work in a similar way to the human brain and nervous system (1). Involves the use of "layers" and "nodes" which, given a certain complexity, can enable deep learning. Several neural network architectures exist, each with their own advantages and disadvantages: • Feed forward neural networks (FFNNs) • Recurrent neural networks (RNNs) • Autoencoders (AEs) • Convoluted neural networks (CNNs) • Generative adversarial networks (GANs)
Online consultation	A subset of telemedicine, and one of many terms undefined in the literature used to describe a two-way, free-form, digital communication between patients and their health care providers, using text, audio, or video, synchronously or asynchronously. May thus include eVisits, virtual visits, and direct-to-consumer telemedicine. Uses information communication technology software, meaning the term excludes traditional telephone communication. Does not include one-way communication or isolated transfer of single parameters such as vital signs, electrocardiograms, lab results, i.e. telemonitoring, distinguishing the term from the broader term "telemedicine". *In this thesis, the preferred umbrella term used for this purpose is "digital visits".*
Patient portals	A secure online website that gives patients access to personal health information from anywhere with an Internet connection. Using a secure username and password, patients can view health information such as recent doctor visits, discharge summaries, medications, immunizations, allergies, and lab results. Some patient portals also allow patients to securely message their health care provider, request prescription refills, schedule appointments, check benefits/coverage, update contact information, make payments, complete forms, and view educational materials (18).
Physician	A person who has been trained in medical science, whose job is to treat people who are ill or injured (1). Does not necessarily indicate that specialty training is complete. The term is synonymous with the term "doctor" in this thesis.

Primary care	As defined by Swedish law, outpatient health care offered without delimitations with regards to diseases, age, or patient populations. Provides medical assessment, treatment, nursing, prevention, and rehabilitation when no particular medical, technical or other particular competence is required (15). In this thesis synonymous with “family medicine”, “general medicine”, and “general practice”. Is also considered a medical specialty for physicians, which in Sweden requires 60 months of clinical training.
Primary care physician (PCP)	A physician working in a primary health care center. May or may not have completed residency training as a general practitioner/general medicine specialist/family physician.
Primary health care center (PHCC)	A broad term to describe the building in which primary care is provided by doctors with or without assisting staff. Synonymous with health center (1), but also to variations such as the Swedish term “vårdcentral”, which includes mandatory presence of nurses, as well as the Norwegian term “legesenter” and the American/British term “doctor’s office” which do not necessarily have nurses present.
Social media	Websites and applications that enable users to create and share content or to participate in social networking (3).
Software	The programs used by a computer for doing particular jobs (1).
Supervised learning	A type of predictive machine learning in which the data comes with labels, where the label is the target we are interested in predicting (5).
Synchronous communication	Synchronous is defined happening or existing at the same time (1). Synchronous communication thus requires two parties to be present simultaneously, so that information exchange can occur without delay.
Telehealth	The delivery of health care services, where patients and providers are separated by distance (11). May involve using text, audio (including conventional telephone calls), or video, synchronously or asynchronously, as well as monitoring vital signs or other patient data.
Telemedicine	The delivery of health care services, where patients and providers are separated by distance (11). May involve using text, audio (including conventional telephone calls), or video, synchronously or asynchronously, as well as monitoring vital signs or other patient data.
Telemonitoring	A subset of telemedicine, using an automated process for transmission of data on a patient’s health care status from the patient’s home to their health care settings (19).
Test data	A sample of data held back from training a machine learning model, used to give an unbiased estimate of the skill of the final tuned model when comparing or selecting between final models (20).
Training data	A sample of data used to fit a machine learning model (20).
Unsupervised learning	A type of machine learning in which the data has no labels. An unsupervised learning model can still extract information from data, for example, it can group similar elements together (5).
Validation data	A sample of data held back from training a machine learning model used to give an estimate of model skill while tuning the model. Will become less common in modern machine learning if the practitioner tunes model using so-called k-fold cross-validation (20).

Virtual visits	Synchronous digital visits where patients access care through live video (21). Unlike direct-to-consumer telemedicine, virtual visits cannot involve audio-only communication. Definitions in the literature are, however, inconsistent.
Web cookie	A computer file with information in it that is sent to the central server each time a particular person uses a network or the internet (1).
Welfare technology	A common Nordic term for technology used for environmental control, safety and well-being in particular for elderly and disabled people. A similar term used in Europe is Ambient Assisted Living technology (22).

Preface

I have always had a genuine interest in optimizing various aspects of my life. Naturally, I have sought to find the "best" answers to most questions and have subsequently found that the scientific process allows me to empirically, and with as little bias as possible, give me the answer. Results demonstrated by high quality data reflect a reality as free as possible from personal convictions and cognitive bias.

During my medical studies, I had voluntarily conducted epidemiological research at the department of cardiology, both during the semester, during the summer, and as part of my master thesis. This sparked my interest in the research process, but I discovered that my main interest was in primary care, and not specifically in cardiology.

Thus, after medical school, I contacted my current main supervisor, Patrik Midlöv, regarding research opportunities within primary care. I was informed that there was a new project available concerning digital care that could suit me well given my background.

I thus met Patrik, my co-supervisors and some of my co-authors and was informed about an initial outline of four potential studies, which I found very exciting. As the project likely involved four publications, I was given the opportunity to make these a part of a PhD thesis. I accepted and proceeded on the journey towards creating what you are currently reading.

Context of the thesis

My research group is part of the Center for Primary Health Care Research (CPF). CPF is a collaborative organization between Region Skåne and Lund University, with a vision of conducting pioneering clinical research for maximal primary care quality population health. The research group of Family Medicine and Community Medicine conducts research within cardiovascular disease, infectious disease, drugs in the elderly, health care equity and equality, migration, and, as of more recently, eHealth. My colleagues are conducting research within other aspects of eHealth, including telemonitoring of hypertension, clinical decision support systems or wound management, and assessment of various digital visit platforms.

The current series of studies has been planned in part thanks to an initiative from a representative of Doctrin AB, a company specializing in digital solutions for health care providers and interested in having their products independently assessed by peer-reviewed research.

One paper was also published in collaboration with the KTH (Royal Institute of Technology division of Computational Science and Technology in Stockholm) as the co-authors from this division had experience in creating and testing machine learning models essential for the study.

Popular scientific summary

Patients in Sweden are increasingly using digital doctor visits. A common type of digital visit is the so-called eVisit, where patients fill out a digital questionnaire and proceed to chat with a doctor. There is very little research regarding how eVisits impact decision-making in Swedish health care. This thesis consists of four studies evaluating various aspects of eVisits in the platform "Flow", which is used by several Swedish health care providers today.

Study 1 looks at if artificial intelligence makes similar decisions, regarding if patients should seek urgent physical care, compared to human doctors, based on answers in the digital patient questionnaire. The study found that artificial intelligence and human doctors rarely agreed if an eVisit patient needed to proceed to an urgent physical visit. Comparing decisions between doctors also showed that doctors rarely agreed with each other.

Study 2 looks at how doctors and nurses from three primary care clinics using the platform experienced digital communication with patients. Results show that staff found it difficult to interpret patient symptoms using text, and that they needed time to adapt their way of working to assess patients using chat.

Study 3 looks at if doctors more often prescribe antibiotics to patients with infectious symptoms assessed using eVisits compared to patients assessed in usual physical visits at a clinic. Results show that eVisits are not linked to higher prescription of antibiotics compared to corresponding physical visits for sore throat, urinary tract symptoms or cough/common cold/influenza symptoms.

Study 4 looks at if patients who have had an eVisit for assessment of urinary or airway symptoms more often have physical doctor visits afterwards compared to patients who have had a physical visit at a clinic. Results showed that around 13 percentage points more eVisit patients had an extra doctor visit within 48 hours, but that there were no differences after this when comparing visits within two weeks compared to patients with an initial physical doctor visit. Almost 70% of eVisit patients had no physical doctor visit within two weeks.

Results from study 3 and 4 should be interpreted with caution as the eVisit group and physical group likely differ in several ways, including age, health, and it should

also be observed that the eVisit group knew beforehand that they were part of a study, while the physical group did not. However, results from both studies remained unchanged when adjusting analyses for various group differences including age. Results are also in agreement with other studies from the USA. More independent studies from Sweden should reach similar conclusions in order to make the conclusions from these studies more certain.

All in all, the results from this thesis show that eVisits for airway and urinary symptoms don't seem to be linked to more antibiotic prescription or more physical care after the visit (except for the first 48 hours as expected). As staff find it difficult to interpret symptoms and rarely agree regarding level of care for eVisit patients, eVisits should be seen as one of many options for patients to use when wishing to contact their health care provider. Focus should be placed on increasing interactions between patients and staff to make decisions together, rather than automating decisions using artificial intelligence.

Populärvetenskaplig sammanfattning

Det blir allt vanligare att patienter i Sverige använder digitala läkarbesök. En vanlig form av digitala läkarbesök är så kallade e-besök, där patienten fyller i ett digitalt frågeformulär och därefter kommunicerar med läkare via chatt. Det saknas forskning gällande hur e-besök påverkar vårdbeslut i svensk sjukvård. Denna avhandling består av fyra studier som utvärderar olika aspekter av e-besök i plattformen ”Flow” som används av flera vårdgivare i Sverige idag.

Studie 1 undersöker om artificiell intelligens fattar liknande beslut, gällande om patienter ska söka akut fysisk vård, som mänskliga läkare utifrån patienters svar på digitala frågeformulär. Studien visade att artificiell intelligens och mänskliga läkare sällan var eniga i när ett e-besökspatient behöver söka akut fysisk vård. Även mellan läkare var besluten sällan lika.

Studie 2 undersöker hur läkare och sjuksköterskor från tre vårdcentraler som använder plattformen upplever digital kommunikation med patienter. Resultatet visar att personal upplevde svårigheter i att tolka patientens symtom via text, och att de behövde tid för att anpassa arbetssättet på vårdcentralen för att hantera patienter via chatt.

Studie 3 undersöker om läkare oftare skriver ut antibiotika till patienter med infektionssymtom som haft ett e-besök jämfört med patienter som har haft ett fysiskt vårdcentralsbesök. Resultatet visade att e-besök inte kopplades till högre förskrivning av antibiotika jämfört med motsvarande fysiska besök för halsont, urinvägsinfektion, och hosta/förkylning-/influensasymtom.

Studie 4 undersöker om patienter som har haft ett e-besök för bedömning av urinvägs- eller luftvägssymtom oftare söker fysisk läkarvård efteråt jämfört med patienter som har haft ett fysiskt vårdcentralsbesök. Resultatet visade att ca. 13 procentenheter fler e-besökspatienter hade ett extra läkarbesök inom 48 timmar, men att det utöver detta inte sågs några skillnader jämfört med fysiska läkarbesökspatienter inom 2 veckor. Nästan 70% av e-besökspatienter hade inget fysiskt läkarbesök inom 2 veckor.

Resultaten från studie 3 och 4 får tolkas med försiktighet då e-besöksgruppen och fysiska gruppen sannolikt skiljer sig på flera sätt, såsom ålder och samsjuklighet, samt att e-besöksgruppen visste i förväg att de ingick i en studie medan fysiska gruppen inte gjorde det. Dock förblev resultaten i båda studier oförändrade vid analyser som tog hänsyn till skillnader i bland annat ålder mellan grupperna. Resultaten stämmer även med en del andra studier från USA. Fler oberoende studier i Sverige bör komma fram till liknande resultat för att slutsatserna ska bli säkrare.

Sammantaget visar resultaten av avhandlingen att e-besök för luftvägssymtom och urinvägssymtom inte verkar kopplas till en överförskrivning av antibiotika eller extra fysiska läkarbesök i efterförloppet (förutom i akutskedet som förväntat). Då vårdpersonal upplever osäkerhet kring tolkning av patientens symptom och sällan är eniga i beslut om vårdnivå bör e-besök endast utgöra ett alternativ vid behov av kontakt med vården. Fokus bör läggas på ökad dialog mellan patient och vårdpersonal för att fatta gemensamma beslut snarare än automatisering av beslut med artificiell intelligens.

General introduction

I would like to present a case illustrating my vision for how digitalization of primary care can look in the future. Mike is a 55-year-old man with type 2 diabetes and hypertension. His primary health care center (PHCC) has not had the staffing required to schedule him every twelve months for his yearly check-up as recommended. Instead, he has been scheduled every 20 months. These visits have been limited to 30 minutes and the last time focused on bloodwork and prescription renewals, so Mike's physician never had time to assess other symptoms such as his swollen ankles.

Twelve months have passed since Mike last visited his physician. He has in the past months experienced rashes around his swollen ankles and this time contacts his PHCC digitally via their new service. Using his smartphone, Mike answers a series of questions about the rash, and attaches a photo. The system, noting Mike's comorbidities, also asks relevant questions related to Mike's diabetes and hypertension, including compliance and side effects related to his medications, analysis of Mike's lifestyle factors affecting his cardiovascular risk and his motivations to adjust these. The system automatically detects low physical activity as the lowest hanging fruit for reducing Mike's cardiovascular risk, as his levels of physical activity are low while he has high motivation and belief in his ability to increase his exercise levels. The system has also reviewed Mike's medications and recommends switching Mike's diabetes medication to one with better evidence for cardiovascular prevention given Mike's comorbidities and prior medications.

The primary care nurse, who knows Mike well, reads Mike's symptom report, and notes his swollen ankles and prescribes compression socks as well as a cream for the rash, and via a 15-minute video visit, motivationally interviews Mike resulting in a joint decision to start jogging again three times weekly as he once loved to do.

However, the system also indicates that Mike has had progressive difficulties breathing in the past months and notifies the nurse about this, recommending additional evaluation by Mike's physician with an electrocardiogram, cardiopulmonary auscultation, and NT-proBNP bloodwork. The physician approves the suggested work-up allowing Mike to visit the clinic's local "health hub" where he can sit down for bloodwork, an automated ECG recording, and cardiopulmonary auscultation. Data is interpreted by a machine learning algorithm and results are reported back to Mike's physician who schedules a 10-minute physical visit according to their matched schedules.

The system reminds the physician to follow-up the nurse's prescriptions which have reduced Mike's swelling and rashes. Mike's physician verifies Mike's lower-limb pitting edema and goes on to inform him that the "health hub" has detected elevated NT-proBNP as well as pulmonary rales and recommends Mike be evaluated with an echocardiogram to verify a suspected diagnosis of congestive heart failure, which is automatically scheduled when Mike approves this. During this visit, Mike's physician answers Mike's questions about the condition, and provides reassurance along with appropriate self-care advice, including further encouragement to practice sustained physical activity, which Mike now feels is extra important. They also discuss various medications and decide to lower the dose of Mike's beta-blockers and increase the dose of his angiotensin converting enzyme inhibitors to make it easier for Mike to jog at higher intensities. The conversation, clinical findings, agreements between Mike and his physician, and adjusted physicians are automatically documented through NLP and Mike can access his medical record to review his treatment plan and current medications and is able to inform his physician if he ever stops taking any medications and why. Furthermore, Mike's smartwatch tracks his physical activity in relation to his goals and gives him and his doctor direct feedback on his lifestyle changes.

One may consider the long-term downstream effects of Mike's health, as well as the health of the entire population, in a primary care system adopting digitalization in this way. A system automating the standardized screening and data-collecting processes of primary care, allowing for more time spent on interpersonal interaction, via video or physically when needed, may dramatically increase primary care capacity, and subsequently population health.

While the above scenario may represent one form of digital utopia, there may be many other set-ups that ultimately emerge from existing technologies. The question is how to best integrate these technologies into primary care, in a patient-centered and secure way. This thesis looks at some of the possibilities related to this integration.

The rise of telemedicine

The digital era

During the last decades, technological advancements have led to a gradual digitalization of almost all processes related to consumers' daily routines. While not all countries currently have the infrastructure to adopt digital technologies, there is a clear global trend of increased access to smartphones worldwide, with 1.06 billion users in 2012 and 3.6 billion expected users by 2023 (23). Activities from the morning alarm to scheduling, transport, communication, banking, shopping, entertainment, and even dating, have all been digitalized in some form. The COVID-19 pandemic has further catalyzed the implementation of digital tools for work and communication, and consumers are increasingly expecting digital access to various services, including health care (24). Telemedicine has thus evolved from simple communication via telephone and postal mail to digital tools enabling new possibilities of health care provision without requiring the patient to physically attend a clinic or hospital, with the potential to improve access and continuity of care, but with an equivalent potential risk of health care fragmentation, over-utilization, and subsequent increased health care cost (25).

Forms of digitalization in telemedicine

While telemedicine commonly involves provision of health care when patient and provider are separated geographically, there are several digital tools that can be used in the context of telemedicine.

Telemonitoring allows devices capable of registering clinical parameters, including vital signs, patient-reported data, to electronically transmit this data to a health care provider, enabling them to monitor certain diseases.

Automated patient history software lets patients report symptoms, including structured questionnaires, when initially contacting or being followed up by their health care provider.

Digital visits allow patients to use text or video on their smartphone, tablet, or computer to remotely consult their health care provider in real-time using synchronous virtual visits, or through asynchronous messaging using eVisits.

Additional emerging telemedicine technology includes teleauscultation through digital stethoscopes, teledermatology through digital dermatoscopes and telecardiology through home electrocardiograms and smartwatches. These technologies, if proven reliable, may expand the diagnostic capabilities of telemedicine clinicians.

Beyond this, patients are recording personal health-related data using smart-watches, smartphone applications, social media, and web cookies, all of which may potentially be utilized by health care providers in the future.

Furthermore, some providers in Sweden are using fully automated patient-provider chats to triage patients using pre-defined algorithms based on existing phone triage protocols, though no provider has yet to adopt more advanced artificial intelligence (AI) using machine learning or deep learning for provider decision support.

The role of each of these telemedicine variations is still emerging. If they are to be used separately or in combination remains to be explored in various clinical contexts.

Digital visits in primary care

While organ specialist outpatient clinics and inpatient care may benefit from increased telemedicine adoption, primary care accounts for 61% of all health care visits at 18% of public health care costs in Sweden (26). Thus, telemedicine adoption can potentially have a large impact on primary care organization and resource utilization.

Furthermore, Swedish primary care currently faces issues of low access to care and lack of continuity of care, contributing to low patient satisfaction (27). Given the low barrier of access using digital visits, it is therefore not surprising that several private health care providers have successfully brought such services to the Swedish market around 2013 to 2014 ("digital-only" primary health care providers). In December 2017, 30 000 digital visits to physicians were registered in Sweden, accounting for 2% of all primary care visits (28). By January 2020 the corresponding number had increased to 126 000 consultations and as the COVID-19 pandemic commenced, in March 2020, 206 000 consultations were registered (29).

Digital visit have thus disrupted primary care in Sweden, and several primary health care providers, both public and private, have created their own platforms, deployed various digital tools, and different protocols for patient management.

There is therefore a large heterogeneity in digital visits, making research evaluating their effects challenging. Studies need to be focused enough to make relevant evaluations on novel technology, but also provide generalizable knowledge to optimize safe implementation of telemedicine technology.

For instance, one national systematic review published as a report concluded that there was insufficient evidence for assessment of new symptoms using digital visits, but only included studies with virtual visits i.e., synchronous video-based communication, meaning the findings cannot be generalized to other forms of digital visits, such as eVisits (30).

Key variations in digital visit platforms

To correctly interpret and plan research in telemedicine, it is essential to establish a framework regarding which aspects of digital visit services can vary. A digital visit may be considered to consist of three phases, pre-consultation, during consultation, and post-consultation. Each phase may implement various telemedicine technology and offer different possibilities (Figure 1)

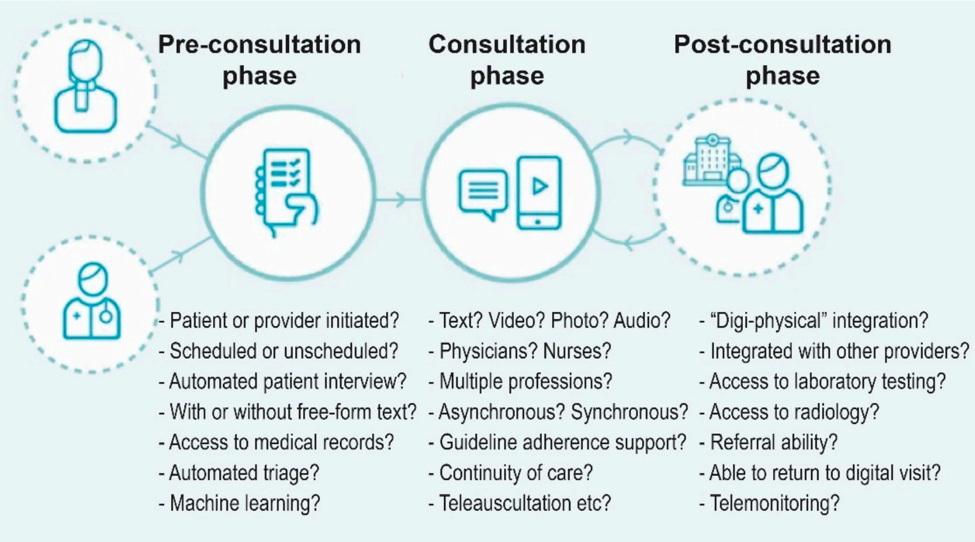

Figure 1
The three phases of a digital visit with possible variations at each phase. Original image from Doctrin AB, modified by AE and used with permission from Doctrin AB.

Considering the possibilities above results in many variations of what a digital visit may look like. Research focused on digital visits may thus fail to highlight the impact, beneficial or not, of the various components of a visit. Beyond this, considering the larger context of telemedicine integration as part of a complex system makes predicting outcomes challenging. There is no consensus regarding how the optimal telemedicine system should be designed (31).

Specifics of digital visits assessed in this thesis

The digital visit platform, Flow, evaluated in the current thesis (henceforth referred to as 'the platform') is developed by Doctrin, a private MedTech company, and sold to several health care providers in Sweden. While the platform has evolved and added additional features and functions over time (including the option to proceed to virtual visits), the features available in the platform during the time the study was conducted are explained in detail below (Figure 2). Most importantly, the platform was focused on eVisits.

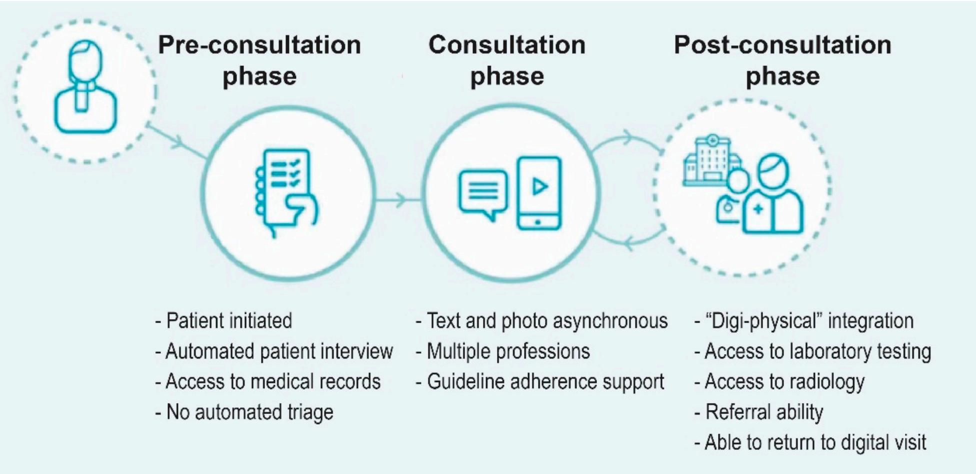

Figure 2
Key features of the eVisit platform assessed in this thesis. Original image from Doctrin AB, modified by AE and used with permission from Doctrin AB.

Pre-consultation with automated patient histories

After digital identity verification, the platform allows patients to select their chief complaint from an existing list of symptoms. This initiates an electronic questionnaire, which initially lets patients use free-form text to specify their ideas, concerns, and expectations (ICE) from the consultations as is best practice in primary care (32). This is followed by an algorithm-controlled symptom-specific set of questions (including multiple choice, drop-down, rating scales, and free-form text questions) where subsequent questions are generated based on an algorithm considering prior answers. Images can also be attached when relevant. Answers are presented to health care staff as a structured symptom report to support staff in making subsequent recommendations.

Consultation with asynchronous text-based communication

Once the automated patient history is completed, the patient and health care staff can communicate using a two-way text-based chat. Depending on the health care provider's choice, the first staff to contact the patient may be a nurse or a physician. The chat allows the staff to inform patients regarding the assessment of the automated patient history report and creates further dialogue to establish an action plan. Patients can send additional images in the chat if needed.

While text-based dialogue occurs in real-time, communication occurs asynchronously as either party may leave and re-access the platform before the chat is concluded. This allows for staff to physically consult each other to aid clinical decision-making regarding patients in the platform, but also allows staff to attend to telephone appointments, office visit appointments, and other patients in the platform, simultaneously. Staff can also send additional symptom-based patient questionnaires and clinically validated rating scales for additional information. All staff who have access to the platform can invite each other to participate in the chat, to allow multi-disciplinary management depending on the specific patient's needs.

These features set the platform apart from synchronous video-based digital visit platforms, which do not allow for parallel patient management as they instead represent digitization of existing office visits.

Post consultation with "digi-physical" integration

Once the assessment is complete, the clinician can determine if the patient can be managed by self-care, a prescription, or requires additional work-up with, for example, laboratory testing, or if there is a need for a physical office visit. In the latter case, staff can schedule a visit at a physical clinic within the same health care provider within 48 hours if needed, or refer the patient to other health care providers, including emergency departments. Scheduling a visit within the same health care provider allows staff to forward the automated patient history report to the relevant clinic and thus allows for "digi-physical" management, though the physician receiving the scheduled physical appointment may or may not be the same physician attending the eVisit at the time of the study. Thus, the platform serves as a first point of contact with physicians determining the adequate level of care, be it telephone, digitally or physically. In traditional Swedish primary care, this is usually conducted by nurse telephone triage (see 'Triage' in the next segment).

In the current thesis, "digi-physical" care could represent the possibility for Capio Go physicians to transition the eVisit to a scheduled physical visit within 48 hours at other Capio PHCCs if indicated (papers III and IV), or PHCCs using the platform to offer eVisits to registered patients, with nurses or physicians scheduling patients for a physical visit when appropriate (paper II).

What do we know about eVisits in primary care?

Staff buy-in vital for technology implementation

Implementing eVisits into clinical practice is, like most types of change, likely to be met with resistance (33). Indeed, previous systematic reviews mention physician reluctance for use as a barrier to successful implementation of digital tools (34-36). Previously implemented eVisit technology has in other health care contexts been found to be limited in its use (37, 38). In telepsychiatry, where outcomes and diagnoses have been shown to be comparable to physical visits, health care providers have been identified as the barrier for successful implementation (39, 40). At the same time, research indicates that physicians using asynchronous communication can appreciate development of a specific communication skill set related to this form of communication (41).

Potential benefits of eVisit technology may thus never be realized if staff are not willing to adopt the technology. Change management theories suggest involving key stakeholders (in this case primary care staff) in problem identification for successful change implementation. Specifically, normalization process theory specifies key processes part of successful digital health system implementation (42):

I. **Coherence**: work to let users uniformly "make sense" of what the system is, how it differs from existing practice and for what purpose it is to be used.

II. **Cognitive participation**: work to actively engage and involve users in the technology.

III. **Collective action**: work to practically operationalize use of the technology on organizational, group and individual levels.

IV. **Reflexive monitoring**: work to reflect over the usefulness of the technology.

Practices wanting to implement digital communication theoretically need to work with all four processes. This explains why a planned implementation, with implementation champions, and continuous evaluation and iteration are necessary for successful eVisit implementation (43). Staff education alone is not sufficient

(44). For successful eVisit adoption, it is thus essential to understand staff perspectives on working with such technology.

Pre-consultation automated patient history

The patient-provider consultation is arguably the central component of primary care and the work of general medicine specialists (45). There are many components of a successful consultation, including early identification of the patient's pre-consultation ICE with the patient leading the initial part of the consultation before the physician gathers additional information, resulting in a final shared decision on how to proceed (32). The information-gathering stage may potentially be replicated in a software algorithm as symptom-specific questions are relatively standardized in a "decision-tree" fashion.

Use of such software has been extensively reviewed. Using a computer algorithm as part of an automated patient history software to generate questions may collect more complete clinical data as the software does not forget nor is affected by stress and other externalities affecting human cognitive performance. Research also indicates that such data is accepted by patients, has high re-test reliability, and can provide more accurate data than available in the EHR. Furthermore, patients may share clinically meaningful information with the software that they otherwise would not share with a human clinician (46, 47).

From the clinician perspective, physicians value information from other humans higher than information from an automated patient history, even if the software provides more data. Large amounts of data, even though clinically relevant, may even be counterproductive as human cognitive limitations prevent such data from being fully processed and integrated into clinical decisions (46). Research on patient-related clinical outcomes is thus needed to verify the usefulness of automated patient history software.

Triage

In Sweden, to prioritize and route patients to the correct level of care has traditionally been conducted through nurse telephone triage. A variety of triage systems exist, usually based on expert consensus with varying levels of details and time required for triage (48). While triage is widely used globally, evidence indicates low reliability and unknown validity and cost-effectiveness (49, 50).

Digital alternatives to this approach have recently emerged as a more data-based, reliable, and time-efficient approach to triage but are yet to be rigorously evaluated.

Some platforms offer "digital triage", a term that is inconsistently defined in the literature. Some work as clinical decision support systems to health care staff in medical history taking to make traditional triage easier. Others describe digital triage as a fully automated decision-support system, which also implements data-based decisions using machine learning without the need for human involvement in this decision-making process. The latter means that the validity of such a system may change over time thus making validity particularly challenging to evaluate.

Consultation using text

At the time of planning this thesis, no qualitative research was published on staff experiences of digital two-way communication using eVisits in the Swedish primary care context.

Qualitative research on one-way text-based communication suggests that primary care physicians (PCPs) had generally positive experiences of such communication (51) regarding benefits to patients potentially saving time, with simultaneous concerns regarding security and poor integration into clinical practice with subsequently higher workloads (10, 38).

Outside of eVisit context, studies on two-way text-based communication were mainly mHealth studies based on mobile text messaging in low- to middle-income countries without a specific software platform (52). This research suggests that mHealth made health workers feel more connected to each other, co-operating better for higher care quality, as well as allowing for more work flexibility and an improved patient-provider relationship to a wider geographical range. Even though workers experienced improved workflow, some felt it created more work, with a desire for better integration into existing health systems, and that patients still needed face-to-face contact.

Clinical decisions during eVisits

Common chief complaints managed using eVisits

Previous research exploring the demographics related to eVisits demonstrated a range of chief complaints, with non-symptom-related administrative queries, such as refilling prescriptions or (re)scheduling appointments, being most common, followed by infectious symptoms (53-56) and rashes (57). While patients seek care for a wide variety of non-infectious symptoms, including musculoskeletal, dermatological, and psychiatric queries, the most common infectious symptoms include airway symptoms such as sinusitis pain and common cold symptoms, as well as urinary tract symptoms. Patients rarely seem to report high risk symptoms and hospitalizations following digital visits (58).

Infections in physical primary care

As the COVID-19 pandemic has demonstrated, digital visits play a key role for the assessment of infectious disease. Even before the pandemic, infections constituted 30% of physical primary care consultations in Sweden (59), with upper respiratory tract infections and urinary tract infections being most common (60). Guideline adherence in the management of these conditions is historically poor (61, 62) and thus warrants establishing infrastructures for improved guideline adherence for optimal patient outcomes.

Primary care and the threat of antibiotic resistance

Clinical decision-making is especially important for infections involving prescription of antibiotics, as widespread antibiotic resistance is arguably one of the largest threats to public health, and is predicted to cause more deaths than cancer by 2050 (63). Antibiotic resistance is associated with excessive antibiotic use (64), which has been increasing both globally (65) and in Europe (66). Livestock farming accounts for most antibiotic use in some countries, but such use has been limited within the European Union (67). The second major source of antibiotic consumption is within primary care, which in Sweden accounts for 61% of medical antibiotic consumption (68). Thus, reducing excessive prescription of antibiotics in primary care remains a viable target to preventing widespread antibiotic resistance.

It is of upmost importance to evaluate how various forms of digital visits influence prescription patterns. Local reports suggest some private digital-only primary health care providers over-diagnose and thus over-prescribe antibiotics (69), but it is still unknown if prescriptions differ between synchronous virtual visits and asynchronous eVisits.

