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The digitalization of emergency department triage: the perspectives of health professionals and patients

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Abstract

Background Digitalization in the healthcare sector offers several organizational advantages, ranging from enhanced service quality to cost savings. However, its adoption often progresses slowly and faces challenges, especially in critical settings like emergency departments, requiring prompt, clear, and efficient communication. As such, this study aims to comprehensively assess the factors influencing the preference for digitalized tools over traditional methods from the perspectives of both service providers and users.

Methods We employ two ad hoc stated preference surveys in which we ask respondents to reveal their preference in simulated triage scenarios. Three main alternatives are proposed: traditional procedures, a fully digitalized solution with no direct patient-professional interaction, and a hybrid option that combines traditional and digital aspects. Scenarios and alternatives vary according to predetermined attributes, selected among the features acknowledged to impact the triage efficiency and efficacy: the possibility to communicate in a known language, the completeness of information retrieved from the patient, the time dedicated to triage activity, and the level of privacy. Responses are analyzed by means of discrete choice models.

Results Our findings reveal a preference for the hybrid approach, wherein patients use digital tools to input relevant information, followed by an interview with healthcare professionals. Nevertheless, distinct alternative- and case-specific features can favor the preference toward other kinds of triage. Respondents prefer shorter triage times and the opportunity to interact in a known language, while the level of privacy does not significantly impact their choices. Interestingly, the presence of an algorithm assigning urgency code diminishes the probability that healthcare professionals select the fully digitalized option.

Conclusions This study provides important insight into the utilization of digital tools in emergency departments. The results can be used by hospital managers and policy makers to develop digital tools that meet the needs of both users and healthcare professionals. This, in turn, may result in cost savings and improved quality of service.

Keywords Digitalization, Emergency department, Digital health, Triage, Stated preferences, Choice modeling

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Introduction

Over the past few decades, digitalization has offered numerous prospects for organizations to enhance their performance. Through the utilization of digital technologies, platforms, and infrastructures, organizations have successfully implemented suitable resource management strategies, resulting in increased efficiency and enhancement in the quality of their services or products [1–3].

In the healthcare sector, digitalization has been a multifaceted and promising phenomenon to advance current cost-related dynamics that generally encounters more complex challenges in its efforts to meet both the needs and expectations of clinicians and patients. Digitalized technologies designed to support healthcare services have proliferated in this sector, spanning from the use of electronic medical records to the adoption of wearable technologies allowing remote patient monitoring. The use of such solutions has faced an important rise after the COVID-19 pandemic, which has impacted the way in which healthcare professionals and patients relate and communicate [4, 5].

There are numerous benefits associated with the use of digital tools from the point of view of both healthcare professionals and patients. As an example, remote monitoring increases accessibility to health services, improving service quality by ensuring continuity of care. Additionally, digitalization in support (or substitution) of the work of healthcare professionals can lead to important cost savings, thus helping to face the scarcity of available healthcare resources [6]. Although digitalization results as promising from various perspectives, the adoption of these tools frequently encounters resistance from healthcare professionals who exhibit reluctance to change their working methods or raise significant concerns regarding safety [1, 7]. At the same time, despite digitalization being part of everyone's daily life, patients often express mistrust in relying solely on digitalization as an alternative to the patient-healthcare staff interaction [8].

This study aims to better understand and evaluate the factors that influence the propensity (or aversion) toward the digitalization of emergency departments' triage. With respect to other healthcare contexts, emergency departments (EDs) represent an intriguing setting to analyze. First, the interaction between patients and healthcare professionals is evaluated during an urgent condition, where speed and efficiency are emphasized, often at the expense of communication. Second, EDs significantly suffer from overcrowding. Overcrowding per se comes with several issues, such as the possible worsening of healthcare conditions, patient dissatisfaction, and thereby extra costs [9, 10]. As such, EDs often take advantage of the opportunity to evaluate and integrate appropriate innovative (digital) solutions to improve service quality and reduce costs [3, 6, 10–12].

On one side, traditional diagnostic and testing tools have evolved, including tomography, ultrasound, and echography, among others (e.g., [13–15]). On the other side, various technologies and digital approaches have been implemented to support decision making and improve ED processes. Considering pre-ED access and in-ED patient management, these include centralized ambulance real-time dispatch systems [16], delay announcement platforms [17], the collection and storage of patients' medical condition data in digitalized repositories [18], the use of virtual triage- [19] and telemedical physician- triage systems [20], the implementation of predictive and artificial intelligence-driven approaches for triage and patient streaming [5, 21–23], as well as the innovative use of wearable tracking technology in the emergency setting [24]. Furthermore, this progress has extended to downstream activities, with the digitalization of bed management activities aimed at alleviating one of the primary causes of overcrowding in the ED: ED boarding (e.g., [25]).

Taking into account the peculiarities of EDs, both digitalization-related positive effects and healthcare professionals' and users' concerns are exacerbated, making ED an interesting setting in which to investigate the role of digitalization. This study focuses on the full triage process—defined as the set of activities needed to register and assign priorities based on the severity of the patient's condition upon arrival at the ED [26]—and the extent to which digitalization can be utilized as an alternative to traditional procedures. While the recent literature has extensively demonstrated the related advantages, only a few studies have focused on individuals' willingness to use digitalized tools and the conditions that influence their preferences for traditional procedures over digitalized ones, especially in the context of ED. A few studies focus on fully digitalized solutions, exploring how different patient profiles are more prone (or reluctant) to use symptom checkers in access to ED [27], and assessing the workload efficiency derived by the use of self-triage [28]. However, to the best of our knowledge, there is a lack of investigation regarding how both individuals' characteristics and digitalized tools' attributes influence individual preferences toward digitalization.

The contribution of this paper to the literature is threefold. First, we investigate which is the value associated with digitalized (and hybrid, that is, a mix of digitalized and traditional procedures) solutions in the context of emergency departments compared to traditional procedures. Second, we explore the features that influence individuals' preferences toward digitalized tools, accounting for their demographic characteristics, such as age and gender, as well as alternatives' attributes (e.g.,

triage time, completeness of information retrieved by patients, and privacy). Third, we study the preferences from two different perspectives, namely, the points of view of both healthcare professionals and individuals who may use the digitalized solution as patients.

