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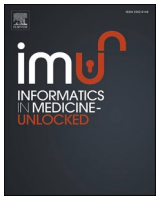

Determinants of patient trust in gastroenterology televisits: Results of machine learning analysis

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ABSTRACT

Background: The introduction of telemedicine into gastroenterology practice has been a major change over the past decade. Particularly during the COVID-19 pandemic, it has been very helpful for patients with chronic gastrointestinal disease as it has allowed continued healthcare delivery. Patient acceptance of televisits is key for its implementation in usual clinical practice, but lack of patient trust may limit its adoption. During the COVID-19 pandemic, we have embraced televisits instead of the traditional in-person medical examinations.
The aim of the study was to evaluate the feasibility of televisits and factors influencing patient trust.
Methods: Patient trust in televisits was assessed through a validated questionnaire (PATAT). We employed machine learning (decision trees and random forests) in order to clearly understand the relationships between covariates influencing patient trust.
Results: Most televisits were successfully performed (186/218, 86.2%) and highly trusted (155/163, 95.2%). According to the decision tree, 'The video service is easy to use' in the parent node had the most influence on patient trust. Trust in the care organization, in the treatment, and in guaranteed data protection policies were the other factors influencing patient trust. In the random forest analysis, the use of known and user-friendly video services (12.8%IncMSE) and confidence in the data protection policies (12.4%IncMSE) were the two variables contributing most to trust in televisits.
Conclusion: Most patients with chronic gastrointestinal disease agreed to receive a televisit and trusted it. Knowledge of factors determining patient trust is essential to improve patient–doctor communication in order to increase the use of telemedicine in gastroenterology.

1. Introduction

Telehealth includes all those technologies that allow for long-distance interaction between patients and healthcare professionals for the delivery of healthcare-related services [1]. Its ability to overcome distance enables both patients and healthcare professionals to enjoy greater flexibility and efficiency, resulting in time-saving, cost reduction, and improved and wider access to healthcare [2]. Telehealth modalities can be classified as asynchronous (e.g., emails) or synchronous (e.g., televisits or video consultations), the latter modalities being less common but having great potential. In the last decade, there have been rapid technological advances with the widespread diffusion of internet-connected remote devices such as smartphones. Although telehealth has the potential for greater use, a face-to-face consultation is still the predominant doctor–patient interaction. However, telemedicine is being increasingly used in medical practice [3].

Since the beginning of 2020, national healthcare systems worldwide have been challenged by the coronavirus disease 19 (COVID-19) pandemic. To respond to this emergency, the healthcare systems had to immediately adapt, changing the organization and delivery of their services radically. Telemedicine has emerged as the ideal solution to overcome the impossibility of standard face-to-face visits, to guarantee and continue patient care, and to avoid cancelling and rescheduling

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List of abbreviations in order of appearance

COVID-19	Coronavirus Disease 19
FDA	Food and Drug Administration
CDC	Centers for Disease Control and Prevention
DT	decision trees
RF	random forests
IBD	inflammatory bowel disease
CeD	celiac disease
PATAT	PAtient Trust Assessment Tool
MSE	mean squared error
SARS-CoV-2	severe acute respiratory syndrome coronavirus 2
IOIBD	International Organization for the Study of Inflammatory Bowel Diseases

appointments while reducing the risk of viral spread and infection. Health agencies such as the Food and Drug Administration (FDA) and the Centers for Disease Control and Prevention (CDC) have invited healthcare providers to embrace telehealth during the COVID-19 emergency [4,5]. Italy, especially the Lombardy region, was the first Western country to be badly affected by the virus, resulting in a national lockdown which lasted 2 months [6].

Several studies on telemedicine have investigated its clinical reliability, usefulness, and cost/time effectiveness, and have reported high rates of patient satisfaction.

A US study conducted by Serper et al. at the beginning of the COVID-19 pandemic in an academic gastroenterological and hepatological practice showed a high rate of satisfaction in telemedicine tools by patients and clinicians, although some concerns were expressed about the lack of a physical examination, fees, privacy, and technology [7].