Diagnostic testing as part of eVisits

As an accurate diagnosis is a prerequisite for antibiotic prescription on proper indications, the utilization of diagnostic tests in the context of eVisits is a relevant outcome for quality assessment. For instance, evidence suggests using negative rapid strep test (RST) as a “stopping-rule” after considering prescribing antibiotics for suspected streptococcal tonsillitis (70).

Previous research in the American health care context indicates that eVisits are associated with a lower frequency of imaging and laboratory testing (71, 72). Similar trends have been seen in research on virtual visits. It remains unclear whether these trends reflect digital visits having a relatively lower proportion of patients with indications for further diagnostic testing, or whether it reflects physician reluctance to order such testing.

eVisits and antibiotic prescribing

Antibiotic prescription rates associated with eVisits for various conditions have mostly been evaluated in the American health care setting. As the American health care system is more market-controlled, prescription rates may, to a larger extent, be influenced by factors such as patient satisfaction, compared to the European health care setting (73, 74). Comparisons have mostly been made between eVisits and various physical primary care settings, with mixed results.

Regarding airway related diagnoses such as tonsillitis, bronchitis or sinusitis, some studies indicate higher prescription rates in eVisits (72), while others find lower rates (75).

Regarding urinary tract diagnoses, studies indicate higher (72) or no statistically significant differences in prescription rates for eVisits (76).

Apart from eVisits, studies on virtual visits also have mixed results with higher antibiotic prescription rates compared to primary care settings in some cases (71), lower rates for sinusitis (77, 78). Compared to urgent and emergent care settings, no statistically significant differences in antibiotic prescription rates have been noted (8, 79). A larger analysis of virtual visits indicates no statistically significant differences in prescription rates (80).

This variation indicates that antibiotic prescription rates in the telemedicine setting are context dependent. Indeed, an audit study found significant variation in guideline adherence between virtual visit providers (81). Studies have also mostly focused on prescription rates related to certain diagnoses, rather than chief complaints. This may not be ideal for comparing prescription rates, as clinicians may adjust their diagnosis ad hoc to justify their prescription. In Sweden, for instance, physicians may register the diagnosis pharyngitis when deciding not to prescribe antibiotics and register the diagnosis tonsillitis when deciding to prescribe antibiotics. Thus, studies using cohorts based on chief complaint rather than registered diagnosis are warranted. In addition, more studies on eVisits, as opposed to virtual visits, are warranted.

Health care utilization after digital visits

The influence of digital visits on primary care utilization and resources

While several digital visit providers propose that their systems allow for more efficient primary care consultations and reduce primary care workloads (82, 83), evidence suggests that using digital visits as the first line of assessment is more likely to increase PCP workloads due to so-called “supply-related demand” (6, 84). For example, while physical visits may decrease following digital visit implementation, total health care contacts may increase (85, 86). Similarly, telemonitoring, while reducing hospital readmissions, may increase overall health care utilization (87). When considering effects on physical visit utilization only, some studies indicate a reduced (53, 88, 89) or stable (90) utilization when digital visits are implemented. There is disagreement as to whether attending to this increased demand for primary care represents an important fulfilment of a previously unmet health care need, or an unnecessary misuse of primary care resources.

Research on digital visit cost suggests lower per-episode cost (71, 91, 92), but a higher total health care cost due to supply-related demand (93), though some research also indicates health care cost savings (94), especially when considering patient-related cost-savings (28). Choosing to implement digital visits for certain patient groups, such as those with chronic conditions, may be an alternative if health care cost savings are a priority (95).

Finally, it is worth considering that the mean age distribution of digital visit users is lower than that of the typical primary care population (55, 96, 97) which may result in a relative reduction in primary care access for comorbid elderly populations with lower digital literacy if digital visits become ubiquitous. Conversely, younger populations who previously did not access health care services (98), as well as remotely located populations (99), may benefit from health care interventions through digital visits, which may have positive downstream effects on public health, though this remains a hypothesis.

Revisit frequency after eVisits

While there are various interpretations of the meaningfulness of additional health care contacts generated by supply-related demand, a separate issue is related to how efficacious digital visits are in concluding generated visits without additional need for physical care. From the patient perspective, 93% of urinary tract infection patients using digital visits have reported they would have otherwise sought physical care (100). However, patient perceptions may not correspond to their actual behavior.

Previous research on digital visits for management of certain acute airway-related infectious symptoms found, without control groups, that roughly two thirds of visits were concluded without the patient having any further health care utilization. Findings from studies comparing digital visits to office visits in various primary care contexts are conflicting, finding higher (78, 101), lower (102), or no differences in subsequent health care utilization (71, 72). Most research is conducted on virtual visits in the American health care setting as opposed to eVisits in non-American health care settings. One large primary care study in the American setting found that eVisits "trigger" additional 6-7% additional office or phone visits (84). Another large, well-controlled, cohort study found that re-visit frequency was higher after direct-to-consumer telemedicine assessment of infectious symptoms compared to physical assessment (10% vs. 6% follow-up within 21 days) (80).

It may be worth considering that failure to conclude an errand through a digital visit does not necessarily render the digital visit inappropriate, as such visits may provide a patient history and set the basis for a more efficient physical follow-up visit focused on patient-centered physical examination without physicians being preoccupied with identifying patients' ICE. More research is needed in various clinical contexts, as findings currently are mixed with regards to efficiency of physical visits following digital visits (55).

Digitalization using machine learning

The use of AI to process vast amounts of clinical data is perhaps the most intriguing aspect of health care digitalization. The use of machine learning is claimed to lead to faster and better clinical decisions compared to humans due to its ability to process large data volumes, although evidence of its efficacy is limited (103). While AI is a broad term which includes simple software algorithms, the contemporary colloquial use of the term "AI" is usually referring to some form of machine learning, including deep learning, where suggested decisions may adapt on prior data in various contexts. The lack of structured medical record data and data transfer between systems limits the amount of data available for such systems to function optimally (104). Contemporary use of machine learning for diagnosis has been most successful using radiographic data such as fundus imaging and mammography or magnetic resonance imaging but has, in most contexts, only been able to provide decision support rather than substitute clinicians in setting a medical diagnosis (105). However, simpler algorithm-based clinical decision support systems have also been shown to improve prescribing (106).

Acquiring structured data from patients upon presentation for diagnosis through "symptom checker" are rarely rigorously evaluated and, while potentially saving clinician time and resources, may also put patients at risk (107). The field is, however, rapidly evolving, and some symptom checkers may be sufficiently accurate for clinical use (108). Nevertheless, known research has not yet evaluated how these digital tools affect patients in a clinical setting.

Unstructured data may still be clinically useful, but performance of such approaches may still need improvement. One interesting study used deep learning on over 700,000 unstructured patient records to predict patient diagnosis in 10 training patients. Compared to using simple characteristics from the EHR (medications, procedures, lab-tests) as predictors, deep-learning-methods were better able to predict diagnoses, predicting diabetes particularly well (109). The clinical implications and applicability of such systems are still emerging.

Rationale for the thesis

At the time of starting this thesis, no peer-reviewed internationally published clinical research existed concerning digital visits in Sweden. Several private health care providers exclusively offer digital visits, resulting in a perception of a fragmented primary care system in Sweden with reduced continuity. Publicly funded local authorities were implementing their own digital visit services, and research regarding patient-safety, effects on clinical decisions and health care consumption in the Swedish context did not exist. It was also not obvious what role eVisits specifically should have in primary care.

As our research group had a high level of professional clinical experience and familiarity in clinical research, the focus was not placed on economic factors related to digital visits. Relevant clinical research questions related to eVisits included effects on health-related outcomes such as effects of risk factors for chronic diseases, morbidity, and possibly mortality. However, such outcomes may require complex interventions and data collection over longer periods of time than the current thesis allows. Therefore, focus was placed on process-related outcomes such as triage decisions, prescriptions, laboratory testing, health care contacts and clinical decision making. To add a complementary qualitative dimension to the understanding of eVisits in Sweden, stakeholder experience was also chosen as a relevant outcome to explore in this thesis. We also sought to explore how machine learning could be used to automate certain processes of clinical decision-making, such as triage.

All in all, integrating results from the process related outcomes in this thesis together with existing research in the field, as well as clinical primary care experience, can culminate in an evidence-based proposal for what role eVisits should have in the Swedish primary care context.

Aims

Overall aim

To evaluate eVisits with regard to digital communication between patients and health care staff, clinical decision-making, and subsequent care utilization in Swedish primary care.

Specific aims

I. To investigate interrater reliability between human physicians and an automated machine-learning-based triage method, as well as evaluating interrater reliability of triage decisions between a panel of physicians assessing the same patient histories from an automated patient history software.

II. To explore how family medicine physicians and nurses experience the implementation and use of digital communication in the form of automated patient history software and chat-based patient-provider communication.

III. To investigate if eVisit management of sore throat, other respiratory symptoms, or dysuria was associated with higher rates of antibiotic prescription compared with usual management using physical office visits.

IV. To investigate whether there were any differences in associated frequency of physical healthcare contacts following initial management of respiratory and urinary symptoms using traditional office visits compared to "digi-physical" management.

Methods

Study designs

Different methods were used to evaluate various outcomes related to eVisits in primary care (Table 1). Paper I used a simple comparative method to compare human triage decisions with machine-learning-based decisions.

To best capture end-user experience of using the eVisit platform in the primary care team, paper II used a qualitative approach with focus groups consisting of both nurses and physicians.

Finally, quantitative outcomes such as antibiotic prescriptions and follow-up visits of eVisits compared to traditional office visits were evaluated in papers III and IV, respectively, using an observational cohort study methodology. Office visit patients were recruited retrospectively by letters sent to their home address after their visit. eVisits were recruited prospectively in the platform prior to their visit.

Table 1 Summary of study characteristics included in the current thesis.

	Paper I	**Paper II**	**Paper III**	**Paper IV**
Design	Comparative study	Qualitative study	Observational study	Observational study
Sample	Anonymized automated patient history reports triaged by human panel and machine learning model (n=276)	Primary care physicians (n=9) and primary care nurses (n=10) from three primary health care centers across Sweden using the platform	eVisits (n=3847) and office visits (n=759) for adults with sore throat, dysuria, or respiratory symptoms	Adult eVisit patients (n=1188) and office visit patients (n=599) with respiratory or urinary symptoms
Primary outcome	Triage agreement between humans and machine learning model	Staff experience with the implementation and use of automated interviewing software and asynchronous communication	Antibiotic prescription within three days of the index visit	Subsequent physical visits to physicians within two weeks of the index visit, excluding the first 48 hours
Assessment	Need of urgent physical examination as per panel majority vote or model decision	Focus-group interviews	Prescription recorded in electronic health record	Physical physician visit recorded in Region Skåne's Care Database (RSVD)
Statistical analyses	Inter-rater reliability using Cohen κ, percentage agreement	Qualitative content analysis as per Graneheim and Lundman	Chi-squared test, multiple binary logistic regression	Chi-squared test, multiple binary logistic regression

Setting and participants

The Swedish health care system

Sweden's primary care system is almost entirely publicly funded, with only 6% of the population having access to private health care insurance (110). Public health care has a decentralized organization, being provided by 21 local so-called regions (roughly corresponding to counties). Home care and elderly care, however, are provided by 290 municipalities, of which there are several in each region. Each region varies in how they fund their health care systems, with combinations of capitation and pay-per-services models implemented throughout the country. Patients pay minor fees out-of-pocket for visits, hospitalization days and medications, up to a national ceiling of around 1100 SEK (125 USD or 110 Euro) per year for visits and 2300 SEK (265 USD or 225 Euro) per year for medications, after which all costs are publicly funded.

Patients in need of health care assessment may call the national service number 1177 for nurse triage regarding where to seek care. Patients may also choose to contact a PHCC, usually open between 8am and 5pm, or out-of-hours urgent care clinics open between 5pm and 10pm or seek care directly at the emergency department of their nearest hospital.

Regions have their own PHCCs, but also make agreements with private health care sectors who bill regions for primary care services. This includes digital health care services, which today are provided by all regions as well as private health care providers with regional financial agreements. Since the patient choice reform of 2010, patients can register at any PHCC they wish, and the center is then reimbursed by the region.

As each region had separate processes for implementation and reimbursement of digital visits, many private digital health care providers registered in the Jönköping region, which was perceived to accept and encourage development of telemedicine (personal correspondence with private health care provider management). Capio Go also registered in the Jönköping region on the 31st of May 2018.

Data sources

The company creating the platform or the local health care providers provided access to data used in this thesis. As the platform was implemented throughout Sweden, several private PHCCs were using it when the thesis commenced.

Paper I

While the platform was being used in slightly different ways at each clinic, all clinics were asking patients for an automated patient history based on their presenting symptom, which was then summarized as a report to health care staff for assessment. Data from these symptom reports were fully anonymized and stored allowing us to use the symptom reports to evaluate how they were assessed by humans versus a machine learning model in paper I.

Paper II

We were also informed regarding which PHCCs in the country were using the platform and were able to purposively contact site managers to invite staff for participation in focus group interviews for paper II. The PHCCs recruited were owned by either Capio or Praktikertjänst, two of Sweden's largest private primary health care providers.

Papers III and IV

For the remaining papers, data regarding patients initially assessed using office visits were acquired from 16 Capio PHCCs in Skåne Region; a county accounting for around 13% of Sweden's population. Data regarding patients initially assessed using eVisits was acquired from Capio Go, Capio's national digital primary care service, offering eVisit assessments seven days a week from 7am to 10pm since May 2017. eVisits conducted at Capio Go use the same basic software as the platform used by some PHCCs. While Capio Go offers eVisit services nationally, they are only able to schedule patients who decide to register at a Capio PHCC. Patients registered at other PHCCs are asked to contact their clinic for continued management.

For both papers III and IV, we chose to only include adult patients, as the consent process was more complicated for children. Paper III included office visit patients with a visit to either one of the 16 PHCCs in Skåne i.e., a county-wide population. eVisit patients were included if they had been in contact with Capio Go i.e., a nation-wide population. Comparing discrepancy was less relevant for paper III as antibiotic prescription was assessed as the primary outcome. For paper IV, where subsequent health care contacts was the primary outcome, only Capio Go patients residing in Skåne were included, to make sure that both groups had access to similar health care facilities after their index visit.

Procedure

Paper I

For paper I, human physician triage decisions based on digital symptom reports were registered using a web-based platform where physicians could access the platform through a unique link. Decisions were registered digitally and could then be compared to the machine learning model, which was presented the same symptom reports in analyses conducted by our co-authors at KTH. Comparative analyses were also conducted by our co-authors at KTH and discussed with the entire research group before drafting the manuscript.

Paper II

For paper II, focus group interviews were conducted by two co-authors travelling to each PHCC. For each interview, we decided who will use the interview guide and who will observe participants and guide the main interviewer in making sure everyone participates. Subsequent coding and creation of categories was also conducted by one co-author, with support from remaining co-authors for interpretation and theme generation.

Papers III and IV

For papers III and IV data, the recruitment process was set up in collaboration with Capio, who use software developed by Medrave AB able to search through medical records and extract data in Excel format, while only allowing the health care provider to extract personal data if needed.

For eVisit patients, we implemented an invitation to participate into the platform during the automated patient history taking software and implemented a mandatory "yes/no" keyword registration in the medical record regarding if patients had consented. Medrave could then access this keyword to extract Excel sheets from patient medical records with relevant patient data.

For office visits, Medrave AB created an algorithm for searching free-form text for certain key words, we were able to identify patients who had been in contact with Capio's PHCCs in Skåne regarding airway symptoms or urinary tract symptoms. As Capio did not have updated addresses to all these individuals, we coordinated an application to the Swedish state personal address register (SPAR) so that Capio was able to send letters for patient recruitment. As response letters were returned, we registered and stored responses until we had adequate power to proceed to data collection. Patients who consented to participate in the study were reported to Capio who then used Medrave to extract Excel sheets from patient medical records with relevant patient data.

Excel sheets with data from eVisit patients and office visit patients were merged and data from Region Skåne's Care Database (RSVD) were also added to the spreadsheet. RSVD provides data on all registered contacts in the Skåne region, with the exception of some fully private health care providers without reimbursement from the Skåne region. RSVD also includes visits registered in regions outside of Skåne, but with less specifics regarding the nature of these visits. Most outcomes were thus automatically extracted, with some variables manually extracted and added. Several medical students aided us in manual data extraction and validation of automatically extracted data through review of electronic medical records. All analyses related to paper III and IV were conducted with support from all co-authors.

Measurements

This thesis evaluates several aspects of the eVisit-based process of care and for each part of the process, a specific measure was chosen (Figure 3).

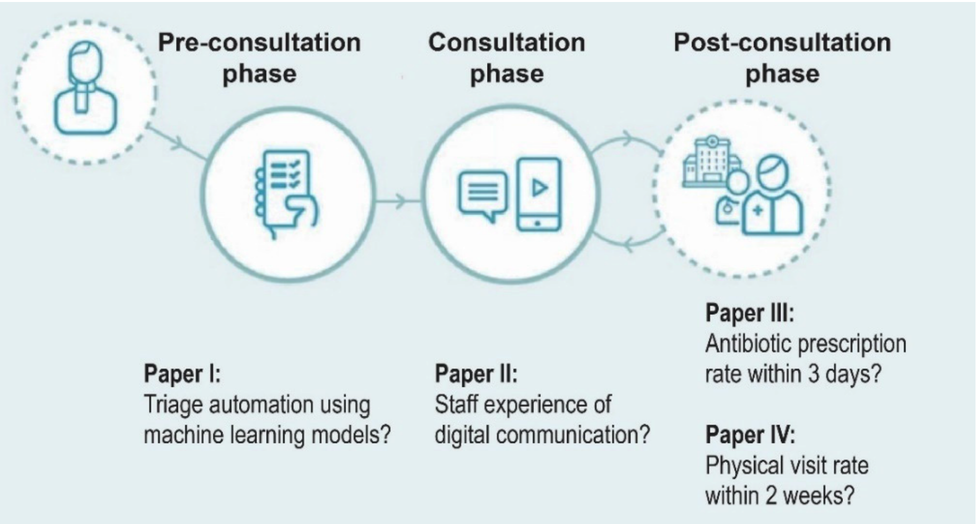

Figure 3
Illustration of the eVisit-based process of care with chosen measures for this thesis indicated in red.

The first part of the eVisit involves a patient-generated medical history report, which is triaged by staff to give the patient the appropriate level of care, be it a continued eVisit, a scheduled office visit or emergency care services. We explored to what degree machine learning could be used to make this decision and chose to compare triage decision to the majority decision of a panel of five physicians.

We also sought to explore the user experience of the automated patient history report together with two-way text-based patient-provider communication. While we initially strived to get both patient- and staff perspectives, we decided to prioritize staff perspectives as understanding and optimizing staff experiences ultimately allows them to do their best to help patients. As no quantitative variable adequately captures the depth of human experience, we chose a qualitative approach with categories, sub-categories and themes that better summarizes staff experiences.

After the automated patient history and text-based communication, eVisits for infectious symptoms involve clinical decisions, including whether to prescribe antibiotics. Since eVisits may involve watchful waiting up to 72 hours, paper III measured antibiotic prescriptions within three days of commencing the eVisit, and thus compared this to antibiotic prescriptions within three days of office visits.

Finally, eVisits may be followed by subsequent physical visits within or beyond primary care. Paper IV primarily focused on subsequent additional physician assessment within two weeks of the initial assessment, excluding additional physical assessment within the first 48 hours as is part of the "digi-physical" model of care.

Statistical analyses

Paper I

Each paper involved a unique analytical approach given the variations in methodology. Paper I, a comparative study, involved an initial analysis to generate the machine learning model, which was entirely conducted at KTH. Subsequently, the model's triage decisions were tested in comparison to the majority vote of a panel of five human physicians. As we only had two triage groups ("No need for urgent physical examination" or "Need of urgent physical examination"), using percentage agreement as a primary outcome may overestimate the level of agreement due to chance. We therefore used Cohen's kappa, which presents percentage agreement minus the probability of agreement due to chance, where kappa < 0.2 generally is regarded as low agreement, and >0.8 as almost perfect agreement (111). Cohen's kappa is also ideally used in samples with two raters (the human panel vs the machine learning model) and where all samples are rated by all raters (fully crossed) as was the case in our study. We considered alternatives such as Siegel and Castellan's kappa, which are more appropriate if raters tend to choose one option over others.

Paper II

Regarding paper II, a qualitative study, qualitative content analysis of focus group interviews was conducted using Graneheim and Lundman (Graneheim & Lundman, 2004), where manifest categories and sub-categories are generated after coding, followed by latent analysis into themes related to staff experience of using the platform. While there are alternative approaches to qualitative analysis, this approach allowed us to involve researchers not present at the focus group interviews in our analysis (triangulation). Analysis related to paper II was conducted in NVivo version 12.

Papers III and IV

Papers III and IV involved a more classic quantitative analysis related to cohort studies, with t-tests for comparing continuous variables, Chi squared tests to compare categorical variables, and regression analyses to adjust for confounding variables. The major difference between paper III and IV was that paper III analyzed a larger cohort on the "visit" level, while paper IV focused on a smaller cohort residing in Skåne, analyzed on the "patient" level. The rationale behind this was that the indication of antibiotic prescription, the primary outcome of paper III, is assessed "de novo" at each visit, even though the patient has previously been assessed. Health care contacts, the primary outcome of paper IV, are related to the same patient as one may assume that the likelihood of additional contacts is reduced with each subsequent visit in the context of acute infectious symptoms. Thus, analysis on the "visit" level may have led to the same patient being included twice in the analysis and resulted in an underestimation of subsequent health care contacts. Analyses related to papers III and IV were conducted in IBM SPSS Statistics version 26.

Additional literature searches

As eHealth is a relatively novel field with a rapidly increasing publication rate, the current discussion will not be able to consider the totality of the evidence available. Rather, the discussion is based on the non-systematically reviewed literature incidentally encountered through various meta-analyses, review articles, conferences, collegial dialogue, and sporadic literature searches. Speculation may be made with regard to research questions answered by existing publications of which the author is unaware.

To identify recently published literature when writing the framing report of the thesis, PubMed was searched using various search terms (Figure 4). All titles were reviewed, with abstracts of potentially relevant titles reviewed, and finally selected papers fully reviewed. The search terms used are listed below:

- 2021-12-26: "Primary Health Care" [Mesh] AND "Remote Consultation" [Mesh]: Between 2018 and 2021. 137 hits. 61 abstracts reviewed.
- 2021-12-27: "Digital-first" OR "digital first". 24 hits. 6 abstracts reviewed.
- 2021-12-27: (eVisit OR "digital online consultation" OR telehealth OR telemedicine OR "digital consultations" OR "virtual visit" OR "e-consultation") AND "primary care" AND (asynchronous OR chat). Between 2018 and 2021. 67 hits. 16 abstracts reviewed.

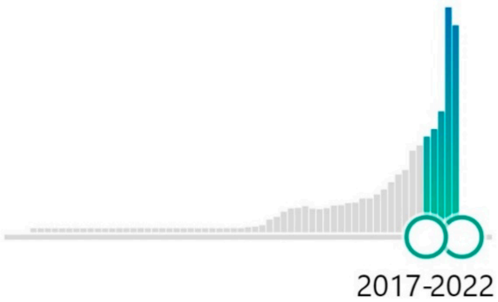

Figure 4
Pubmed search conducted on November 27th 2021 using the term “eHealth”. Annual publication rates are increasing rapidly, with 3652 publications in 2017, when the current thesis started, compared to 8790 publications in 2020.

Ethical considerations

All studies in the thesis have been approved by the Swedish Ethical Review Authority (see reference numbers in each individual paper). Generally, ethical considerations have been focused on ensuring participants consent to having parts of their EHR shared as part of papers III and IV.

Regarding paper I, the collaborating companies had to ensure that the automated patient history reports did not contain any data that would allow triaging physicians to identify the patient.

Results

Results below are presented following the eVisit-based process of care, starting from the automated patient history, and ending with the possibility for "digi-physical" care (Figure 3).

The automated patient history

As a basis for triage decisions (paper I)

Paper I demonstrated that agreement in triage decisions between physicians triaging the same automated patient histories was low (Light's kappa 0.20, range 0.10 – 0.30) when triage decisions were dichotomized to either urgent physical assessment (urgently to a PHCC or emergency department) or no need for urgent physical assessment (eVisit or not urgently to a PHCC). Subsequently, agreement between humans and a machine-learning-based triage was low (Cohen's kappa 0.17 for the majority vote of the panel of physicians and Cohen's kappa between 0.03 and 0.24 when comparing to individual physicians).

Looking at each of the five physicians' triage decisions, there was considerable variation in the degree to which physicians chose to proceed with an eVisit (From 29.4% to 69.2% of cases), schedule a non-urgent PHCC visit (2.7% to 14.4% of cases), or to schedule an urgent PHCC visit (16.7% to 50.8% of cases) (Unpublished data).

Among cases triaged to an eVisit, physicians were given the option to specify their intention with the eVisit as either requesting more information or giving self-care advice. Of the 747 cases triaged to an eVisit, 361 (48.3%) were specified as planning to request more information beyond that presented in the automated patient history report, while 84 (11.2%) were specified with the intention to give self-care advice. In the remaining 302 (40.4%) cases triaged to eVisit, physicians did not specify their eVisit intentions (Unpublished data).

Table 2
Triage decisions after reading 299 automated patient history reports (unpublished data related to paper I)

	eVisit	Non-urgent PHCC visit	Urgent PHCC visit	Emergency department visit	Inappropriate for triage	Missing
PCP 1	186 (62.2%)	25 (8.4%)	72 (24.1%)	6 (2.0%)	10 (3.3%)	0 (0.0%)
PCP 2	88 (29.4%)	36 (12.0%)	152 (50.8%)	3 (1.0%)	20 (6.7%)	0 (0.0%)
PCP 3	146 (48.8%)	8 (2.7%)	126 (42.1%)	6 (2.0%)	8 (2.7%)	5 (1.7%)
PCP 4	207 (69.2%)	37 (12.4%)	50 (16.7%)	0 (0.0%)	5 (1.7%)	0 (0.0%)
PCP 5	120 (40.1%)	43 (14.4%)	117 (39.1%)	4 (1.3%)	12 (4.0%)	3 (1.0%)

Staff experiencing digitally filtered primary care (paper II)

The results above from paper I demonstrate varying triage decisions based on automated patient history reports, consistent with the theme of "digitally filtered primary care" experienced by staff in paper II (Table 3). The automated patient history was experienced as a filter of information with both the benefit of *superhuman capacity* with regard to the volume of clinical data collected and presented, but simultaneously *an incomplete system not suitable for all patient queries* and some words interpreted with *ambivalence and uncertainty,* resulting in *incomplete information transfer.*

Table 3
Categories and sub-categories relate to the theme of digitally filtered primary care (Paper II)

Sub-categories	Categories	Theme
Not suitable for all queries Digital communication as a partial solution An incomplete system	Doesn't Suit Everyone and Everything	Digitally filtered primary care
Incomplete information transfer Ambivalence and uncertainty Superhuman capacity Affects the patient–provider relationship	Fears and Benefits of Digital Communication	

Staff felt that communication through text was challenging as cues otherwise available through phone, such as voice tone or respiratory distress, or through an in-person visit, such as body language or findings of a physical examination, were unavailable. Words had to be interpreted literally, even when patients may exaggerate their symptoms.

> *In a conversation… one consciously ignores some things… Here it's 'on print'… that they have 'numbness in half of their body'… which looks a little worse than if they say it in a context where it is completely obvious that they don't… The 'human filter', it vanishes. – GP 4*

Staff therefore experienced that the information presented in text could be interpreted in various ways, resulting in uncertainty in how severe a patient's symptoms may be. Primary care nurses, who in most clinics conducted the first line of assessment in the platform, could therefore experience certain situations where triage could be challenging.

> *Yes, because I'm thinking if you look at the group presenting with anxiety and depression, for example, they get a lot of questions and then many of them specifically report suicidality or such, and… when one calls them, it isn't at all like they have written. – Nurse 4*

Asynchronous text-based patient-provider communication

Staff needed to adjust to a novel medium of communication (paper II)

Apart from the automated patient history report generated by the platform, paper II also explored staff experience related to chat-based communication with patients in the platform. While previous patient portal systems had allowed patients to send electronic text messages to their PHCC, the platform allowed for two-way communication. As this type of communication was more common in patients' everyday lives, as well as being offered by other private digital-only primary health care providers, staff felt that there were *expectations to be digital* from patients. Thus, there was a sense that the digital transformation was inevitable and partly involuntary. Naturally, there was an ongoing transition in workflow, as staff and management were experimenting with various scheduling models and strategies to address challenges that would arise, such as patients or staff not answering the chat when desired, or conversations about potentially severe symptoms where patients hadn't responded by the end of the day. Through continuous evaluation and improvement, staff experienced an *improved digital experience over time* (Table 4).

> *First it was a bit easy to make mistakes…if one had maybe five ongoing queries and maybe two girls around the same age or so to speak, it was easy to write to the wrong patient. ... until one develops a routine. – Nurse 1*

The chat-based approach with a pre-defined clinical issue in the automated patient history report *streamlined communication* with patients for simpler less complicated clinical issues such as prescription renewals or simple skin rashes. Staff felt that clinical decisions could more easily be discussed with colleagues as leaving the chat, or inviting staff to participate in the chat, was experienced as less cumbersome compared to asking patients managed through the phone to hold on or to be redialed.

Thus, the platform was experienced as facilitating clinical decision making in uncomplicated cases where staff felt they could trust the text-based data, but in more complicated, less clear clinical scenarios, the platform created uncertainty and was experienced as less useful.

Table 4
Categories and sub-categories relate to the theme of adjusting to a novel medium of communication (Paper II)

Sub-categories	Categories	Theme
Streamlined communication Improved interdisciplinary cooperation Unpredictable workload	Altered practice workflow	Adjusting to a novel medium of communication
Expectations to be digital Improved digital experience over time	Accepting the digital society	
Improved management of certain patient groups Accessible continuity	Safe and secure for patients	

Antibiotic prescription rates (paper III)

Odds ratios indicated significantly higher odds of being prescribed antibiotics within three days for office visits compared to eVisits, with the exception of patients with a chief complaint of dysuria where no significant differences between office visits and eVisits were noted (Figure 5).

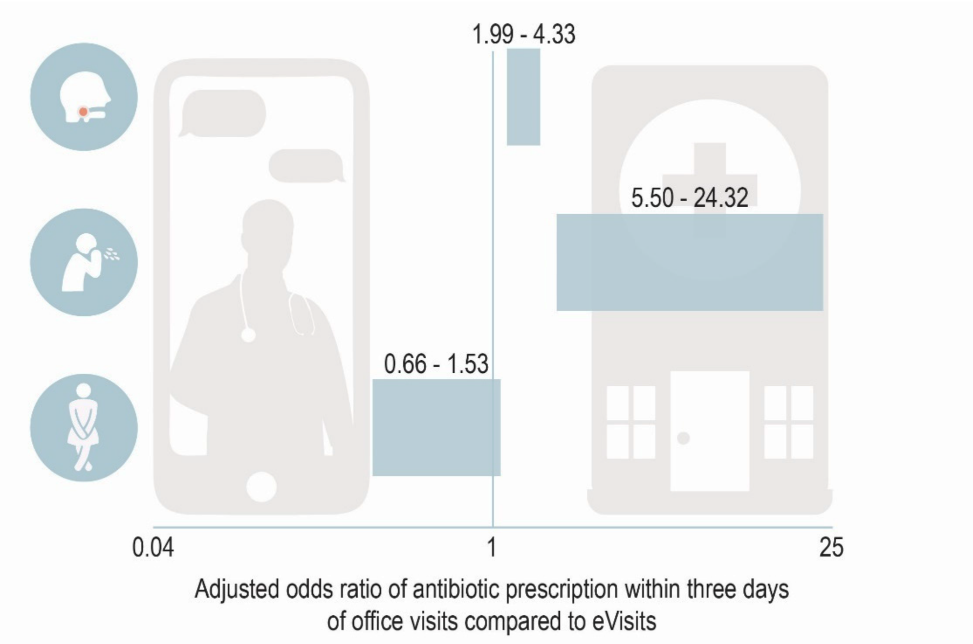

Figure 5
Adjusted 95% confidence intervals of odds ratios for antibiotic prescription within three days after office visits compared to eVisits (Paper III). The top icon represents sore throat, the middle icon cough/common cold/influenza, and the lower icon dysuria. Adjusted odds ratios generated from a multiple binary logistic regression model with antibiotic prescription as the dependent variable, and age, visit type, diagnoses of tonsillitis, viral upper and lower respiratory tract infection, pneumonia, and 'other' as independent variables.

