Characterization of Telemedicine Patients to Discover Patient Journeys Using Process Mining

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Abstract: Process mining has established itself as a highly valuable tool in healthcare and demonstrated its effectiveness in process discovery, compliance verification and workflow optimization across a variety of clinical settings. However, its application in the analysis of telemedicine medical care has not been explored in depth. The present paper introduces the first stage of the research "Improving the patient journey in telemedicine using process mining" which aims to optimize the care process in telemedicine. In this initial stage, the characterization of patients who utilize this model of care in a hospital network in Chile between 2020 and 2023 is conducted. Accordingly, statistical information from the Red de Salud UC-Christus healthcare network is used to determine the most frequent characteristics of patients in socio-demographic, health-insurance and clinical terms. Profiles of typical patients who have received treatment via telemedicine will then be constructed. The preliminary results presented herein will serve as a basis for selecting the type(s) of patients who are of particular interest to institutional authorities. In the latter stages of the project, information from the electronic clinical records of the selected patient profiles will be used to build event logs and thereby construct patient journeys through process mining.

1 INTRODUCTION

Telemedicine has become an important tool with which to bring healthcare closer to the general population (World Health Organization [WHO], 2019; Welsh, 2002). Its use has reduced care costs, improved clinical outcomes and increased user satisfaction (Manocchia, 2020). Moreover, the COVID-19 pandemic has given rise to significant interest in this type of care and has, moreover, become a public health necessity (Zheng Wong et al., 2021). Therefore, a more in-depth analysis of its implementation is required in order to ensure that health system users continue to receive quality care.

Data science has been an extremely useful resource in the study of new implementations in medicine. One of these is process mining, which has proven to be highly effective in several lines of research. Therefore, the present study proposes the use of this discipline in the construction of the patient journey with telemedicine. This first stage of the project focuses on the characterization of telemedicine patients in a private hospital network in Chile, with the aim of determining the most appropriate patients to whom this novel technique can be applied.

This paper first outlines the background of the topic and the current context of telemedicine in Chile, in Section 2. Section 3 introduces the objective of this first stage of the research. Section 4 details the methodology used in the analysis of the available information and the subsequent construction of the patient profiles by the private hospital network. Section 5 discusses the results obtained. Finally,

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section 6 presents a brief conclusion of the results and the possible future implications of these findings.

2 BACKGROUND

2.1 Telemedicine

Telehealth encompasses a wide range of tools that use telecommunication systems for medical purposes (Welsh, 2002). Among these tools, telemedicine is defined as the use of information and communication technologies for the exchange of valid information to ensure diagnosis, treatment and prevention of diseases (WHO, 2019).

The use of telemedicine has multiple benefits, with Mendoza-Alonso et al. (2021) listing these as: saving time and money, reducing patient absences, improving health outcomes, decreasing the likelihood of infections, offering personalized care, and lowering costs for providers and insurers. However, the same authors state that telemedicine still faces certain challenges regarding its correct implementation, particularly in terms of access to stable communication networks that are necessary for its appropriate implementation.

The COVID-19 pandemic had such a profound impact on the global healthcare system that it prompted a growth in demand for remote medical care around the world (Zheng Wong et al., 2021). With that in mind, telemedicine has been effective in increasing access to health and medical information for both patients and physicians since its inception (WHO, 2019). Chile has been no exception to this reality, and the Chilean State has set several related objectives, including to decongest health systems, improve access to health services, and address the main challenges involved in implementing this model (Universidad de Desarrollo [UDD] et al., 2020). In addition, certain strategies have been proposed to bring telemedicine closer to the population (Centro Nacional de Sistemas de Información en Salud [CENS], 2022). These include guidelines, protocols and laws that have expanded their use in health services. (UDD et al., 2020; Mendoza-Alonzo et al., 2021; Chilean Law No. 21.541, 2023).

2.2 Patient Trajectories

The patient journey is defined as the time series of encounters with healthcare facilities, healthcare professionals, a hospital unit or a home health agency (Beleffi et al., 2020). The patient journey study has been used as a tool to assess patient satisfaction with the care process, clinical outcomes, and even to ensure patient safety during a hospital stay.