Lahat et al. have reported a high rate of satisfaction and acceptance of telemedicine among gastroenterological patients with chronic diseases needing regular follow-up, such as inflammatory bowel disease (IBD) [8].

Other studies performed in different countries have shown similar promising results, with good patient satisfaction and willingness to receive telemedicine [9–11].

However, patient trust in telemedicine is a crucial factor. Orrange et al. have highlighted how trust in a telemedicine service is associated with satisfaction [12].

Patient trust in a telemedicine service can be considered as the patient's willingness to rely on that health service (and the factors that make up that service) as a part of their treatment. Trust is a patient's willingness to rely on a telemedicine service for personal gain (such as improved quality of care, time savings, or avoiding attendance at hospital during the COVID-19 pandemic).

It has been demonstrated that trust is multidimensional and is most likely the sum of trust in several factors that constitute the telemedicine service (care organization, professional staff, treatment, technology), each of which can be trusted to a greater or lesser extent) [13].

However less is known about patients' trust determinants during the COVID-19 pandemic.

Decision trees (DT) and random forests (RF) are two machine learning techniques which have been increasingly utilized in the last few years due to their ability to uncover non-linear relationships between covariates and outputs [14–16].

The aim of our study was to assess patient trust in televisits and its determinants through a machine learning technique applied to a large database of televisit questionnaires. The aim was to identify strategies to improve the use of telemedicine. We used machine learning statistical tools (DT and RF) to assess which factors influenced patient trust in telemedicine in order to fully understand the relationships between covariates and outputs through relaxation of linear relationships and underlying model assumptions.

2. Methods

Our Gastroenterology Unit at Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico in Milan (Italy) is a tertiary referral center for IBD and celiac disease (CeD) patients. During the COVID-19 pandemic, we have embraced telemedicine and, in particular, televisits (visits performed using video communication) in order to continue our gastroenterological and nutritional follow-up. From March 2020 to May 2020, all consecutive patients with a scheduled gastroenterological follow-up visit were first contacted by telephone. Patients with mild-to-moderate symptoms (e.g., diarrhea, abdominal pain, weight loss, biohumoral alterations, or those who especially requested it, were offered televisits in addition to the telephone call. In case of patients with severe disease or experiencing a medical emergency, regular visits to our outpatient clinic were allowed, or, if necessary, the patient was hospitalized. Rescheduling was considered for patients in clinical remission and with no major laboratory test changes. We also suggested televisits for nutritional counselling for our patients.

From June 2020 to February 2021, we proposed televisits for selected patients, such as those living far (at least an hour of travel) from the hospital, even if they normally used asynchronous communication (e.g., emails), and to those who requested it after the initial televisit performed during the first general lockdown. Patients who did not have an internet connection or were unable to use a smartphone were excluded.

The Google Meet (or Hangouts) and Microsoft Teams platforms were approved for use in this study by our hospital and some individual institutional accounts were provided and used for video calls. At the end of the televisit, all patients were invited to enroll in the study. As they agreed, subjects received an email and were directed via a link to an online structured questionnaire on the EUSurvey platform (https://ec.europa.eu/eusurvey/) supported by the European Commission, which allows the collection of sensitive data with no user identification via IT tracking, profiling cookies, geographical location, or personal/sociodemographic/health data. Two reminders were sent if the patients did not answer the questionnaire immediately.

The structured anonymous questionnaire enquired about: (i) demographic characteristics and medical history including: age, sex, disease type (IBD or CeD), immunosuppressive therapy, and comorbidities (other social variables such as years of education, income, professional status and residential area (e.g., city, neighborhoods) were not investigated); and (ii) patient trust in televisits using an adapted Italian version of the PAtient Trust Assessment Tool (PATAT) questionnaire, which has already been validated in other outpatient settings [7,11] This questionnaire (Table 1) investigates five areas of trust: (A) care organization, namely reputation, feeling at ease with and trusting the organization; (B) care professionals, namely doctor's judgment or medical advice; (C) treatment, namely clarity concerning treatment and options, and treatment effectiveness; (D) technology, namely ease of use and safety of the platform; and (E) telemedicine services, namely effectiveness and ease of use. Trust in telemedicine was defined as a score of at least 4 out of 5 on a Likert scale for the statement: 'I can trust this telemedicine service', which was considered the output for which the possible determinants influencing it were to be analyzed.