The double perspective is analyzed by means of two ad-hoc developed surveys based on stated preferences. Specifically, for both types of respondents (users and healthcare professionals), we implement a set of simulated triage scenarios in which we propose three different alternatives, varying from the traditional procedures currently adopted by EDs to fully digital options. By taking into consideration the attributes of different alternatives and the characteristics of scenarios, we collect individuals' stated preferences to be evaluated by means of discrete choice models.

The results suggest a potential propensity to use digital tools in the context of emergency departments from both healthcare professionals' and patients' perspectives. The extent to which these tools are potentially utilized depends on several factors, including their characteristics and the surrounding conditions. In detail, the language in which patients and healthcare professionals can communicate is an important factor in the choice of utilizing a digital tool, with professionals favoring digital solutions in the presence of language barriers and users preferring direct interactions when they can communicate with healthcare professionals in a known language. Furthermore, the presence of an algorithm that determines patient urgency levels decreases the likelihood of healthcare professionals using the digital tool. Finally, the time employed in the triage activity is a relevant variable, but only for patients, who do not place significant importance on privacy issues. These findings contribute to a comprehensive understanding of the potential of the use of digital tools in emergency departments, highlighting the conditions driving their utilization. An appropriate design and implementation of digitalized technologies could help hospital managers mitigate overcrowding, reducing costs and increasing overall operational efficiency.

The remainder of this paper is organized as follows. Methods section describes the experimental design developed to assess respondents' preferences and discusses the methodology employed in the study. Results section reports the outcomes of our research, highlighting the relevance of the derived results. Finally, in the Discussion and Conclusion sections, we syntetize the main insights derived from our study, reporting the conclusive remarks of our work.

Methods

This work explores healthcare professionals' and patients' preferences toward digitalization by means of two distinct surveys.[1] Healthcare professionals were recruited from a pool of doctors, nurses, and healthcare assistants working in the emergency departments of ASST Bergamo Est, a multi-hospital network located in the North of Italy. The responses from potential users were collected via social media channels as well as through students and PhDs' mailing lists of a university located in the North of Italy. For both groups of respondents, the surveys are organized into two main sections. The first section maps respondents' profiles, collecting data on the socio-demographic characteristics. The second section is specifically dedicated to the investigation of respondents' preferences toward digitalized tools during the triage process.

Before collecting responses, we conducted a pilot study with a group of 20 students and PhDs from a university in northern Italy, as well as a small group of healthcare professionals from ASST Bergamo Est. Specifically, we asked the pilot participants to complete the survey and provide comments on any potentially unclear questions. The pilot facilitated some refinements of the scenarios in the second section. Overall, we collected responses from June to August 2023, for a total of 507 responses for users and 69 for healthcare professionals. After data cleaning of incomplete or inconsistent responses, our final sample comprises 445 users (for a total of 1275 scenarios) and 63 healthcare professionals (for a total of 178 scenarios).

The next Survey respondent profiling and Experimental design of triage scenarios and alternatives sections describe the profile of the enrolled respondents and the design of hypothetical scenarios to test digitalization propensity, respectively. In the Choice model section, we present the discrete choice model utilized to assess respondents' preferences.

Survey respondent profiling

In the first survey section, we examine the individual characteristics of the respondents, gathering socio-demographic data. Detailed information regarding the variables collected for both users and healthcare professionals is available in Table 1. These encompass details on demographic factors, such as age (*Age*), gender (*Male*), and nationality (*Italian*), in addition to English language proficiency (*English Fluent*), and the propensity to use digital tools for healthcare purposes (*Digital Aversion*). The user sample mainly consists of Italian females (with only 31% of the respondents identifying as male), with an average age of 29 years (in the range between 19 and 74

[1] The surveys used to collect responses are available in the supplementary material.

Table 1 Respondent profiles' descriptive statistics

Variable		Users	Healthcare Professionals
Age	Mean (sd)	28.86 (10.91)	41.56 (11.96)
Male	No. (%)	136 (30.66%)	18 (28.57%)
Italian	No. (%)	435 (97.81%)	62 (98.41%)
English Fluent	No. (%)	361 (81.02%)	28 (44.44%)
Digital Aversion	No. (%)	44 (9.97%)	2 (3.18%)
Educated	No. (%)	227 (51.09%)	
Student	No. (%)	235 (52.81%)	
No Chronic Diseases	No. (%)	322 (72.36%)	
Never accessed the ED	No. (%)	143 (32.12%)	
Triage Nurse	No. (%)		26 (41.27%)
Years of Experience	Mean (sd)		8.75 (7.53)
Average Triage Time	Mean (sd)		6.60 (2.80)

years). Approximately 81% of the respondents indicate a high proficiency in English. Similarly, healthcare professionals in our study are primarily Italian females (with only 29% identifying as male). However, only 44% consider themselves highly proficient in English. The average age of healthcare professionals is higher than that of users, at 42 years, with ages ranging from a minimum of 22 to a maximum of 62.

The assessment of digital aversion for healthcare purposes varies between healthcare professionals and users, as they are retrieved by two distinct questions. Specifically, we categorize users as 'digital averse' if they indicate a preference for solely traditional tools to the question "Do you prefer to use technological/digital tools (e.g., electronic prescriptions) or traditional ones (e.g., printed paper prescriptions) to manage your health?". On the contrary, healthcare professionals are classified as digitally averse if they find significant advantages in their interactions with other healthcare professionals instead of utilizing digital tools. Notably, the proportion of digitally averse individuals is quite low, comprising only 10% of users and a mere 3% of healthcare professionals.

Other individual-specific characteristics are collected for the two types of respondents. Specifically, we ask users for their level of education, their employment status, if they suffer from chronic diseases, and if they have ever experienced access to the emergency department. 51% of the users have a degree or a higher level of education (*Educated*) and around 53% of them are students (*Student*). Most users do not suffer from one or more chronic diseases (72% of the population declares not to suffer from a chronic disease—*No Chronic Diseases*) and, interestingly, 32% of the respondents never needed to access the ED in their entire life (*Never accessed the ED*).

In the case of healthcare professionals, we expand our data collection to include their professional role within ED, years of work experience, and, if they are responsible for triage, the average time spent on triage activities. Around 42% of the sample consists of triage nurses (*Triage Nurse*), while the remainder comprises doctors, healthcare assistants, and other types of nurses working in the ED. The average number of years of experience (*Years of Experience*) is equal to 9, ranging from 1 to 28 years. Finally, the average time allocated to the triage activities (*Average Triage Time*) amounts to 7 minutes, with a range spanning from 2 to 15 minutes.