Secondary outcomes in a subgroup of the cohort residing in Skåne with a chief complaint of sore throat indicated that eVisit patients more often had three or more Centor criteria documented (45.3% vs. 26.4%, $p < .001$) and had less cases diagnosed with tonsillitis, with more tonsillitis cases prescribed antibiotics on proper indications (97.7% vs. 40.0%, $p < .001$) (Table 5).

Table 5
Antibiotic-related outcomes among patients with sore throat residing in Skåne (Paper III). †: hypothesis testing not performed.

	eVisits (n = 289)	Office visits (n = 312)	P value for difference
Documented fever	116/289 (40.1%)	46/125 (36.8%)	.523
Documented tonsillar exudates	136/289 (47.1%)	37/125 (29.6%)	.001
Documented lymphadenopathy	182/289 (63.0%)	39/125 (31.2%)	< .001
Documented absence of cough	151/289 (52.2%)	96/125 (76.8%)	< .001
Three or more documented Centor criteria	131/289 (45.3%)	33/125 (26.4%)	< .001
Of which RST taken	105/131 (80.2%)	23/33 (74.2%)	.464
Of which positive	55/105 (52.4%)	10/23 (43.5%)	.439
Of which prescribed antibiotics	51/55 (92.7%)	10/10 (100%)	.379
RST taken within three days	132/289 (45.7%)	171/298 (57.4%)	.005
Of which indicated (three or more Centor criteria)	105/132 (79.5%)	23/70 (32.9%)	< .001
Of which negative	72/132 (54.5%)	107/171 (62.6%)	< .001
Of which prescribed antibiotics	4/72 (5.6%)	28/107 (26.2%)	< .001
CRP taken within three days	68/289 (23.5%)	137/312 (43.9%)	< .001
Of which over 100	13/68 (19.1%)	12/137 (8.8%)	.033
Antibiotics within three days (all diagnoses)	68/289 (23.5%)	124/312 (39.7%)	< .001
Diagnosed with tonsillitis (%)	81/289 (28.0%)	104/312 (33.3%)	†
Of which prescribed antibiotics within three days (%)	51/81 (63.0%)	86/104 (82.7%)	†
Of which RST taken (%)	44/51 (86.3%)	64/78 (82.1%)	†
Of which positive RST result (%)	43/44 (97.7%)	53/64 (82.8%)	†
Of which three or more Centor criteria (%)	42/43 (97.7%)	8/20 (40.0%)	< .001

"Digi-physical" staff experience (paper I)

Staff experienced patients feeling more secure with an easily accessible platform where they easily could communicate with staff with which they had an existing secure patient-provider relationship. Staff generally acknowledged that the advantage of using the platform in combination with a physical PHCC was the possibility of continuity of care and a much more seamless "digi-physical" experience for patient, meaning that patients registered at the PHCC could interchange between in-person visits and chat-based communication. For instance, patients could report their patient history to their physician and then schedule an in-person physical examination or ask follow-up questions to their physician after an in-person visit.

All focus groups mentioned feeling that the platform gave them an advantage over the private digital-only primary health care providers. This "digi-physical" model adopted by each PHCC using the platform was thus even more seamless than the "digi-physical" model offered by Capio Go, which has a separate staff working in the platform and sending the automated patient history report to staff at the patient's nearest Capio PHCC.

> *...I perceive that for my patients, mostly the sickest or most worried ones, it's a huge reassurance and very personal. When they can chat with me, and I can say like 'We don't need to book a new appointment'... 'Take it easy and be in touch. It may take a day before I answer, but I will answer.'... then they have a face associated to the person writing... then one can sometimes even crack a joke in the chat – GP 4*

Subsequent physical visits (paper IV)

Approximately 16% of patients with respiratory and urinary symptoms initially managed with an eVisit had an in-person physician visit within 48-hours as part of the "digi-physical" model of care. This was significantly higher than patients initially managed with an office visit at their PHCC, where only around 3% had an additional in-person assessment within 48 hours. Disregarding the first 48 hours, where the eVisit provider has processes in place to schedule patients for an office visit when needed, there was no significant difference in the proportion of patients with an in-person physician visit within two weeks of initial eVisit assessment compared to initial office visit assessment (Figure 6).

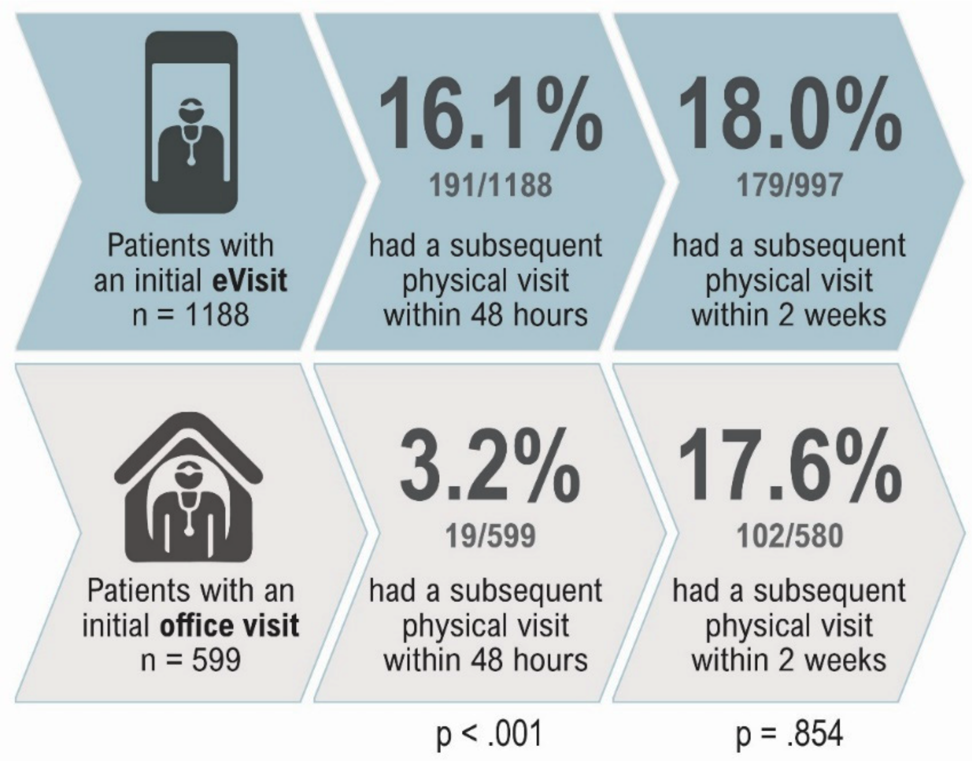

Figure 6
Proportion of patients with a subsequent in-person physician visit after initial assessment through an eVisit or an office visit.

Subsequent digital visits in the Jönköping region

Digital visits including Capio Go

During the study period when all known private digital-only primary health care providers, including Capio Go, were registered in the Jönköping region (May 31st, 2018, to April 30th, 2019) there were 1207 index visits in the study sample, with 707 (58.6%) having at least one follow-up registered in another region within two weeks. 702 (98.7%) of these were registered in the Jönköping region.

There were statistically more registered contacts in the Jönköping region within two weeks in the eVisit group compared to the office visit group (693/979 (70.8%) vs. 5/228 (2.2%), $p < .001$) (unpublished data).

Digital visits likely only including "digital-only" providers

During the study time period when Capio Go was not registered in Jönköping, but other private digital-only primary health care providers were (March 29th, 2018, to May 31st. 2018) there were 261 index visits in the study sample.

There was no detectable significant difference in registered contacts in the Jönköping region within two weeks in the eVisit group compared to the office visit group (6/212 (2.8%) vs. 0/55 (0.0%), p = .207) (unpublished data).

Discussion

Principal findings

This thesis has, through evaluation of one of Sweden's most commonly used eVisit platforms, evaluated the usefulness of automated patient history combined with a text-based two-way communication between patients and providers in various stages of the digital process of primary care.

Physicians seem to vary greatly in how they interpret and triage the same set of automated patient history reports, making automation of the triage process using human decisions based solely on patient-reported data in the automated patient history unreliable.

Qualitatively, staff experience that eVisits differ from phone contacts and physical visits with regards to the type of patient data available for decision making (text and images as opposed to voice and body language/physical examination, respectively), creating an experience of "digitally filtered primary care" when using the platform. In certain clinical contexts, especially simple uncomplicated clinical issues with continuity of care, the communication modality offered by the platform had no experienced risks compared to traditional management. At the same time, the platform provided an efficient basis for clinical decision-making, both temporally (cases can be managed parallel instead of in series), and with regards to automated data collection and presentation (the automated patient history reports), compared to phone contacts and physical visits, requiring staff to "adapt to a novel medium of communication".

Using the platform to assess patients with sore throat was not associated with higher antibiotic prescription rates compared to in-person physician visits, even after adjusting differences in age and documented visit diagnoses.

While significantly more eVisit patients with respiratory- and urinary symptoms assessed using the platform had a higher associated in-person physician visit rate within 48 hours (as per "digi-physical" protocol) compared to patients with an initial office visit, no significant differences were noted in in-person physician visits after this initial period when following patients for two weeks.

Contextual factors for result interpretation

Paper I isolated the automated patient history

To fairly interpret the results, highlighting the various contexts in which the platform was used in each paper is relevant. Paper I isolated the automated patient history component, presenting it to a panel of physicians with various degrees of experience working with the platform and eVisits. This, among other factors, may influence to what extent physicians chose to triage automated patient history reports as in need of urgent physical examination. Furthermore, the format in which the extensive clinical information presented in the medical history reports is under constant development with the goal of making reports less overwhelming for staff, which may mean that agreement between physicians may become higher if information is presented in a more standardized fashion.

Paper II explored the platform at physical PHCCs

In paper II, the PHCCs used the platform to communicate with both previously unknown patients and patients that had previously been assessed physically. At some PHCCs, staff were able to transition from communication in the platform to physical assessment with staff scheduling visits to themselves if needed, allowing for person-level continuity. The continuity dimension seemed to be a valued component of digital communication, likely influencing the results as related to staff experience using the platform.

Papers III and IV assessed the platform in a separate organization

In papers III and IV, the platform was used as a standalone system with separate staffing from those working at physical primary health care centers. This meant that there was continuity on the health care provider-level, but as the physical PHCCs had separate staffing, the extent to which the automated patient history reports were successfully transitioned is unclear and may have been suboptimal compared to having person-level continuity. Patients who have an eVisit with a physician they know, and trust may be less likely to seek care opinions at other health care facilities. A large recent Norwegian study found large effect sizes and a dose-response relationship between physician continuity and reduced mortality, acute hospitalization, and use of out-of-hours care though such effects have yet to be demonstrated in the eVisit setting (112). Similarly, physicians may be more likely to recommend patients for an in-person visit or more likely to prescribe antibiotics (113) due to uncertainty created through assessing a patient they have not previously met in-person, though the impact of continuity on these factors in the digital visit setting remains speculative in the absence of context-specific research.

General contextual remarks

Apart from the level of eVisit experience among health care staff and the level of continuity, the language and technological literacy of the target population may, in particular, have influenced results in all papers. As the platform was only available in Swedish, non-Swedish speaking patients may have difficulties communicating clearly in the platform, affecting assessment of the automated patient history report, staff experience, treatment decisions and subsequent in-person visits. Similarly, the level of technical literacy in the population interacting with the platform may have influenced these outcomes. At the time of the study, essentially the entire Swedish population up to retirement were using the internet, as well as 56% of those aged over 76 (114). The latter number increased to 67% following the COVID-19 pandemic (115). This, along with several other factors, means results from this thesis cannot be generalized to other countries and health care systems.

Finally, as previously mentioned, the platform is constantly developing new features based on end-user and academic feedback. Thus, the automated patient histories are today clearer with regard to some of the limitations experienced by staff in paper II. The platform also features the ability to switch to a synchronous video visit, blurring the lines between eVisits and virtual visits. Thus, results should be interpreted with consideration for the inevitable discordance between academic peer-review and agile product improvement.

Methodological influences and limitations

Paper I

Choice of triage categories

Several methodological choices may have influenced the results in the current thesis and must be accounted for appropriate interpretation of results. Paper I identified low agreement between the majority vote and an automated machine-learning-based triage model when assessing the same set of automated patient history reports. The model was trained based on training data from one specific “expert physician” with both primary care and eVisit experience. Results may have differed if training data was provided from a wider range of physicians (though five new triage models based on each panel member did not perform significantly better than the used model). Furthermore, the physicians in the current study originally triaged reports to one of four categories:

1. Proceed with an eVisit/chat-based consultation
2. Refer the patient to a PHCC for non-urgent care
3. Refer the patient to a PHCC for urgent care
4. Refer the patient to the emergency department

These were then dichotomized into two categories: in need of urgent physical assessment (categories 3 and 4), and not in need of urgent physical assessment (categories 1 and 2). It is, however, not certain that proceeding with an eVisit is synonymous with triaging a patient to not needing urgent physical assessment. Physicians may simply have intended to acquire more information through the chat to be able to differentiate referring a patient for urgent primary care or directly to the emergency department. Indeed, at least 48.3% of reports triaged to an eVisit were specified as requesting more information beyond that presented in the automated patient history report. Results of paper I may thus have been different if all triaging physicians were asked to choose between the dichotomized triage categories directly.

Human decisions as triage gold standard?

The chosen outcome of paper I was agreement between machine-learning-based decisions and human decisions. If a machine learning model can make comparable decisions to human physicians, this would indicate that triage could be automated. An alternative approach would be to evaluate a clinical outcome, such as number of cases referred to an emergency department, longitudinally, as part of a randomized controlled trial or a cohort study. As we did not have access to any clinically implemented machine-learning-based tool, this was not possible.

Furthermore, there is also no ideal gold standard for triage evaluation. Using human decisions as the gold standard for triage decisions has several advantages as opposed to using the recommended level of care by a predetermined rule-based triage algorithm. Firstly, human decisions reflect the current clinical reality, as most primary care triage systems currently use medical staff to triage incoming calls. Secondly, rule-based triage may fail to consider contextual factors, which may make some reported symptoms less relevant; severe pain, weight loss, difficulty breathing, chest pain, and dizziness are all examples of such symptoms that need to be interpreted in their relevant context by a human. Finally, as there is no ideal triage algorithm, and as most algorithms are based on expert consensus, choosing one system as a gold standard may not be appropriate.

Inter-rater reliability measure

Inter-rater reliability (a measurement of what proportion of observed variance is explained by similarity between raters) between the machine learning model and the panel majority vote was measured using Cohen's kappa, and agreement between human assessors was measured using Light's kappa (the mean of all Cohen kappa pairs). This is the appropriate choice given two raters and a fully crossed sample (all included medical history reports were triaged by panel majority vote and the machine-learning model) without restricted range among raters. Cohen's kappa does not correct for uneven prevalence of urgent versus non-urgent triage decisions, in which case Byrt's kappa would be more relevant. We did not perform analysis with this kappa variant, which could potentially have given different kappa values. However, since our kappa values were relatively low, there would need to be a major difference in kappa values for our conclusions to change. Cohen's kappa was 0.17 in our study and Krippendorff suggests that tentative conclusions can be made once kappa is above 0.67 (116).

Paper II

Paper II used mixed focus group interviews to explore primary health care staff experiences of digital communication using the platform. In-depth interviews with individual participants would be an alternative approach but may not have captured insights generated from the interaction between physicians and nurses.

While we purposely sampled PHCCs that had implemented the platform, we may not have captured experiences of digital communication among staff in PHCCs who chose to abandon the use of the platform. Thus, our findings related to staff wishing to continue using the platform after a period of adaption may not be generalizable to all practices using the platform. It may have been relevant to sample PHCCs who had attempted to use the platform but decided to discontinue its use for additional potential insight into staff experiences.

Papers III and IV

Potential bias due to differing recruitment strategies

For papers III and IV, evaluating antibiotic prescription rates and subsequent in-person physician visits after eVisits compared to office visits, the ideal approach would be a randomized controlled trial. Unfortunately, it was not possible to randomize our target populations to the various PHCCs included in the study. The next best approach would be a prospective cohort study where participants were recruited prior to the evaluated outcomes. While we were able to recruit eVisit patients prospectively in the platform, we were unable to organize recruitment locally at each of the sixteen PHCCs included in the study prior to assessment. Instead, office visits were recruited retroactively using letters. Patients with a concluded office visit consenting via a written letter may also differ from patients consenting digitally prior to commencing their eVisit, presenting a potential source of sample bias in our sample.

Furthermore, the prospective recruitment and documentation of patient consent in the eVisit group meant that physicians were aware that they were part of a study in the eVisit group compared to the office visit physicians. This halo effect may have caused more favorable outcomes in the eVisit compared to the retrospectively recruited office visit group.

Potential bias due to patient identification strategy

While eVisit patients were all identified and invited to participate prospectively in conjunction with their eVisit, office visit patients were identified based on a properly documented chief complaint and invited retrospectively through letters of consent sent to their home address. As physicians vary in the way that they document chief complaints, this stage may already present bias as properly documented cases may differ from less properly documented cases. Chief complaints were automatically documented among all eVisit cases, making the eVisit group identified for recruitment and the office visit group identified for recruitment potentially less comparable.

Undocumented Centor criteria

Secondary outcomes of Paper III include documented Centor criteria (absence of cough, fever ≥ 38.5°C, tonsillar exudates, and cervical lymphadenopathy). These were documented in free-form text at the physicians' discretion in the office visit group, and through a mandatory checklist in the EHR in the eVisit group. Thus, the eVisit group had infrastructure outside of the platform, namely the EHR, facilitating proper documentation. The improved Centor criteria documentation in the eVisit group may reflect the platform enabling a focused chief complaint. Centor criteria presented in an automated patient history report and a subsequently focused EHR checklist, or management placing more emphasis on protocols for guideline adherence.

In the office group, undocumented symptoms were considered an absence, meaning that lack of documentation regarding cough was considered a Centor criterion. Furthermore, fever was not required to be specified ≥ 38.5°C to be considered a Centor criterion.

In the eVisit group, no physical examination was conducted, meaning that the physician decides if the patient history and attached photos alone are enough to regard Centor criteria present. While this may be possible for assessing absence of cough, fever, and tonsillar exudates, it is less certain whether lymphadenopathy can be assessed using the patient history.

Thus, the secondary findings related to Centor criteria in this thesis are merely hypothesis generating and the groups on paper III may not be comparable with regard to prevalence of Centor criteria. A study designed specifically for validating physical examination findings, such as Centor criteria in the eVisit setting, is warranted. One possible design could involve physicians to assess and document Centor criteria in a similar way for both eVisits and office visits to draw more certain conclusions (117).

Comparison to office visits or phone visits most relevant?

As previously described, patients in Skåne county have several options regarding where to seek primary care but are generally triaged by nurses before a physician assessment. Thus, paper IV focused on subsequent additional physician assessment as this would demonstrate that patients' cases were likely medically unresolved, as opposed to measuring nurse visits which may simply reflect patient concerns. However, as patient behavior is also of interest, we also measured nurse telephone contacts, which typically reflect patients contacting their PHCC. We were, however, unable to differentiate between provider-initiated and patient-initiated telephone contacts in our current dataset. Had this been possible, it may have been preferable to compare patients with an initial eVisit assessment to patients with an initial telephone assessment, as these two modalities often constitute the first line of assessment in a non-triaged primary health care population.

Interpretation of results in relation to aims

Paper I

Paper I aimed to investigate interrater reliability between human physicians and an automated machine-learning-based triage method, as well as evaluating interrater reliability of triage decisions between a panel of physicians assessing the same patient histories from an automated patient history software. To assess human physician triage, the majority vote of a panel of physicians was used, and the automated machine-learning-based triage was trained based on data from a specific physician. Given the specific appearance of the automated patient history report, the specified triage categories in relation to the platform, the limited experience of triaging physicians in assessing digital medical history reports, the limited scope of training data and the use of panel majority vote as gold standard, the primary results cannot be generalized to assume that machine learning cannot be applied to clinical triage. Rather, the results demonstrate the difficulty arising from low triage consensus in the current setting, and that the specific machine learning model trained by one physician was unable to predict triage decisions of other physicians.

Paper II

Paper II aimed to explore how family medicine physicians and nurses experience the implementation and use of digital communication in the form of automated patient history software and chat-based patient-provider communication. The mixed focus groups exploring staff experience of digital communication were conducted in a relatively small sample of three primary health care clinics, where staff had worked with the platform between one and six months. Given the prolonged process of iteration and change implementation, staff experience of the platform may shift over time, limiting transferability findings related to the platform to other contexts. However, results related to the difficulties of text-based communication may be transferable to other contexts as these difficulties persist even with long experience using the platform. However, product development related to the platform aims to minimize ambiguity in the automated patient history text which also may mean that results related to text ambiguity in the platform are not fully dependable. For instance, the platform has recently added a feature where patients can describe acknowledged symptoms in free form text (i.e., clarify what they mean by "dizziness" or "chest pain").

Paper III

Paper III was designed as a non-inferiority study, with the aim of investigating if eVisit management of sore throat, other respiratory symptoms, or dysuria was associated with higher rates of antibiotic prescription compared with usual management using physical office visits. While results demonstrate a statistically significantly lower prescription rate following eVisits compared to office visits, the results are primarily interpreted that eVisit assessment of sore throat in the current context isn't associated with a higher prescription rate compared to in-person office visit assessment. While results persist after adjusting for age and set diagnoses, we cannot rule out the possibility that the eVisit population has relatively milder symptoms compared to those assessed in-person, both due to self-selection by patients and due to stricter triage systems deployed at physical PHCCs. Thus, it is possible that the prescription rates in the eVisit group would be higher had the sample been randomized, but this remains speculative. It is also not certain that the results are generalizable to other eVisit platforms or health care providers, as we cannot decipher whether health care provider documentation protocols, automated patient history, or some other aspect of the platform was the driving factor behind the results.

Paper IV

Paper IV aimed to investigate whether there were any differences in associated frequency of physical healthcare contacts following initial management of respiratory and urinary symptoms using traditional office visits compared to "digi-physical" management. The study is adequately powered even after excluding patients with physical visits in the first 48 hours after their index visit. There is therefore a low risk of type II error and results demonstrate that there is likely no difference between the two approaches, if deemed acceptable that eVisits will have an initially higher proportion of subsequent in-person physician visits within 48 hours as per "digi-physical" protocol. As we had comprehensive data on in-person physician visits in the entire county, it is unlikely that a significant number of subsequent in-person visits were missed. However, we cannot be certain to what extent that the subsequent visits were related to the index visit in each group. One American study comparing follow-up visits related to the initial diagnosis found slightly higher follow-up rates for eVisits compared to physical visits (118).

As the platform was used as a standalone system within the same health care provider, able to schedule patients to primary health care visits, the results cannot be generalized to other platforms. They also cannot be applied to a context where the platform is used with continuity between patient and physician both digitally and in-person, as eVisit physicians could only occasionally assess patients registered at the PHCCs in which they physically worked.

Speculation related to secondary outcomes

Is triage unnecessary?

Beyond the primary findings, several secondary findings create intriguing hypotheses warranting further evaluation in adequately designed and powered studies. Paper I highlights the large variation in triage decisions made by physicians assessing the same set of medical histories. This illustrates how variation in clinical reasoning between physicians in certain contexts may make consistent medical assessments difficult to achieve using humans as decision-makers. Between physicians, there was a twofold variation in reports triaged to eVisits (between 29.4% and 69.2%) or emergency care (between 1% and 2%), a threefold variation in the proportion of reports triaged to urgent primary care (between 16.7% and 50.8%), and a six-fold variation in the proportion of reports triaged to non-urgent primary care (between 2.7% and 14.4%).

While it is unclear what the intentions of proceeding to an eVisit were, the greater variations in triage to the PHCC demonstrate the difficulty in triaging and prioritizing primary care visits. Study design may have influenced this variation, and physicians may have been more consistent in their final decision if they had been allowed to chat with patients prior to triage. Consistency may also have been different if the study was conducted with registered nurses who, in Sweden generally, have significantly more clinical experience of primary care triage.

Inconsistency in triage does not necessarily mean that assessments are lacking quality. Primary care assessments may simply be prone to more variation as complexity and uncertainty is high and health care professionals more readily need to use their professional judgement. Even inconsistent clinical decisions may constitute decisions within the professional scope (119).

As consistency in triage seems difficult to achieve, these findings would support minimizing resources dedicated to triage beyond assessing the obvious need for emergency care, and instead increasing the relative number of resources dedicated to patient value-provision though same day access to assessment by a health care professional.

eVisits improve guideline adherence?

The eVisits in paper III involved a “digi-physical” approach to telemedicine, where patients can visit a nearby laboratory for testing if needed or proceed to a scheduled physical visit. Beyond finding lower antibiotic prescription rates among eVisits compared to office visits, a subgroup of eVisits with a diagnosis of tonsillitis and prescribed antibiotics had almost full guideline adherence with regard to documenting three or more fulfilled Centor criteria, as well as having a positive rapid antigen test for group A streptococci (97.7%, 42/43). The corresponding guideline adherence rate was significantly lower among office visits with a diagnosis of tonsillitis and prescribed antibiotics (40.0%, 8/20).

Regarding other laboratory testing, C-reactive protein was ordered more often among office visits with a documented diagnosis of tonsillitis but ordered C-reactive protein was more often highly elevated in eVisit visits with a documented diagnosis of tonsillitis. Guidelines for pharyngotonsillitis management state that C-reactive protein is of limited utility in the diagnosis of tonsillitis (120), but may in paper III represent physicians suspecting differential diagnoses, such as pneumonia. Higher C-reactive protein levels, among eVisit patients who were tested, supports this hypothesis. It is unclear if the testing rate of C-reactive protein in the eVisit setting reflects a reluctance of physicians to order testing, a reluctance among patients to proceed to testing, improved physician guideline adherence in relation to tonsillitis diagnosis, or a healthier patient population where differential diagnoses for tonsillitis are less commonly suspected compared to the office visit setting.

The secondary findings of paper III related to prescriptions with relevant documentation of diagnoses, Centor criteria and laboratory testing supports the hypothesis that eVisits led to improved guideline adherence compared to office visits. This is also supported by the significantly lower rate of RST testing on correct indications in the office visit group compared to the eVisit group (32.9% vs. 79.5%, $P = <.001$). It is possible that the barrier to testing is lower in the office visit setting. Physicians may also be able to deny a patient antibiotic prescription more easily through the eVisit chat. Furthermore, staff in paper II experienced emotionally loaded discussions as being more manageable using the platform. However, differences in guideline adherence may not be fully ascribed to eVisits per se, but may also reflect the eVisit provider having more rigorous protocols for documentation or having hired a selected group of physicians more prone to follow guidelines given the ongoing media controversies related to over-prescription of antibiotics related to digital visits at the time (69, 121).

Centor criteria prevalence different in eVisits?

Prevalence of various Centor criteria among eVisit sore throat patients creates some intriguing hypotheses regarding Centor criteria assessment in the eVisit setting. Tonsillar exudates, lymphadenopathy and cough are all significantly more prevalent among eVisit documentation compared to office visit documentation. Are patients misinterpreting and over-reporting clinical symptoms or does this represent patients with clear tonsillitis symptoms more readily self-selecting to the eVisit modality? Clinical experience indicates that sore throat patients usually palpate their swollen tonsils or myalgic sternocleidomastoid muscles, which may be misinterpreted as lymphadenopathy in the eVisit setting. As previously mentioned, studies validating physical examinations in the digital visit setting are warranted. One recent study deploying a self-examination kit for remote COVID-19 assessment, including a thermometer, pulse oximeter, sphygmomanometer, and a digital stethoscope, found no adverse effects during the two-month study duration (122).

Findings are hard to interpret due to previously described methodological issues, as well as lack of clarity regarding if the documentation is based directly on patients' answers in the automated patient history questionnaires or if physicians have scrutinized reported symptoms in the chat or by rigorous assessment of images.

Others argue that Centor criteria for the management of sore throat are obsolete (123). However, a recent prospective cohort study on pharyngotonsillitis in an adult Swedish primary care population indicates that three or more Centor criteria improves the positive predictive value of group A streptococci when combined with a positive RST (124).

As antibiotic treatment for tonsillitis in Sweden is indicated for symptom reduction rather than prevention of rheumatic fever or invasive streptococcal infection (125), clinicians may simply need to assess if symptom severity justifies potential antibiotic prescription and then use rapid antigen testing as a stopping rule (70).

eVisit patients more often in the "wrong" level of care?

Secondary findings in paper IV also provide insight into possible differences between patients choosing to have their first assessment as an eVisit compared to patients who choose an office visit. Visits within 48 hours provide a good measure of what level of care may be relevant in the urgent setting. Emergency department visits within 48 hours occurred in a minority of cases in both groups (0.9% (11/1188) of eVisit patients and 1.7% (10/599) of office visit patients), though the study was not powered to determine if there was a statistically significant difference between groups.

Patients' ability to "self-triage" to the appropriate level of care can be deduced from the current results of paper IV. Consider three levels of care: digital care, primary care/out of hours care and emergency care. Ideally, patients should self-select so that no change in the level of care is needed within 48 hours. 16.1% (191/1188) of eVisit patients had a physical visit within 48 hours, while 1.7% (10/599) of office visits had an emergency department visit within 48 hours. This suggests that patient "self-triage" i.e., the adequate level of care isn't as optimal among eVisit patients compared to office visit patients.

Conversely, it is not certain what proportion of office visit patients could, in fact, have replaced their office visit with an eVisit. Research evaluating this "superfluous" level of care among office visits, and "inadequate" level of care among digital visits may help providers better understand the level of guidance patients need for improved "self-triage".

"Digi-physical" care increasing workloads to maintain patient safety?

Paper IV shows no increase in utilization after eVisits beyond what is recommended based on health care provider protocols within 48 hours. Of the 16.1% of eVisit patients with infectious symptoms with physical care within 48 hours, most had been recommended physical follow-up. Sensitivity analyses excluding eVisit patients recommended a physical visit within 48 hours demonstrated robust results with regards to no significant differences in subsequent physical visits within two weeks when comparing eVisit patients to office visit patients. While this suggests that physical care was utilized only when needed, the "double assessment" with an eVisit and a subsequent physical visit may result in additional primary care workloads, which may indirectly have a negative impact on patient safety.

Multiple digital engagements with the same provider the norm?

Perhaps most interesting are the findings related to subsequent visits within two weeks registered in the Jönköping region. eVisit patients had a significantly larger proportion of Jönköping contacts within two weeks during the time when Capio Go was registered there, but there were no significant differences when only other digital health care providers were registered there. This indicates that the current population does not "shop" online among different digital visit providers, but rather tends to stay with one provider over time. The high proportion of subsequent Capio Go visits within two weeks indicates that these visits usually involve multiple contacts, likely representing follow-up with regards to symptom development, treatment response or laboratory testing.

This means that one eVisit, while being shorter, may require multiple engagements from physicians compared to one office visit, which may not require physicians to re-engage with patients to the same degree. Considering the cognitive cost of switching between tasks (126), this finding may raise concerns as to how efficient the total episode of care is among eVisits compared to office visits. Research comparing total physician time required per patient, including time taken to re-engage, between eVisits versus office visits may provide further insights into the implications of this finding.

Interpretation in relation to other research

Categorizing outcomes for appraisal of eVisit evidence

Due to the heterogeneity of telemedicine and the contexts in which it can be used, review articles are numerous and vary in their conclusions regarding existing evidence and gaps in the literature. One early review focusing on eVisits in the American health care setting highlighted the need for head-to-head research on efficiency, patient health, and satisfaction (34).

For the broader term digital visits (including both communication using video or text), an analysis from the United Kingdom released around the time that this thesis commenced highlighted the need to rigorously evaluate effects on demand, workload, and equity (127). A subsequent systematic review of digital visits highlighted the need for research on patient safety and patient health outcomes (128), and a scoping review on digital visits in the "digital-first" model of primary care conducted for the National Health Service in the United Kingdom specified scarce and contradictory evidence regarding numerous outcomes including patient health, care quality, access, continuity, confidentiality, costs, and accuracy of diagnosis, triage and signposting, as well as lack of research comparing synchronous to asynchronous models (129).

Finally, and perhaps most relevant for the current thesis, the most recently identified systematic review on eVisits found comparable clinical outcomes in the conducted research in comparison to in-person care as well as reduced costs, mixed evidence regarding quality of care and health care utilization and no research on access to care or regarding which conditions are best suited for eVisits (130).

To establish a holistic view of eVisits and their impact on the health care system, it may be useful to categorize relevant outcomes. However, existing reviews vary in how outcomes are categorized and described, with many outcomes overlapping.