The secondary endpoint was feasibility evaluated as the percentage of patients who had either the technology and/or the ability to perform televisits, and the percentage of patients who agreed to have a televisit instead of the usual in-person examination.

2.1. Statistical analysis

Absolute and relative frequencies were calculated for the categorical (qualitative) variables, and quantitative variables were summarized by their means. Differences among variables in groups of patients who

Table 1
Patient trust in televisits. Results of the PAtient Trust Assessment Tool (PATAT) questionnaire for inflammatory bowel disease patients conducted by the Gastroenterology Unit, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico (or Policlinico of Milan), Milan, ItalyThe
primary endpoint was patient trust in telemedicine. This was expressed as more than 75% of patients giving a score of at least 4 out of 5 on a Likert scale for three selected key statements: 'I can trust this telemedicine service' (E.1), 'I can trust that possible problems with this telemedicine service will be properly solved' (E.2), and 'I feel at ease when working with the Google/Microsoft video service' (E.4).

		Percentage of patients giving a score ≤3	Percentage of patients giving a score ≥4
A	**Trust in the care organization**		
A.1	The Policlinico of Milan IBD (or CeD) Center has a good reputation	3.4	96.6
A.2	At the Policlinico of Milan IBD (or CeD) Center, they handle my personal information carefully	5.5	95.5
A.3	At the Policlinico of Milan IBD (or CeD) Center, they take action when something goes wrong	5.8	94.2
A.4	At the Policlinico of Milan IBD (or CeD) Center, I feel at ease	3	97
A.5	At the Policlinico of Milan IBD (or CeD) Center, they take my specific needs into account	5.8	94.2
B	**Trust in care professionals**		
B.1	I trust my doctor's judgment about my medical care	2.4	97.6
B.2	My doctor provides me with all the information on all potential medical options	1.8	98.2
B.3	My doctor keeps all my medical information private	3.9	96.1
B.4	I always follow my doctor's advice	10.9	89.1
B.5	My doctor does not do everything he/she should about my medical care	89.3	10.7
C	**Trust in treatment**		
C.1	The treatment I receive is effective	14.5	85.5
C.2	It is clear to me what the treatment I receive entails	6.7	93.3
C.3	Together, my doctor and I chose this treatment	15	85
C.4	The treatment I receive is not helping me enough	87.6	12.4
C.5	It was explained well to me what my treatment entails	13.1	86.9
D	**Trust in technology**		
D.1	When I use the Google/ Microsoft video service, I am in control	33.6	66.4
D.2	Everything that I do on the Google/Microsoft video service remains private	22.1	77.9
D.3	The personal information that is stored at Google/Microsoft will not get lost	30.6	69.4
D.4	The Google/Microsoft video service is easy to use	24.5	75.5
D.5	Legal policy and technological safeguards make the Google/ Microsoft video service a safe environment	25	75
E	**Trust in the telemedicine service**		
E.1	I can trust this telemedicine service	4.8	95.2
E.2	I can trust that possible problems with this telemedicine service will be properly solved	10.3	89.7
E.3	I can trust this service less than other online services	79.4	20.6
E.4	I feel at ease when working with the Google/Microsoft video service	12.7	87.3
E.5	I do not like to enter my personal data on Google/Microsoft	83.2	16.8

accepted and who refused televisits were calculated with the χ^2 or Fisher's exact test, and a p value ≤ 0.05 was considered statistically significant. All data were analyzed using the statistical software R version 4.0.4 (R Core Team, Boston, MA, USA). Machine learning tools were used to reveal the non-linear influence of different patient features on trust in telemedicine. Relaxing the hypothesis of linearity constraints of more traditional statistical analysis, it is possible to detect more heterogeneous effects on the relationship between features and the dependent variable. DT is a supervised learning technique classified as a white-box model. The main output from DT identifies mutually exclusive subgroups of the population whose members share common characteristics that influence the dependent variable [13]. DT has been employed for its ability to provide a simple readable scheme of the interaction of different patient features on trust in telemedicine, while relaxing linearity constraints. RF is defined as an ensemble learning method based on many DT which consider random subsets of observations from the original dataset. A DT with randomly selected predictors is built on every subset [14]. The RF produces the final ranking of the explainability of the predictors [15]. Differently from DT, RF provides the opportunity to rank all the features according to their importance in explaining the trust in telemedicine. In particular, the more important a feature is in the RF model, the greater its importance in influencing the telemedicine trust score.