Several tools can be used to describe the patient journey, one of which is process mining (Andrews et al., 2020; Dahlin et al., 2019, Abo-Hamad, 2018). Process mining is the bridge between traditional model-based process analysis and contemporary data analysis techniques, such as data mining and machine learning (van der Aalst, 2016). Unlike other process modeling tools, process mining uses data as empirical evidence to build process models. It enables institutions to optimize their workflows from different perspectives. This is achieved through three core activities that lie at the heart of process mining: discovery, conformance checking, and optimization (van der Aalst, 2016).

To perform these tasks, process mining needs an event log as its means of input (van de Aalst, 2016). The event log corresponds to a table that stores data related to the activities performed in a single process. The information stored in this table must contain at least a case ID, the name of the activity and a timestamp (van der Aalst, 2016). This information allows for the activities performed for a process to be traced in each of the cases. In this way, a process diagram of the workflow of the institution in question can then be constructed (Imran et al., 2022; Kratsch, 2021).

Process mining has been applied in distinct industries and has achieved positive results across the board (Ito et al., 2020). The healthcare sphere has been no exception, and several studies have demonstrated the benefits of its use in the medical field (Kusuma et al., 2021). In particular, the review conducted by Rojas et al. (2016) demonstrates the utility of this technique in healthcare. The healthcare system benefits from the application of process mining because clinical practice requires a detailed record of the activities performed by healthcare personnel on the patient. Additionally, electronic clinical records facilitate the traceability of events (Rojas et al., 2016, Kusuma et al., 2021). Crucially, the information contained within electronic clinical records can be used to build event logs for process mining (Arias et al., 2020, Munoz-Gama et al., 2022).

A particular use of process mining in healthcare is its ability to discover the patient journey throughout the care process (Andrews et al., 2020; Dahlin et al., 2019, Abo-Hamad, 2018). Event logs help to identify the steps patients follow through the different departments of a hospital (Yang & Su, 2014; Rojas et al., 2017). Patient pathway analysis allows inefficiencies in the system to be uncovered (Sulis et al., 2022) so that institutions can take steps to improve their use of resources and increase patient safety and satisfaction (Sulis, 2022; Munoz-Gama et al., 2022).

Although data science is widely used in healthcare (Su et al., 2022; Sarriegi, 2021; Liu, 2020), few studies have investigated the use of process mining in telemedicine (Kampeera, 2023; Corallo et al., 2021). This is important because process mining is quite flexible and can be adapted to different environments, taking advantage of the data available for workflow analysis (van der Aalst, 2016). It therefore has tremendous potential to analyze the patient journey and help to identify patterns that facilitate a more in-depth understanding of that journey.

With that in mind, this project aims to use process mining to construct the telemedicine patient journey, and subsequently compare this trajectory with that of patients who receive face-to-face treatment. The objective is to determine whether telemedicine is equivalent to the traditional care model with respect to clinical and administrative aspects of the care process.

In this first stage of the project, the data contained in the information system of a private hospital network will be analyzed to characterize the patients who have received medical and non-medical care via telemedicine. To undertake this characterization, socio-demographic (sex, age, area of residence), health insurance (publicly or privately financed) and clinical (medical specialty) aspects will be considered.

3 OBJECTIVES

The objectives of the present study are to characterize the patients who receive telemedicine care according to their socio-demographic realities and the medical specialty sought via this model, to subsequently discover patient journeys using process mining.

The purpose is to determine the benefits and drawbacks of using process mining in the analysis of patient trajectories in different clinical settings, particularly in telemedicine and face-to-face care.

4 METHODOLOGY

First, an exploration of the available information will be carried out to identify the types of patients who choose either telemedicine or face-to-face care. For the present study, the patient database of the Red de Salud UC-Christus network in Santiago de Chile will be used. In particular, the commercial database of the Red de Salud UC-Christus network is analyzed, which contains not only socio-demographic information on patients, but also data regarding the clinical specialties in which this model of care is available, in addition to the type of financing the institution receives from these patients. The use of anonymized data has the approval of Scientific Ethical Committee of Health Sciences of the Pontificia Universidad Católica de Chile.

Second, the most relevant patient characteristics will be defined. Specifically, analysis will be undertaken of sex, age, district and region of residence, financing, number of patients and number of consultations for each of the health specialties that provide telemedicine care.

Third, the characteristics will be explored according to the interest of the clinical experts of the Red de Salud UC-Christus network. First, the total number of patients and consultations undertaken will be made for both sexes between 1st June 2020 and 1st June 2023. Subsequently, a similar analysis will be conducted over three one-year periods. The number of patients and consultations related to each of the specialties accessed during the three years will then undergo analysis. The place of residence of the patients will also be considered for all specialties.