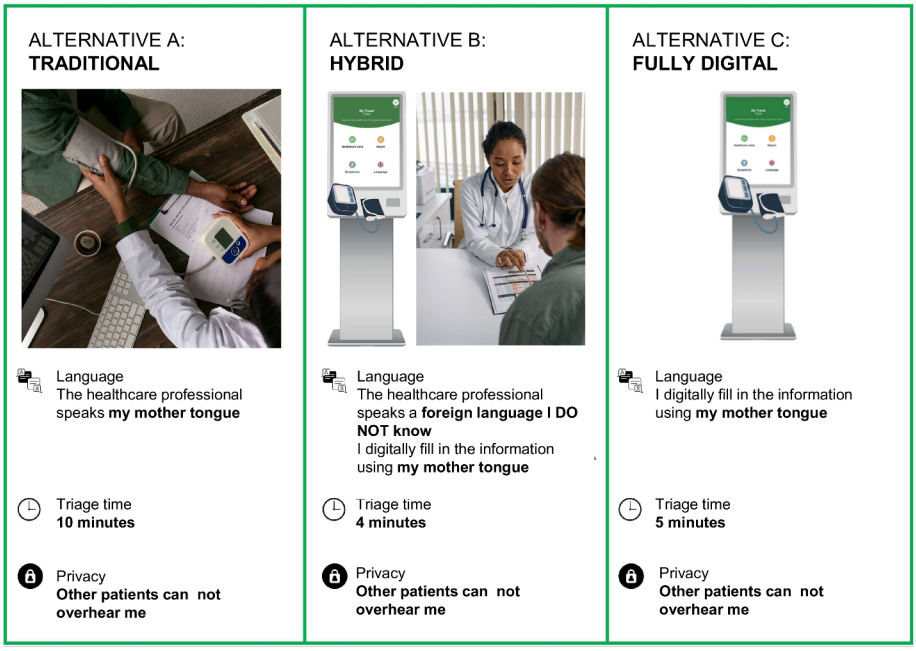
These individual-specific characteristics play a pivotal role in comprehending how individual features may influence their choices regarding the utilization of digital tools as an alternative to traditional procedures when accessing the ED. In the Choice model section, we elaborate on how these variables are integrated into our model.

Experimental design of triage scenarios and alternatives

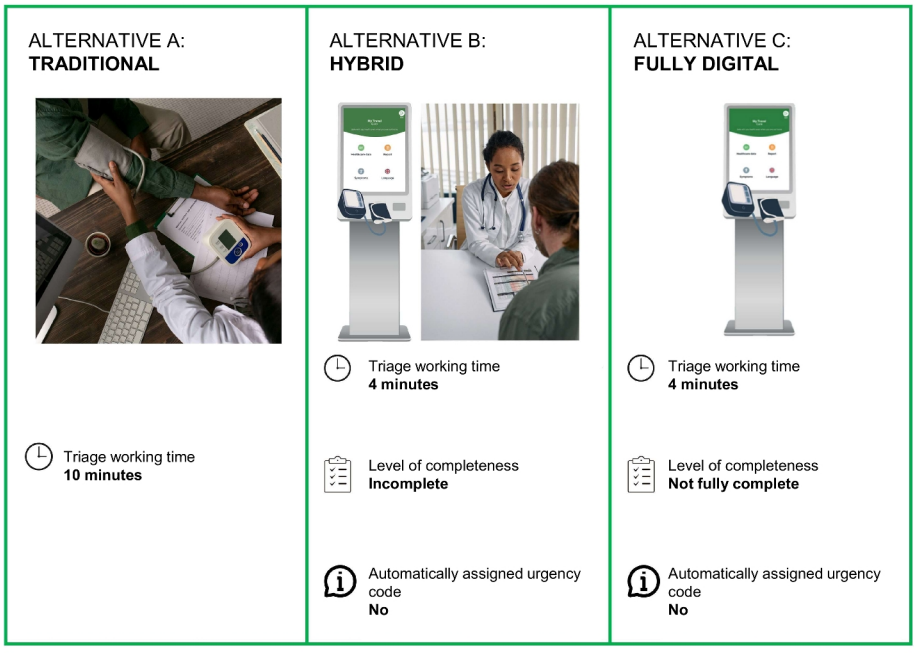
Stated preferences (SP) is a methodology widely used in the transportation literature (e.g., [29]), which has recently been demonstrated to provide valid and effective results also in the healthcare context (e.g., [30–34]). Differently from revealed preferences, which are collected by observing individuals' behavior, and thereby choices, this approach presents individuals with hypothetical scenarios and asks them to express their preferences. This feature is particularly useful in our context, as it allows exploring the propensity of usage of digitalized solutions, which are not currently adopted, and thus unobservable in real-world settings.

In detail, we propose three distinct scenarios to each respondent (whether healthcare professional or user), and, for each scenario, we ask them to rank three triage alternatives based on their preferences (See Fig. 1 for an example of a set of alternatives for users and healthcare professionals).[2] Scenarios are designed to differ in several aspects, namely scenario- or case-specific characteristics (Table 2). These include the time of the day (i.e., morning, afternoon, or night), the level of ED crowding (measured in the average patients' waiting time when accessing the ED), the primary reason for the patient ED's visit (always nonurgent situation, that is represented by a low Emergency Severity Index—ESI level), and, for healthcare professionals, the language spoken by patients. Language options comprise the respondents' mother tongue (i.e., Italian, the main language spoken in the hospital), a foreign language that healthcare professionals

[2] Having the respondents' preferences related to three alternatives ($I = \{a, b, c\}$) allows us to observe more than one choice per each scenario (e.g., [35]). Being $Pr(a, b, c)$ the probability of ranking the three alternatives from the most preferred (a) to the least preferred (c), we have $Pr(a, b, c) = Pr(a|I) \cdot Pr(b, c) = Pr(a|I) \cdot Pr(b|I - \{a\}) \cdot Pr(c|I - \{a, b\})$, thus meaning that we observe two choices per each scenario: the choice of a over alternatives b and c, and the choice of b over c (see [35] for further reference). This feature is particularly useful in case of a small number of observations. In this study, we apply this property to the analysis of healthcare professionals' preferences (Column 2 in Table 8).