Here, an attempt is made to group outcomes as mutually exclusively as possible in order to provide an overview of the literature and place this in relation to the findings of the current thesis. The following categories have therefore been created. Relevant papers in this thesis, which partly provide insight into the relevant outcome, are specified in parentheses where relevant:

- **Patient experience (not addressed in this thesis):** Includes subjective willingness to use eVisits by patients, including perceived barriers and facilitators to use, as well as patient satisfaction and perceived access. Also includes perceived breaches in confidentiality and patient integrity.
- **Patient behavior (paper IV):** Includes patient health care utilization and adherence to clinician recommendations, as well as expected and unexpected health care utilization.
- **Resource utilization, cost, and efficiency (paper IV)**: Includes costs (either in terms of time or monetary costs) of eVisits for all involved stakeholders. Includes total cost per patient per unit time but also per episode costs. Also includes effects on patient waiting times related to available resources in relation to demand.
- **Health care provider experience (paper II):** Includes subjective willingness to use eVisits by health care staff, including perceived barriers and facilitators to use, as well as staff satisfaction and perceived workload.
- **Health care provider behavior (papers I, III and IV):** Includes empirically measured eVisit effects on clinical decision-making, including triage decisions, scheduling choices with regard to staff and continuity, referral rates, prescription rates and diagnostic testing, and registered diagnoses.
- **Patient health outcomes (not addressed in this thesis):** Includes empirically measured clinical endpoints of improved patient health such as effects on morbidity, symptom reduction, effects of laboratory outcomes, risk factors, treatment complications, and mortality. Does not include patient satisfaction or patient behavior such as unexpected emergency department visits unless those visits are ascribed to unexpected morbidity due to misdiagnosis.
- **Equity (papers III and IV):** Identified exacerbated disparities in any other of the outcomes above in various segments of the population related to the implementation of eVisits. Includes potential equity concerns identified due to differences between eVisit users and non-users.

Note that the category "quality of care" and "patient safety" and "access" have been excluded as they overlap. All outcomes above may be considered parts of quality of care. Patient safety may be compromised due to effects on provider behavior, patient behavior, resource utilization, patient health outcomes or equity. Access to care may be considered a subjective patient experience, part of provider behavior in terms of management of patients making contact, related to resource utilization in terms of waiting times in relation to available resources, and related to equity in terms of differences in utilization between different patient groups.

Each outcome is discussed in relation to the current thesis below.

Patient experience

While this thesis does not focus on patient perspectives related to eVisits, existing novel research on patient perspectives remains relevant for complete understanding of thesis results. A recent qualitative study on patient perspectives on the same platform assessed in the current thesis found similar results as those emerging in paper II.

Patients found the service convenient and efficient, especially for submitting photos or if calling their providers induced anxiety. They expressed difficulties in knowing which questions in the automated patient history were most relevant as the questionnaires were focused on health care provider perspectives. Patients also expressed disappointment over lengthy asynchronous chat conversations, as opposed to their expectation of a synchronous "live" chat. Concerns were raised regarding access for groups with low digital literacy and disabilities (131). Another study on patients in the emergency department setting has also reported that relevant automated patient history questions may help them better organize their dialogue with their physician (132).

These findings are in line with staff experiences in paper II regarding safe and secure access for patients, adaptation to an asynchronous workflow, and the need for a more patient-centered automated patient history.

Patient behavior, resource utilization, and experienced workload

Perceived and objective workload changes

Research on objectively measured workload related to digital visits seems extremely limited, and findings on staff experience related to workload remain mixed, with concerns of increased workloads prior to digital visit implementation but staff also experiencing increased efficiency in managing workloads. (129). Staff in paper II did highlight concerns of increased workloads to begin with and expressed concerns of increases in workload related to interpretation of symptoms in the platform, but after a period of adjustment there seemed to be no relevant effects on workload.

A recent modelling study of the "digital-first" model of care indicated that "supply-related demand" is a likely consequence of widespread digital visit access (6). As stopping the deployment of such technology is unfeasible, the relevant challenge lies in managing the potential workload associated with this increased demand. As explored in paper IV, this involves understanding subsequent health care utilization among patients who contact the health care system. Furthermore, given the likelihood of disproportionate access by a relatively healthier patient population, it is crucial that the health care system prioritizes case management to avoid inequity due to a "first come, first served" scenario.

It is, however, worth noting that increased utilization due to supply-related demand may be transient. A recent Spanish study found that eVisit users' health care utilization is reduced to eVisit nonuser levels within a year (133). Similar trends in transient utilization increases have been seen when opening up physical care using the "see-and-treat" approach (134).

Telephone triage influence om workloads and resource utilization

Studies on workload related to telephone consultations may give some insight into what to expect from eVisit implementation. Results from a large UK randomized controlled trial of telephone triage by physicians showed longer physical subsequent visit durations despite visits being booked with the same physician (135). Any reductions in same-day visits were compensated by increased visits the following day (136, 137). Total staff workloads seem unchanged using telephone triage (138), but workloads were instead redistributed, with a neutral effect on cost (139).

A recent master thesis, which simulated a qualitatively generated multi-criteria decision-making triage system triaging certain patients directly to physicians, found that such a system outperformed conventional triage, where all patients are initially managed by a nurse and physician only utilized when nurses are unable to meet patient needs, in terms of clinician salary cost and visits per patient (140).

Thus, eVisit implementation into existing primary health care clinics is likely to increase demand and thus workload, even though the degree of time saved using automated patient histories isn't quantified by any of the above research. Paper II highlights how certain aspects of workloads may increase if automated patient histories include undesired clinical information. However, if used in the correct clinical scenario, automated patient histories may help staff experience eVisits as being more efficient.

Multiple eVisits part of the normal digital trajectory?

The “normal” trajectory” of follow-up after an eVisit is also relevant for assessing impacts on workload. Paper IV indicates that a minority of eVisit patients may require additional urgent physical follow-up to preserve patient safety when compared to corresponding office visits. However, it is not obvious if eVisits should be compared to office visits or telephone visits for evaluating how eVisits should be implemented into routine practice.

A subsequent study, without an office-visit control group, found a 23.1% two-week follow-up rate after eVisits for mixed chief complaints (but respiratory and urinary symptoms were most common, similar to paper IV). Our paper did not explore the effect of antibiotic prescription on the risk of follow-up, but this paper found a slightly higher risk of follow-up when antibiotics were not prescribed (141). A recent descriptive publication with a three month follow-up of eVisits for common primary care symptoms found that two-thirds of patients had at least one active follow-up for the same condition, often in the form of a non-urgent office visit but also in the form of additional eVisits (142). Finally, secondary findings from a recent Swedish publication investigating 30-day follow-up rates for various visit types before and during the COVID-19 pandemic found similar physical follow-up rates for index physical visits, digital visits, and traditional telemedicine contacts (phone or letter), but a substantially higher digital visit follow-up rate for index digital visits compared to other index visit modalities (143). This is in-line with the unpublished data from the current thesis, indicating that 70% of eVisit patients had additional eVisits within two weeks.

Thus, multiple visits over prolonged periods of time may be the norm for eVisits, perhaps as a patient safety compensation for the lack of physical examination. “Spreading out” the consultation over several visits may allow the physicians to better follow the trajectory of patient symptom development as part of the diagnostic process. EHR documentation routines may need to adjust to minimize over-documentation and increased workloads associated with this novel flow of care.

Managing increased workloads using ICE

Providers may need to develop strategies to manage increasing workloads. For example, one physician in paper II mentioned that patients who frequently made contact more easily could be managed due to the feeling of security provided by the platform. One study conducted in a PHCC with over 13 000 patients found that there were six persistent high frequency patients with 10 or more eVisits per year, but managed these using team discussion, patient interviews and scheduled appointments every 14 or 30 days and identifying unmet patient needs (144).

This highlights the importance of developing the ability to identify and address patient ICE during first contact (32, 145). Staff in paper II did indeed highlight continuity as well as identified ICE in the automated patient history reports as the valuable components of successful eVisits. Using ICE providers can maximize their chances of providing patients value in whichever modality of care patients appear in, without unnecessary referral to physical care due to high degrees of uncertainty on the phone or during an eVisit. Proactively identifying patient needs has been suggested as a need for improvement in remote consultations for patients with dementia (146). The author is unaware of any research directly evaluating the impact of the ICE strategy on health care utilization and total visit duration in the eVisit context.

Managing increased workloads using continuity

Primary care often involves primary encounters with a wide array of undifferentiated patient presentations (147, 148) and difficulties in soliciting the patient's agenda (149), creating high degrees of uncertainty. It has been proposed that the distinct specialty of family medicine relates to the management of uncertainty (150). Thus, it is not surprising that the majority of eVisit patients with well-defined chief complaints, such as infectious symptoms in paper IV, can be managed without subsequent physical care. Conversely, only a minority of eVisit patients with a broader range of chief complaints are managed entirely online (55, 151).

In paper II, simple queries were experienced as more easily managed than complex ones. This is in-line with a pilot of an eVisit platform in the UK that found most staff felt eVisits duplicated workloads due to complex queries in need of additional follow up, while one physician, who was experienced in phone triage, reported managing most non-acute eVisit cases without needing a physical visit. Physicians who could follow-up their own patients with continuity also felt that the physical consultation was quicker (152). These studies, however, do not primarily measure workload-related to eVisit implementation.

One recent Canadian study where patients were allowed to communicate with their own PCP in a modality of their choice found that only 5.6% (807/14317) of digital visits resulted in patients being recommended physical follow-up (153). A UK study analyzing content of primary health care email conversations between physicians and patients found that most emails were clinical in nature, with a median of two emails over a three day period, but inevitably led to physicians also conducting some administrative work, which would otherwise have been managed by a receptionist (154). Enabling continuity through, for example, smaller panel sizes may therefore be essential if workloads related to eVisits are to be appropriately managed.

Remote work with digital visits to reduce perceived workloads

While integrating telemedicine into physical care may involve higher workloads for the primary care system as a whole, physicians working remotely with full-day digital visits seem to experience low workloads and a high sense of autonomy, while acknowledging assessing relatively simple cases and potential risks with regards to patient safety for certain populations (155).

Similar to paper II, nurses using asynchronous communication in the national triage service 1177 experienced a less stressful working environment, but also challenges related to assessing multiple patients at once and assessing text-based symptoms without non-verbal cues, resulting in a reduced ability to use professional judgement, i.e. a reduced range of occupational professionalism (156).

Allowing primary care staff to occasionally work remotely with digital visits may serve as one strategy in making the working environment more sustainable, attracting more staff to work within primary care. At the same time, implementing novel technologies in the workplace too rapidly may provoke "change fatigue" among staff and thus worsen the working environment (157).

Current proportion of telemedicine visits may be suboptimal

Several studies indicate that the current visit modality distribution may be suboptimal. Many physical visits can be replaced by telemedicine alternatives as perceived by PCPs (158) and patients (159). A Belgian out-of-hours clinic implementing telephone contact prior to physical visits could manage 40% of patients through telephone and reduced physical visits by 45% (160).

Follow-up costs and system-level costs of eVisits

While no cost-analyses were conducted in the current thesis, results may indicate potential effects of eVisit use on how health care resources are utilized, both within and outside of primary care. As previously mentioned, per-episode cost savings as well as patient cost savings may be realized through widespread implementation of digital visits (71, 91, 92). A UK study comparing patients choosing telemedicine follow-up found shorter visit durations compared to patients choosing physical follow-up (161). However, secondary findings in the current thesis from the Jönköping region indicates that the majority of eVisits have additional eVisits within two weeks. It is not clear if the increase in the number of contacts in the form of additional follow-up digital visits, as well as supply-related demand for eVisits, will counteract per-episode cost savings.

With regard to costs in other parts of the health care system, one recent publication by Babylon health, a 24/7 available eVisit platform implemented in the United

Kingdom, suggests lowered acute hospital spending associated with patients using the platform (162). This would agree with secondary findings of paper IV, where most physical visits within 48 hours of index were within primary care for eVisits, while most subsequent physical visits within 48 hours of office visits were hospital emergency department visits. However, the study was not powered to identify differences in hospital health care contacts between eVisits and office visits, and as the number of emergency department visits was relatively small (10 out of 599 office visit patients), no conclusions can be drawn based on these secondary findings. Furthermore, it is expected that the "next" level of care after an eVisit would be a primary care visit, while the "next" level of care after an office visit would be an emergency department visit.

Assuming supply-related demand, relative costs of highly accessible primary care may increase while hospital-related costs decrease as digital visits are deployed, but effects on system level costs and long-term impact of digital visits on total health care utilization remains unknown (163). On one hand, there is a risk of increased total utilization due to supply-related demand (6). On the other, there is the potential for a transient increase in utilization and long-term cost-savings for both patients and providers by offering patients the most efficient modality to provide value based on ICE.

Health care provider willingness to adopt eVisits

Low eVisit adoption among staff

While numerous eVisit technologies currently exist, uptake remained low (129). Paper II indicates that implementing the platform involved a significant degree of adaption and iteration, represented by the theme 'adjusting to a novel medium of communication'. Staff eventually found the platform useful and wished to continue using it. However, all practices included in the study had adopted the platform for several months, limiting insight into staff experiences where implementation has failed.

An eVisit platform piloted in the UK on 36 practices between 2015 and 2016 demonstrated relatively low utilization by patients, and none of the practices took up the platform for market prices after the pilot (152).

COVID-19 as telemedicine catalyst?

Given the increasing demand for digital health services since 2017 (164), augmented by the COVID-19 pandemic (143, 165, 166), willingness to adopt eVisits may be higher today. An international patient survey exploring increased patient telemedicine use during the COVID-19 pandemic found that more than half of respondents are interested in future use of telemedicine (167).

Prior to the pandemic, staff had a high intention to use telemedicine given self-efficacy to do so (168). In Spain, use of a popular eVisit platform, eConsulta, tripled during the COVID-19 pandemic (169). However, a recent study investigating primary care utilization during the pandemic found that, while the proportion of remote contacts increased in the first COVID-19 wave, this was mainly the result of telephone and letter contacts, as well as due to a large reduction in physical primary care visits. The absolute number of digital visits actually decreased during the pandemic based on the acquired data (170). Thus, barriers to digital visit adoption seem to remain and long term evidence on successful implementation is lacking (128).

eVisits involve a specific skill set and requires training

eVisits adoption may be limited if clinicians aren't trained in clinical assessment through asynchronous communication. Research indicates that asynchronous communication involves a specific skill set that differs from existing synchronous telemedicine alternatives (171). Staff in paper II raised several challenges related to the platform, including lack of integration into the EHR, prolonged consultations, and patients with potentially life-threatening symptoms not responding in the chat. These concerns are consistent with other qualitative work on the platform (131, 172) as well as with other platforms (129). Research identifying such challenges and how to address them is still emerging.

Health care provider behavior and patient health outcomes

Automating triage decisions

Paper I indicates that using human decisions as training data for machine learning to automate triage is likely not feasible given current access to clinical and outcome data and given inconsistent human decisions. Automating triage would likely need to use a combination of pre-defined rules, modified by machine learning using clinical outcomes as training data. The patient safety of such a system compared with a conventional system is yet to be evaluated as far as the author is aware. A systematic review on symptom checkers and digital triage systems found weak evidence on patient safety, low diagnostic accuracy, and limited evidence on patient compliance to triage advice, and found algorithm-based triage approaches more risk averse than health professionals (173). Internal analyses by Doctrin, the company behind the platform in the current thesis, has also found fully automated triage to be more risk averse, more often resulting in advice to seek emergency care, compared to nurses. Subsequently, implementing fully automated triage has been discouraged until more evidence is available regarding clinical safety (174).

A more recent systematic review focused on associations between telephone-based digital triage (i.e., with human involvement) and utilization, user experience and clinical outcomes found mixed results regarding health care utilization, though most studies demonstrated a reduction or no change, with higher adherence to more urgent triage advice. "Under triage" with patients not given sufficiently high triage advice and associated hospital admissions was highlighted in secondary outcomes of several studies. Patient satisfaction was generally high, but less so when the patient perceived being under-triaged or irrelevant triage questions (175).

A mixed-methods master thesis created and simulated an evaluation of a primary care system for triaging eVisit patients to either a physician or a nurse. The qualitative component of the thesis found that staff experienced no national consensus on triage procedures, and that triage decisions were thus carried out based on professional judgement. While staff agreed that the medical assessment of patient symptoms such that patients were guided to where they were likely to be helped was most important, even a small risk of patients needing physician competence made deciding the level of care difficult (140). This is in-line with previously cited reviews as well as a recent systematic review on decision support software-integrated telephone triage, concluding that research on triage consistency is still inconclusive despite widespread triage use, and that factors related to the triage operator, i.e., professional judgement, remain the most important factor for triage consistency (176). While emerging studies on artificial-intelligence-based triage may suggest improved performance compared to various gold standards such as human consensus (177), many use clinical vignettes and fail to specify type of artificial intelligence and what training data was used to generate the studied model. None of these publications evaluate triage of real-world patients in an eVisit setting and a recent systematic review failed to find any such published or ongoing studies (178).

Effects on antibiotic prescription

Paper III shows that, for common infectious symptoms, eVisits were not associated with a higher prescription rate of antibiotics compared to office visits. However, this was in the context of a health care provider with established protocols for prescriptions and the ability to schedule patients for physical examination. Other health care providers may differ in their prescription rates, making it difficult to discern if the low eVisit prescription rate is attributable to eVisits per se or stricter provider protocols for eVisits compared to office visits. This may explain why a recent systematic review concludes that the impact of remote consultations on antibiotic prescribing is still unclear (179).

Furthermore, the Swedish authorities advise against antibiotic prescription in the digital visit setting in the name of patient safety (180). Exceptions are made in the context of switching a previously prescribed antibiotic, known underlying diseases, or an established patient-doctor relationship. For digital visits regarding tonsillitis, the recommended prescription rate is thus < 5%, which is substantially lower than the rate of 63% identified in the subgroup of visits with a documented diagnosis of tonsillitis in paper III. This rate is also roughly similar to data from 2012 on antibiotic prescribing in a large cohort of Swedish PHCCs found that 86% of visits with a diagnosis of tonsillitis were prescribed antibiotics (181) and a Swedish analysis comparing another eVisit health care provider to physical care and out-of-hours care for various diagnoses finding that tonsillitis was associated with a 52% prescription rate for eVisits, 55% for office visits, and 71% for out-of-hours care. However, in the latter study, no hypothesis testing was conducted to establish statistical significance between the groups (182). It is important to remember that the 21.2% rate in the sore throat eVisit group of paper III is relatively low compared to the other studies given that not all eVisit patients were diagnosed with tonsillitis.

Pneumonia diagnosis in the eVisit setting

Swedish authorities also advise against diagnosing pneumonia using digital visits (180). The 16 eVisit patients with a documented diagnosis of pneumonia in paper III may thus raise concerns regarding patient safety. However, it is unclear if these cases were a prior diagnosis or new diagnosis thus making conclusions difficult to draw regarding this secondary finding. In a retrospective Chinese study, which evaluated the utility of digital visits during the initial COVID-19 wave, it found that 10% of digital visits were diagnosed with suspected pneumonia based on symptom severity alone (183).

Misdiagnosis related to unexpected visits after eVisits

Some staff in paper II highlighted the difficulties in assessing the severity of written symptoms as a potential risk to patient safety, while others highlighted the perceived increased patient safety through the automated patient history forms where questions, which may otherwise not have been asked, present opportunities for differential diagnoses. One physician also expressed an agnostic view of the consultations being more clearly defined early in the interaction, starting "*the conversation at a different point*" during a subsequent physical visit. Part of managing uncertainty in primary care involves keeping the conversation open to avoid "premature closure" and diagnostic error (184). Further research is needed to specifically evaluate adverse outcomes such as misdiagnosis associated with preceding eVisits with an automated patient history.

One American study suggests that diagnostic accuracy for low-acuity conditions is similar for physical visits and eVisits (118). One may expect increased health care utilization associated with misdiagnosed cases. Given that no additional physical care utilization was observed beyond that which was recommended by the eVisit physician in paper IV, misdiagnosis related to acute infectious symptom assessment using eVisits may not be a major issue. Then again, 17.2% of eVisit patients recommended self-care or no-follow up had a physical visit within two weeks, but without corresponding data from the office visit group, this finding is hard to interpret.

With regards to virtual visits, one recent large cohort study in the American primary care setting found no differences in emergency department visits or rates of hospitalizations in adjusted analyses comparing office visits to telephone contacts or virtual visits (185).

Digital visit effects on risk factors and disease improvement

As previously stated, health-related patient were beyond the scope of this thesis. However, existing research in the American health care setting has found no statistically significant differences in eVisit users versus matched non-users with regards to glycated hemoglobin or low-density lipoprotein levels between 2008 and 2013 (84). Another study found equivalent blood pressure control when comparing matched eVisit patients to usual care for patients with relatively well-controlled hypertension (186). Smaller studies identified in a recent systematic review have found associations between eVisits and lower abnormal international normalized ratios among patients on anticoagulants, improved serum urate in gout patients, and better acne control (130).

A recent randomized controlled trial found similar improvement in non-urgent psychiatric disorders when comparing asynchronous versus synchronous telemedicine in primary care with no adverse events (187). Finally, one randomized controlled trial found no increase in physical activity when offering a desktop support program to inactive chronically ill patients (188), while a randomized controlled trial using a mobile phone app-based intervention with push-notifications demonstrated a delayed increase in physical activity in a population-based sample (189).

A word on patient safety

Taken as a whole, the results from the thesis support the idea that eVisits can be conducted with preserved patient safety. This is in-line with an audit of 13 digital primary care providers in Sweden that concluded that prerequisites exist for digital visits without compromising patient safety (190).

To what degree these prerequisites are implemented, and subsequent effects on patient health outcomes warrant additional beyond effects seen on risk factors and disease improvement above. Best practices in management of various symptoms using digital visits are still being developed and validated (191), such as those for remote assessment of COVID-19 (192).

Equity

Swedish health care policy promotes health care provision based on the principle of need and solidarity (193). Paper III and IV found that eVisit patients were, on average, 10 years younger compared to office visit patients, indicating self-selection by a relatively healthy patient population. In support of this hypothesis, a recent Swedish study found that digital visit patients were younger, had higher educational attainment, higher income and were more likely to be born in Sweden (194). Similar user demographics have been seen in other health care contexts (169, 195). Assuming physician resources are limited, this "digital divide" risks resulting in an unintentional discrimination against patients unable to utilize telemedicine solutions (196, 197).

This issue is, however, not unique to digital visits. All means of access to primary health care present unique barriers and facilitators to access. For instance, access using a telephone-first approach may make it difficult for a patient with hearing or speaking difficulties as well as non-native language speakers to access care (198). Conversely, physical access may be difficult for elderly patients with chronic conditions (199). While research consistently indicates that digital visit patients, on average, are healthier, relatively prioritized populations such as elderly patients, patients with mobility issues and anxious patients may be better served using these eVisits (129). For highly prioritized primary care patient groups to adopt and access digital visits, a patient-centered, culturally tailored and patient-guided development of the technology is required (200). Specific facilitators and barriers to utilization by vulnerable patient populations need to be better understood (201) and interventions demonstrating increased equity of access in the context of digital care are absent as far as the author is aware.

Additional access modalities thus increase the possibility for access by previously unattended patient populations, with a parallel risk of reduced equity if increased workloads lead to a portion of patients seeking care being left unattended resulting in a "first come, first served" scenario.

Implications for government and current national primary health-care developments

Government-commissioned health care investigations

Findings in this thesis may have consequences for decisions related to the ongoing restructuring of primary health care in Sweden. The Swedish government commissioned an investigation in 2016 to analyze how the health care system can use health care professionals' resources more appropriately and efficiently (202). Results and suggestions from the investigation were followed by a series of additional governmental investigations commissioned between 2017 and 2021 with the goal of analyzing prior suggestions and supporting state, regions, municipalities, and other authorities and stakeholders in achieving a modern, equal, accessible, and efficient health care system with focus on primary care (203-207)

The 2016 investigation concluded that Sweden had an efficient health care system with favorable outcomes relative to the proportion of public resources devoted to health care. However, inefficiency was created through a decentralized organization with relatively high detailed management compared to professional autonomy and innovation, as well as a lack of continuity and integrated decision support. The investigation concluded that value in health care is created through interaction between patients and providers – be it physically, digitally or via phone. A more primary care focused, patient-centered approach to health care could thus increase efficiency.

Existing proposals for use of digital tools in Sweden

Digital tools were assessed as playing a role in the proposed primary care transformation, as digital visits can occur in proximity to the patient as the need for health care arises, with patients considered an untapped potential in terms of resource available for self-care, appointment booking, and documentation in medical records. As telemedicine allows for segmentation of patient needs, this visit modality may be utilized in specific scenarios such as simpler symptom assessment, automated patient history, follow-up, and monitoring, allowing physical primary care to focus more on complex care. The Swedish government national budget has also proposed that digital tools should, when possible, be the first-hand modality to contact public sector services, across state, region and municipality (208).

One proposal in the investigation includes a “digital-first” entry into primary care for triage through the national health care telephone service 1177, providing self-care advice where relevant and forwarding patients to the relevant level of care. Furthermore, the investigation proposed integrated decision support for diagnostics and treatment in the EHR. These processes need to be integrated with physical care as subsequent treatment in some cases may still require existing health care infrastructures.

Potential for increased proportion of digital visits

Currently, the national telephone triage service 1177, available around the clock, answers roughly five million calls per year (1177.se). Beyond this, a substantial, but unquantified, number of triage calls are conducted at each PHCC. 61% of physical visits are conducted within primary care, with 4146 visits per 1000 citizens per year, of which 1313 to physicians and 2833 to non-physicians. Outside of primary care, the corresponding numbers are 2638 visits in total, of which 1321 to physicians and 1317 to non-physicians, and emergency department visits accounting for 233 visits (209). Within primary care, 98% of first-time visits are conducted physically while roughly one-seventh of follow-up visits are conducted using telemedicine, most likely via telephone (210).

Whether a larger proportion of patients can be initially assessed using telemedicine without compromising patient safety remains unclear, but the high proportion of patients in paper IV with infectious symptoms successfully managed using exclusively eVisits supports this possibility. As discussed previously, physicians (158) and patients (159) perceive many visits as being able to be conducted digitally, and examples exist of out-of-hours clinics substantially reducing physical care simply by offering telephone-first approaches (160).

Surprisingly, there is limited evidence of patient health outcome and patient behavior effects of replacing routine check-ups for chronic conditions such as chronic obstructive pulmonary disease, asthma, diabetes, hypertension (186) or elderly multimorbid patients with digital visits. Introducing yearly digital visits in these populations would be less likely to represent new utilization compared to assessment of infectious symptoms, and further research in this field is warranted.

The findings in the current thesis support further integration of eVisits into certain components of the Swedish health care system. Assessment of simple clinical scenarios through eVisits, where a relatively lower diagnostic resolution may suffice, does not seem to be associated with over-prescription as demonstrated by paper III. Given staff experienced the platform as useful primarily for simple complaints, this principle may speculatively be extrapolated so that any "clinically simple" scenario may be managed using eVisits. However, as paper IV demonstrates, allowing the health care provider to "convert" the eVisit to an in-person visit when deemed necessary seems to be a viable strategy. Given these findings, together with the low per-episode costs associated with telemedicine (71, 91, 92), the thesis supports a national policy of eVisits as one of many options for patients wanting to contact primary care.

Caveats to increased eVisit implementation

The findings in this thesis findings also raise some potential concerns that need to be taken into consideration upon eVisit implementation. Firstly, paper I demonstrates the known difficulty of "correct" triage in the primary care setting. Primary care triage may thus need to be simplified to identify patients with such alarming symptoms that need direct assessment at the emergency department. More refined triage, such as differentiating whether a visit should occur within two weeks or eight weeks, seems more difficult to achieve and may arguably be irrelevant as high accessibility, with continuity where relevant and possible, may be considered the cornerstone of the ideal primary care system.

Initial primary care assessment should, perhaps, focus on identifying the patient's ICE, followed by routing patients to non-primary care units where relevant, or continued management within primary care. As some assessments need a physical examination, as seen in paper IV, where 16% of the eVisit group had an in-person visit within 48 hours, and as some patient populations are limited in their ability to utilize telemedicine, patients should be allowed to choose which modality they prefer to make initial contact with their health care provider.

Staffing and resources may thus need to be carefully reallocated to prioritize primary ICE assessment and route patients to the most relevant resource for continued management (211). Prioritizing early identification of ICE was one finding that emerged from staff interviews in paper II, but also supported by the literature on primary care consultation methodology (32, 145, 212). To avoid discrimination of patients unable to use any one modality, all modalities should be offered to patients, and health care providers, as well as regulators, should put systems in place to avoid favoring access in any one modality.

A proposed model for telemedicine in primary care

The World Health Organization presents five key components of a well-functioning health care system (213):

1. Improving health status.
2. Defending the population against threats to their health.
3. Protecting people against consequences of ill health.
4. Providing equitable access to people-centered care.
5. Making it possible for people to participate in decisions about their health and health system.

The first three points may be considered patient health outcomes related to treatment, prevention, and complication reduction, respectively. Telemedicine's contribution to these points will become clearer as research with patient health outcomes emerges.

The latter two points, however, are related to provider behavior in relation to patients contacting the health care system. Here, the existing literature demonstrates that eVisits have a role to play.

Combining the results of the current thesis with the results of the government issued investigations and the reviewed literature, a suggested model for the ideal process for patient management within Swedish primary care is provided below with each stage detailed in the subsequent subheadings (Figure 7).

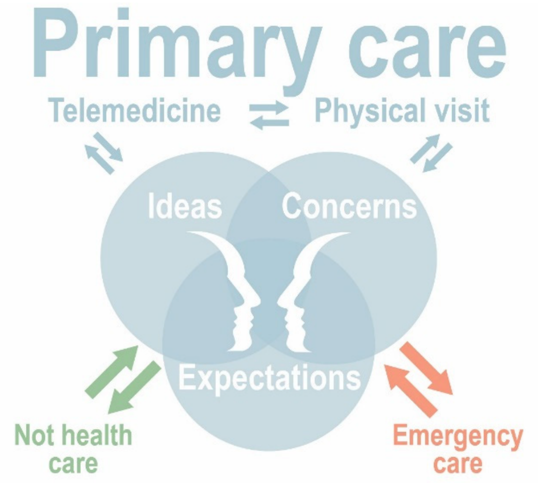

Figure 7
A proposed ideal model for patient management in primary care, enabling access through all modalities of care and early patient-centered consultation, simplified triage and flexible continued management.

1. High primary care access through modality of choice

Heterogeneity in patient resources and ability to communicate means that the health care system should offer multiple modalities for patients to contact their PHCC. Patients should have same day access to a primary assessment through telemedicine (eVisits, patient portals, telephone, or video), or physical visits.

The challenge lies in allocating resources to allow for same-day access across all modalities without unintentional inequity by, for instance, rapid response in one modality compared to slower response through another. For example, if a PHCC offers telemedicine assessment within 20 minutes, where younger and relatively healthier patients primarily make contact, while at the same time offering physical assessment within four hours, where elderly or patients with disabilities primarily make contact, there may be an unintentional bias by not assessing patients with the greatest need for health care first (194).

Health care providers therefore need to make sure access times and patient turnover rates are similar across all modalities. Other health care professions than physicians may need to be made available for adequate access bandwidth. Sweden currently has roughly 7000 general medicine specialists working part-time (on average 85%), and a population of roughly 10 million people, meaning that there are roughly 1680 patients per full-time physician (214). This is higher than the recommended level of 1000-1500 (215), and the relative proportion of general medicine specialists is not increasing (214).

Providers may be tempted to encourage patients to use other modalities, but this will also inevitably result in access inequity. From a patient-centered perspective, patients must be allowed to assess through which modality they best feel that they can express their concerns, and providers must monitor all access modalities to prioritize same-day initial assessment of all patients making contact across all modalities, while prioritizing continued assessment based on available resources. Setting up accessible physical care may be particularly challenging as these visits may be more difficult to conclude as effectively as other modalities, resulting in disproportionately more staffing resources dedicated to those making physical contact. One recent large Canadian study found that 46% of over 30 000 invited patients registered in the platform, with 44% of registered patients completing at least one telemedicine visit over 17 months. 82% of patients preferred asynchronous communication, while 11% preferred audio, and 7% video when making a virtual visit request (153).

2. Focus on early ICE identification

Regardless of chosen modality, primary assessment should clarify how the healthcare system can provide value to the patient. Standardized procedures for symptom assessment, laboratory testing, or red flag assessment will not provide value to patients unless they expect diagnostics or reassurance. Standardized prescription, physiotherapy assessment, or self-care advice will not provide value to patients unless they expect treatment. All of the previously stated interventions will not provide value to a patient expecting a sick note or a medical certificate to present to a specified authority. As primary care patients are heterogeneous with endless variation in chief complaints, ICE is crucial in determining which subsequent actions will provide value to the patient.