Once this information has been aggregated, the patient profiles related to the telemedicine model will be created. To do so, the most frequently attending sex will be analyzed first, followed by their most likely place of residence (the most common district), the most demanded specialty, and finally the most commonly used type of health insurance. Analysis of the other sex will then take place according to the same order. Subsequently, a profile will be devised which considers the second and third most common place of residence. This characterization will help to provide a more in-depth understanding of the population that chooses the telemedicine model of care, to focus the subsequent phases of the project on more precise data.

Finally, the criteria with which to determine the type of patient whose journey is to be discovered will be defined. Clinical and administrative characteristics of interest to clinical experts will be considered, as well as institutional interests related to the growth of the Red de Salud UC-Christus network.

In future research, a quality control of the data extracted from the electronic clinical records of the healthcare institution will be performed, followed by the construction of the necessary event log to model the patient journey through process mining. Subsequently, process discovery algorithms will be applied to this event log to obtain the patient journey.

In the final analysis, the patient journeys obtained in the previous step will be compared, in conjunction with clinical experts, who will guide the work according to the requirements of the institution's medical team.

5 RESULTS

5.1 Characterization

The present study analyzed data related to patients from the Red de Salud UC-Christus network who received telemedicine care during the three-year period studied, from 1st June 2020 to 1st June 2023. The data was obtained from the commercial statistics belonging to the hospital network, which includes information on age, sex, place of residence, health insurance, number of patients, number of consultations and specialties.

A total of 152,422 patients and 354,660 consultations were obtained, of which 52.6% of patients are female and 30.8% are male, with the remainder failing to disclose information on their sex. The average age of the patients is 39.3 years for females and 38.4 years for males. Figure 1 shows the distribution of patients by sex and age.

Regarding medical specialties, 92 were analyzed in total. The most sought specialties were adult psychiatry, general medicine, and adult neurology, with more than 13,000 patients accessing each one during the three-year period studied. Figure 2 shows the top ten specialties in terms of overall patient numbers.

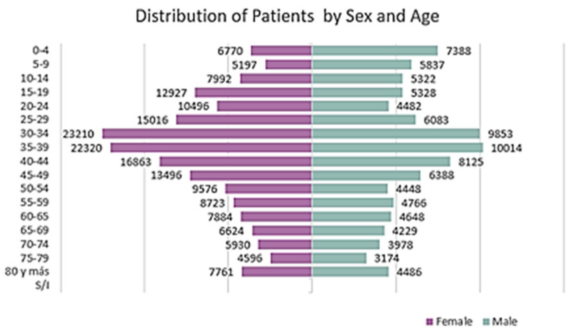

Figure 1: Distribution by sex and age of patients using telemedicine in the Red de Salud UC-Christus network between 1st June 2020 and 1st June 2023. Patients from the 30-40 age range are the most active users of telemedicine.

Regarding the geographical location of the patients, it was found that of the 16 regions that constitute Chile, the Metropolitan Region accounted for 62.5% of all telemedicine care recieved, followed by the Los Lagos Region with 8.3%. No other region accounts for more than 8.3% of the national total. The municipalities with the highest number of consultations were Santiago, Las Condes, Ñuñoa and Antofagasta.

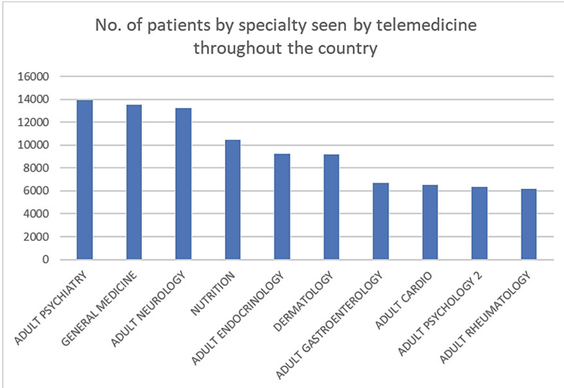

Figure 2: No. of patients accessing each specialty across the country between 1st June 2020 and 1st June 2023, in relation to the ten most commonly accessed specialities.

Regarding distribution within the regions, it was found that the population that uses the Red de Salud UC-Christus network telemedicine the most lives in the largest cities and that the number of patients decreases in more peripheral areas near those cities. For example, in the metropolitan region, which has 62% of the patients, most of them are in the city of Santiago, where the UC-Christus Network is located, while the outlying cities have fewer patients.