A DT was employed to execute a non-parametric statistical procedure to explore the features most related to telemedicine trust. When constructing the DT, the algorithm first searches for the feature that has the biggest information gain, the 'parent' node. The procedure then examines all other possible features, selecting that with the highest information gain. In general, DT algorithms begin with one 'node' or group that contains the entire sample, the 'parent node'. The procedure then examines all possible independent variables iterating again the same information gain check. The parent node is then split into two descendent nodes depending on the variable selected. The tree-growing methodology continues, following the same iterations on the generated nodes. Given the nature of our output (numeric), we consider regression trees. In this framework, the DT algorithm bases the split performed on the mean squared error (MSE).

The second machine learning model used is RF. In our model, we consider regression trees. The produced ranking displays two indicators: %IncMSE and IncNodePurity. %IncMSE is the most robust and informative measure. It represents the increase in MSE obtained, excluding that covariate from the tree's sample. IncNodePurity reports the importance of each variable when it is included in the tree's sample.

3. Results

A total of 248 patients had mild-to-moderate symptoms or biohumoral alteration and so were deemed suitable for televisits. However, 30 (12.1%) of these were excluded because they did not have an internet connection or did not feel able to perform a video call.

Consequently, we scheduled 218 televisits (87.9%), and 188 of these were successfully performed (86.2%) (Fig. 1). There were no significant differences in baseline characteristics between the patients who accepted televisits and those who did not (Table 2).

Overall, 163 questionnaires were filled in after the televisits (86.7%) as shown in Fig. 1.

Regarding trust in the telemedicine service, a score of least 4 was given by 95.2% of patients. A high percentage of patients (93.9–96%) allocated a score of at least 4 to items related to trust in our care organization. Similarly, there was high patient trust in care professionals, with 88–98% of patients giving a score of least 4 (Fig. 2, Table 1).

The DT with the output variable 'I can trust this telemedicine service' is shown in Fig. 3. 'The video service is easy to use' factor in the parent node had the most influence on trust in telemedicine. Analysis of the effect of nodes on score showed that trust in the center (A.3 and A.4), in technology (D.1), and in data protection policies (D.5) were the main drivers of the output variable, while 'The treatment I receive is effective' (C.1) accounted for patient trust in their treatment.

The results for %IncMSE and IncNodePurity are shown in Fig. 4. The two variables with the highest correlation on the telemedicine trust output were D.4 and D.5 (confidence in the technologies and trust in the data protection policies), with each contributing more than 10% to % IncMSE (12.8%IncMSE and 12.4%IncMSE, respectively) and 7.11 IncNode Purity and 11.1 IncNodePurity, respectively.

4. Discussion

During the COVID-19 pandemic, telehealth has been very useful for patients with chronic gastrointestinal disease as it has allowed the continued delivery of medical care while also helping contain the spread of SARS-CoV-2 among patients and healthcare professionals [17–20]. However, it still has only a marginal role in daily clinical practice and is mostly limited to text messages or email, even though the patient often finds these forms of communication unsatisfactory due to the off-line interaction and the delay in responding to queries [21]. A recent position paper has given information to gastroenterologists on using telemedicine correctly [18].

4.1. Theoretical implications

There have been some studies on telemedicine for IBD patients. Li et al. reported positive findings among a small cohort of IBD patients accessing video consultations [22]. A study by George et al. showed that telehealth visits had good accessibility, accurately addressed clinical problems and patient concerns, and were time efficient. They also found that over 90% of patients were in favor of accessing telehealth in the future [23]. More recently, enthusiasm for telehealth was confirmed among adult CeD patients during the first wave of COVID-19 in March 2020. In this study, 86% of the patients interviewed answered positively when asked about their opinion on remote telemedicine visits, with approximately 17% explicitly requesting them [24]. No differences in quality of life were reported between tele-monitored IBD patients and IBD patients attending traditional in-person visits [25].