(a) Users



(b) Healthcare Professionals

Fig. 1 Example of simulated scenarios for users (**a**) and healthcare professionals (**b**)

understand, or a foreign language not known to healthcare professionals.

Each alternative also presents different characteristics, namely alternative-specific attributes. These variables and the related values were selected by a multidisciplinary team, composed of academics and healthcare professionals operating in the field of emergency medicine. The attribute levels are therefore derived from a combination of literature and personal experience, being strictly dependent on the context and procedures applied. As a result, we include all the variables that are considered determinants of a satisfying experience for both users and healthcare professionals. Besides testing for the overall value associated with digitalization (e.g., [2, 36]), we explore the impact of time spent in triage activities, the guaranteed level of privacy for users (e.g., [37–40]), and the efficiency and efficacy of communication (e.g., [41–43]).

Table 2 Scenario- and alternative- features proposed in the two distinct surveys

Respondents	Scenario Characteristics	Alternative Attributes
Users	- Time of the day	- Type (traditional, hybrid, fully digital)
	- ED crowded level	- Time
	- Main reason of access to ED	- Healthcare professional spoken language
		- Privacy level
Healthcare Professionals	- Time of the day	Type (traditional, hybrid, fully digital)
	- ED crowded level	- Working time
	- Main reason of access to ED	- Level of completeness of the information digitally inserted by patients
	- Patient spoken language	- Urgency code assignment method

Table 3 Values of the alternative-specific attributes in the scenarios proposed to users

Type	Time (minutes)	Healthcare professionals' spoken language	Privacy level
Traditional	8	My mother tongue	Other patients can not overhear me
	10	A foreign language I know	Other patients can overhear me
	12	A foreign language I do not know	Other patients overhear me for sure
Hybrid	4	My mother tongue	Other patients can not overhear me
	5	A foreign language I know	Other patients can overhear me
	6	A foreign language I do not know	Other patients overhear me for sure
	7		
	8		
Fully digital	5	The users input information in their native language	Other patients can not overhear me
	6		
	7		
	8		

First, each alternative specifies the type of triage that is performed: *Traditional*, *Hybrid*, or *Fully digital*. Traditional triage represents the current procedures implemented when a patient accesses the ED. It involves the interaction between patients and healthcare professionals that results in the assignment of an urgency code, corresponding to a specific ESI level. On the contrary, in the case of a fully digitalized triage, there is no interaction between patients and healthcare professionals. Patients are directed to use a digital tool—a kiosk—to input all the necessary information. The kiosk is designed to be filled out in the patients' native language. Finally, hybrid triage involves a combination of traditional and fully digital approaches. In this case, the patient first fills out the information using the kiosk in her native language, followed by an additional interview with healthcare professionals.

In addition to the triage type, the alternatives exhibit other distinct attributes. For healthcare professionals, these encompass the working triage time and the level of completeness of patient-inputted information via the kiosk. The level of completeness of patient-entered information is categorized into four distinct levels for healthcare professionals. The 'Incomplete' level contains only demographic characteristics. The 'Not Fully Complete' level adds vital signs to the demographic data. The 'Partially Complete' level encompasses demographics, vital signs, and symptoms. Finally, the 'Complete' level includes the patient's past medical history in addition to the information in the 'Partially Complete' level.

In addition to the working triage time and the level of completeness, a fully digital solution may include an algorithm for assessing patients' severity levels ('Assigned by the digital tool') as an alternative to the evaluations conducted by healthcare professionals ('Assigned by the triage nurse'). It is important to note that, in the case of the assessment performed by healthcare professionals in the digital option, there is no direct interaction between the patient and the healthcare professional. Rather, the nurse assigns the urgency code based solely on the information inputted by the patient. This information is always available to healthcare professionals in their native language (in both hybrid and fully digital alternatives).

For patients, alternative attributes include the total triage duration, the language spoken by healthcare professionals (in the case of traditional and hybrid triage), and the level of privacy, specifically whether there is a possibility for other patients to overhear the patient's communication with healthcare professionals.[3] For users, in the case of a fully digital solution, there is always an algorithm that identifies the level of patient severity. The values of attributes for users and healthcare professionals are available in Tables 3 and 4, respectively. For each scenario, the survey always proposes a traditional alternative to compare with hybrid and fully digital triage options. The three-alternative combinations are derived by means of a full factorial design, guaranteeing orthogonality and preventing multi-collinearity. To ensure realism, we remove from the set of triplets generated by full factorial

[3] Please note that the language spoken by users and healthcare professionals is considered as a case-specific variable in the survey for healthcare professionals, while it varies with each alternative for users. The spoken language as well as the level of completeness of digitally inputted information are two proxies of communication efficiency and efficacy.

Table 4 Values of the alternative-specific attributes in the scenarios proposed to healthcare professionals

Type	Time (minutes)	Level of completeness	Urgency code assignment method
Traditional	6		Assigned by the triage nurse
	10		
Hybrid	2	Incomplete Partially complete	Assigned by the triage nurse
	3		
	4		
	6		
Fully digital	0	Not fully complete	Assigned by the triage nurse
	2	Complete	Automatically assigned by the digital tool*
	3		
	4		
	6		

*In this case only, the working triage time is equal to zero

design any combinations that present either dominant or completely dominated alternatives.

Choice model

Both the preferences of users and healthcare professionals are analyzed using Alternative Specific Conditional Logit (ASCL) models, which are also known as McFadden's Choice Model [44]. Like other discrete choice models, ASCL assumes that an individual q chooses the alternative $i \in I$ only if the utility generated by alternative i exceeds that of all other alternatives $j \neq i \in I$. Additionally, ASCL models allow to account for two types of independent variables: case-specific and alternative-specific attributes. In our specific context, ASCL proves to be particularly effective. In each of the three distinct scenarios (cases) for each respondent q, we encounter case-specific variables that remain constant across alternatives, such as individual characteristics (e.g., gender and age) and scenarios' attributes (e.g., ED crowded level) as well as alternative-specific variables, such as the triage time, among others. The utility function associated with any alternative $i \in I$ for each individual q in each scenario is the following:

$$U_{qi} = \alpha_i + \beta_i X_{qi} + \gamma Z_q, \tag{1}$$

where α_i is the vector of alternative-specific constants, X_{qi} stands for the triage alternative specific regressors, and Z_q are individual- or case-specific variables. Consistently, the probability that a specific choice $i \in I$ is taken by individual q ($P_q(i)$) is computed as follows:

$$P_q(i) = \frac{\exp(\alpha_i + \beta_i X_{qi} + \gamma Z_q)}{\sum_{i=1}^{I} \exp(\alpha_i + \beta_i X_{qi} + \gamma Z_q)}. \tag{2}$$

In our analysis, α_i is composed by three alternative specific constants, *that is*, whether the triage follows the traditional procedures (*Traditional*), introduces a fully digital solution (*Fully Digital*), or proposes the hybrid option (*Hybrid*).