In addition, the data was analyzed over three 12-month periods in order to observe the evolving behavior of patients as the COVID-19 pandemic progressed. Specifically, the following periods were determined: 1st June 2020 to 31st May 2021 (20-21);

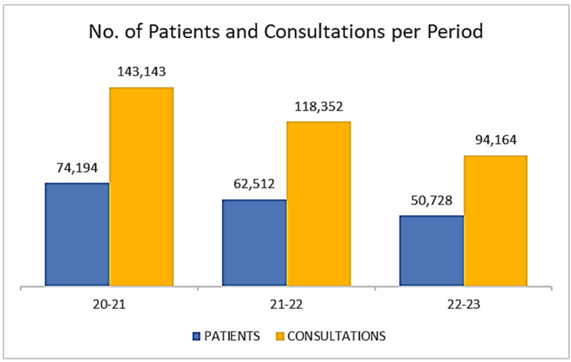

Figure 3: Number of patients and consultations for the 20-21, 21-22 and 22-23 periods. A gradual drop in both parameters is observed year-on-year.

1st June 2021 to 31st May 2022 (21-22); and 1st June 2022 to 1st June 2023 (22-23). Figure 3 shows the decrease in patients and consultations in the periods described. The number of patients is shown in blue and the number of consultations in yellow. The number of patients decreased by 11.7% between 20-21 and 21-22, and by 22.6% between 21-22 and 22-23. Furthermore, consultations fell by 17.3% between 20-21 and 21-22 and by 20.43% between 21-22 and 22-23.

Subsequently, patients were analyzed according to their sex and type of health insurance scheme held. Chilean healthcare operates with a mixed financing system that includes privately financed and administered companies (the majority of insurers), privately financed State-owned companies, and public institutions with mixed public-private contributions and State administration. Table 1 shows the number of patients by sex for each type of insurance held in the period 2020-2023. Note that the discrepancy between the number of patients listed in Table 1 compared to the number listed on the healthcare network's general database is due to the fact this more detailed data is not necessarily available for all patients.

The largest single group of patients (49,931, or 38.35%) financed their telemedicine care through 'Other financing', i.e., by means of another type of insurance or private payment. The second largest group of patients are beneficiaries of Fonasa, the main public insurance provider in the country (19,527 patients), representing 15.00%. Private financing reaches 45.84% (59,694 patients) and only one type exceeds the total number of Fonasa patients (Colmena). State-owned companies constituted only 1,020 patients, representing just 0.78%.

Table 1: Number and sex of patients who received telemedicine care in the Red de Salud UC-Christus network between 1st June 2020 and 1st June 2023 by health insurance type.

Insurance company		No. of Patients		
Company type	Company Name	Female	Male	Total
Other financing	CONVENIO/PARTICULAR	30769	19162	49931
State Institution	FONASA	13612	5915	19527
	CAPREDENA	3	1	4
	DIPRECA	11	5	16
	SISAN	10	9	19
Private Company	BANMEDICA	5331	3487	8818
	COLMENA	13539	7939	21478
	CONSALUD	4591	2696	7287
	CRUZ BLANCA	9958	6109	16067
	MAS VIDA	2062	1101	3163
	VIDA TRES	1703	1178	2881
State Company	F.SALUD BANCO ESTADO	85	41	126
	CODELCO/COBRE	508	386	894
Total		82182	48029	130211

5.2 Patient Profiles

This data can then be utilized to compile profiles of patients who receive telemedicine care from the hospital network. The patient profile consists of the characteristics most likely to be found in any patient of the healthcare institution, and considers each characteristic as the most common for each profile, based on sex and geographic location:

Sex: Female
Approximate age: 35-39 years old
Residence: Santiago, Metropolitan Region
Specialty: Psychiatry
Financing: Convenio/Particular (Medical contract/Private)

Sex: Male
Approximate age: 34-38 years old
Residence: Las Condes, Metropolitan Region
Specialty: General Medicine
Financing: Convenio/Particular (Medical contract/Private)

Sex: Female
Approximate age: 35-39 years old
Residence: Viña del Mar, Valparaiso Region
Specialty: Neurology
Financing: Fonasa

The methodology proposed for data analysis and patient profiling can be replicated in other institutions with detailed socio-demographic information such as that presented in this article.