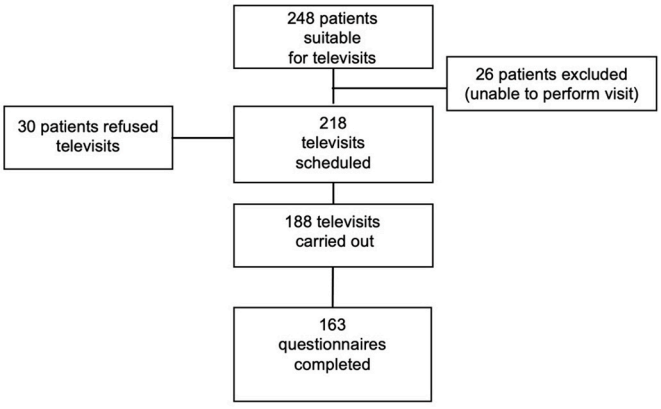

Fig. 1. Study flowchart.

Table 2
Baseline characteristics of patients who accepted and who refused televisits.

	Patients who accepted the televisit (n = 188)	Patients who refused the televisit (n = 30)	p Value
Age (years), median (range)	42,3 (19–78)	41 (22–70)	0.71
Female, n (%)	60 (31.9%)	11 (36.6%)	0.60
Disease duration (years)	13.7	11.5	0.52
Overall numbers	188	30	
Inflammatory bowel diseases	133 (70.7%)	22 (73.3%)	0.77
Celiac disease	55 (29.2%)	8 (26.6%)	0.77
Concomitant immunosuppressive therapy, n (%)	102 (54%)	14 (46.6%)	0.43
Comorbidities, n (%)	39 (20.7%)	4 (13.3%)	0.59

Despite encouraging results, the following factors may limit the adoption of telemedicine in routine practice: (a) some national health authorities do not have clear laws or regulations governing the delivery of telehealth; and (b) some reimbursement plans may restrict its use.

The attitudes of both healthcare providers and patients to telemedicine have changed as a result of the pandemic. Indeed, during lockdowns when usual clinical activity was severely limited, telemedicine was the only way to guarantee care for chronic disease.

A survey conducted by the International Organization for the Study of Inflammatory Bowel Diseases (IOIBD) on the use of telemedicine by IBD specialists during the COVID-19 pandemic found a significant increase in televisits, although telephone consultations still accounted for over half of all telemedicine activity [26]. Also, video consultations were considered to be the only visit modality that would be implemented in the future [26].

4.2. Practical implications

Our center adopted televisits as a preferred modality as they have many advantages compared with other types of telemedicine: they allow medical examinations to be carried out in a setting similar to usual outpatient clinics and the clinician can see the patient's facial expressions, which is important in medical consultations. Furthermore, it also is important for patients to see the doctor's face, ensuring eye contact and strengthening the doctor–patient relationship.

During the COVID-19 pandemic, our patients have agreed to receive follow-up televisits instead of in-person medical examinations and have trusted this novel approach. According to our DT analysis, the factors influencing patient trust were trust in the medical center, trust in the treatment, employment of a user-friendly video service, and data protection policies. RF analysis showed the only two variables clearly impacting patient trust in televisits were patient confidence in using video-service tools and trust in the data protection policies. The contribution of the other features was smaller and homogeneous. However, it should be noted that the RF results are weak since the dataset was small.

Trust in the medical center and trust in treatment are not exclusively associated with telehealth but are necessary for its successful use. Factors determining the acceptance of televisits, such as patient confidence in using video-service tools and the guarantee of data protection, should be taken into account when televisits are proposed to patients, and adjusted accordingly.