While the majority of patients may expect reassurance and diagnostics, assuming this is the case with every chief complaint may result in suboptimal resource utilization. For example, a patient making contact listing a range of various joint pains may expect treatment of pain from a specific joint or simply seek reassurance to exclude hypothyroidism as an underlying cause of generalized pain, without wishing to engage in physiotherapy for treatment. By correctly identifying ICE in the initial assessment, the patient may acquire value from a simple short synchronous telemedicine visit where joints are visible, as opposed to scheduling a physical visit to a physiotherapist. To aid in rapid identification of ICE regardless of the modality in which patients make contact, staff should be educated in consultation methodology (32) and automated patient histories may be used if they aid patients in openly expressing their concerns.

3. Simplified triage

After ICE has been identified, the initial assessment needs to determine if patients need emergency care services to adequately rule out certain diseases. In some cases, primary care assessment may rule out emergency care management, while in other cases patients need to be advised to directly contact emergency services.

Regardless of the level of detail in the triage system used, some patients who need emergency care services will inevitably be triaged to primary care, vice versa. Therefore, both emergency care services and primary care will need to collaborate to provide patients value where possible and change the level of care when needed. Similarly, while a substantial portion of patients may benefit from self-care advice, patients, who do not expect treatment, will not perceive self-care as valuable and should instead have access to primary care addressing relevant expectations, including diagnostics and reassurance where relevant. Research on patient-centered information provision through telemedicine, including self-care where relevant, is lacking and needs further development.

A segment of patients will also have ICE beyond what primary care is able to offer and may thus be triaged to “not health care”. As primary care manages a relatively broad range of issues, policymakers may need to support primary care providers in distinguishing primary care from, for example, social, cosmetic and wellness services and how to best collaborate with these services to help patients.

4. Flexible case management

Once the above is clarified, relevant resources need to be allocated for patient value provision. Here, there exists a balance between scheduling a visit to a generalist able to address multiple patients’ needs in one visit, versus segmenting patient needs so that various professions may bring patients value without continuity.

Considering limited resources and turnover of patients and staff, total physician continuity may not be feasible, thus meaning that continuity needs to be prioritized for certain patient populations. Higher degrees of multimorbidity and chronic issues may mean that segmentation of needs may be less optimal and that physical visits with continuity may be preferred, with follow-ups using telemedicine. Conversely, continuity may be less relevant for relatively healthy patients with less chronic conditions, hence that segmentation and telemedicine approaches may be more useful.

Regarding visit modality, patients may have chosen a modality through which identified patient needs cannot be fulfilled, and providers should thus be able to flexibly shift between modalities when relevant. This includes shifting from asynchronous to synchronous telemedicine or requesting additional photos and patient forms after a physical visit through an asynchronous telemedicine follow-up. Telemedicine may reduce the burden of treatment for patients with chronic conditions and shifting to telemedicine follow-up for selected patient populations may thus be a viable option for improving patient quality of life (216).

Beyond this, primary care staff may utilize mobile health technology during home visits and to better coordinate care. However, these solutions are currently limited in their use due to the heterogeneous nature of home care visits and complexity in use compared to conventional pen-and-paper approaches (217). Simplification, adaptability, and low threshold for use will determine if mobile technology will be adopted in practice.

Southcentral Foundation as a promising example

A promising example of an organization successfully integrating telemedicine into primary care is Southcentral Foundation's "Nuka System of Care" in Alaska. Formed in 1996 after a federal law allowed Alaskan Native tribes to take ownership over entities delivering health care services, replacing the term "patient" with "customer-owner". Customer-owners, rather than professionals, drive the system, instead of being seen as beneficiaries of a bureaucratic government-controlled health care system. A large portion of board members, employees and committee members consist of Alaska Native customer-owners, with internships and recruitment planning the next generation's role within the organization. This allows consistent promotion of local values, multidimensional wellness, and a sense of responsibility to make informed choices on sustainable priorities for the healthcare system.

Providers are expected to establish trusting, accountable and long-term relationships with customer-owners, promoting shared decision-making and innovation. Patient panels are assigned to integrated care teams including a nurse case manager, an administrative support staff, a physician, and a medical assistant. Team members share an office space to collaborate during case management more easily. Full time consultants, including behaviorists, dieticians, pharmacists, midwives, social workers and various organ specialists are available for team consultation (218). Customer-owners are offered same-day access to their team through a modality of their choice. Executives report 50% of patient-provider interactions made through asynchronous telemedicine, with each physician having 7-9 physical visits per day, 15-20 synchronous telemedicine contacts per day, and 30-40 asynchronous telemedicine contacts per day (Douglas Eby, 2019).

Since its integration in 1996, patients with a listed physician increased from 35% to 95%, appointment waiting times decreased from four weeks to same day access and phone wait times decreased from two minutes to less than 30 seconds. There has also been a sustained 36% reduction in hospital days, 42% reduction in emergency and urgent care usage, 58% reduction in specialty clinic visits, reduced staff turnover, a 25% increased childhood immunization, and 94% customer satisfaction (218). While these outcomes cannot be attributed to telemedicine alone, Southcentral Foundation's approach to integrating asynchronous telemedicine into their organization demonstrates how eVisits likely have a role to play in a patient-centered health care system.

All in all, digitalization of health care will likely need to facilitate, rather than eliminate, human-to-human interaction. While some aspects of the health care system may benefit from standardization, it seems unlikely that all patients making contact with the health care system will be content with an automated standardized response, but an inevitable portion will require joint decision-making in dialogue with a trusted health care professional (219). Professional decision-making in this dialogue requires more than manuals and empirical knowledge available to a digital system. It involves regarding the unknown, the senses, emotional "gut feelings", and experiences as well as the use of technical skills such as various types of physical examinations (119). Thus, digital tools should aim to help professionals spend more time interacting with patients to apply their professional judgement (220).

"Primary care isn't manufacturing, it's not linear. It's about doctors and patients and how well they connect. It's about messy human relationships. And it's about partnering"

- Douglas Eby (Vice President of Medical Services, Southcentral Foundation)

Conclusions

eVisits with a preceding automated patient history as used in one of Sweden's most commonly used platforms have a relevant role in Swedish primary care with regards to assessment and treatment of simple uncomplicated infectious symptoms.

Symptoms, as reported through eVisits, may be difficult for staff to interpret, contributing to inconsistent triage of digitally reported symptoms, both by physicians and when using a machine learning model trained by physician triage decisions. Automating triage with such an approach is therefore not feasible.

Primary care staff using eVisits experienced "digitally filtered primary care" as text and images available for decision making suited simpler clinical scenarios, but also allowed for more continuity of care and influenced the doctor-patient relationship. Staff needed to "adapt to a novel medium of communication", with parallel patient conversations and pre-filled patient history reports resulting in a different experience compared to conventional primary care.

Using the platform to assess patients with sore throat, dysuria or respiratory symptoms was not associated with higher antibiotic prescription rates compared to office visits, even after adjusting group differences in age and documented visit diagnoses.

While significantly more eVisit patients with respiratory- and urinary symptoms assessed using the platform had a higher associated in-person physician visit rate within 48 hours (as per "digi-physical" protocol) compared to patients with an initial office visit, no significant differences were noted regarding in-person physician visits after this initial period when following patients for two weeks.

Clinical implications: suggestions for efficient eVisit use

The Swedish National Board of Health and Welfare defines prerequisites for good health care as care that is evidence based and appropriate, safe, patient-centered, effective, equitable and provided within reasonable time (221). Thus, eVisits in Swedish primary care should be implemented in a manner that increases these prerequisites.

Interpretation of the current thesis and reviewed literature supports the following recommendations for practical applications:

- Use a patient-centered approach to automated patient histories by clarifying patient ICE prior to deciding whether to deploy provider-centered automated patient history questionnaires, which usually focus on symptom-related differential diagnoses and identification of red-flag for triage. This order of operations allows data presented to be more relevant to both patients and providers.
- Present data from the automated patient history in a structured way to minimize cognitive overload, by minimal initial information with the possibility for providers to request additional details when desired. Red flag symptoms or symptoms suggesting a need for physical care may be particularly highlighted or color-coded.
- When using eVisits for diagnostics, use the automated patient history to identify contextual factors indicating the need for alternative forms of telemedicine or physical care.
- Where possible, use eVisits to increase continuity and strengthen patient-provider relationships by, for example, following up patients with eVisits or routing patients to physicians who have previously assessed a particular patient.
- Primarily use eVisits when patients need to address an isolated identifiable need, such as an uncomplicated infection, routine follow-up of diabetes, hypertension, or single prescriptions, and avoid eVisits when patient ICE are complex, multiple or difficult to identify.
- For patients with chronic diagnoses and multiple prescriptions where a holistic approach is necessary, consider only using a patient-centered automated patient history and proceeding to other visit modalities.
- As simpler patient queries, to a larger extent, may be managed through telemedicine, expect patients with more complex needs scheduled for physical visits and increase scheduled time per physical visit accordingly. As focused patient sessions may be prolonged, managers should consider prolonging intermissions to allow for more sustainable working environments.
- Plan an implementation strategy to encourage eVisit use along with scheduled time to evaluate and share successful eVisit strategies (222).

- AI-based automated clinical decision-making for general primary care purposes has not yet been clinically evaluated with regards to effects on patient behavior. If it does become available, automated decisions should be deployed only when providing patients value, and not distance patients from clinicians (220). For example, automatically deployed self-care advice may be clinically indicated, but fail to provide reassurance to certain patients, and should thus only be presented if aligned with patients' ICE.
- Educate patients in the possibility to use any channel for primary care access, while also being clear when text-based communication is synchronous ("live") or asynchronous (longer response-times).

Needs for future research regarding eVisits and automated medical histories in primary care

General points and potential study designs

- Given heterogeneity in telemedicine solutions, the barriers associated with integration into clinical practice, and continuous iteration in both the telemedicine software used as well as practice protocols, adaptive randomized controlled trials with methods for evaluating telemedicine software despite continuous software updates after randomization are needed.
- Comparative studies validating findings reported in automated medical histories compared to such as lymphadenopathy, pain localization and peritonitis, compared to gold standard physical examination would be useful in expanding the diagnostic potential of automated medical histories. Such studies could also elucidate to what extent the physical examination can safely be conducted by the patient using telemonitoring devices.
- Large prospective cohort studies using big data analysis of automated medical history data to find new data which may be highly predictable with regards to certain diagnoses or prognoses.
- As clinical work and software engineering come from separate academic disciplines, more studies involving collaboration between these disciplines are warranted in order to fully realize digitalization of health care.
- National quality indicators for digital care beyond those existing for infectious disease, elderly care and narcotic prescriptions (223) are warranted.

Patient experience

- While patient experience in the eVisit setting is relatively well studied, the main barriers and facilitating factors for use among elderly and other vulnerable groups needs further study.
- Factors that matter most for perceived access to care in the eVisit setting, including the impact of triage and automation on perceived access.
- Experience of automated self-care advice, in which contexts it is perceived as useful and in which contexts it isn't.
- Patient experience related to contacting a provider using multiple modalities at the same time (physically, digitally and/or through a conventional phone call).
- Patient experience of "ICE-based" triage versus regular triage.
- How efficiently various modalities of care are perceived to meet perceived needs of various patient populations.

Patient behavior

- Adherence to triage advice given by humans and/or given automatically.
- Health care utilization after eVisit triage versus telephone triage.
- Adherence to lifestyle modification advice via eVisits versus office visits.
- Adherence to prescribed medications via eVisits versus office visits.
- Effects on total health care utilization with versus without access to eVisits.
- Primary care eVisit implementation effects on hospitalization, out-of-hours and emergency department utilization.
- eVisit implementation effects on patient views of the role of the health care system and potential medicalization risks.
- Interventions to increase patient adoption of eVisits

Resource utilization, cost, and efficiency

- Cost-redistribution and total system level costs since eVisit implementation.
- Cost-effectiveness of digital automated triage.

- Time-saving effects of different variations of automated patient interviews before eVisits, before telephone calls, and before physical visits to the same or to a different health care staff member.
- Effects of eVisits on total time spent per patient (considering multiple eVisit encounters and associated time spent on documentation).
- Impact of eVisit implementation on PHCC waiting times.
- Changes in staffing demand following eVisit implementation.
- Efficiency of eVisits prior to physical visits versus no eVisit and referring certain patients directly to physical visits.
- Automated machine-learning-based triage accuracy in terms of predicting final level of utilized care upon first contact.
- Business models and economic systems optimal for reimbursing eVisits.

Health care provider experience

- Long-term experiences of eVisit communication after having worked with eVisits for several years.
- Time-duration from eVisit implementation until staff feel that the technology is fully adopted as part of every-day routine practice. Facilitators and barriers to full technology adoption.
- Experiences of patient versus provider initiated eVisit communication.
- Prevalence of switching between eVisits, telephone and physical visits modalities for various conditions and patient groups.

Health care provider behavior

- Triage decisions in the eVisit setting compared to triage decisions using conventional phone triage
- Effects on the proportion of patients with physician continuity
- Effects on referral rates to specialty care directly from an eVisit without physical examination.
- Frequency of radiological testing ordered directly from an eVisit without physical examination.

- Types of diagnoses (previously undiagnosed) made through eVisits without physical examination compared to diagnoses made through office visits or phone contacts in primary care settings.
- Development of protocols for "rules of engagement" and best practice for eVisits in the primary care setting.
- How is the content of a physical consultation versus an eVisit consultation different given the same chief complaint? What opportunities for holistic management of patient needs emerge or are lost in each communication modality?

Patient health outcomes

- eVisit implementation effects on population mortality and morbidity.
- eVisit efficacy for symptom reduction for chronic pain or psychiatric conditions compared to telephone or physical visits.
- eVisit implementation effects on risk factors for chronic conditions such as glycated hemoglobin, low-density lipoprotein levels, blood pressure, smoking status, physical activity, diet.
- eVisit misdiagnosis and medical error reporting frequency compared to other modalities of care.
- Through adverse effects and misdiagnosis data decipher what clinical issues not to assess using eVisits.
- Effects on quality of life for various patient populations, including multimorbid patients.
- Replacing routine check-ups for chronic conditions such as chronic obstructive pulmonary disease, asthma, diabetes, or hypertension with eVisits and effects on diagnosis-related complications.
- Effects of automated triage on mortality and morbidity.

Equity

- Currently underserved populations with barriers to access care through eVisits and comparisons to underserved populations with barriers to access care via telephone or physically.

- Interventions to improve adoption by groups who currently cannot utilize eVisits.
- Feasibility of integrating language translations into eVisits.
- Common issues with managing multimorbid patients using eVisits.
- Population level data on eVisit implementation effects on which segments of the population ultimately utilize the health care system. Is there a disproportionate total health care utilization by relatively healthy segments of the population, or efficient segmented management of patient needs enabling physical care to focus on complex multimorbid patients?

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Paper I

Original Paper

Human- Versus Machine Learning–Based Triage Using Digitalized Patient Histories in Primary Care: Comparative Study

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Abstract

Background: Smartphones have made it possible for patients to digitally report symptoms before physical primary care visits. Using machine learning (ML), these data offer an opportunity to support decisions about the appropriate level of care (triage).

Objective: The purpose of this study was to explore the interrater reliability between human physicians and an automated ML-based triage method.

Methods: After testing several models, a naïve Bayes triage model was created using data from digital medical histories, capable of classifying digital medical history reports as either in need of urgent physical examination or not in need of urgent physical examination. The model was tested on 300 digital medical history reports and classification was compared with the majority vote of an expert panel of 5 primary care physicians (PCPs). Reliability between raters was measured using both Cohen κ (adjusted for chance agreement) and percentage agreement (not adjusted for chance agreement).

Results: Interrater reliability as measured by Cohen κ was 0.17 when comparing the majority vote of the reference group with the model. Agreement was 74% (138/186) for cases judged not in need of urgent physical examination and 42% (38/90) for cases judged to be in need of urgent physical examination. No specific features linked to the model's triage decision could be identified. Between physicians within the panel, Cohen κ was 0.2. Intrarater reliability when 1 physician retriaged 50 reports resulted in Cohen κ of 0.55.

Conclusions: Low interrater and intrarater agreement in triage decisions among PCPs limits the possibility to use human decisions as a reference for ML to automate triage in primary care.

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KEYWORDS

machine learning; artificial intelligence; decision support; primary care; triage

Introduction

Health care digitalization has the potential to mitigate increasing primary care workloads [1,2]. Time-constrained primary care physicians (PCPs) interrupt patient queries within the first 30 seconds of consultations [3], contributing to inadequate gathering of medical histories [4,5]. To reduce PCP workload and to ensure patients are directed to the appropriate level of care, nurse-led telephone triage is commonly used [6,7]. However, nurses face similar time constraints as physicians, which results in incomplete gathering of medical histories [8] and inappropriate levels of care recommended in up to 31% of cases [9,10].

Leveraging the wide use of smartphones, a large portion of patient history can today be acquired before the patient interacts with his/her health care provider. Automated patient interviewing software has been shown to gather reliable and relevant clinical information [11], and may thus save clinicians time and reduce workloads.

Existing "symptom checkers" can provide triage recommendations directly to patients. However, their accuracy is low, ranging from 33% to 78%, with higher accuracy reported only for more acute conditions [12]. Furthermore, patient adherence to symptom checker recommendations seems low at just 65% [13], compared with 81%-100% adherence to advice from triage nurses [7]. Thus, clinician decision-support software may be a better solution for optimizing triage.

With rapid developments in machine learning (ML), labeled automated patient interviewing software data offer a promising opportunity for enhancing triage software accuracy, providing appropriate access to primary care. Recent research shows promising utility of ML to aid in emergency department triage compared with commonly used algorithms [14]. However, the performance of such a system compared with human triage has, to the best of our knowledge, never been evaluated. Furthermore, ML research in the primary care setting is lacking, despite over 60% of health care visits being conducted in primary care [15].

Thus, this study sought to investigate interrater reliability between human physicians and an automated ML-based triage method, as well as evaluating interrater reliability of triage decisions between a panel of physicians assessing the same patient histories from an automated patient interviewing software.

Methods

Context

The automated patient interviewing software technology used in this study (produced by Doctrin AB, Stockholm, Sweden) is being used by several primary care providers in Sweden since 2017. Patients access the platform using their smartphone, tablet, or computer, choosing their chief complaint from a prespecified list. An automated medical history is then taken, allowing patients to briefly formulate ideas, concerns, and expectations in free-form text, and subsequently answer a symptom-specific multiple-choice survey. The software selects suitable subsequent survey questions based on the patient's answers (Table 1).

Table 1. Examples of automated patient interviewing software survey questions. Chosen answers subsequently appear in reports used for triage.

Survey question	Answer format
"How long have you had a cough?"	Short answer: specify number of days, months or years
"How has your cough been since it started"	Multiple choice (one option allowed): "Not changing" "Getting worse" "Improving" "Gone away"
"Do you have any of the following symptoms?"	Multiple choice (multiple options allowed): "Runny nose" "Shortness of breath" "Chest pain" "Sore throat" "Swollen glands" "Fever"
If a patient reports fever: "What was the highest temperature you have had when you measured it?"	Multiple choice: "37°C" […] "Over 40 C"
"How many days in a row have you had fever?"	Short answer: specify number of days

Answers are presented to a PCP as a summarized report for review and further doctor–patient communication may occur asynchronously through a live text chat (eVisit). Physicians can prescribe medications, order laboratory samples, provide patient information, or remain available online for up to 72 hours for conservative management. Anonymized data from the automated patient interviewing software report and subsequent chat are saved in a database used for this study. Clinical decisions regarding triage and treatment are, however, recorded separately in the patient medical record and were not accessible for study.

Data for Classification

Data used in this study were composed of 2 subsets. The first subset consisted of 300 automated patient interviewing software reports labeled by a selected expert PCP with over 10 years of clinical experience and a year of experience with online consultations. The reports represented the 10 most common chief complaints in the platform (common cold, cough, eye redness, genital problems, hay fever, rash, headache, sinus symptoms, sore throat, and urinary tract infections) with an equal marginal distribution between chief complaints. Automated patient interviewing software reports were triaged by the expert PCP to one of 4 levels: (1) Start a digital chat-based consultation; (2) Refer the patient to a primary care center for nonurgent care; (3) Refer the patient to a primary care center for urgent care; or (4) Refer the patient to the emergency department.

The second subset was 300 new automated patient interviewing software reports labeled by a panel of 5 PCPs (1 intern [AE], 2 residents, and 2 specialists). Sample sizes were chosen for feasibility reasons. Each PCP individually triaged automated patient interviewing software reports with an identical distribution of chief complaints as in the first subset. Each automated patient interviewing software report was labeled with a triage level as determined by a majority vote by the panel.

Triage categories in both subsets were then dichotomized into 2 triage levels used for further analyses: (1) No need for urgent physical examination (triage levels 1 and 2) or (2) Need of urgent physical examination (triage levels 3 and 4).

Exclusion Criteria

Because of incorrect formatting of one of the reports in the triage interface used by the panel, 299 automated patient interviewing software reports were triaged instead of 300.

Automated patient interviewing software reports describing cases with an ongoing medical contact or a different chief complaint from the one specified were classified as inappropriate for triage, which occurred in 37 reports classified by at least one panel member. These were manually reviewed by one of the authors (AB) for inclusion or exclusion by expert opinion, resulting in the exclusion of 17 cases from the analysis.

If the panel voting strategy did not result in a majority for 1 triage level, the automated patient interviewing software report was also excluded from the analysis, which occurred in 6 cases.

Initially, 22 automated patient interviewing software reports had missing triage data from some panel members. After applying the exclusion criteria, 16 automated patient interviewing software reports with missing triage data remained for analysis.

Model Analyses

To examine the potential of our ML-based approach for triage, we used the available data and corresponding dichotomized triage categories in a series of classification tests with 3 classifiers: (1) a simple linear naïve Bayes classifier, which assumes statistical independence of input features; (2) logistic regression, commonly used for binary classification problems; and (3) random forest, an ensemble decision tree approach, which is considered particularly suitable for high-dimensional problems.

Because of many questions from the automated patient interviewing software reports only appearing very rarely in the small-sized training data, feature space was reduced by only including those which were used in more than 5% of the training samples. This resulted in 243 features. As a few fields included brief free-form text, the classifiers were trained and tested both with and without information extracted from these text data. Text was handled by first removing common Swedish stop words. The remaining commonly used words appearing in more than 10% of the training samples were included as a bag-of-words model where each word was treated as an input feature to the classifier [16]. This resulted in a total of 53 features.

First, we trained the models on the first subset and tested them in a single pass on the second subset with labels based on the majority vote of the 5 PCPs. We complemented this analysis with a cross-validation approach on the data without text information to better estimate generalization capabilities across the 2 subsets of data. We performed 10-fold cross-validation by dividing the union of the 2 subsets into 10 data clusters, where the mixture of the 2 subsets in 9 out of 10 clusters was used for training and the remaining cluster accounting for 10% (ie, 1/10) served as a test set. By applying this scheme 10 times with different 10% test folds, we could obtain an estimate of the second moment of the generalization classification performance. The cross-validation results were followed up with a nonparametric Friedman test.

We made an attempt at investigating the key input features that had a decisive role in classification. To this end, we ranked the coefficients in the regression models built using naïve Bayes and logistic regression methods as well as variable importance with a random forest approach [17]. We employed the correlation of rank, Kendall τ estimator, to examine the consistency of feature ranking produced by the 3 classifiers:

$$\tau = [(n_c - n_d)]/[n(n - 1)/2]$$

where n is the number of features, n_c is the number of concordant feature pairs, and n_d is the number of discordant feature pairs. The pairwise relation between feature pairs (f_i, g_i) and (f_j, g_j) is considered as concordant if the ranking order between features f is the same as for features g, that is, rank (f_i,) > rank (f_j,) and rank (g_i,) > rank (g_j,), or rank (f_i,) < rank (f_j,), and rank (g_i,) < rank (g_j,). If neither of these relation pairs is preserved, feature pairs are referred to as discordant.

Finally, in order to exploit diagnostic evaluation made by each individual PCP in the second data subset, rather than directly considering the majority vote as the data sample label, we built 5 independent naïve Bayes classifiers. Each one of them was trained on labels from the second subset corresponding to 1 of the 5 panel PCPs. We then evaluated the majority vote of the dichotomized responses of individual classifiers and employed a cross-validation scheme to estimate generalization properties.

Human Versus Model Analysis

To measure the agreement between the PCPs and a classification model, we chose a naïve Bayes approach (referred to as “the model”). Cohen κ [18] was calculated to evaluate interrater reliability of triage level within the panel, as well as interrater reliability between the model results and the panel:

$$\kappa = (p_o - p_e)/(1 - p_e)$$

where p_o is the observed ratio of agreement between 2 raters and p_e is the probability of chance agreement. Cohen κ provides a measure of agreement between raters while accounting for chance agreements. This is in contrast to percentage agreement, which merely quantifies the ratio of cases with the same classification in relation to different classifications made by 2 or more assessors, without accounting for chance agreements. A Cohen κ<0.20 is generally regarded as low, 0.21-0.40 as fair, 0.41-0.60 as moderate, 0.61-0.80 as substantial, and 0.81-1.00 as almost perfect agreement [18].

Additional Analyses

To explore how the brief free-form text influenced the classification, the classifier was retrained without features extracted from the brief free-form text. This analysis was conducted with a linear naïve Bayes approach.

To evaluate intrarater reliability of the training data, 50 of the 300 automated patient interviewing software reports available were chosen for retriage by the same expert PCP. These reports were chosen randomly from the full set but checked to include an even variation of all available symptoms. Cohen κ was used to assess agreement with prior triage.

Furthermore, to evaluate the impact of missing data on our results, we reran the analyses with automated patient interviewing software reports with missing triage data excluded.

Ethical Considerations

The study was approved by the Swedish Ethical Review Authority on April 24, 2019 (reference number 2019-01516).

Data Sharing Statement

Data on triage decisions made by panel members and our expert PCP are available to the Department of Clinical Sciences in Malmö at Lund university, to the Department of Computational Science and Technology at the Royal Institute of Technology, and to Doctrin AB, Stockholm Sweden 10 years following publication. Data can be accessed for a prespecified purpose after approval by all 3 parties above.

Results

Comparisons Between the Three Models

After exclusion, 276 automated patient interviewing software reports were usable as labeled test-set data (Figure 1). The single-pass test results as well as cross-validation outcomes are presented in Table 2. There was no evidence for rejecting the null hypothesis (*P*>.10), so the performance of all 3 classifiers is considered comparable even though one can observe a trend favorable for random forest.

Figure 1. Flowchart of automated patient interviewing software report exclusion criteria.

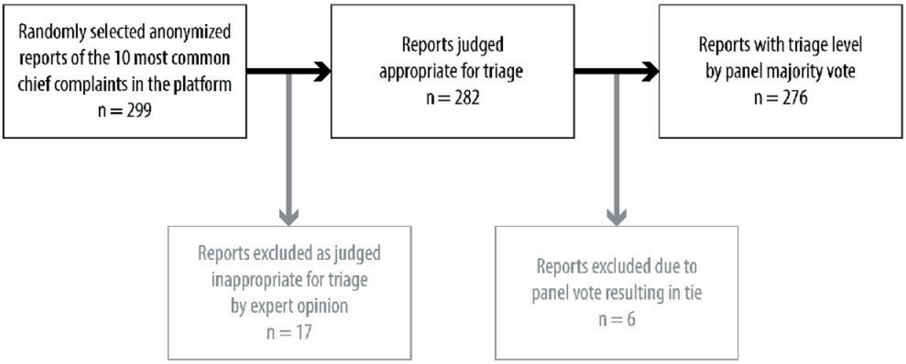

Table 2. Classification results obtained with naïve Bayes, logistic regression, and random forest in a single-pass test as well as in 10-fold cross-validation over the entire combined data set.

Classifier	Test results (training on the first and test on the second data subset), %	10-fold cross-validation (the first and second subsets combined), %[a]
Naïve Bayes	64.1	66.6 (7.6)
Logistic regression	60.1	64.5 (9.0)
Random forest	67.4	69.5 (7.7)

[a]The values for cross-validation are the mean and standard deviation of the classification accuracy obtained over 10 test folds.

Five Classifiers Versus One

Mean cross-validation accuracy calculated using the ensemble performance (majority vote) of the 5 naïve Bayes classifiers, each trained on the labels of one panel member, was 65.3% (SD 8.2%). Comparing this with the model, that is, the single naïve Bayes classifier (mean cross-validation accuracy 66.7% [SD 8.0%]), the null hypothesis could not be rejected (Wilcoxon signed-rank test, n=10, *P*>.24).

Decisive Features for Classification

Because the 3 classification approaches offer insights into feature weighing in the regression function that determines the classification boundary, we investigated more closely the distribution of such feature importance factors (see the "Methods" section). The results are inconclusive as the distribution is rather uniform and the pairwise correlations between feature rankings, Kendell τ (see the "Methods" section), produced by the classifiers are moderate (max 0.32 between naïve Bayes and random forest). This result implies that the given average level of accuracy can be achieved based on different sets of features.

Agreement Between Model and Human Triage

Because there was no statistically significant difference in the performance reported by the 3 classifiers, we decided to rely on the naïve Bayes approach in the next stages of our work due to its intuitive linear formulation. Cohen κ between the naïve Bayes model and the panel majority vote triage was 0.17 (Table 3), with 64% agreement. Excluding the information contained in brief free-form text resulted in the corresponding Cohen κ of 0.15. Within the reference group, average Cohen κ was 0.20, ranging from 0.10 to 0.30.

These results did not differ when analyses were rerun with missing cases excluded. No statistically significant difference in distribution of chief complaint symptoms could be found between reports with and without missing data (chi-square test, *P*>.99).

Using panel majority vote as the gold standard, the model correctly classified 74% (138/186) of nonurgent cases, but only 42% (38/90) of urgent cases. Adding free-form text data had a negligible effect on these numbers (Table 4).

When 50 automated patient interviewing software reports were selected for retriage by our selected expert PCP, Cohen κ was 0.55 with 78% agreement between retriage and previous triage.

Table 3. Assessment of the triage performance: agreement between the naïve Bayes model and each panel member as well as their majority vote, and average interrater agreement among the panel members.[a]

Panel	Panel member versus naïve Bayes model (Cohen κ)	Panel member versus rest panel members (Cohen κ)
PCP1	0.09	0.21
PCP2	0.03	0.21
PCP3	0.24	0.18
PCP4	0.08	0.21
PCP5	0.13	0.17
Majority vote	0.17	N/A

[a]PCP1 had the least amount of clinical experience, whereas PCP4 and PCP5 had the most amount of clinical experience.

Table 4. Contingency table of model triage with panel majority vote as the gold standard.

	Truly urgent	Falsely nonurgent	Truly nonurgent	Falsely urgent
Naïve Bayes model trained on full information including brief free-form text	42% (38 out of 90 cases voted urgent)	58% (52 out of 90 cases voted urgent)	74% (138 out of 186 cases voted nonurgent)	26% (48 out of 186 cases voted nonurgent)
Naïve Bayes model trained with brief free-form text information excluded	42% (38 out of 90 cases voted urgent)	58% (52 out of 90 cases voted urgent)	73% (135 out of 186 cases voted nonurgent)	27% (51 out of 186 cases voted nonurgent)

Discussion

Principal Results

To our knowledge, this is the first study to evaluate human versus ML performance in primary care triage based on a digitalized patient history. The first principal finding of this investigation was that interrater reliability in human triage using automated patient interviewing software reports is low (Cohen κ 0.20). Consequently, our second principal finding was that interrater triage reliability between a statistical model trained on automated patient interviewing software reports and a human panel was low (Cohen κ 0.17).

Findings were robust when cases with missing triage data were excluded from the analysis. The performance of the model was mostly decided by the surveys as removing the free-form text had only marginal impact on Cohen κ (reduced to 0.15). Furthermore, the intrarater reliability was moderate, as seen by retriage of 50 automated patient interviewing software reports by the same PCP (Cohen κ 0.55).

Comparison With Prior Work

While we acknowledge that κ values seldom are comparable across studies [19], previous data have generally found high interrater reliability between triage nurses [20-22]. However, these studies were conducted in high-acuity emergency department settings, where indicators of urgency arguably are more clearly defined [23].

The primary care setting presents a particular challenge in that conditions are of low acuity, making the line between urgent and nonurgent care more difficult to draw. This is supported by the low intrarater agreement for our expert PCP as well as the low agreement between our panel members. Indeed, acquiring a true gold standard for triage is a well-known issue [24]. “Correct” triage is difficult to define, and thus difficult to label and automate using ML. We could not identify any particular features in the data that were linked to the model’s triage decision. As far as the clinicians are concerned, we did not study their clinical reasoning before reaching a triage decision, that is, we do not know on which features their decision was based.