X_{qi} is constituted by different variables according to the two different types of respondents in our analysis. For users, the alternative specific attributes denoted as X_{qi} encompass factors such as the duration of triage activities (*Triage Time*), the language spoken by healthcare professionals (or offered by the digital tool in the case of a fully digital solution), and the privacy level. For the language spoken by healthcare professionals, our model incorporates a dummy variable (*Language Not Known*), equal to 1 if healthcare professionals speak a foreign language that the user does not understand, and 0 otherwise. For the privacy level, the model includes the dummy variable *High Privacy*, which has a value of 1 when the privacy level corresponds to "Other patients can not overhear me", and 0 otherwise. In contrast, for healthcare professionals, the only alternative-specific attribute included in X_{qi} is the healthcare professionals' working time during the triage (*Triage Time*).

Similarly, Z_q presents distinct features in relation to case-specific variables. For both users and healthcare professionals, Z_q comprises gender (a dummy variable, *Male*, assigned a value of 1 if the respondent identifies as male, and 0 otherwise), age (*Age*), the level of ED congestion, measured in minutes and accounting for the average patient waiting time (*ED congestion*), a dummy variable indicating a high proficency in English (*English Fluent*, equal to 1 if the respondent declares having a high level of English proficiency), and a dummy variable reflecting the respondent's general willingness not to use digital tools in healthcare contexts (*Digital Aversion*), measured as described in the Survey respondent profiling section. Furthermore, in the analysis of users' preferences, we incorporate a variable accounting for their educational level (*Education*, equal to 1 if the subject holds a degree or a higher level of education, and 0 otherwise). For a better understanding of healthcare professionals' preferences, we include *Language Not Known*, a dummy variable equal to 1 if the patient speaks a foreign language the healthcare professional does not understand, and 0 otherwise.

Results

Analysis of respondents' preferences

Table 5 shows the proportion of times that *Traditional*, *Hybrid*, and *Fully Digital* solutions are chosen as preferred for both users and healthcare professionals, in the case in which the scenario offers one alternative per triage type (i.e., 1143 scenarios over 1275 and 129 scenarios over 178 for users and healthcare professionals,

Table 5 Preferences by triage type for users (1143 scenarios) and healthcare professionals (129 scenarios)

Users' Preferences				
		Second Preferred Alternative		
First Preferred Alternative		Traditional	Hybrid	Fully Digital
Traditional	21.6%	-	49.4%	50.6%
Hybrid	**57.9%**	59.1%	-	40.9%
Fully Digital	20.5%	67.1%	32.9%	-
Healthcare Professionals' Preferences				
		Second Preferred Alternative		
First Preferred Alternative		Traditional	Hybrid	Fully Digital
Traditional	32.6%	-	61.9%	38.1%
Hybrid	**47.3%**	66.7%	-	33.3%
Fully Digital	20.2%	45.2%	54.8%	-

respectively). Overall, the hybrid solution results in being the most preferred for both users and healthcare professionals. More than half of users (57.9%) choose *Hybrid* as the first option, followed by the traditional (21.6%) and the fully digital (20.5%) alternative. The proportion of healthcare professionals choosing the hybrid alternative is close to 50% (47.3%), followed by the tradional (36.2%) and fully digital (20.2%) options. Interestingly, for the second preferred alternative, users and healthcare professionals behave differently. Users that chose *Traditional* (*Fully Digital*) as the most preferred alternative tend to opt for the fully digital (traditional) option as the second choice. Contrarily, the hybrid option is the second most preferred for healthcare professionals who chose both *Traditional* and *Fully Digital* as the first option.

These primary results suggest a promising propensity toward digitalized solutions, especially when considering the hybrid option. With respect to other alternatives, this solution encompasses the advantages of traditional procedures, such as the interaction with healthcare professionals guaranteeing a more appropriate evaluation of patients' healthcare status, while proposing a digital tool that may facilitate communication, especially in the case of a foreign language spoken by the patient (or healthcare staff). Indeed, the trade-off that exists between the traditional and the fully digital option mainly relates to three key factors, namely time, language, and trust in digital tools. From the patient's perspective, the fully digital solution has the advantage of allowing them to communicate in their native language. However, they lack the possibility of being visited by a triage nurse, therefore a high trust in the digital algorithm assigning the ESI level is needed. From the perspective of the healthcare professional, a fully digital solution greatly reduces the time needed for triage activities and allows patient-to-healthcare professional communication in the professional's native language. However, also in their case, it is needed trust in *i*) the ability to fill out the correct information by users, *ii*) the completeness of the information needed for an evaluation, and, eventually, *iii*) in the automated assignation of the urgency code as well.

Table 6 Differences in users and healthcare professionals' individual- and scenario-specific variables by type of choice

Users				
		Chosen alternative (No. of cases)		
Variable		Traditional (247)	Hybrid (662)	Fully Digital (234)
Individual-Specific Variable				
Age	Mean (sd)	29.94 (11.86)	28.52 (10.26)	28.24 (10.64)
Male	No (%)	63 (25.51%)	189 (28.55%)	86 (36.75%)
Digital Aversion	No (%)	37 (14.98%)	54 (8.16%)	15 (6.41%)
Educated	No (%)	113 (45.75%)	3770 (55.89%)	124 (52.99%)
English Fluent	No (%)	183 (74.09%)	545 (82.33%)	199 (85.04%)
Scenario-Specific Variable				
ED Congestion	Mean (sd)	34.74 (16.49)	37.68 (16.31)	38.08 (17.08)
Healthcare Professionals				
		Traditional (42)	Hybrid (61)	Fully Digital (26)
Individual-Specific Variable				
Age	Mean (sd)	44.55 (12.07)	40.41 (12.04)	37.46 (10.40)
Male	No (%)	10 (23.81%)	18 (29.51%)	5 (19.23%)
Digital Aversion	No (%)	0 (0%)	2 (3.28%)	1 (3.85%)
English Fluent	No (%)	12 (28.57%)	32 (52.46%)	9 (34.62%)
Scenario-Specific Variable				
ED Congestion	Mean (sd)	40.00 (17.32)	36.64 (16.55)	37.50 (14.23)
Language Not Known	No (%)	13 (30.95%)	19 (31.15%)	10 (38.46%)