Patient-related factors that may limit telemedicine acceptance include the fact that in-person visits traditionally start with a handshake. However, the pandemic has halted this practice. In addition, physical

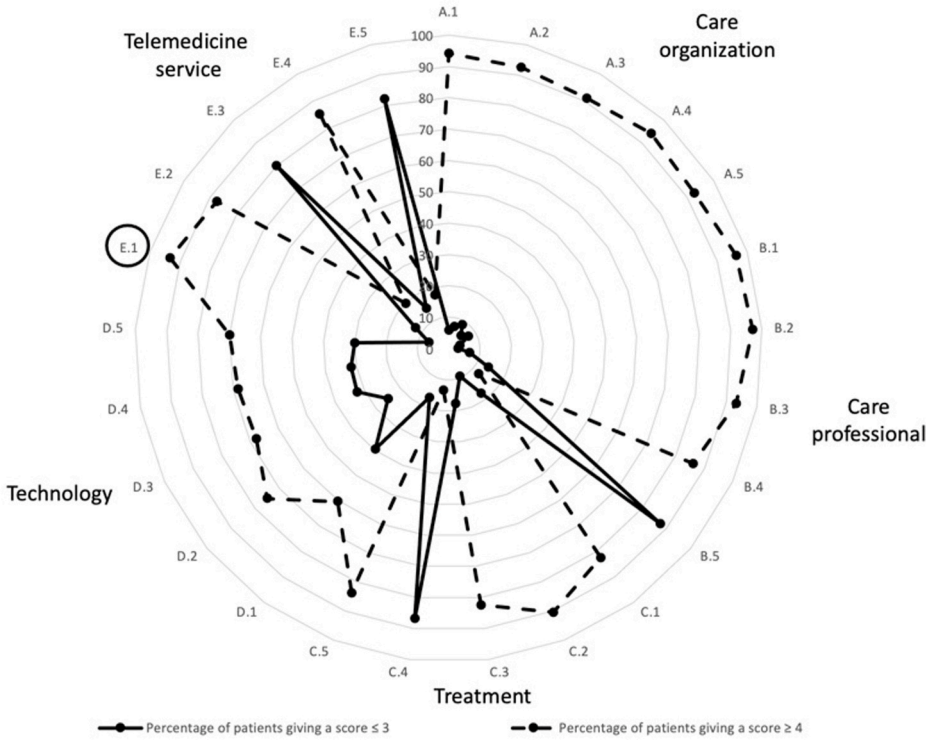

Fig. 2. Patient trust in televisits
A radar chart of the patients' trust scores. Five areas of trust were investigated: care organization (1.1–1.5), care professionals (2.1–2.5), treatment (3.1–3.5), technology (4.1–4.5), and telemedicine services (5.1–5.5). The continuous line refers to the patients giving a score ≥4 (out of 5) on a Likert scale. The dotted line refers to the patients who gave a score ≤3. Statements 2.5, 3.4, 5.3, and 5.5 were negative. As regards patient trust in telemedicine services, items 5.1, 5.2, and 5.4 received a score of least 4 from 95%, 90%, and 84% of patients, respectively.