Interpretation

A well-known bottleneck for the creation of reliable ML algorithms is the lack of large enough amounts of labeled training data but this study calls the reliability of labels themselves into question. Labeled data need to be consistent across different raters and over time. Consequently, while adding more automated patient interviewing software data to the training set exploited by the model could improve interrater reliability with humans, the interrater reliability between the humans themselves sets a limit on how useful an algorithm could be if labels are fully decided from human data. While the addition of free-form text did not offer any advantage to the performance of the model, as assessed by our gold standard, it is possible that larger amounts of free-text data would allow the model to leverage these data for improved performance.

Human clinical decision making is likely more prone to be affected by externalities such as stress and mental fatigue [25]. Such externalities may have been present to different extents among our panel, resulting in markedly variable triage decisions compared with each other and the model.

Furthermore, the low agreement between the panel and the model in our study may be due to the fact that variation in human interpretation of text-based cues from automated patient interviewing software data in a primary care setting [26] prevents PCPs from determining urgency as consistently as the model, given access to the same amount of data. It should be noted, however, that in the clinical setting, PCPs would acquire additional data through the eVisit chat before making a triage decision.

The model is trained on triage data from a senior expert PCP, but results show no trend toward higher agreement between more senior PCPs and the model. This suggests that triage decision making depends more on other factors such as PCP temperament and risk aversion than mere experience [27].

Accepting the panel majority vote as the gold standard, nonurgent cases were more often classified correctly compared with urgent cases (74% [138/186] vs 42% [38/90], respectively), even though higher triage accuracy would be expected for urgent conditions where red flags are more well-defined [12]. Selection bias through a disproportionately larger amount of training data on nonurgent automated patient interviewing software reports may explain part of this disparity. On the contrary, this disproportionality may still be representative of a primary care cohort which would utilize such a digital tool for mostly low acuity conditions. However, given the low agreement between panel members, one may also question the suitability of use of the panel majority vote as the gold standard.

Strengths

This study has several strengths. First, it is one of few studies comparing human with ML performance using the same test data set for both groups. It is uniquely conducted in an eVisit primary care setting, where the need for reduced workload is high and where the ML algorithm has access to the same data as the clinician in the eVisit setting would. This contrasts with clinical or electronic health record–based ML tools which may not have access to key clinical data not recorded in the electronic health record [28]. Our data set was largely complete with only 1.4% missing data points. We also used training set data independent of validation test-set data, which is not always the case in other published research in the field [29]. Finally, the findings add nuance to the existing literature of ML versus human physicians [30].

Limitations

The results should be interpreted with consideration to several limitations. Our sample is not representative of a physical primary care population, as reports were acquired from an online consultation service database of self-selected patients being less likely to have life-threatening conditions [31]. Our data did not allow for out-of-sample external validation, as we do not know how these automated patient interviewing software reports ended up being triaged in their clinical setting. Lack of external validation also means that our low interrater reliability was likely overestimated [29]. However, even if externally valid endpoint data could aid in defining a decision as “correct” retrospectively [32], defining “correct” triage prospectively may not be possible as some clinical outcomes cannot be predicted. In addition, the lack of consensus and use of a voting strategy in our panel are unconventional methods of defining a gold standard to compare ML-based performance and make comparison with other studies difficult. Future studies may use consensus techniques such as Delphi [33], incorporating PCP and emergency physician expertise, to mitigate lack of panel triage consensus.

Given the lack of agreement between our panel PCPs, using 1 expert PCP to provide training data may not be optimal. However, we did not observe any significant differences in cross-validation accuracy in this model compared with the ensemble performance of 5 models separately trained by each panel member.

Finally, our data set did not allow us to evaluate how the temporal provision of data affects the triage process in a way that would mimic the iterative clinical decision-making process. Thus, training data sets which make this possible may open up new opportunities for devising ML approaches that better mimic the human decision-making process.

Practical Implications

This study refutes implementation of the current ML model to fully automate binary triage in primary care, despite naïve Bayes being a reasonable ML algorithm to approach this problem. However, in the clinical setting, these reports are used as decision support in the interaction with patients, implying that uncertainties may be addressed by further interaction with the patient. Further development of the model with the suggestions made above may allow for fully automated triage in the future.

Conclusions

While digitalized patient histories have the potential to mitigate primary care workloads, leveraging patient history data to automate triage with ML methods is challenging given the difficulty for human physicians to triage consistently in a primary care setting. Future research should evaluate if external validation and temporal provision of training data may improve automated triage performance, as well as attempt to better identify which features drive triage decisions in a primary care setting.

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Authors' Contributions

AB, PH, SB, and PM were responsible for study concept and design; AB and AE were responsible for data acquisition; PH and SB performed analysis; AE was responsible for manuscript drafting; all authors were responsible for data interpretation, critical revision of the manuscript for important intellectual content, and final approval of the version to be published.

Conflicts of Interest

AB is the Chief Medical Officer of Doctrin AB, one of the project parties in this Vinnova-financed project. Other authors have no conflicts of interest to declare.

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Abbreviations

ML: machine learning
PCPs: primary care physicians

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Paper II

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Experiences of digital communication with automated patient interviews and asynchronous chat in Swedish primary care: a qualitative study

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ABSTRACT

Objectives To explore staff experiences of working with a digital communication platform implemented throughout several primary healthcare centres in Sweden.

Design A descriptive qualitative approach using focus group interviews. Qualitative content analysis was used to code, categorise and thematise data.

Setting Primary healthcare centres across Sweden, in both rural and urban settings.

Participants A total of three mixed focus groups, comprising 19 general practitioners and nurses with experience using a specific digital communication platform.

Results Five categories emerged: 'Fears and Benefits of Digital Communication', 'Altered Practice Workflow', 'Accepting the Digital Society', 'Safe and Secure for Patients' and 'Doesn't Suit Everyone and Everything'. These were abstracted into two comprehensive themes: 'Adjusting to a novel medium of communication' and 'Digitally filtered primary care', describing how staff experienced integrating the software as a useful tool for certain clinical contexts while managing the communication challenges associated with written communication.

Conclusions Family medicine staff were ambivalent concerning the use of digital communication but, after a period of adjustment, it was seen as a useful communication tool especially when combined with continuity of care. Staff acknowledged limitations regarding use by inappropriate patient populations, information overload and misinterpretation of text by both staff and patients.

Strengths and limitations of this study

- This is the first focus group study describing both physicians' and nurses' experiences of two-way digital communication between patients and providers in primary care settings.
- Theoretical saturation and high participant engagement allowed for rich descriptions and transferability of our findings to other contexts.
- Limitations include lack of multiple coders and a potential bias toward physician perspectives as the interviewers were both physicians.

INTRODUCTION

The patient interview and physical examination are central to family medicine consultations. In Sweden, patients are increasingly using digital communication to access primary care.[1] Swedish healthcare holds a high international standard,[2] but low continuity and poor accessibility to primary care contribute to low patient satisfaction.[3] Whether digital communication can address or aggravate these challenges is currently unknown.[4] Furthermore, staffs' low technical literacy and resistance to change may be common barriers to implementation,[5] limiting potential benefits of such technology from being realised.

Heterogeneity between digital communication tools is high, making it difficult to draw general conclusions about their usefulness. Some use synchronous video communication, while others are asynchronous 'chat-based'. Different variations of automated patient interviewing software can also be used to gather key information prior to consultations.

The current study evaluates a digital communication platform (developed by Doctrin AB, referred to as 'the platform' in this paper) implemented across several primary healthcare centres (PHCCs) in Sweden for use as an alternative point of access to primary care. Patients choose among a prespecified list of queries and access an automated patient interviewing software on their computer, tablet or smartphone, freely writing their ideas, concerns and expectations as is common in family medicine consultations.[6] They then answer a query-specific questionnaire, including the possibility to attach images, with answers presented to the healthcare provider (usually a nurse) who can proceed to communicate via asynchronous chat-based two-way communication. General practitioners (GPs) or other staff can join the chat if required. If a query cannot be concluded via digital communication, the patient is scheduled for a relevant physical appointment.

A Norwegian study recently found that GPs generally had positive experiences with using digital communication.[7] Meanwhile, UK studies found that GPs felt such communication benefitted the patients and saved time, but GPs also raised concerns about security, increased workloads and poor integration into clinical practice.[8 9]

None of the above studies evaluated two-way digital communication systems, where both the patient and the provider can send digital messages. Such communication has been studied in the context of specific diseases[10–12] or mobile phone text messaging without an adapted platform software.[13]

Furthermore, leveraging reports summarising patient ideas, concerns and expectations prior to digital communication may be important for staff to more effectively help patients without additional workloads.[8] Therefore this qualitative study aimed to answer the following research question:

> How do family medicine physicians and nurses experience the implementation and use of digital communication in the form of automated patient interviewing software and chat-based patient-provider communication?

METHODS

Qualitative approach and research paradigm

This study deemed an interpretivist paradigm suitable for understanding the phenomena of staff experience working with digital communication.[14] Focus group interviews, commonly used to study attitudes and needs of medical staff,[15] were thus chosen as the data-collection method. GPs and nurses form pre-existing groups working together as a team during focus group interviews, allowing for 'naturalistic' exchanges during data collection. This may give a deeper understanding of the target phenomenon. Open discussions allow participants to debate the studied phenomenon from a personal point of view and facilitate expression of beliefs and attitudes left undeveloped in an individual deep interview.

Context

Three PHCCs were purposefully sampled from a wide range of national PHCCs using the platform. Samples were chosen to provide a mix of urban and rural settings, as well as smaller and larger panel sizes. In each sampled PHCC, all GPs and nurses with experience of using the platform were invited to participate, with the goal of recruiting a minimum of six participants per group with an even distribution of GPs and nurses.

Participants gave written consent to participate in the focus group interview.

Patient and public involvement

Patients or the public were not involved in this study.

Data availability statement

Interview transcripts and coding data is available on request.

Data collection

Interviews were conducted between 5th and 12th June 2019 with a moderator (VMN) introducing topics with open-ended interview-guide questions (online supplementary appendix 1), facilitating the discussion with follow-up questions and summaries to verify interpretations. The interview guide was iteratively modified in response to evolving study findings. For data triangulation, an interview assistant (AE) observed and registered non-verbal communication but also aided the moderator in facilitating the discussion. Demographic data and quantitative data on months of experience working with the platform were also collected from all interview participants with a short questionnaire. Interviews were audio recorded (Olympus VN-8700PC) and transcribed verbatim.

Data analysis

Qualitative content analysis as presented by Graneheim and Lundman[16] was used as it is a suitable inductive approach for describing human experience while also allowing for triangulation of analysis by researchers without contact with studied persons.[17] Analysis was conducted in Swedish with NVivo 12. Relevant quotes were translated into English. The first author (AE) coded the data set (examples given in table 1), with regular discussions with two other authors (VMN and BBB) at all levels of analysis. All three authors where involved in thematisation. The manuscript was drafted using the Standards for Reporting Qualitative Research guidelines.[18]

Table 1 Examples of meaning units, condensed meaning units and codes

Meaning unit	Condensed meaning unit	Code
…if it has any medical consequences, it's too soon to tell, there's too few, a too small sample	*Too small sample to know medical consequences*	*Medical consequences unknown*
…and to be able to consult colleagues and the doctors and such… I see that as positive, compared with using the phone	*Easier to consult colleagues compared with the phone*	*Enables colleague consultation*

Table 2 PHCC, staff and interview characteristics

	Interview duration (min)	Location	Patients managed	Number of staff (as cited)	Age group	Number of females	Mean years with license (range)	Mean months in platform (range)
PHCC 1	49	Urban	9 000	3 Nurses (Nurse 1–3)	20–50	3	4.3 (3–5)	2.7 (2–3)
				1 GP (GP 1)	50–60	1	18 (18–18)	4 (4–4)
PHCC 2	43	Urban	27 000	2 Nurses (Nurse 4–5)	20–40	2	6 (1–11)	3 (3–3)
				3 GPs (GP 2–4)	40–50	1	10 (9–11)	4 (1–6)
PHCC 3	39	Rural	8 000	5 Nurses (Nurse 6–10)	30–60	4	17.4 (1–31)	3.5 (2–4)
				5 GPs (GP 5–9)	30–60	4	15.2 (3–23)	3.6 (3–4)

GP, general practitioner; PHCC, primary healthcare centre.

RESULTS

Study unit characteristics

Characteristics of PHCC participants and the interviews are summarised in table 2.

During analysis, 14 subcategories emerged, grouped into five categories, abstracted into two themes: 'Adjusting to a novel medium of communication' and 'Digitally filtered primary care' (table 3). Below, each category is described in detail.

Fears and Benefits of Digital Communication

Participants expressed an ambivalence towards the use of digital communication. Some felt curious and excited, while others expressed scepticism to the usefulness of such technology. PHCC 1 and PHCC 3 had relatively few patients using the platform, while PHCC 2 used the platform extensively. All participants felt it was too early to evaluate long-term risks and consequences of its use.

Nurses from the two urban PHCCs felt that the platform allowed patients to fully express their concerns without interruption, as some text presented by the automated patient interview was directly written by the patient.

> And it's really their words. It's not our interpretation of their words. That's also… it becomes more certain, I think. – Nurse 3

Staff perceived an advantage of using software to ensure that relevant questions were always asked, without individual stress or other externalities affecting the

Table 3 Themes, categories and subcategories

Theme	Category	Subcategory
Adjusting to a novel medium of communication	Altered Practice Workflow	Streamlined communication
		Improved interdisciplinary cooperation
		Unpredictable workload
	Accepting the Digital Society	Expectations to be digital
		Improved digital experience over time
	Safe and Secure for Patients	Improved management of certain patient groups
		Accessible continuity
Digitally filtered primary care	Doesn't Suit Everyone and Everything	Not suitable for all patient queries
		Digital communication as a partial solution
		An incomplete system
	Fears and Benefits of Digital Communication	Incomplete information transfer
		Ambivalence and uncertainty
		Superhuman capacity
		Affects the patient–provider relationship

consultation. The ability to reflect over messages before sending them was perceived as beneficial, especially for emotionally loaded discussions. On the contrary, staff highlighted that some patients experienced the chat as 'robotic', speculating that this could affect the patient–provider relationship.

Several participants mentioned that the automated patient interview allowed for acquisition of patient history data beyond what would otherwise be feasible during a regular phone call. While the presented information was perceived as useful, covering important differential diagnoses, staff felt overwhelmed for clinical decision-making. There seemed to be a reluctance towards over-information, with GPs from PHCC 2 concluding that the most valuable information came from the first three free-text questions about patient ideas, concerns and expectations.

> …it's about having just enough information in those questionnaires so that one can digest it… there is a balance… between too much and too little information too, so that it stays relevant… – GP 2

The platform was perceived to provide a unique value through the asynchronous chat, as clinical decisions could be communicated with several short messages without excessive conversation. Sending images was perceived to be useful, providing a unique benefit over telephone consultations, especially for dermatological queries. The platform did not include synchronous video consultations at the time, but these were speculatively perceived as less beneficial, as they were thought to too similar to telephone consultations.

> One aspect is the automated patient interview tool and the other is the asynchronous communication. So those two things are new… I almost think that the asynchronous communication is the biggest benefit. I do. – GP 4

All groups felt that communicating via text led to some loss of communication nuance. One GP repeatedly emphasised the shortcomings of written communication, giving the impression of being particularly cautious about widespread use of this new technology. While facial expressions and body language were already absent in telephone consultations, cues like tonality were further removed when moving to text-based communication. Staff felt that these cues, in certain situations, provided important 'between the lines' context for interpretation of the reported symptoms.

> That's probably why… fully artificial-intelligence-run systems refer 15 per cent to the emergency department… Because if one interprets peoples' words literally, then the whole healthcare system crashes. – GP 4

Patient interpretations of symptoms were perceived to not always be in-line with clinician interpretations. Misunderstood questions were not reformulated by the automated patient interview as would otherwise be possible in a live conversation.

> What does 'dizziness' mean? … There are many terms that mess things up. Because we're talking about different things, a certain symptom is one thing for the patient and another for me… so it's hard to just ask specific questions in a questionnaire like that. – GP 2

Most often, staff experienced symptoms to be less severe than reported when asking follow-up questions. GPs feared trivialising patient symptoms over time. Such risks were perceived lower with telephone consultations where severity was more confidently assessed. Consequently, some GPs felt that they tended to ask more follow-up questions via the platform compared with telephone consultations.

> Yes, because I'm thinking if you look at the group presenting with anxiety and depression, for example, they get a lot of questions and then many of them specifically report suicidality or such, and… when one calls them, it isn't at all like they have written. – Nurse 4

The human ability to scrutinise reported information when consulting patients was deemed as central to the consultation process, but the automated patient interview was perceived to lack this ability.

> In a conversation… one consciously ignores some things… Here it's 'on print'… that they have 'numbness in half of their body'… which looks a little worse than if they say it in a context where it is completely obvious that they don't… The 'human filter', it vanishes. – GP 4

Staff also expressed frustrations over being involuntarily responsible for irrelevant symptoms reported by the platform, including obsolete chronic symptoms or symptoms indicative of potentially severe disease.

> Do you have abdominal pain?' Yes… they have had abdominal pain for 50 years. But we don't need to talk about that today. I would never ask the question in a normal conversation… or an obvious tension headache, but… visual impairment, asymmetrical pupil size… like 'Aha, maybe we should order an ambulance instead?! – GP 3

This resulted in divergent agendas between GPs and patients where GPs focussed on addressing irrelevant but potentially urgent symptoms, while patients expected to get their primary less urgent concern addressed.

> …it's not the questions I want the answer to, but which I have to assess… and it's extremely annoying… and now there's also a pop-up… saying that I am responsible for all the information I'm getting… Then I feel [the platform] limits me… that it takes longer than if I had done it another way. – GP 3

Frustrations were also expressed regarding patients skipping questions, not reading staff responses, taking hours to answer follow-up questions or failing to confirm suggested appointments.

Altered Practice Workflow

In all PHCCs, nurses initially managed most queries in the platform. Staff from PHCC 2 estimated that around 30% of queries were forwarded to GPs for further evaluation. Initially several nurses experienced stress of using the platform in addition to keeping track of electronic health records and other digital systems, as well as managing multiple parallel queries, especially when combined with physical visits and telephone consultations.

> First it was a bit easy to make mistakes…if one had maybe five ongoing queries and maybe two girls around the same age or so to speak, it was easy to write to the wrong patient. … until one develops a routine. – Nurse 1

However, staff generally felt that they handled digital queries faster and better over time. Miscommunication prevention, adjusting staffing at other workstations, scheduling adjustments and stress management strategies were examples of ongoing adjustments. The platform was then perceived as adding variation to the workday. There was a general sense that staff were content with the current state of affairs after a relatively hectic initial implementation of the new technology. Some PHCCs assigned rooms for work with the platform, with staff appreciating a less noisy environment.

All groups experienced shorter and more streamlined consultations, with easier appointment booking, information sharing and expressed reluctance of no longer having to redial patients not answering their phones.

> …visits are better prepared and that's both good and bad. For example… someone seeking care for mental illness, who has already filled in rating scales etc, one enters the conversation at a different point. It's not like, 'Good day, what are you here for?'. Instead you have a lot of information before, when one starts the conversation… if it has any medical consequences is too soon to tell… – GP 9

Many felt that the chat-format made it easier to consult colleagues and gather information before answering certain patient queries, improving the interdisciplinary collaboration and the perceived working environment.

Challenges still remained, as staff expressed that certain patients took several hours to respond. By the end of the day, potentially urgent symptoms may thus have been left unaddressed. PHCC 3 managed this with a standardised message, informing patients to seek out-of-hours clinics for urgent symptoms.

Accepting the Digital Society

There was a general perception that digitalisation was not a choice. Parallels were drawn to implementation of telephone communication in family medicine, and pressures to use existing means of communication.

> … if you have an entire panel who speaks English, then it's reasonable that we also speak English… we can't close our eyes to the fact that people communicate this way. We can't say 'we don't use phones, we use messages in bottles'… We have to adapt… – GP 4

Patients using the platform were perceived as being different from those seeking traditional care, with patients expecting fast responses, similar to a commercial customer support chat. Despite the challenges of adapting to the digital era, there was a general sense that the platform was perceived better over time.

> When it came we were a bit scared that it would be a lot… that we wouldn't be able to handle it, but today I feel that we are all pretty positive and that we more easily can communicate with patients and it will only get easier – Nurse 7

In fact, all practices expressed a desire to stay digital, with two PHCCs incentivising patients to use the platform by offering shorter waiting time for appointments or automatically redirecting certain patients from the phone.

Safe and Secure for the Patient

The platform was perceived to aid in triage by giving an overview of incoming presenting symptoms and reported symptoms. There was a general perception of improved access to care as staff felt that patients more quickly could engage in dialogue with nurses compared with telephone visits.

> Many appreciate that 100% availability which it really provides. [Patients] can write and will get through… that's very reassuring – GP 2

Staff were also surprised that the platform was occasionally used by elderly individuals and patients with socioeconomic difficulties.

> It was a patient who otherwise has a very strained life. I was very surprised that she could use it, but it's worked well for her… a single mother with three small children… working full-time and finds phone calls from the practice difficult during working hours… So we can send her a text, or chat with her and manage things when it works for her… She thought it was great. – GP 1

PHCC 2 experienced a transition from initially viewing the platform as a triage tool to a tool for improving continuity of care, giving the PHCC a unique advantage over private 'digital only' family medicine providers. One GP felt that his frequent visitors could be managed more effectively with chat follow-ups. Following stable chronic conditions, selective serotonin reuptake inhibitor treatments and dermatological diagnoses were other examples of platform use for improved continuity. Staff were uncertain, however, whether the platform had substantially reduced physical visits in general.

> …I perceive that for my patients, mostly the sickest or most worried ones, it's a huge reassurance and very personal. When they can chat with me and I can say like 'We don't need to book a new appointment'… 'Take it easy and be in touch. It may take a day before I answer, but I will answer.'… then they have a face associated to the person writing… then one can sometimes even crack a joke in the chat – GP 4

Doesn't Suit Everyone and Everything

All groups acknowledged that digital communication didn't suit all patient queries. Although some technically literate elderly patients used the platform, staff felt others were less confident often resulting in phone calls being made to clarify the issue. Staff generally felt the patients with simple queries were manageable in the platform, while complex queries or cases of low continuity were situations where the platform was perceived as less useful. In multiple instances, staff explained that queries which required prolonged dialogue via text often resulted in a phone call as this was perceived as a more effective way of managing and concluding such queries.

A number of technical improvements were lifted to adapt the platform to local prerequisites.

> Many queries are pretty simple… 'I want to renew a prescription', 'what did my tests show?', 'why is there such a long waiting time'. In these situations, one isn't dependent on any finessed nuances… – GP 9

GPs envisioned digital communication as an additional tool to existing ways of working. Few queries were managed completely digitally, but rather 'digi-physically' as digital communication could on many occasions contribute to overall management of a patient, followed by an occasional physical examination. Classification into digital or physical care was thus seen as a false dichotomy, as transitioning between modes of communication often was perceived as useful depending on the clinical situation.

DISCUSSION

Main findings

PHCC staff initially experienced implementation of the platform as both uncertain and exciting. Over time, views of the platform seemed to shift from a foreign entity with a specific purpose to an integrated part of practice complementing other modes of patient communication. Challenges remained, but there was a general sense that staff wished to remain digital.

Themes

The theme 'adjusting to a novel medium of communication' highlights how staff experienced having to accept and integrate asynchronous communication into practice, but also experiencing value in management of certain patients as well as improved continuity.

The theme 'digitally filtered primary care' highlights that staff experienced patient data presented both in overwhelming detail in terms of symptom reports, but also with loss of communication nuances which created an uncertainty in the management of some patients.

General discussion

Our findings conceptualise digital communication as both an alternate means of information exchange (a transactional process) as well as a means of developing and maintaining doctor-patient relationships (a transformational process), two dominating paradigms in the communication literature.[19] Additionally, implementing digital communication had effects beyond patient communication, that is, on practice organisation and working environment.

Qualitative research on primary care staff experiences of implementing automated patient interview software combined with two-way asynchronous digital communication is limited. Johansson and Ivarsson recently presented survey data on nurse experiences of a pilot version of the platform.[20] Like our study, they found that nurses experienced improved triage, high patient satisfaction, issues of care supply to specific patient populations and issues with managing information technology systems.[20] Our results add depth to these findings, as well as focussing primarily on staff experiences of digital communication beyond the platform itself.

In a separate publication, Johansson *et al* interviewed GPs after two months of using the same pilot platform.[21] Similar to our study, GPs expressed that the patients' self-reported medical history and asynchronous communication had a unique benefit, that visits were well prepared and that collegial collaboration increased. Furthermore, the GPs experienced that symptom severity was difficult to assess, that working with multiple IT systems was cumbersome and that not all queries were suitable. Our study adds staff experiences past two months of using the fully developed version of the platform, where staff express wishing to stay digital and further integrate the platform into practice.

Unlike our study, other studies have found that GPs experienced digital communication as poorly integrated into clinical practice, adding to increasing workloads.[8 9] These were platforms without two-way communication and patient-centred questionnaires, and queries weren't triaged by nurses prior to reaching GPs, indicating that our findings are context-specific.

Our findings are consistent with a Cochrane review concluding that health workers felt that two-way text-based communication can facilitate the patient-provider relationship, but that specific situations still warrant face-to-face consultations.[13]

The finding that two-way digital communication focusses queries while letting patients better express their concerns is consistent with studies on nurses in the context of prostate cancer management.[10]

The risk of misunderstandings given two-way written digital communication has also been expressed by clinicians in the context of managing diabetes[11] and young people with long-term conditions.[12] The last study also concluded that digital communication is best implemented when there is an existing patient-provider relationship of trust.[12] Continuity of care thus remains a central component of a highly functioning primary care system.[22]

Strengths

Several factors add to the trustworthiness of our findings. First, credibility increased by prolonged engagement, peer debriefing from coding to categorisation and data triangulation with non-verbal observations. The two interviewers had experience with using digital communication in primary care, creating a mutual understanding of the context the participants worked with. Investigator triangulation with a third researcher without a background in digital communication added an alternative perspective on the data for a richer interpretation. Highly engaged participants allowed for thorough descriptions of our goal phenomenon, adding transferability of our findings to similar contexts. Purposefully sampled PHCCs from both rural and urban settings added generalisability to our findings.

No new subcategories emerged from the final focus group, suggesting that 'theoretical saturation' was reached.[23] However, we cannot exclude that further focus groups would yield a different final perspective.

Limitations

Due to limited resources, we were unable to conduct secondary coding. We didn't conduct member checks which limits credibility. Lack of an audit trail also limits confirmability and consistency. This was a small study with three PHCCs and thus the experiences described may not represent those of most staff using the platform. The technology is new, and presumably currently adopted by PHCCs interested in using it.[24]

Mixing GPs and nurses may have influenced the results as GPs in some focus groups were perceived to answer more readily than nurses. However, mixing groups also allowed for instant exploration of experiences shared by both professions. Finally, as interviewers were both GPs, participant engagement and interpretation of results may have been skewed in favour of GP over nurse perspectives.

CONCLUSIONS

Family medicine staff experience a period of adjustment to integration of digital communication in a time when such communication is extensively used and expected by patients. Despite concerns about inappropriate use and difficulties interpreting text, staff experience digital communication as a potentially useful choice of communication in certain contexts, especially when combined with continuity of care. Future research should explore which specific clinical contexts are best suited for digital communication.

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Paper III

Original Paper

Antibiotic Prescription Rates After eVisits Versus Office Visits in Primary Care: Observational Study

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Related Article:
This is a corrected version. See correction statement in: https://medinform.jmir.org/2021/11/e34529

Abstract

Background: Direct-to-consumer telemedicine is an increasingly used modality to access primary care. Previous research on assessment using synchronous virtual visits showed mixed results regarding antibiotic prescription rates, and research on assessment using asynchronous chat-based eVisits is lacking.

Objective: The goal of the research was to investigate if eVisit management of sore throat, other respiratory symptoms, or dysuria leads to higher rates of antibiotic prescription compared with usual management using physical office visits.

Methods: Data from 3847 eVisits and 759 office visits for sore throat, dysuria, or respiratory symptoms were acquired from a large private health care provider in Sweden. Data were analyzed to compare antibiotic prescription rates within 3 days, antibiotic type, and diagnoses made. For a subset of sore throat visits (n=160 eVisits, n=125 office visits), Centor criteria data were manually extracted and validated.

Results: Antibiotic prescription rates were lower following eVisits compared with office visits for sore throat (169/798, 21.2%, vs 124/312, 39.7%; $P<.001$) and respiratory symptoms (27/1724, 1.6%, vs 50/251, 19.9%; $P<.001$), while no significant differences were noted comparing eVisits to office visits for dysuria (1016/1325, 76.7%, vs 143/196, 73.0%; $P=.25$). Guideline-recommended antibiotics were prescribed similarly following sore throat eVisits and office visits (163/169, 96.4%, vs 117/124, 94.4%; $P=.39$). eVisits for respiratory symptoms and dysuria were more often prescribed guideline-recommended antibiotics (26/27, 96.3%, vs 37/50, 74.0%; $P=.02$ and 1009/1016, 99.3%, vs 135/143, 94.4%; $P<.001$, respectively). Odds ratios of antibiotic prescription following office visits compared with eVisits after adjusting for age and differences in set diagnoses were 2.94 (95% CI 1.99-4.33), 11.57 (95% CI 5.50-24.32), 1.01 (95% CI 0.66-1.53), for sore throat, respiratory symptoms, and dysuria, respectively.

Conclusions: The use of asynchronous eVisits for the management of sore throat, dysuria, and respiratory symptoms is not associated with an inherent overprescription of antibiotics compared with office visits.

Trial Registration: ClinicalTrials.gov NCT03474887; https://clinicaltrials.gov/ct2/show/NCT03474887

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KEYWORDS

telemedicine; antibiotics; streptococcal tonsillitis; cystitis; respiratory tract infection; virtual visit; virtual; eVisit

Introduction

Direct-to-consumer telemedicine is an increasingly used modality to access primary care in Sweden [1]. Such visits can take the form of asynchronous chat-based visits (eVisits) or synchronous video-based visits (virtual visits). While telemedicine has the potential to address many challenges facing primary care [2] and provide an appropriate alternative for minimizing risk of COVID-19 during the current pandemic [3], concerns have been raised regarding overprescription of antibiotics [4] and potential ramifications to increasing widespread antibiotic resistance. Antibiotic resistance is already predicted to cause more deaths than cancer by the year 2050 [5].

Most research has been conducted on data derived from synchronous virtual visits in American health care settings, where antibiotic prescription is historically higher [6], possibly due to a more market-controlled health care system with incentives for high patient satisfaction [7]. Consequently, there have been mixed results regarding antibiotic prescribing following virtual visits in various contexts [4,8-18], with most studies focusing on urinary tract infections (UTIs) and upper respiratory infections. For example, depending on the health care provider, virtual visits for sinusitis have been associated with both higher [14] and lower [10,13] prescriptions rates compared with office visits. Comparisons to urgent care settings often demonstrate lower prescription rates for virtual visits [8,9].

In Sweden, primary care accounts for 61% of medical antibiotic consumption [19], with 30% of consultations concerning infections [20], most commonly upper respiratory tract infections, tonsillitis, and UTIs [20,21]. Guideline adherence in management of these conditions is poor [22-24]. A study on virtual visits reported that 50% to 60% of cases diagnosed with viral pharyngitis had rapid streptococcal antigen testing (RST) performed or no antibiotics prescribed, while 90% of those diagnosed with streptococcal pharyngitis had RST performed or antibiotics prescribed [25]. However, no comparison was made with office visits. There is thus a paucity of literature concerning eVisit investigations, particularly in terms of head-to-head comparisons to office visits, as highlighted by systematic reviews [26,27].

The aim of this study was to investigate if management of sore throat using a specific eVisit platform led to significantly higher rates of antibiotic prescription compared with usual management using office visits. Secondary outcomes include prescription rate following dysuria and other respiratory symptoms, type of antibiotics prescribed, documentation of Centor criteria (used to identify the likelihood of a bacterial infection in adult patients complaining of a sore throat), and set diagnoses.