To conduct a more comprehensive investigation of alternative-specific characteristics as well as individual-specific characteristics driving particular choices, we provide additional descriptive statistical analyses. First, we examine how individual- and scenario-specific attributes somehow impact users' and healthcare professionals' first-preferred alternatives (Table 6). By focusing on users, there are no significant disparities in average age among respondents who opt for the three available alternatives. However, a slightly higher proportion of males exhibit a preference for fully digital solutions in contrast to the other alternatives. The proportion of individuals recognized as digital averse is lower when the fully digital alternative is the most favored option. Furthermore, individuals possessing a degree or higher level of education and declaring fluency in English are more prevalent among those who select digitalized (either hybrid or fully digital) alternatives. Lastly, the level of ED congestion does not appear to have a substantial influence on

the chosen alternative, with slightly higher waiting times observed when a fully digital solution is the preferred choice.

Moving to healthcare professionals, the average age of those opting for fully digital (or hybrid) solutions is notably lower, by 7 (3) years, compared to individuals favoring the traditional alternative. Likewise, a slightly higher proportion of males express a preference for the hybrid solution. Consistently with users' outcomes, the proportion of digitally averse individuals and those proficient in English is higher among those who favor digitalized options as opposed to the traditional alternative. Contrarily to users, ED congestion levels are, on average, higher in the cases leading individuals to prefer traditional procedures, although these differences do not reach great differences. Lastly, the fully digital solution appears to be more frequently selected when patients speak a language that is not known by healthcare professionals.

A second set of descriptive statistics, focusing on alternative-specific variables, is shown in Table 7. The table provides insights into the frequency of alternative-specific features that varies within triage type. Columns 1, 2, and 3 display descriptive statistics when the triage choice type corresponds to *Hybrid* for users, *Hybrid* for healthcare professionals, and *Fully Digital* for healthcare professionals, respectively.[4] Overall, when the hybrid solution is selected, in around 35% of the cases the privacy level is categorized as "Other patients can not overhear me" (i.e., *Higher Privacy* equal to 1). Coherently, the hybrid option is less favored when the healthcare professional interviewing the patient, after a first digital imputation of healthcare information by the patient, does not speak a known language (*Language Not Known* equal to 1). Shifting our focus to healthcare professionals, the completeness of digitally inputted information appears not to have a clear influence on healthcare professionals' choices. The hybrid alternative is more favored when the level of information digitally inputted by patients is 'Partially Complete,' as opposed to 'Incomplete.' Conversely, the fully digital option is more frequently selected when the level of completeness is categorized as 'Complete,' in contrast to 'Fully complete.' Furthermore, in the presence of an automated algorithm (*Algorithm* equal to 1) responsible for assigning urgency codes corresponding to the ESI level, thereby substituting the role of the triage nurse, the fully digital solution is less preferred. Specifically, in only 15.38% of the cases where the fully digital option is preferred, an automated algorithm for urgency code assignment is present.

Table 7 Frequency of alternative-specific attributes by the most preferred triage type for users (1) and healthcare professionals (2 and 3)

		(1)	(2)	(3)
Alternative-Specific Variable		**Users - Hybrid**	**Healthcare Professionals - Hybrid**	**Healthcare Professionals - Fully Digital**
High Privacy	No (%)	267 (34.77%)		
Language Not Known	No (%)	166 (21.61%)		
Incomplete	No (%)		38 (46.34%)	
Fully Complete	No (%)			4 (10.26%)
Algorithm	No (%)			6 (15.38%)

[4] Please note that in this case, we rely on the most preferred choice in the full sample of data, encompassing the scenarios where multiple alternatives of the same type are available (e.g., two hybrid solutions with distinct alternative-specific features, compared to traditional procedures).

These preliminary findings highlight the key factors influencing both users and healthcare professionals, although a more comprehensive analysis, encompassing the joint assessment of case-specific and alternative-specific variables, is provided in the Alternative Specific Conditional Logit Findings section.

Alternative Specific Conditional Logit Findings

The results of the ASCL model for both users and healthcare professionals are available in Table 8. While the previous section aims at addressing the influence of specific attributes on preference choices, the ASCL model offers an inclusive approach by simultaneously considering all factors that may affect responses, allowing for a more comprehensive understanding of the phenomenon. In the ASCL model, we utilize the *Traditional* alternative as the baseline, investigating how case-specific variables influence the preference toward digitalized solutions.

The analysis provides different outcomes for users and healthcare professionals. The results of the discrete choice model applied to users' stated preferences are available in Column 1 of Table 8. Overall, users exhibit a preference for alternatives characterized by shorter triage times and situations where the healthcare professional speaks a known language. Specifically, an additional minute of triage time leads to a 16.13% reduction in the probability of selecting the alternative. When the language of the healthcare professional is unfamiliar, there is a 36.5% reduction in the likelihood of choosing that alternative. Interestingly, privacy does not appear to significantly impact users' decision-making, corroborating our findings in the descriptive statistics presented in the Analysis of respondents' preferences section. Although auditory privacy is recognized to be important for patients in the ED, influencing their satisfaction [37, 38, 40], our findings are in line with the theory that there is a lack of privacy concerns when healthcare concerns prevail (e.g., [39]), such as in the case of an emergency situation. Despite a large majority of respondents favors the hybrid solution as their top choice, the associated alternative-specific

Table 8 Results of the ASCL model for users (1) and healthcare professionals (2)