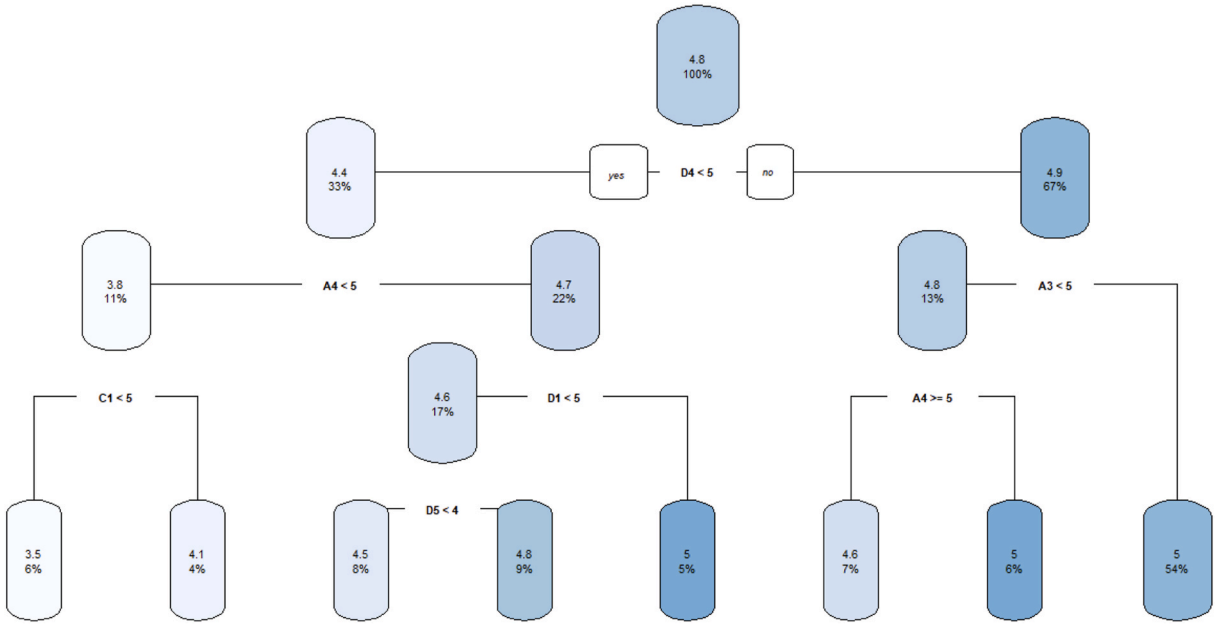

Fig. 3. Decision tree of factors influencing patient trust in televisits.
Note that every node (and leaf) contains the average telemedicine trust score obtained by this subgroup and the percentage of the sample. For every node, the splitting procedure is presented: the left branch corresponds to a 'yes' answer to the condition, while the right one corresponds to a 'no'. Finally, the color intensity represents the mean value of the telemedicine trust score associated with the node (leaf). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

examination is often considered fundamental to the patient visit [27], although the time required for this has been decreasing with the increased utilization of advanced imaging and laboratory data [28].

The COVID-19 pandemic has made alternatives to the usual medical examination more acceptable, even for patients with low trust in technology, as people have become more familiar with video calls.

The feasibility of televisits has been highlighted in our study. Among our patients, 89.5% were able to perform a televisit and 86.2% agreed to use this tool as an alternative to the traditional in-person visit. However, we noticed declining use of telemedicine by patients over time. This might be because during the first lockdown, only emergency out-patient visits were possible, and so televisits were the only way patients could be medically examined. Also, at the beginning of the pandemic, patients were probably more concerned about the risk of infection, especially the