Methods

eVisit Platform

This retrospective cohort study specifically evaluates an eVisit platform (referred to as "the platform" in this paper) used by a major private health care provider. The platform combines automated patient interviewing software with an asynchronous 2-way text-based chat between patient and health care provider. Patients access the platform using their smartphone, tablet, or computer device and choose their chief complaint from a prespecified symptom list. A digital patient history is then taken, allowing the patient to formulate ideas, concerns, and expectations [28] in free-text with the addition of symptom-specific multiple-choice questions based on algorithms. Questions may address UTI symptoms and patient-assessed Centor criteria [29], such as “Do you have any of the following symptoms together with your sore throat?” with choices of “fever,” “swollen lymph nodes on the neck,” “severe pain when swallowing,” “cough,” “white exudates on your tonsils or in the back of your throat” (image not mandatory but recommended). If a patient reports fever, the question “Have you measured your body temperature?” may be asked with choices “no” or “yes” with an option to specify the highest value in degrees Celsius. Photos can be attached when relevant; this is recommended for the management of sore throat. Answers are summarized and presented to a physician for review, and further doctor-patient communication occurs through a text-based conversation, similar to text messaging, with patients and providers messaging each other at their convenience. Physicians can prescribe medications, order laboratory samples, provide patient information, or stay available for up to 72 hours for conservative management. If deemed necessary, the physician can schedule an office visit at a primary health care center of the same health care provider. At the time of the study, the platform used no machine learning technology.

Setting and Population

As the private health care provider offers both office visits and eVisits using the platform since July 31, 2017, data could be acquired for both visit types. A total of 16 primary health care centers in the county provided office visit data, while national eVisit data was acquired from the online platform. Inclusion criteria were physician visits with a chief complaint of sore throat, cough, cold/flu symptoms, or dysuria as specified by free-form text in the electronic medical record (EMR) as identified by data extraction software (Multimedia Appendix 1). We also included visits with a recorded diagnosis code J030 (streptococcal tonsillitis), J069 (acute upper respiratory infection), or N300 (cystitis). Visits were included if they occurred between March 30, 2016, and March 29, 2017 (office visits only) or March 30, 2018, and March 29, 2019 (eVisits and office visits). Exclusion criteria were patients aged younger than 18 years, male patients with dysuria, and identifiable visits for similar chief complaints in the past 21 days.

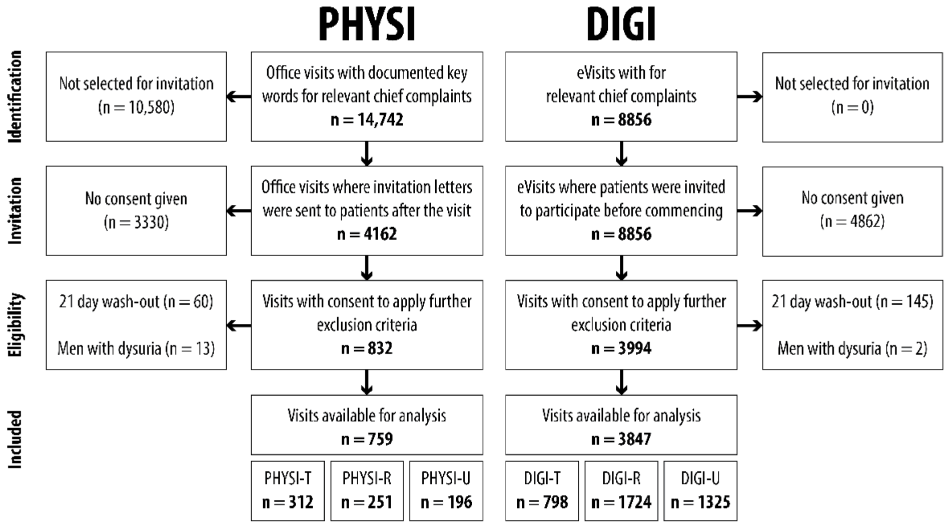
Power Calculation and Recruitment

Previous data from Sweden suggested an antibiotic prescription rate of 59% for patients with sore throat–related diagnoses [20]. Using a binary outcome power calculation with a noninferiority limit of 10%, an alpha level of .05, for 80% power, we estimated needing 300 sore throat visits per group.

Digital consent was acquired from eVisit patients at the beginning of the visits and recorded in the EMR. Written consent was acquired from office visit patients, with sore throat patients receiving letters including 2 reminders if no reply was received. Recruitment was completed after consent was acquired from at least 300 sore throat patients in each group. After recruitment, remaining exclusion criteria were applied before analysis commenced (Figure 1).

The health care provider identified 14,742 potential office visits eligible for participation. Letters were then sent to a random selection of 2000 patients with suspected sore throat, 1000 patients with suspected dysuria, and 1000 patients with suspected symptoms of cough, common cold, and influenza, comprising 4162 visits. For office visits with a chief complaint of sore throat (PHYSI-T), 87 patients were recruited after 1 month. An additional 117 patients were recruited after a second letter was sent 2 months later, and an additional 96 patients were recruited 1 month after the third recruitment letter was sent out. A total of 8856 relevant eVisits were identified, from which patients were also invited to participate. In total, we recruited patients from 832 office visits and 3994 eVisits. After exclusion of dysuria visits with male patients and visits within the 21-day washout period, 759 office visits and 3847 eVisits remained for analysis (Figure 1). Office visits were in 99.1% of cases identified via keywords in the free-form text the EMR, while 0.1% (2 sore throat visits, 22 respiratory visits, and 18 dysuria visits) were identified through set diagnoses.

Figure 1. Flowchart of patient recruitment. PHYSI: primary care office visits; DIGI: eVisits; PHYSI-T: office visits with a chief complaint of sore throat; PHYSI-R: office visits with a chief complaint of common cold/influenza or cough; PHYSI-U: office visits with a chief complaint of dysuria; DIGI-T: eVisits with a chief complaint of sore throat; DIGI-R: eVisits with a chief complaint of common cold/influenza or cough; DIGI-U: eVisits with a chief complaint of dysuria.



Diagnostic Criteria and Guideline Adherence

Swedish national guidelines recommend identifying at least 3 Centor criteria (tonsillar exudates, swollen tender anterior cervical nodes, lack of cough, and presence of fever over 38.5° Celsius) prior to ordering an RST [29]. Guidelines recommend that RST should only be performed if the advantages of antibiotic treatment are deemed to outweigh the disadvantages for the individual patient and subsequently recommend penicillin V as first-line treatment [30]. All cases of ordered RST in the presence of Centor criteria were assumed to be due to primary health care physicians deeming the advantages of antibiotic therapy outweighing the disadvantages. In the office visit group, Centor criteria are documented after a physical examination by a physician. For the eVisit group, patients self-assess and report Centor criteria in the automated patient interviewing software [25]. Answers are evaluated by a physician who then chooses which criteria to document in a specified template by, for example, being required to check a box specifying that temperature was above 38.5° Celsius. The physician may choose to document Centor criteria differently from how patients report the criteria depending on what information is acquired during the 2-way patient-provider chat.

Data Collection

Baseline variables included chief complaint, visiting date, age, and gender. The primary outcome was antibiotic prescription within 3 days following sore throat as the chief complaint, which is similar to previous studies [11,31,32]. Secondary outcomes included antibiotic prescription within 3 days of visits for dysuria and cough/common cold/influenza, type of antibiotic prescribed, documentation of Centor criteria, laboratory tests ordered within 3 days (c-reactive protein [CRP] and RST). Guideline adherence for sore throat patients was also assessed in terms of following indications for antibiotic prescription.

Data extraction software was used to automatically extract data [33,34] with subsets manually validated by reading all free-form text in the EMR and evaluating deviations from automatically extracted data. Variables that were manually evaluated included chief complaint (n=783), Centor criteria (n=285), CRP ordered (n=294), RST ordered (n=284), antibiotic prescription (n=782), and antibiotic type (n=183).

As automatic extraction of free-form text was not possible, Centor criteria for PHYSI-T were manually extracted from a randomly selected subset of the cohort (n=125) while automatically extracted Centor criteria were manually validated for a subset of DIGI-T visits (n=160), resulting in a total of 285 visits with manually validated Centor criteria. Protocols were used for all interpretation of free-form text (Multimedia Appendix 1). For example, free-text documentation stating "fever" was deemed a Centor criterion since only a minority of cases specified temperature in this context.

Statistical Analyses

Analysis was conducted using SPSS Statistics version 26 (IBM Corporation). A 21-day washout period was applied, excluding past eVisits or office visits for similar chief complaints, similar to previous methods [4]. For this washout, sore throat, cough, and common cold or influenza were all deemed similar chief complaints as they are all respiratory symptoms.

Visits for cough and common cold or influenza, each a separate chief complaint for eVisits, were grouped together for analysis as these chief complaints often result in similar diagnoses, resulting in a total of 6 groups for analysis: sore throat office visit (PHYSI-T) and eVisit (DIGI-T), cough/common cold/influenza office visit (PHYSI-R) and eVisit (DIGI-R), and dysuria office visit (PHYSI-U) and eVisit (DIGI-U). Variables on type of antibiotics prescribed were recategorized to separate antibiotics not commonly recommended by guidelines (Multimedia Appendix 2). For analyses of guideline adherence, manually collected Centor criterion data were dichotomized so that undocumented symptoms were assumed to be absent.

The first diagnosis recorded at each visit was recategorized as UTI, viral upper and lower respiratory tract infection, tonsillitis, and 3 common diagnoses seen as more severe conditions following each of our chosen chief complaints: pneumonia, peritonsillar abscess, and pyelonephritis. Symptom-based codes and nondiagnostic codes were grouped as nonspecific or symptom-based diagnosis and remaining diagnoses were grouped as other (Multimedia Appendix 3). Continuous data were presented with mean and standard deviation and analyzed with Student *t* test, while categorical data were presented with percentage and analyzed with chi-square test.

We hypothesized that there would be no clinically relevant difference in antibiotic prescribing. Hypothesis testing was conducted by comparing office visits to eVisits for each chief complaint. As age and set diagnoses are potential confounding factors for the tendency to prescribe antibiotics, multiple binary logistic regressions were conducted for each chief complaint with antibiotic prescription as the dependent variable and visit type as the independent variable in an enter regression model. The models were then adjusted for age and diagnoses of tonsillitis, viral upper and lower respiratory tract infection, pneumonia, and other diagnoses. eVisits were used as the reference group.

No data were missing for the primary outcome analyses. For secondary outcomes, visits with missing data were compared with visits with valid data for patient age, prescription of antibiotics. and antibiotic choice to test whether data was missing at random. Visits with data missing at random were excluded from the analyses.

Exploratory analyses were conducted for sore throat patients from one county (n=289 for DIGI-T and n=312 for PHYSI-T) where data on Centor criteria and related variables were available for random subsets of the data. Two measures of guideline adherence for sore throat management were explored:

- Proportion of RST performed on properly documented indications (ie, 3 or more documented Centor criteria)
- Proportion of visits diagnosed with tonsillitis that were prescribed antibiotics with a positive RST performed on properly documented indications

Ethics and Registration

The study was approved by the Swedish Ethical Review Authority (reference number: 2019-00463). Permission to use regional medical record data was also granted (reference number: 062-18). The study was registered at ClinicalTrials.gov [NCT03474887] and reported using a Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist.

Data Sharing Statement

Data are available to the Department of Clinical Sciences in Malmö at Lund University and can be accessed for a prespecified purpose after approval upon reasonable request.

Results

Manual Validation of Data

Manual validation showed high accuracy of extracted data, with 98.7% (773/783) accuracy for antibiotic prescription within 3 days and chief complaint for office visits correctly classified in 98.5% (133/135) for PHYSI-T but less often so for PHYSI-R (212/234, 90.6%) and PHYSI-U (95/103, 92.2%). For PHYSI-U patients, many cases of misclassified patients had lower abdominal pain rather than dysuria.

Baseline Demographics

For all chief complaints, baseline demographics revealed a significantly higher patient age among office visits compared with eVisits. For both sore throat and respiratory symptoms, around one-third (343/1110, 30.9%, and 721/1975, 36.5%, for sore throat and respiratory symptoms, respectively) of the visits involved male patients, with slightly more men in DIGI-T compared with PHYSI-T (Table 1).

Table 1. Baseline demographics.

Chief complaint	Age in years, mean (SD)	*P* value for difference	Sex, male, n (%)	*P* value for difference
Sore throat (n=1110)	—[a]	<.001	—	.03
DIGI-T[b] (n=798)	35.1 (11.5)	—	262 (32.8)	—
PHYSI-T[c] (n=312)	44.5 (17.5)	—	81 (26.0)	—
Respiratory (n=1975)	—	<.001	—	.28
DIGI-R[d] (n=1724)	42.8 (14.5)	—	637 (36.9)	—
PHYSI-R[e] (n=251)	60.0 (16.2)	—	84 (33.5)	—
Dysuria (n=1521)	—	<.001	—	—
DIGI-U[f] (n=1325)	42.1 (15.4)	—	0 (0.0)	—
PHYSI-U[g] (n=196)	60.0 (18.9)	—	0 (0.0)	—

[a]Not applicable.

[b]DIGI-T: eVisits with a chief complaint of sore throat.

[c]PHYSI-T: Office visits with a chief complaint of sore throat.

[d]DIGI-R: eVisits with a chief complaint of common cold/influenza or cough.

[e]PHYSI-R: Office visits with a chief complaint of common cold/influenza or cough.

[f]DIGI-U: eVisits with a chief complaint of dysuria.

[g]PHYSI-U: Office visits with a chief complaint of dysuria.

Diagnoses

Based on the first diagnosis recorded by the physician, a total of 185 different diagnosis codes were recorded across the entire cohort, with 107 different diagnosis codes for office visits and 98 different diagnosis codes for eVisits.

Nonspecific or symptom-based diagnoses were recorded among 25.3% (973/3847) of eVisits compared with 14.2% (108/759) of office visits, while other diagnoses were recorded for 1.8% (70/3847) of eVisits compared with 19.1% (145/759) of office visits.

Tonsillitis was recorded among 25.8% (206/798) of DIGI-T compared with 33.3% (104/312) of PHYSI-T. Viral upper and lower respiratory diagnoses were recorded among 61.3% (1057/1724) of DIGI-R compared with 48.6% (122/251) of PHYSI-R.

A total of 0.7% (19/2522) recorded diagnoses were for pneumonia across DIGI-T and DIGI-R compared with 2.3% (13/563) across PHYSI-T and PHYSI-R. Peritonsillar abscess was recorded in 0.8% (6/798) of DIGI-T compared with 0.6% (2/312) of PHYSI-T. There was one recorded diagnosis of pyelonephritis among PHYSI-U and none among DIGI-U.

Antibiotic Prescription

Compared with eVisits, antibiotic prescription within 3 days of the visit was significantly higher for office visits for sore throat and respiratory symptoms. No significant difference in prescription rate was observed for dysuria visits (Table 2).

For respiratory symptoms and dysuria, office visits more often led to the prescription of antibiotics outside of guideline recommendations for tonsillitis and pneumonia, respectively (Table 2).

Odds ratio of antibiotic prescription as the dependent variable following a PHYSI-T visit compared with DIGI-T was 2.46 (95% CI 1.86-3.26; *P*<.001). Adjustment for age and differences in recorded diagnoses had a marginal impact on odds ratios (Table 3).

Table 2. Antibiotic-related outcomes. No data were missing among presented variables. See Multimedia Appendix 2 for guideline-recommended antibiotics.

Chief complaint	Antibiotic prescription within 3 days of visit, n (%)	*P* value for difference	Guideline-recommended antibiotics, n (%)	*P* value for difference
Sore throat (n=1110)	—[a]	<.001	—	.39
DIGI-T[b] (n=798)	169 (21.2)	—	163 (96.4)	—
PHYSI-T[c] (n=312)	124 (39.7)	—	117 (94.4)	—
Respiratory (n=1975)	—	<.001	—	.02
DIGI-R[d] (n=1724)	27 (1.6)	—	26 (96.3)	—
PHYSI-R[e] (n=251)	50 (19.9)	—	37 (74.0)	—
Dysuria (n=1521)	—	.25	—	<.001
DIGI-U[f] (n=1325)	1016 (76.7)	—	1009 (99.3)	—
PHYSI-U[g] (n=196)	143 (73.0)	—	135 (94.4)	—

[a]Not applicable.
[b]DIGI-T: eVisits with a chief complaint of sore throat.
[c]PHYSI-T: Office visits with a chief complaint of sore throat.
[d]DIGI-R: eVisits with a chief complaint of common cold/influenza or cough.
[e]PHYSI-R: Office visits with a chief complaint of common cold/influenza or cough.
[f]DIGI-U: eVisits with a chief complaint of dysuria.
[g]PHYSI-U: Office visits with a chief complaint of dysuria.

Table 3. Regression models for antibiotic prescription for office visits compared with eVisits.

Chief complaint	Antibiotic prescription within 3 days of office visits vs eVisits, UOR[a] (95% CI)	*P* value	Antibiotic prescription within 3 days of office visits vs eVisits, AOR[b,c] (95% CI)	*P* value
Sore throat (n=1110)	2.46 (1.85-3.26)	<.001	2.94 (1.99-4.33)	<.001
Respiratory (n=1975)	15.63 (9.58-25.53)	<.001	11.57 (5.50-24.32)	<.001
Dysuria (n=1521)	0.82 (0.58-1.15)	.25	1.01 (0.66-1.53)	.98

[a]UOR: unadjusted odds ratio.
[b]AOR: adjusted odds ratio.
[c]Each regression model was adjusted for age and diagnoses, tonsillitis, viral upper and lower respiratory tract infection, pneumonia, and other.

Antibiotic Choice

Antibiotic choice was similar for DIGI-T versus PHYSI-T as well as DIGI-U versus PHYSI-U (Figures 2 and 3, respectively). Antibiotic prescriptions following DIGI-R most often led to prescriptions of penicillin V, while PHYSI-R most often led to prescriptions of doxycycline (Figure 4). Penicillin V accounted for 89.3% (151/169) of all prescribed antibiotics among DIGI-T and 77.4% (96/124) of all prescribed antibiotics in PHYSI-T.

Among the 13 sore throat visits included in "Other" (6 DIGI-T, 7 PHYSI-T visits), there was one DIGI-T and one PHYSI-T visit each with UTI diagnoses receiving pivmecillinam, and one PHYSI-T visit with a diagnosis of acute bronchitis receiving doxycycline. Remaining visits had only sore throat–related diagnoses and were followed by prescriptions of doxycycline, erythromycin, and amoxicillin with and without clavulanic acid.

Figure 2. Prescription rates for various antibiotics following chief complaint of sore throat.

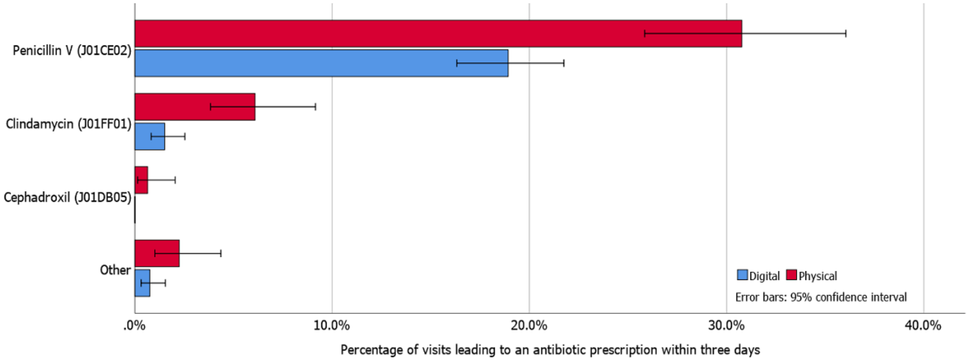


Figure 3. Prescription rates for various antibiotics following chief complaint of dysuria.

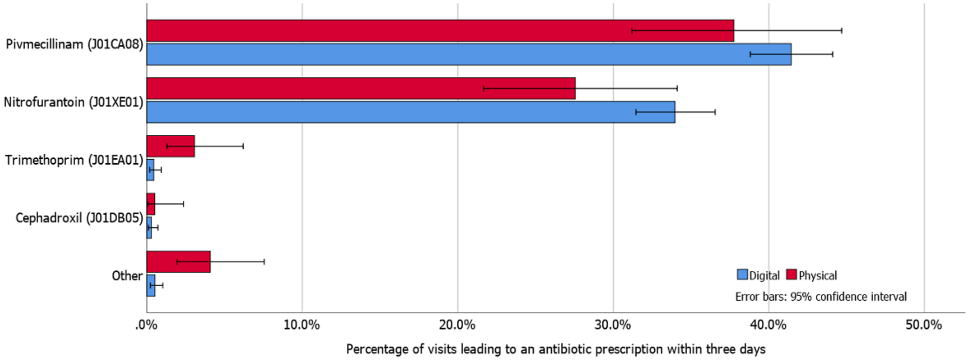
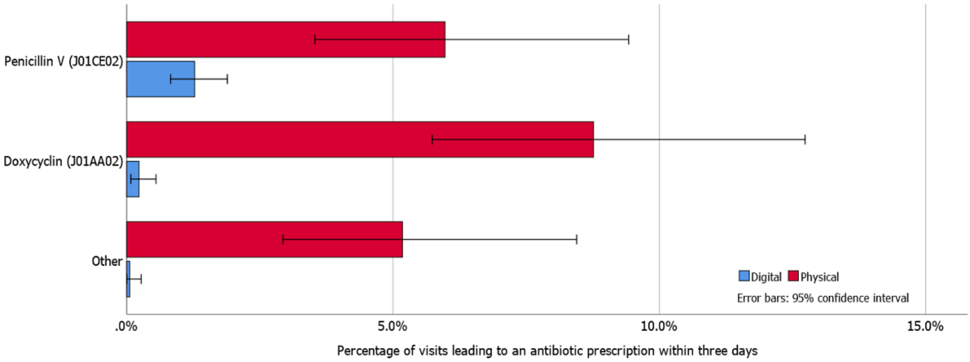


Figure 4. Prescription rates for various antibiotics following chief complaint of respiratory symptoms.



Among the 15 dysuria visits included in “Other” (7 DIGI-U, 8 PHYSI-U visits), 7 PHYSI-U visits led to prescriptions of trimethoprim sulfamethoxazole, methenamine, or ciprofloxacin without a relevant diagnosis to support the prescription given current guidelines, while one PHYSI-U visit led to a diagnosis with pyelonephritis and prescription of ciprofloxacin accordingly. A total of 5 DIGI-U visits had non-specified UTI diagnoses; 3 of these patients were prescribed ciprofloxacin, 1 trimethoprim sulfamethoxazole, and 1 lymecycline. The remaining 2 DIGI-U patients were diagnosed with acute cystitis and prescribed ciprofloxacin.

Among the 14 respiratory visits included in "Other" (1 DIGI-R, 13 PHYSI-R visits), 4 PHYSI-R patients were prescribed amoxicillin, erythromycin, or cefadroxil without a diagnosis supported by guidelines, and 2 PHYSI-R visit patients were prescribed amoxicillin with the diagnosis of pneumonia. A total of 3 PHYSI-R visit patients were diagnosed with concurrent UTIs, 2 of whom were prescribed pivmecillinam and 1 trimethoprim sulfamethoxazole. The remaining PHYSI-R visit patients were diagnosed with chronic obstructive pulmonary disease or acute exacerbation and were prescribed amoxicillin.

Documentation of Centor Criteria

All 4 Centor criteria were documented for 100% (798/798) of DIGI-T visits and 28% (35/125) of PHYSI-T visits. Documentation did not differ among PHYSI-T visits prescribed antibiotics versus cases not prescribed antibiotics (13/45, 28.9%, versus 22/80, 27.5%, complete documentation, respectively). Specifically, presence or absence of tonsillar exudates, fever, lymphadenopathy, and cough were not documented in 4.8% (6/125), 21.6% (27/125), 26.4% (33/125), and 57.6% (72/125) of PHYSI-T visits, respectively.

Among the subset of sore throat patients from a specific county, there was no significant difference in documented fever between DIGI-T and PHYSI-*t* (116/289, 40.1%, vs 46/125, 36.8%; P=.52). PHYSI-T more often had absence of cough (96/125, 76.8%, vs 151/289, 52.2%; P<.001). DIGI-T had significantly more documented swollen tender anterior cervical nodes (182/289, 63.0%, vs 39/125, 31.2%; P<.001) and tonsillar exudates (136/289, 47.1%, vs 37/125, 29.6%; P=.001; Multimedia Appendix 4).

Among manually reviewed cases with documented tonsillar exudates among DIGI-T, 86.6% (116/134) had a photo attached of varying quality in terms of visualizing tonsillar exudates.

Guideline Adherence for Sore Throat

Exploratory analyses of sore throat visits with Centor criteria data (Multimedia Appendix 5) showed that RST testing was more often performed on properly documented indications in terms of Centor criteria among DIGI-T compared with PHYSI-*t* (105/132, 79.5%, vs 23/70, 32.9%; P<.001).

Among visits that were diagnosed with tonsillitis and prescribed antibiotics, there were more cases of positive RSTs performed on properly documented indications among DIGI-T compared with PHYSI-*t* (42/43, 97.7%, vs 8/20, 40.0%; P<.001).

Discussion

Principal Findings

Rates of antibiotic prescription following eVisits for sore throat, cough, common cold, and influenza were significantly lower than for office visits, while no differences in prescription rates were noted for dysuria. This difference persisted after adjusting for age and set diagnoses.

Limitations

Results should be interpreted with consideration for several limitations. First, as the groups were not randomized, we were unable to establish causality between visit type and antibiotic prescription rate. However, randomization in this context was not feasible as risk of spillover was high with patients free to seek other forms of care.

We cannot exclude that the lower prescription rate among eVisits reflects a self-selected group with different symptom severity, comorbidity frequency, patient expectations, and time constraints compared with those seeking office care. Differences between physicians working in the digital platform versus in the office setting may be another factor influencing differences in prescription rates.

Differences in recruitment strategy may have impacted the results. During eVisits, patients self-selected their chief complaint, which was then documented and used for recruitment, while office visit physicians chose which symptom to document as the chief complaint. eVisit physicians were not blinded for participation to the study, which may have influenced the outcome.

Regarding sore throat, the results of this study may not apply to countries preferentially using other scoring systems such as the McIsaac score to determine whether to perform an RST [35].

Finally, while we used a 21-day washout period, we cannot exclude that some visits may have been preceded by a visit from another health care provider within the washout period. Across the entire cohort, there were 12 patients who had both an eVisit and an office visit, with the eVisit preceding the office visit in 8 cases. However, visits were always separated by at least 21 days, making conversions clinically unlikely and warranting a novel assessment regarding indications for antibiotic prescription. Our sample size was relatively small but adequate to address the research question.

Strengths

Despite the above, this study has several strengths. As far as the authors know, this is the first study specifically comparing antibiotic prescription following asynchronous eVisits to office visits outside of the American health care setting. The dataset comes from one of the few health care providers of both eVisits and office visits, thus making the groups more comparable. Using chief complaint as opposed to diagnosis as inclusion criteria means prescription rates may better reflect clinical practice as many clinicians tend to choose diagnoses based on their choice to prescribe antibiotics, regardless of guideline adherence. Using data extraction software ensured reliability of data, and manually reviewing subsets of the data added validity regarding physician assessment and documentation. Findings were robust through logistic regression and several subgroup analyses.

Interpretation

Beyond potential unidentified confounding factors, the lower antibiotic prescription rate in DIGI-T may reflect the health care providers' use of a structured documentation platform requiring physicians to actively mark each Centor criterion prior to ordering an RST. It has previously been hypothesized that availability of guidelines may be the driving factor behind improved guideline adherence in virtual visits [8], and decision support systems have previously been shown to improve guideline adherence [16,36].

One must also consider the risk of misdiagnosis with eVisits. There is a risk that the system would lead the physician into a logical conclusion and apparently guideline-coherent decision, increasing the risk of cognitive biases such as confirmation bias, which may not have occurred face-to-face in an office setting.

eVisits may also facilitate physicians to better manage emotionally demanding patients [37], possibly reducing the risk of prescribing antibiotics without proper indications. In addition, eVisits provide a convenient way for physicians to use watchful waiting prior to antibiotic prescription as patients easily can access the chat within 72 hours of a consultation.

DIGI-T patients are required to visit their nearest primary health care center to take the RST prior to receiving antibiotics, which may create an additional barrier to antibiotic prescription not present in PHYSI-T. These barriers are absent for antibiotic prescription following UTIs, which may explain the similar rates between DIGI-U and PHYSI-U.

As previously mentioned, eVisits involve physician interpretation of patient reported Centor criteria prior to documentation, while office visits involve interpretation of Centor criteria through physical examination prior to documentation. For example, cough may be more correctly reported following eVisits as it is reported much more categorically than when asked in an office setting and interpreted by the physician with a working diagnosis. Conversely, lymphadenopathy may be overreported among eVisits due to self-palpating of cervical myalgia because of a sore throat. The use of patient-reported Centor criteria remains to be validated, prompting some organizations to dissuade management of sore throat patients using eVisits [38]. As future studies are required to validate specific criteria for eVisit diagnosis of streptococcal tonsillitis, this study’s objective was to evaluate adherence to local health care provider protocols.

The seemingly higher proportion of nonspecific or symptom-based diagnoses recorded after eVisits may represent physicians’ reluctancy or inability to make diagnoses through the platform.

A majority of DIGI-T but a minority of PHYSI-T visits with ordered RST had sufficiently documented Centor criteria. Furthermore, a larger proportion of prescribed antibiotics in DIGI-T had a positive RST ordered on correctly documented indications. These findings should be interpreted with caution and warrant replication given their basis in a small random sample of PHYSI-T visits. EMR notes after office visits are often short, and all symptoms may not have been documented in PHYSI-T visits. Thus, PHYSI-T physicians may still adhere to guidelines similarly to DIGI-T, even though this adherence is not documented. It is, however, worth considering that more complete documentation may be a strength of eVisits compared with office visits, regardless of guideline adherence. Antibiotic prescriptions without positive RST following office visits may also be a consequence of general practitioners relying on clinical gaze over laboratory test results [24].

Comparison With Other Studies

As most studies investigating antibiotic prescribing for visits were selected based on recorded diagnoses such as streptococcal tonsillitis, our findings are not directly comparable as each group in this study contains a range of set diagnoses. However, certain patterns can be noted when the current findings are placed in context.

The finding that antibiotic prescriptions are lower following eVisits for sore throat contrasts with most previous research finding higher prescription rates for virtual visits compared with office visits following diagnosis of pharyngitis [4,15,32], with the exception of one study finding lower prescription rates following diagnosis of nasopharyngitis [32]. Differences in antibiotic prescription in this study persisted after adjusting for age and differences in set diagnoses. However, a retrospective cohort study with a large, matched sample noted no differences in prescription rates for pharyngitis [15]. Given this disparity, the findings in this study warrant replication in a different population.

The finding that DIGI-T more often were prescribed antibiotics per guideline recommendations contrasts with previous studies suggesting overprescription of broad-spectrum antibiotics after virtual visits compared with office visits [15,32]. This may demonstrate that the platform specifically improves guideline adherence through a framework encouraging physicians to reflect on guidelines prior to prescription. This is partially reflected by 100% documentation of Centor criteria, higher than reported from other eVisit platforms [25]. Indeed, previous interventions involving the use of symptom templates demonstrate improved documentation [39].

Regarding respiratory symptoms, the lower prescription rate noted in this study is in line with most research on virtual visits finding similar or lower prescription rates for bronchitis and acute respiratory infections compared with office visits [4,15,18,32,40], although some studies found higher broad-spectrum prescription rates for bronchitis [18,32].

For dysuria, previous research noted higher prescription rates following virtual visits [4] as well as eVisits [11] compared with office visits. However, a recent study on management of UTIs using asynchronous eVisits found no differences in antibiotic prescription rates. Our findings support this latter finding and the use of telemedicine for the management of uncomplicated UTIs [12]. This also suggests that eVisits and virtual visits may differently impact antibiotic prescribing.

Conclusions

The use of asynchronous eVisits for the management of sore throat, dysuria, or respiratory symptoms does not appear to lead to an inherent overprescription of antibiotics compared with office visits, even after considering differences in age and recorded diagnoses. Antibiotic prescriptions do not seem to deviate from guidelines more often than usual management using office visits. Findings support the use of structured eVisits in the context of a platform with an infrastructure encouraging guideline adherence. Future research is needed to confirm the findings of this study and validate the use of Centor criteria or another set of criteria to use for differential diagnosis and treatment of conditions related to sore throat in the eVisit setting.

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Authors' Contributions

AE, SC, VMN, LV, AL, UJ, and PM were responsible for study concept and design. AE and TB were responsible for acquisition of data. AE, UJ, and SC performed the analysis. All authors interpreted the data. AE drafted the manuscript. All authors were responsible for critical revision of the manuscript for important intellectual content and final approval.