	(1)	(2)
	Users	**Healthcare Professionals[a]**
Alternative Specific Variables		
Triage Time	**-0.1759*****	0.0439
	(0.0381)	(0.0438)
Language Not Known	**-0.4538****	
	(0.1893)	
High Privacy	0.0042	
	(0.1686)	
ASC_Fully Digital	**-1.5230*****	1.2027
	(0.5089)	(0.8686)
ASC_Hybrid	-0.3907	**1.5822***
	(0.4424)	(0.8341)
Case Specific Variables - Hybrid		
ED Congestion	**0.0092****	**-0.0181***
	(0.0047)	(0.0099)
Age	-0.0026	-0.0120
	(0.0076)	(0.0144)
Male	0.1450	-0.0334
	(0.1753)	(0.3862)
Digital Aversion	**-0.5703****	-0.1694
	(0.2366)	(0.8588)
Educated	**0.2867***	
	(0.1623)	
English Fluent	**0.3613***	**0.6108***
	(0.2154)	(0.3627)
Language Not Known		0.1364
		(0.3366)
Case Specific Variables - Fully Digital		
ED Congestion	**0.0105***	-0.0081
	(0.0057)	(0.0101)
Age	-0.0013	**-0.0257***
	(0.0097)	(0.0156)
Male	**0.5219****	0.4413
	(0.2048)	(0.3993)
Digital Aversion	**-0.8484*****	-0.4931
	(0.3282)	(1.1870)
Educated	0.1331	
	(0.1965)	
English Fluent	**0.6209****	-0.5378
	(0.2790)	(0.3912)
Language Not Known		**0.6264***
		(0.3522)
Observations	3,429	713
No. Cases	1143	292
Log likelihood (LL)	-1074.37	-234.54
Akaike Information Criterion (AIC)	2182.76	503.08
Bayesian Information Criterion (BIC)	2268.46	565.59

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

[a]Given the limited number of observations for healthcare professionals, our analysis considers more than one choice per each scenario (see Footnote 1). We include a fixed effect in the model to control for the differences in the first and second most preferred alternative

constant does not result in being significant for users. Conversely, the fully digital constant (*ASC Fully Digital*) indicates a 78% decrease in the odds of choosing a fully digital triage option.

The inclusion of case-specific variables allows us to better understand which are the scenario- and individual-specific features influencing respondents' choices. Overall, higher ED congestion increases the likelihood of selecting a digitalized solution as an alternative to traditional procedures. In detail, a 10-minute increment in the ED waiting time leads to a 11.09% and 9.59% increase in the probability of preferring a fully digital or hybrid solution, respectively, compared to the traditional option. Demographic characteristics like gender and age reveal relatively minor distinctions in individuals' preferences, only suggesting that the probability of choosing a fully digital solution is higher for males, whereas there are no relevant differences across age ranges. However, other individual-specific features play an important role. First, in line with previous literature [45], being digitally averse reduces the probability of preferring a digitalized solution of 57.19% and 43.46% for fully digital and hybrid alternatives, respectively. Second, proficiency in English has a positive effect on the inclination toward digital tools. Those with a high level of English fluency display a preference for fully digital and hybrid solutions, with odds ratios of 1.86 and 1.43, respectively. Lastly, people with a higher level of education (*Educated*) prefer the hybrid option over traditional procedures (odds ratio equal to 1.33).

We present the results of the ASCL model applied to healthcare professionals' stated preferences in Column 2 of Table 8. As alternative-specific variables, we consider the triage working time and the two constant-specific variables. Notably, the influence of time does not appear to affect healthcare professionals' choices, who have, however, a significant preference toward hybrid solutions (odds ratio equal to 4.86). As for case-specific variables, there are some interesting distinctions compared to users. First, ED congestion reduces the probability of

choosing a hybrid solution over a traditional one. In this case, a 10-minute increase in waiting time results in a 16.55% decrease in the probability of selecting the hybrid option. Fluency in English plays a role only in the likelihood of choosing a hybrid solution (odds ratio equal to 1.84). On the contrary, the influences of some variables are consistent with the choices of users: if the patient speaks a language that healthcare professionals do not know, the likelihood of choosing the fully digital solution increases by 87.08%. Finally, younger healthcare professionals tend to lean more toward digital solutions with respect to traditional procedures.

In summary, these findings confirm a propensity for both users and healthcare professionals to embrace digital tools in an urgent situation, such as access to the ED, but under specific conditions. Users place great importance on the time spent in triage activities and overcoming language barriers, while privacy appears to be of lesser concern. Additionally, they exhibit a stronger preference for direct interaction with healthcare professionals, as suggested by the negative coefficient of *ASC Fully Digital*. On the contrary, healthcare professionals value the hybrid solution, recognizing its advantages in allowing patients to communicate their demographic and healthcare information autonomously and digitally, while also reducing the workload of triage nurses.

Congestion does play a role for both kinds of respondents. Users' preference for digitalized solutions during high congestion may be related to the perception that fewer personnel are available in the short term, being occupied with earlier arrivals. Conversely, healthcare professionals opt for direct patient interaction in congested scenarios. Although this may seem counterintuitive, it can be explained in light of the willingness to possibly prevent opportunistic behavior by patients who attempt to escalate the severity of their health status while digitally entering information into the tool, in order to gain priority. As for other digitalized procedures [1], this would result in additional work for healthcare professionals, who must review patient reports and conduct longer interviews to assess the health status of patients.

The presence of communication barriers between healthcare professionals and patients significantly influences their choices. Users prefer interactions with healthcare professionals who speak their language or a language that they can understand. Moreover, if the patient does not speak a known language, it is preferable to utilize the fully digital solution, which can automatically translate all information into the healthcare professionals' native language. The importance of appropriate communication in this context aligns with the existing literature [41, 42], and our results further corroborate the belief that quick and effective communication is perceived as crucial, ensuring a high-quality ED service.

Although the model jointly tests alternative- and case-specific variables, we conduct an additional analysis to specifically examine the characteristics that lead users and healthcare professionals to choose hybrid or fully digital solutions. This additional analysis is driven by the fact that certain features, such as the level of privacy for users and the level of completeness, as well as the presence of an algorithm that automatically assigns urgency codes for healthcare professionals, are specific to particular type of triage and vary only within those types.