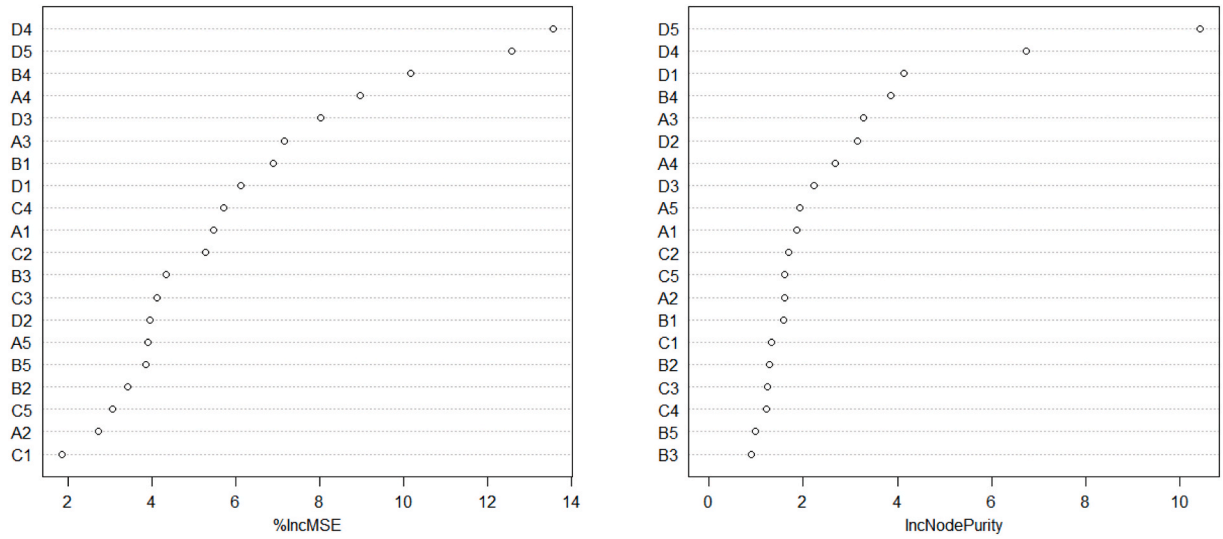

Fig. 4. Random forest of factors influencing patient trust in televisits
We used the default option of the R package 'randomForest'. It realizes randomization with the variable split: the search for the split variable is limited to a random subset of the variables. The output prints two indicators of importance: %IncMSE, which represents the increase in error if the variable is excluded from the model, and IncNodePurity, which measures the variable's importance through the Gini index.

many IBD patients on immunosuppressive therapy. With the resumption of most economic activity and less concern regarding the pandemic, more patients are choosing traditional over video-based visits. Therefore, it is uncertain whether the preference for televisits was due to ease of use rather than fear of SARS-CoV-2 infection. However, these considerations are beyond the scope of our study.

Although clinical outcomes were not included as a study objective, we did not observe a reduction in drug treatment in this cohort of patients. Last but not least, telemedicine potentially helped to reduce the spread of SARS-CoV-2 among patients as well as healthcare providers.

4.3. Limitations and strengths

Our study has some limitations. First, we did not propose televisits to patients who did not have an internet connection or were unable to use a smart device. Therefore, some patients, especially the elderly, were excluded from our analysis. Second, response bias is possible since the patients who accepted telemedicine are probably more confident in using the required tools and so are more likely to trust them. Nonetheless, there were no significant differences in baseline characteristics between patients who accepted and those who rejected televisits. Since the questionnaire was anonymous, we could not analyze the influence of other demographic variables (e.g., age, professional status, literacy) on trust in televisits. Third, there was no control group. We also have to consider that our patients' median age was 41 years. Patients of our cohort are younger than those with other chronic conditions, so they may find new technologies easier to use. Furthermore, our hospital is located in the center of Milan, whose economy relies heavily on IT and digital technology. Therefore, many of our patients may already be familiar with technology and digital services. Consequently, our results may not be reproducible in other patient settings, such as, for instance, among elderly patients or rural dwellers.

Lastly, the modified version of the PATAT questionnaire did not investigate parameters such as years of education, income, professional status, language, and residential area (e.g., city, neighborhood). We did not include these questions so as not to reduce the completion rate of the survey. Knowledge of this information could have contributed to a better understanding if some of these determinants influenced patient trust. However, our hospital is located in the center of Milan, the largest city in northern Italy, and the local economy relies heavily on IT and other digital technologies. Patients may have been very used to operating telematic tools in their jobs. Further studies will investigate if our results are reproducible in other environments (e.g., more rural areas).

Despite these limitations, our study showed that our patients were well able to use telemedicine during the COVID-19 pandemic.

Further studies will investigate the influence of the COVID-19 pandemic, with its social restrictions and fear of SARS-CoV-2 infection.

Hopefully, this study may persuade gastroenterologists to adopt and implement telemedicine more consistently in daily clinical practice, offering televisits as a valid alternative to usual visits, thus expanding their use. In the future, telemedicine may become established as the alternative to standard face-to-face consultation for patients with asymptomatic and symptomatic disease. Telemedicine can also be used to triage patients, determining who requires further examination or in-person consultation and who can undergo remote evaluation.

In the near future, it is likely that, together with televisits [29–33], the use of smartphone apps [34–36] and home-based laboratory tests [37–41] will eventually lead to virtual clinics.

In conclusion, the experience gathered on the effectiveness and performance of telemedicine during the pandemic will encourage its inclusion in clinical practice. However, only time will tell if or for how long the high patient trust shown in telemedicine will last after the end of the COVID-19 pandemic.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Dear Editors, The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be

construed as a potential conflict of interest.

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