Conflicts of Interest

AL is a cofounder of Doctrin AB. AE is currently employed by Capio AB. LV has previously been employed by Capio AB. Other authors declared no conflicts of interest.

Multimedia Appendix 1

Protocol for interpretation of free-form text for validation of data. In uncertain cases, dialogue occurred with a family medicine specialist in order to determine if symptoms should be deemed present or absent. As not all visits were manually validated, all visits were included in the analysis.
[DOCX File , 15 KB-Multimedia Appendix 1]

Multimedia Appendix 2

Anatomic therapeutic chemical classification codes for recategorization of prescriptions according to current Swedish guideline recommendations.
[DOCX File , 15 KB-Multimedia Appendix 2]

Multimedia Appendix 3

Recategorization of diagnoses.
[DOCX File , 13 KB-Multimedia Appendix 3]

Multimedia Appendix 4

Centor criteria for a subset of sore throat patients from a specific county. Denominators based on available data (unavailable data is missing at random).
[DOCX File , 14 KB-Multimedia Appendix 4]

Multimedia Appendix 5

Secondary outcomes related to guideline adherence for a subset of sore throat visits from a specific county. Denominators vary due to missing data (unavailable data is missing at random).
[DOCX File , 14 KB-Multimedia Appendix 5]

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Abbreviations

CRP: c-reactive protein
EMR: electronic medical record
eVisit: asynchronous chat-based visit
PHYSI-T: office visit with a chief complaint of sore throat
RST: rapid streptococcal antigen testing
STROBE: Strengthening the Reporting of Observational Studies in Epidemiology
UTI: urinary tract infection

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RESEARCH

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Health care utilization following "digi-physical" assessment compared to physical assessment for infectious symptoms in primary care

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Abstract

Background: The use of chat-based digital visits (eVisits) to assess infectious symptoms in primary care is rapidly increasing. The "digi-physical" model of care uses eVisits as the first line of assessment while assuming a certain proportion of patients will inevitably need to be further assessed through urgent physical examination within 48 h. It is unclear to what extent this approach can mitigate physical visits compared to assessing patients directly using office visits.

Methods: This pre-COVID-19-pandemic observational study followed up "digi-physical" eVisit patients ($n = 1188$) compared to office visit patients ($n = 599$) with respiratory or urinary symptoms. Index visits occurred between March 30th 2016 and March 29th 2019. The primary outcome was subsequent physical visits to physicians within two weeks using registry data from Skåne county, Sweden (Region Skånes Vårddatabas, RSVD).

Results: No significant differences in subsequent physical visits within two weeks (excluding the first 48 h) were noted following "digi-physical" care compared to office visits (179 (18.0%) vs. 102 (17.6%), $P = .854$). As part of the "digital-physical" concept, a significantly larger proportion of eVisit patients had a physical visit within 48 h compared to corresponding office visit patients (191 (16.1%) vs. 19 (3.2%), $P < .001$), with 150 (78.5%) of these eVisit patients recommended some form of follow-up by the eVisit physician.

Conclusions: Most eVisit patients (68.9%) with respiratory and urinary symptoms have no subsequent physical visits. Beyond an unavoidable portion of patients requiring urgent physical examination within 48 h, "digi-physical" management of respiratory and urinary symptoms results in comparable subsequent health care utilization compared to office visits. eVisit providers may need to optimize use of resources to minimize the proportion of patients being assessed both digitally and physically within 48 h as part of the "digi-physical" concept.

Trial registration: Clinicaltrials.gov identifier: NCT03474887.

Keywords: Telehealth, Telemedicine, eVisits, Primary care, Utilization, Infection

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Background

Utilization of digital primary care visits is rapidly increasing [1] for various clinical issues, including assessment of respiratory or urinary symptoms [2–4]. While synchronous video-based visits (virtual visits) are a commonly used format, asynchronous chat-based visits (eVisits) offer a novel approach where multiple patients can be assessed simultaneously [5]. Of the 13 digital primary care health care providers reviewed by The Swedish Health and Social Care Inspectorate [6], seven include asynchronous text-based communication. Unlike virtual visits or phone consultations, eVisits also allow staff to conduct other tasks at their primary health care center while awaiting patient response, as well as to consult colleagues more seamlessly when needed before responding to patients. Unlike portal messaging, eVisits usually offer an infrastructure that allows for more rapid "live" text chats with automated questionnaires usually integrated prior to the chat commencing.

In Sweden, the government is currently adopting a national vision of achieving good and equal health and welfare by 2025 by becoming the world leader at using digitization and eHealth [7]. Swedish primary care is almost entirely publicly funded by 21 regions, with each region deciding which information technology systems to implement. Each region has public primary health care centers, but regions also reimburse private health care providers for primary care services using various combinations of capitation and pay-per-service. The emergence of several private eVisit providers, billing regions for digital-only primary care services, has been reported to further fragment Swedish primary care, and better integration between eVisits and physical care has been recommended to move towards the national eHealth vision for 2025 [7]. Subsequently, all 21 regions have now developed their own digital primary care platforms. This is in addition to the private digital-only providers, which offer their services nationally.

It is unclear to what extent eVisits can successfully replace office visits for the assessment of infectious symptoms. Using eVisits may improve patient access to care [3], be time-saving [8] and maintain high patient satisfaction [9] while reducing risk of, e.g. transmission of COVID-19 during the pandemic [10]. eVisits may also allow primary care staff to work remotely to a larger extent and harness a more flexible working environment. Finally, cost-savings per episode of care may be realized [2, 4, 11], and knowing which patients are likely to require further physical follow-up after an eVisit may help health care providers decide what clinical issues to directly assess using an office visit.

An emerging strategy, which has been suggested by recent qualitative work, is to maximize the utilization of eVisits where possible, focusing on a "digi-physical" approach where the patient is initially assessed via an eVisit with the possibility to schedule continued management with a physical examination when needed [5]. Previous studies on healthcare utilization following eVisits for minor acute symptoms, including cough [12] and upper respiratory tract symptoms [13], found that roughly two-thirds of patients had their concerns resolved without further interactions with the health care system. Studies comparing eVisits to office visits found either no significant differences [4] or higher [12, 14] rates of subsequent health care contacts following eVisits. Given these inconsistent results in the dawn of increasing eVisit utilization, further studies are needed to investigate subsequent health care utilization following eVisits compared to office visits [3]. Respiratory symptoms have been described as one of the most common chief complaints among eVisit users [12].

The aim of this study was to investigate whether there were any differences in the frequency of healthcare contacts following initial management of respiratory or urinary symptoms using traditional office visits compared to "digi-physical" management. We define "digi-physical" management as patients having their initial clinical encounter through an eVisit, with urgent physical care within 48 h when needed.

Methods

Setting and population

This observational study compared patients residing in the Skåne region, Sweden's third largest county with 1.4 million inhabitants. Patients were managed using "digi-physical" care or using traditional office visits at 16 primary health care centers across Skåne. Apart from the previously mentioned digital primary care providers, patients have the option to seek physical care at their primary health care center, which is usually open between 8 a.m. and 5 p.m. Patients can also seek care at out of hours clinics, open from 5 p.m. to 9 p.m., or visit the emergency department of any hospital. All index visits in the current study were conducted at Capio, one of Sweden's largest primary health care center providers, which has adopted the "digi-physical" model since May 2017, using an eVisit platform developed by Doctrin AB. At the time of the study, Capio was the only known primary health care provider that offered both office visits and eVisits, while other eVisit providers simply referred patients who were deemed to require a physical examination. This meant the patient and physician had to restart the consultation, which resulted in two payments.

Inclusion criteria were visits with a chief complaint of sore throat, cough, cold/flu-symptoms or urinary symptoms as specified by free-form text, or visits with a documented International Classification of Disease code J030 (streptococcal tonsillitis), J069 (acute upper respiratory infection), or N300 (cystitis) [15]. Index visits were selected by identifying each patient's earliest dated physician visit (for the chief complaints included) between March 30th, 2016 and March 29th, 2017 (office visits only) or between March 30th, 2018 and March 29th, 2019 (eVisits and office visits), i.e. before the COVID-19 pandemic. Exclusion criteria were patients aged < 18 years, residence outside of Skåne county, male patients with urinary symptoms and identifiable visits for similar chief complaints in the past 21 days. In addition to this, each patient was only allowed to contribute with one index-visit across the entire cohort. The earliest dated visit was chosen as the included index visit.

The platform

The eVisit platform assessed in this study can be accessed by patients through their smartphone, computer, or tablet seven days a week from 7 a.m. to 10 p.m. Patients choose their chief complaint and proceed to answer a set of symptom-specific questions. Answers are structured in a report presented to a physician who then initiates a two-way text-based communication within 15 min for medical decision-making, including staying available for observation (watchful awaiting) or utilizing “digi-physical” care by scheduling a physician appointment at a physical Capio primary health care center within 48 h if needed. The receiving physician at the primary health care center gets access to the same medical history generated by the eVisit platform and the text from the chat communication between the physician and the patient for an improved transition. Capio has protocols for each chief complaint, with indications for scheduling physical care and key performance indicators to follow-up protocol adherence.

Power calculation and recruitment

Previous research on office visits for upper respiratory tract symptoms reported a 26% two-week follow-up rate [16]. Using a binary outcome power calculation with a non-inferiority limit of 6.5%, an alpha level of 0.05, for 80% power, we estimated needing 564 visits per group. Informed consent was acquired from all included participants. eVisit patients were invited once and consented digitally prior to their visit. For office visit patients, data extraction software (by Medrave Software AB) was used to identify adult patients with key words in the electronic medical records free-form text corresponding to included chief complaints (Additional file 1). A random selection of identified office visit patients were invited through letters, including two reminders to non-responders, posted to their home address after their visit with a signed response returned in a prepaid envelope as previously described [15]. After acquired consent, remaining exclusion criteria were applied resulting in the final cohort (Fig. 1).

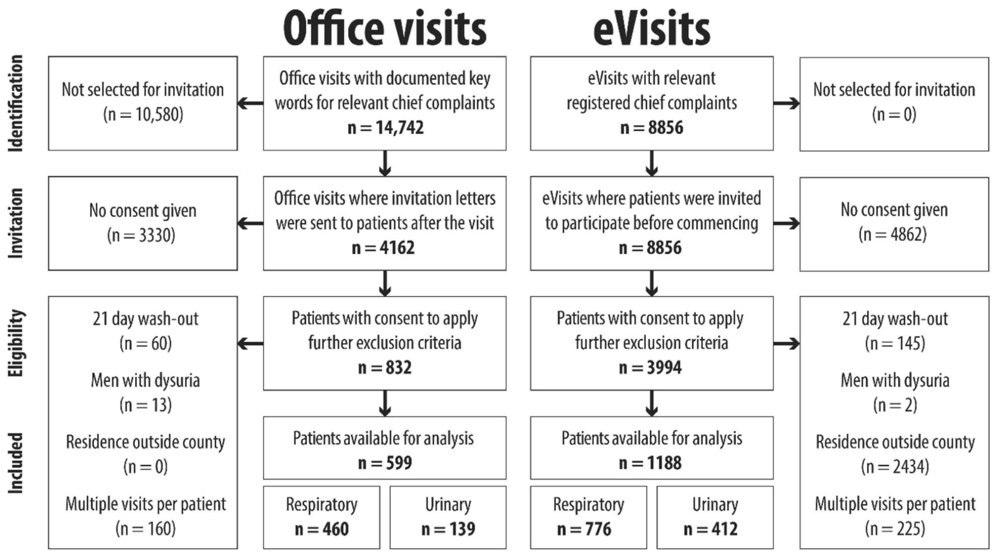

Fig. 1 Flow-chart of patient recruitment

Data collection

Baseline data including chief complaint, visit date, age, sex, and patient residence were acquired from the medical record of the healthcare provider using the same data extraction software that identified patients. Automatically extracted data on chief complaints had previously been manually validated by reading all free-form text in the electronic medical record of the index visit for a subset of visits ($n=783$) [15]. For eVisits only, data were also extracted regarding recommended follow-up by the physician as either self-care, continued eVisit, or recommended outpatient physical visit (urgent or non-urgent) as this was documented as part of the eVisit electronic medical record template. Patient data related to county-wide health care contacts within two weeks of their index visit were acquired from a county-wide registry (Region Skånes Vårddatabas, RSVD) registering all health care contacts billed to the local county council, including set diagnoses and health unit names for each health care contact. The database does not include visits provided through health care providers without a reimbursement contract with the local county council, but such visits only account for around 1% of all healthcare expenditure in Sweden [1].

The primary outcome was proportion of patients with one or more physical visits to a physician within two weeks after the first 48 h of their index visit, as "digiphysical care" per definition involves a proportion of visits inevitably proceeding to physical examination within 48 h of their eVisit assessment. Visits beyond 48 h after index thus represent visits not expected in the "digiphysical" model. To make subsequent utilization beyond this window was comparable to office visits, we excluded physical visits within 48 h of the index visit after both eVisits and office visits in the primary outcome. As most patient-initiated primary care contacts in Swedish primary care are initially managed through nurse telephone triage, the number of outpatient telephone contacts with nurses within two weeks of the index visit (not including the day of the index visit) was evaluated as a secondary outcome. Other secondary outcomes included proportion of additional outpatient physical visits within 48 h of index visit, visit location (primary care, out-of-hours visit, emergency department, or other outpatient clinic), and proportion of patients admitted for inpatient care.

For eVisit patients only, we also calculated secondary outcomes regarding proportions of index visits in which the patient was recommended self-care, continued digital care or physical follow-up, respectively. eVisit-physician-documented recommendation for an urgent visit within 48 h, a non-urgent primary care visit, and referral to other healthcare providers (including emergency departments) were all considered a physician recommendation for physical follow-up. In 13 cases where data regarding recommended follow-up were missing, data were manually collected through review of electronic medical records.

Statistical analyses

Analysis was conducted in IBM SPSS version 26. Visits with a chief complaint of sore throat, cough, and common cold/influenza were all grouped together to a "respiratory" group, while visits for urinary symptoms were considered a separate group.

Student's t-tests were used to compare continuous data and were presented with mean and standard deviation. Chi-square test was used to compare categorical data, presented with percentage.

We hypothesized that there was no clinically relevant difference in the number of physical visits within two weeks when comparing eVisit patients to office visit patients, excluding the first 48 h where a larger portion of eVisits patients are expected to be encouraged to proceed to a physical visit. Hypothesis testing was conducted by comparing patients with index eVisits and index office visits, after excluding patients with subsequent physical visits within 48 h.

Sensitivity analyses were conducted comparing subsequent physical visits including visits within 48 h, but instead excluding eVisit patients recommended various levels of physical follow-up to evaluate robustness of findings.

As chief complaint and age may confound risk of further follow-up, multiple binary logistic regressions were conducted with physical visit or nurse phone contact as the dependent variable and visit type as the independent variable. Office visits were used as the reference group, with the enter regression models adjusted for age and chief complaint.

Exploratory subgroup analyses were conducted to evaluate health care utilization of eVisit patients who received various follow-up recommendations.

Further subgroup analyses were conducted to calculate the proportion of physical visits within various levels of care (ranked from highest to lowest acuity: emergency care, out of hours care (including ambulatory care), primary care, and other outpatient care) during the follow-up period. For patients in contact with multiple levels of care, the highest level of care was included.

Physical visit locations classified as emergency or other outpatient care were manually reviewed by looking up health unit names of the health care contacts as specified in RSVD to make sure the visit location was validly classified. For both groups, inpatient care within the entire follow-up period was also compared.

For a subset of patients with physical visits within two weeks (836 respiratory and 434 urinary complaints), the first three diagnoses recorded in the electronic medical record were manually reviewed together with a specialist in family medicine (SC and PM) and used to assess whether the visit was likely related to or unrelated to the index-visit.

The study was registered at clinicaltrials.gov (Identifier: NCT03474887) and reported using the STROBE-checklist.

Results

Baseline demographics

Among office visit patients, there were significantly more visits for respiratory symptoms and significantly fewer visits for urinary symptoms compared to eVisit patients. Office visit patients were also significantly older than eVisit patients. No differences in sex distribution were noted (Table 1).

Physical visits within two weeks

There were no significant differences in proportion of physical visits after the first 48 h but within two weeks of the index visit when comparing eVisit patients to office visit patients (18.0% vs. 17.6%, $P = .854$). Within 48 h of the index visit, a larger proportion of eVisit patients had a physical visit compared to office visit patients (16.1% vs. 3.2%, $P < .001$). Results were robust to subgroup analyses of each chief complaint as well as after adjusting for age and chief complaint in logistic regression analyses (Table 2). Considering all 1188 eVisit patients, a total of 818 (68.9%) had no physical visit within the entire follow-up period. Sensitivity analyses including all physical visits within two weeks of the index visit demonstrated similar results once eVisit patients recommended follow-up were excluded. Two-week physical visit rates, including the first 48 h, were significantly higher comparing all eVisit patients to office visit patients (370 (31.1%) vs. 123 (20.5%), $P < .001$), but no significant difference remained when excluding eVisit patients recommended primary care follow-up within 48 h (215 (21.5%) vs. 123 (20.5%), $P = .640$). When excluding eVisit patients recommended any form of physical follow-up (both urgent and non-urgent), two-week physical visit rates were 181 (19.1%) vs. 123 (20.5%), $P = .475$, for eVisit patients vs. office visit patients, respectively.

Nurse telephone contacts within two weeks

No significant differences in nurse telephone contacts within two weeks following the index visit were noted between eVisit patients and office visit patients. Results were robust to subgroup analyses of each chief complaint as well as after adjusting for age and chief complaint in logistic regression analyses (Table 2).

Recommended follow-up for eVisit patients

Analysis of the 191 (16.1%) eVisit patients with a physical visit within 48 h showed that 150 (78.5%) had been recommended some form of follow-up by the eVisit physician, including 107 (56.0%) specifically recommended a physical follow-up within 48 h, 28 (14.7%) recommended non-urgent physical follow-up, and 15 (7.9%) recommended a follow-up eVisit.

818 eVisit patients (68.9%) were recommended self-care or no follow-up. Among these, the number of patients who had a physical visit within two weeks, including the index visit date, was 144 (17.6%).

132 eVisit patients (11.1%) were recommended follow-up with an additional eVisit. Among these, the number of patients who had a physical visit within two weeks, including the index visit date, was 37 (28.0%).

238 eVisit patients (20.0%) were recommended some form of physical follow-up. Among these, the number of patients who had a physical visit within two weeks, including the index visit date, was 189 (79.4%).

Among the 238 patients recommended physical follow-up, 163 eVisit patients (68.4% of patients recommended physical follow-up, 13.7% of all eVisit patients) were recommended physical follow-up within 48 h. Among these, the number of patients who had a physical visit within 48 h was 107 (65.6%).

Level of care and unit

Within two weeks of the index visit, most subsequent physical visits during the follow-up period occurred

Table 1 Baseline demographics

	eVisit patients(n = 1188)	Office visit patients(n = 599)	*P*-value for difference
Respiratory chief complaint, n (%)	776 (65.3%)	460 (76.8%)	< 001[a]
Urinary chief complaint, n (%)	412 (34.7%)	139 (23.2%)	< 001[a]
Age, mean (std dev)	41.3 (14.4)	52.5 (19.0)	< 001[b]
Sex, n (% women)	924 (77.8%)	432 (74.2%)	.097[a]

[a] Chi-square test

[b] Student's t-tests

Table 2 Health care contacts within two weeks and regression models for office visit patients compared to eVisit patients

	eVisit patients($n = 1188$)	Office visit patients($n = 599$)	*P*-value
Physical visit within two weeks, n (%)[a]	179 (18.0%)	102 (17.6%)	.854[f]
Following respiratory symptoms, n (%)[b]	126 (20.0%)	77 (17.4%)	.294[f]
Following urinary symptoms, n (%)[b]	53 (14.5%)	25 (18.1%)	.314[f]
Odds ratio[c] **for eVisit patients compared to office visit patients (95% CI)**	1.24 (0.92-1.66)[h]		.152[g]
Physical visit within 48 h, n (%)	191 (16.1%)	19 (3.2%)	< .001[f]
Following respiratory symptoms, n (%)[d]	145 (18.7%)	18 (3.9%)	< .001[f]
Following urinary symptoms, n (%)[d]	46 (11.2%)	1 (0.7%)	< .001[f]
Nurse telephone contact within two weeks, n (%)[e]	101 (8.5%)	50 (8.3%)	.912[f]
Following respiratory symptoms, n (%)[d]	66 (8.5%)	36 (7.8%)	.675[f]
Following urinary symptoms, n (%)[d]	35 (8.5%)	14 (10.1%)	.527[f]
Odds ratio[c] **for eVisit patients compared to office visit patients (95% CI)**	1.04 (0.71-1.52)[i]		.842[g]

[a] Not including physical visits within 48 h of index visit. $n = 997$ eVisit patients and $n = 580$ office visit patients

[b] Percentages refer to patients with the specified chief complaint, excluding patients with a physical visit within 48 h of their index visit. For respiratory eVisit patients $n = 631$ and office visit patients $n = 442$. For urinary eVisit patients $n = 336$ and office visit patients $n = 138$

[c] Each regression model was adjusted for age and chief complaint

[d] Percentages refer to patients with the specified chief complaint. For respiratory eVisit patients $n = 776$ and office visit patients $n = 460$. For urinary eVisit patients $n = 412$ and office visit patients $n = 139$

[e] Not including the index visit date

[f] Chi-square test

[g] Logistic regression

[h] Nagelkerke R Square: 0.0127

[i] Nagelkerke R Square: 0.0008

at primary health care centers. Sixteen patients were admitted for inpatient care during the entire follow-up period, with no significant differences noted between eVisit and office visit patients (Table 3).

Discussion

Principal results

After 48 h, no differences were found in subsequent physical visits within two weeks for eVisit patients compared to office visit patients. The results persisted when adjusted for age and chief complaint. Within the 48-h timeframe, a larger proportion of eVisit patients had a physical visit, 78.5% of which were recommended some form of follow-up as part of the health care provider's protocol for safe "digi-physical" management. Considering all eVisit patients, 68.9% concluded their eVisit without additional physical visits within two weeks.

Table 3 Level of care of physical visits between 48 h and two weeks

	eVisit patients($n = 1188$)	Office visit patients($n = 599$)	*P*-value for difference
Physical visit within two weeks, n (%)*	179 (18.0%)	102 (17.6%)	.854[a]
Of which primary care	128 (71.5%)	73 (71.6%)	N/A
Of which out of hours care	15 (8.4%)	2 (2.0%)	N/A
Of which emergency care	14 (7.8%)	12 (11.8%)	N/A
Of which other outpatient care	22 (12.3%)	15 (14.7%)	N/A
Physical visit within 48 h, n (%)	191 (16.1%)	19 (3.2%)	< .001[a]
Of which primary care	150 (78.5%)	6 (31.6%)	N/A
Of which out of hours care	27 (14.1%)	0 (0.0%)	N/A
Of which emergency care	11 (5.8%)	10 (52.6%)	N/A
Of which other outpatient care	3 (1.6%)	3 (15.8%)	N/A
Admitted within entire follow-up period, n (%)	8 (0.7%)	8 (1.3%)	0.161[a]

*Not including physical visits within 48 h of index visit. $n = 997$ for eVisit patients and $n = 580$ for office visit patients

[a] Chi-square

Strengths and limitations

Results should be interpreted with consideration for several limitations. As randomization was not performed, groups may differ regarding comorbidities, symptom severity and previous health care contacts. The office visit group may, for instance, represent patients seeking care after referral from other healthcare providers, including digital ones, while eVisit patients might be seeking care earlier in their symptom development. This was addressed to the extent possible by excluding previously identified healthcare contacts, including each patient only once across all groups and adjusted regression analyses.

eVisit patients were recruited prospectively before the visit commenced, while office visit patients were recruited retrospectively weeks to months after their visit. The inclusion method might have led to inclusion bias and is therefore a limitation of this study.

No reliable data were available regarding subsequent digital care contacts, including eVisits and virtual visits to the current and other health care providers. Non-physician visits to other physical units such as midwife offices and youth clinics also represent additional subsequent health care utilization not included in the current study thus limiting conclusions regarding total healthcare utilization. It is also uncertain to what extent physical visits were planned provider-initiated or unplanned patient-initiated.

The results of the current study cannot be generalized as they are specific to the context of "digi-physical" care with the specific eVisit platform used by the current healthcare provider. The current sample size is not large enough to detect clinically meaningful differences in emergency department visits or hospital admissions, and all secondary findings should be interpreted with caution.

Nonetheless, the study also has several strengths. To the best of our knowledge, this is the first study comparing the trajectory of "digi-physical" care with traditional primary care office visits based on chief complaint, using index visits from the same healthcare provider. Comprehensive data were available on subsequent health care utilization due to the public health care system in Sweden. No data were missing in the final analysis. Data were manually evaluated and validated via a manual review of electronic health records. Separating visits within 48 h as a part of the "digi-physical" model adds a new dimension to the existing literature of follow-up after eVisits compared to office visits as heterogeneity in clinical presentation means that a portion of eVisit patients inevitably will need to proceed to physical examination as part of the same clinical episode.

An alternative interpretation of our data may be that all subsequent visits after the index visit, including those within 48 h, should be part of the primary outcome as each visit involves a new clinical encounter. However, results from such an analysis would not provide meaningful insights into subsequent utilization after those who need urgent physical examination have been assessed. Results were also robust to sensitivity analyses excluding eVisit patients recommended primary care follow-up within 48 h. The choice of 48 h as the landmark for this distinction, however, may be arbitrary and 24 h or 72 h may be equally relevant.

Physical visits within two weeks

The current eVisit platform differs from traditional direct-to-consumer telemedicine where providers need to refer or recommend patients to seek physical care at their own primary health care center. Here, physical visits could be scheduled to the same health care provider with the automated medical history and chat forwarded accordingly. However, at the time of the study, eVisit physicians usually did not schedule a physical follow-up to themselves. Thus, a second physician once again needed to assess the previous medical history and chat conversation prior to the physical examination. The results of the study may have been different had there been full physician continuity in the "digi-physical" model, since continuity influences health care utilization [5, 17]. We speculate that "digi-physical" management may be made more efficient by allowing for the same eVisit physician to follow-up with a physical visit when needed ("person-level" continuity) rather than a separate physician within the same organization ("provider-level" continuity). Results are also specific to the included chief complaints, which are relatively uncomplicated. Further research is needed to evaluate other chief complaints relevant to primary care, such as routine diabetes follow-ups or psychiatric assessment. Qualitative data suggests that the eVisit platform, may not be optimal for management of more complex clinical issues [5]. While almost 70% of eVisit patients had no additional physical visit within two weeks, it is unclear whether the included eVisits represent substitutions to physical primary care visits, or new utilization due to ease of access to eVisits [18].

After 48 h, visits were more likely patient-initiated as the provider had no protocols for physician-initiated follow-up beyond 48 h. The similar rate of follow-up suggests that initial "digi-physical" management in this cohort successfully concluded visits similarly to initial management using an office visit, although the study was not powered to assess possible differences at the various levels of care. Furthermore, the lack of significant differences in nurse telephone contacts following the date of the index visit suggests that patients do not contact their primary health care center more often after an eVisit compared to office visits. The lower percentage of subsequent nurse telephone contacts within the follow-up period compared to the proportion of primary care physical visits may be explained by "digi-physical" scheduling bypassing nurse telephone triage.

Within 48 h, a greater proportion of patients assessed through eVisits had a subsequent physical visit compared to patients initially assessed through office visits. This disparity reflects the "digi-physical" model of care with protocols requiring eVisit physicians to schedule certain patients, such as those reporting severe dyspnea, for physical follow-up compared to traditional office-based care without such protocols. As eVisit protocols are new and heterogenous when comparing various health care providers, future research should compare and evaluate various protocols over time to find the optimal protocol for safe and cost-effective eVisit management. This includes identifying and defining red flag symptoms such as fever associated with respiratory symptoms.

Manual evaluation of diagnoses recorded on subsequent physical visits within two weeks suggested that most visits were related to the index visit. Physicians may be reluctant to assess red flags indicating possible severe infections in the eVisit setting [5]. "Double" physician assessment following eVisits may raise concerns regarding cost-effectiveness and misuse of physician resources. In Sweden, patients are often initially assessed by triage nurses, which may here represent an alternative solution to apply protocols without physician resources. Unless subsequent visits are made more efficient by the prior digital patient history, as suggested by qualitative research [5], certain chief complaints may be better managed with the traditional model of care. This remains to be elucidated by future research.

No novel findings emerged when exploring each chief complaint separately. For urinary symptoms, "digi-physical" management may represent an alternative to current practice as current guidelines also support management of uncomplicated urinary tract infections without a physical examination [19] and is consistent with previous research that found no differences in antibiotic prescription rates when comparing eVisits and office visits for dysuria [15].

Considering respiratory symptoms, the current findings are in-line with previous research that found higher follow-up rates within 24 and 48 h of telemedicine visits for adult sinusitis [20] and pediatric acute respiratory infections [14]. One American study, with a large, matched population, also noted higher follow-up rates both within 48 h and within three weeks for acute respiratory infections [21]. Two-thirds of respiratory eVisits had no additional visits within two weeks; this is in-line with predictions made after review of primary care electronic medical records [22] as well as previous studies on eVisits [13].

Longer-term studies found lower [16, 23] or no differences [2, 4, 24, 25] in follow-up rates up to three weeks after telemedicine visits for various acute conditions. Some of these studies included telemedicine follow-up in their outcomes [4, 13, 16, 23, 24], while the current study did not. Lower follow-up rates after telemedicine in some of these studies may also be explained by eVisit providers unable to schedule follow-ups, as opposed to the current study with a low barrier to scheduling follow-up appointments within the same healthcare provider when needed.

Recommendation and level of care for eVisits

There is a trend where a "higher level" of recommended follow-up by eVisit physicians is reflected in a larger proportion of patients having a subsequent visit within the entire follow-up period. Even though 370 (31.1%) of eVisits were recommended some form of follow-up (both digitally or physically) and 370 patients (31.1%) had a physical visit within two weeks, physician recommendations were not always in-line with patient healthcare utilization. "Patient adherence" was 79.4% for recommended physical follow-up, and 82.4% for recommended self-care/no follow-up. Previous research on physician triage based on digital patient histories suggests high inter- and intra-rater variability in primary care triage thus making it difficult to optimize this process [26].

Implications for the national eVisit strategy

The results encourage the use of the "digi-physical" approach as congruent with the national eHealth vision for 2025 [7] from an efficiency standpoint as patients, health care providers and regions can resolve a larger portion of medical issues using the "digi-physical" approach without additional subsequent health care contacts. From an access and equality standpoint, however, more research is needed as barriers remain for eVisit use by all segments of the population, such as those with foreign languages, low digital literacy or other disabilities [27].

Conclusion

"Digi-physical" management of respiratory and urinary symptoms in the context of the currently studied eVisit platform results in similar utilization of physical visits within two weeks compared to initial management using traditional office visits. Future research should explore time consumption of scheduled "digi-physical" visits with and without physician continuity. A significantly larger proportion of eVisit patients had a physical visit within 48 h, often having been recommended follow-up by their eVisit physician, compared to corresponding office visit patients. As such, future research may need to explore which clinical issues to refer directly for physical assessment, as well as evaluate the effects of continuity on "digi-physical" utilization.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12875-021-01618-2.

Additional file 1. Key words used by automatic data extraction software for identification of patients with relevant chief complaints for recruitment. Terms were chosen based on clinical experience and reported phrases commonly used according to primary health care staff as reported by primary health care center managers. Key words were not used as part of strings such that the entire phrase had to be present in order for patients to be identified.

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Authors' contributions
Conceptualization: AE, SC, VMN, LV, AL, UJ, PM. Data curation: AE, MS. Formal analysis: AE, UJ, SC. Funding acquisition: AE, PM, SC. Investigation: AE, MS. Methodology: AE, SC, VMN, LV, AL, UJ, PM. Project administration: AE, PM, SC. Resources: PM. Software: PM. Supervision: PM, SC, VMN. Validation: AE, MS. Visualization: AE. Writing original draft: AE Writing review & editing: All authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request up to ten years following publication.

Declarations

Ethics approval and consent to participate
All methods were performed in accordance with relevant guidelines and regulations. The study was approved by the Swedish Ethical Review Authority (reference number: 2019-00463). Permission to use regional medical record data was also granted (reference number: 062-18). Written informed consent was acquired from all participants.

Consent for publication
Not applicable.

Competing interests
AE: currently employed by Capio AB.
AL: stock ownership in Doctrin AB.
LV: previously employed by Capio AB.
Other authors declared no conflicts of interest.

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