Accordingly, we perform three separate logistic regression analyses, dividing the samples based on triage type, with the dependent variable still being the choice made by individuals. This approach allows us to discern the characteristics within each triage type that increase the probability of being selected. The results of this analysis are shown in Table 9. Consistently with our earlier findings illustrated in Table 8, privacy has no impact on choices. Furthermore, for users, a shorter triage time and the presence of healthcare professionals who speak a known language increase the probability of choosing a hybrid solution. This implies that, regardless of the other options, users prefer hybrid solutions that provide faster triage times and interactions with healthcare

Table 9 Results from the logit model dividing the sample by triage type for users (1) and healthcare professionals (2 and 3)

	(1)	(2)	(3)
	Users - Hybrid	**Healthcare Professionals - Hybrid**	**Healthcare Professionals - Fully Digital**
Triage Time	**-0.1563*** **	**-0.2621***	**-0.3990****
	(0.0413)	(0.1409)	(0.1581)
Language Not Known	**-0.8744*** **		
	(0.1384)		
High Privacy	0.1090		
	(0.1293)		
Algorithm			**-1.9315****
			(0.8173)
Fully Complete			0.0050
			(0.6276)
Incomplete		-0.3637	
		(0.3052)	
Constant	1.2207***	0.6546	0.5878
	(0.2326)	(0.5088)	(0.6766)
Observations	1,407	195	161
Log likelihood (LL)	-940.16	-130.65	-85.60
Akaike Information Criterion (AIC)	1888.31	267.29	179.20
Bayesian Information Criterion (BIC)	1909.30	277.11	191.52

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

professionals who speak their language (whether it's their native language or a foreign one they can understand).

As for healthcare professionals, the level of completeness does not significantly affect the choice within both the fully digital and hybrid option samples. Interestingly, time is considered an important variable for healthcare professionals, in the case of both hybrid (odds ratio equal to 0.77) and fully digital options (odds ratio equal to 0.67). This finding confirms that despite the general preference for hybrid solutions as indicated in Table 8, reducing working time remains a valuable feature for healthcare professionals. Lastly, the presence of an automated algorithm significantly reduces the odds of choice by 85.51%, corroborating the preliminary analysis results. This outcome sheds light on the issue of substitution between healthcare professionals and digital solutions, in which digitalization can be perceived as a threat, as it leads to a reconfiguration of tasks [2] and often to greater job uncertainty, reducing work satisfaction [36].

Discussion

Our results offer valuable insights into the potential application of digital tools in EDs, highlighting the conditions driving their adoption and the key influencing factors. Our findings can support hospital managers and policy makers in developing digital tools that accommodate both users and healthcare professionals. Specifically, from a managerial perspective, several advantages can be derived from the introduction of a digital tool that respects the preferences of patients and healthcare professionals. First, there is greater patient empowerment, as patients take an active role in managing their health, directly communicating what is crucial for them. Second, the adoption of digital tools can streamline the triage process, reducing the workload for healthcare professionals and, combined with a reduction in language barriers, potentially improving the overall efficiency of emergency departments. This efficiency can be further enhanced by the fact that digital tools can automatically collect some data, allowing healthcare professionals to focus on more critical tasks, thus reducing overcrowding and improving the quality of services. These combined effects can further lead to potential cost savings.

Our results are also interesting for the academic community, providing valuable insights and opening avenues for future research. This study contributes to the literature on digitalization in healthcare by analyzing how different levels of digitized solutions can be a valid alternative to current procedures, highlighting the importance of various factors that affect choices. Future research can build on our findings and potentially address the main limitations of this study. First, considering the limited age heterogeneity within our sample, it would be beneficial to expand the sample, capturing the preferences of middle-aged and older individuals. Indeed, while Millennials and Zoomers are expected to comprise the majority of patients in the medium to long term, it is also interesting to investigate the readiness of older generations for such kinds of innovation. At the same time, examining preferences within various healthcare policy contexts would allow exploring potential differences attributed to different geographical settings and funding mechanisms. Second, additional features of the digital tool may be included in the simulated scenarios in order to provide further insight into the design of effective digitalized solutions. These may comprise, for example, a mobile application that allows self-triage before accessing the emergency department. Finally, a put-in practice of the hypothetical digital solutions proposed in the survey could help validate the results and test the revealed preferences compared to the stated ones, thereby estimating the benefits of using digitalized solutions in ED procedures.

Conclusion

This study explores the potential of employing digitalization in emergency departments. While the unique characteristics of EDs present challenges for the introduction of digitalization, our research demonstrates that both users and healthcare professionals are open to using digital tools in these environments, subject to specific conditions. By relying on a stated preference approach, we investigate the perspectives of users (i.e., potential patients) and healthcare professionals, shedding light on the features that drive their preference toward digitalization.

In general, the hybrid solution, where patients use a digital tool followed by an interaction with healthcare professionals, emerges as the favored choice (preferred in 58% of cases by users and 47% by healthcare professionals). Truly, this solution combines the advantages of both alternatives: patients can input their information in their native language, while healthcare professionals provide a reliable interaction. Healthcare professionals also benefit from reading a digital report in a familiar language, saving time. Although the fully digital solution is preferred in some cases (20% of instances for both users and healthcare professionals), the presence of an algorithm that automatically assigns patient urgency codes decreases healthcare professionals' preferences toward a digital tool. In fact, this would imply the need for a reevaluation of the roles and tasks of healthcare professionals, which is often perceived as a threat [2, 36]. Corroborating previous literature [41, 42], our results also reveal that effective communication in a known language is crucial in the ED context for both healthcare professionals and users. Healthcare professionals prefer digitalized solutions to facilitate communication when patients do not speak a

language they understand, while users prefer direct interactions with healthcare professionals when they speak a known language. The relevance of a prompt intervention is evident from the patients' preferences for shorter triage durations, while privacy does not appear to be a concern in emergency situations.

Abbreviations

AIC	Akaike information criterion
ASCL	Alternative specific conditional logit
BIC	Bayesian information criterion
ED	Emergency department
ESI	Emergency severity index
LL	Log likelihood
sd	Standard deviation

Supplementary Information

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Supplementary Material 1.

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Authors' contributions

Chiara Morlotti: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing - Original Draft, Writing - review & editing; Mattia Cattaneo: Conceptualization, Methodology, Writing - Original Draft; Stefano Paleari: Project administration, Supervision; Filippo Manelli: Conceptualization, Supervision, Resources; Francesco Locati: Supervision, Resources.

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Data availability

The datasets used and/or analyzed during the current study are for the exclusive use of the authors, as approved by the Committee for the Integrity and Ethics of Research. For any information regarding the data, you can contact the corresponding author.

Declarations

Ethics approval and consent to participate

Ethics approval has been obtained from the Committee for the Integrity and Ethics of Research of the University of Bergamo. Informed consent for personal or clinical details was obtained from all individual participants included in the study. The study is fully anonymous, and no identifying images were collected.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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