5.3 Preparing Event Logs to Discover Project Trajectories

To prepare the event logs, it is necessary to determine the minimum data characteristics that will be required. As described by van der Aalst (2016), event logs store activity information, including case identification data, activity identification and a timestamp that allows for the differentiation of each activity in the flow and ensures the traceability of activities.

In conjunction with the clinical experts, the most relevant profiles will be selected. Subsequently, the event data stored in the electronic clinical record of the Red de Salud UC-Christus network will be extracted. To reiterate, the electronic clinical register already functions based on a structure that allows users to identify the minimum requirements for the construction of an event log. Table 2 provides an example of what an event log would look like for the patients.

Table 2: Example of an event log with clinical data.

Case ID	Activity	Timestamp	Doctor
001	First consultation	2020/06/03 12:05:54	Dr Q.
002	Laboratory test	2021/10/05 11:58:06	Dr M.
004	Radiology test	2020/08/06 15:26:34	Dr Q.
001	Referral to specialty	2021/25/06 14:15:23	Dr L.
003	2nd consultation	2022/04/12 16:03:56	Dr X.
004	Referral to specialty	2020/08/07 15:06:05	Dr Q.

6 DISCUSSION

Preliminary results show that a diverse population of patients is accessing telemedicine care from the Red de Salud UC-Christus network. Yet, it is possible to identify common characteristics that increase the likelihood of finding one type of patient profile over another. For example, the typical telemedicine patient in the network is generally an adult, lives in the Metropolitan Region, and is most likely female. In addition, the data demonstrates that this typical telemedicine patient finances their care privately.

The main specialties requested in telemedicine are psychiatry, neurology and nutrition, which may be due to the fact that these types of consultations are easier to adapt to telemedicine than those requiring physical analysis. However, the field of general medicine is noteworthy because it represents the second most requested type of consultation, in terms of total number of patients. This is explained by the fact that patients first consult in general medicine and are then referred to a specialist.

When analyzing the geographic location of the patients, it is observed that they are mainly concentrated in large cities. This can be explained by the fact that cities have larger populations than small and remote towns. However, it is worth deliberating whether the goal of telemedicine to bring healthcare systems closer to remote populations is still being met, as evidence shows that people with better access to healthcare are those who use this model of care the most.

When analyzing the number of patients and consultations by period, an increasing drop in the number of patients and consultations year-on-year can be observed. There are two possible explanations for this phenomenon: first, the end of the COVID-19 pandemic has resulted in patients preferring face-to-face care once more; and second, patients have decided to seek care in other healthcare centers. Either way, greater amounts of data are required to identify the reasons for the drop in patient numbers.

Since the patient profiles compiled in the present study are based on statistics from the healthcare institution rather than the electronic health record, a more in-depth analysis is required to develop a more detailed profile of users of the health services provided by this hospital network. However, the characterizations herein will allow clinical experts to be consulted on a selection of the patient profiles that are of particular interest to them and the healthcare provider itself.

Another limitation of this project is that the study is carried out in a single health institution. However, the methodology proposed for the characterization can be used in other centers that have this type of registry. This allows for a multicenter comparison of the results.

It should be noted that in the development of this research, challenges related to data quality will arise. To address this issue, the guidelines set out in ISO/IEC 25012 will be followed and the relevance of all data will be discussed with clinical experts.

In addition, it should be mentioned that, when dealing with personal data, the correct use of sensitive information will have to be considered to keep the identity and integrity of users protected. In this same sense, anonymized data will be used with the approval of the Scientific Ethical Committee of Health Sciences of the Pontificia Universidad Católica de Chile.

Another challenge is that the data will not allow traceability of events. This will be addressed by working directly with the administrators of the information systems to ensure that the time stamp of each event is included.

7 CONCLUSIONS AND FUTURE WORK

These preliminary results provide an improved understanding of the universe of patients who use the telemedicine service provided by the Red de Salud UC-Christus network. Moving forward, it will be possible to conduct a more rigorous analysis of how telemedicine care is implemented across the network. Such analysis will give rise to greater clarity on the requirements needed to build an event log with which to identify patient journeys.

Future efforts will involve a more thorough analysis to establish an event log for identifying patient journeys. Further work includes a literature review for additional patient characterization methods, a study on the pros and cons of using process mining in telemedicine research and extracting patient data for journey discovery. The subsequent comparison of telemedicine and face-to-face care journeys aims to identify differences across patient types, specialties, and diagnoses, offering insights for improvement and informed decision-making in patient care.

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