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Exploratory Research for the Identification of a Decision-Making Model for the Adoption and Implementation of Emerging Technology in Healthcare Operations

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ABSTRACT

OBJECTIVES

The most promising medical innovations appear to take a long time to be used in healthcare practice. This research has two main objectives: to understand the factors that limit or promote the adoption of Emerging Technologies (ET) in healthcare and to provide a model for understanding, codifying and improving the current situation.

METHODOLOGY

A case study is used to shed light on the process of adopting ET in healthcare between a teaching hospital (adopter) and a manufacturer of innovation (producer). The primary data, investigated through thematic analysis and literary evidence, consists of nine semi-structured interviews from ET experts on the side of the adopter and the producer.

The Attitude, Decision, and Implementation (ADI) decision-making model is used as the theoretical lens for this study. This framework is a modification of the process described in the theory of Diffusion of Innovation (DoI) (Rogers, 2003) adapted to the peculiarities of the healthcare environment.

RESULTS

From the analysis of the interviews, it is clear that innovation in medicine has several limitations (financial resources, free time of healthcare professionals, correct identification and know-how of the professionals involved, communication, healthcare resistance) against few facilitators (Innovation Champions, appropriate marketing, medical conferences). This study also highlights the absence of a shared and codified model for the adoption of innovation in medicine.

DISCUSSION

The impediments and the facilitating factors that emerged in the analysis of the primary data have been confirmed in literature. Furthermore, the primary data analysis with literary evidence supports the ADI model as a possible decision-making process for the adoption of ET in healthcare. Its three cyclical phases: the creation of an attitude (A) towards the ET, the decision to continue the collaboration between the parties (D), and the implementation of innovation (I) are sustained by primary data and literary evidence.

CONCLUSIONS

The ADI model could improve the efficiency and pace of adoption of ET in healthcare by limiting barriers, exploiting facilitating factors and building a beneficial relationship between users and producers of ET.

Keywords: Innovation; Healthcare; Emerging Technology; Medical; Healthcare Management; Healthcare Economics; HTA; Healthcare Development; Decision Making Model.

INTRODUCTION

Emerging Technology (ET) is created and implemented in accordance with medical scientific evidence [1]. Therefore, if an ET is proven to bring benefits to patients, organisations or healthcare professionals, it should be rapidly put into practice. In reality, it appears that, even though an innovation is successful and available on the market, it takes a long time to be adopted and used in a healthcare environment [2][3].

This article has two main objectives: the first is to shed light on the factors that slow down or promote the adoption of ET in healthcare. The second is the creation of a decision-making model, based on literary evidence and the elaboration of primary data, which can understand and follow the process of adopting innovation in the medical sector.

The theory of Diffusion of Innovation (DoI) [4] adapted to the many peculiarities present in healthcare (e.g., numerous stakeholders with conflicting agendas [5], patient safety issues [6] autonomy of healthcare professionals [7]) is the theoretical lens used in this study.

From the analysis of primary data, and supported by literary evidence, the research suggests a modification of the DoI decision-making model with a cyclical framework based on three phases: forming an attitude towards the ET (A), deciding to adopt the ET (D) and implementing innovation (I). This model is modified to exploit the facilitating factors for the adoption of ET in medicine, limiting the barriers of the process and is written in a jargon that can be understood by both producers and users of innovation.

Having a standardised framework that accurately describes the process of adopting ET in healthcare could be beneficial to those who produce and adopt ET as it could improve the efficiency of the process and the pace of adoption.

INNOVATION IN HEALTHCARE – STATE OF THE ART

Definition of ET

It appears difficult to find in literature a widely accepted definition of ET in medicine [8]. In this research, the explanation of what an innovation is in healthcare is created by combining the concepts of different authors and adopting them to the healthcare context.

ET in healthcare can be defined as a radical, novelty science-based innovation [8] capable of addressing one or more commonly shared problems in the medical sector. This technology must be verified as safe and certified for clinical use. It has also the potential to exert a considerable future impact [10] in improving human health [6] and / or increasing the efficiency and quality of patient care [11].

Adoption of innovation in healthcare

Rogers' Diffusion of Innovation theory (DoI) [4] is the theoretical model used in this study as a starting point to understand the adoption of ET in healthcare.

Rogers' model [4] provides a clear indication of the decision-making process that a technology must go through to be adopted within organisations. This framework, based on five phases, is integrated and modified with literary evidence to be contextualised in the healthcare environment.

Phases 1 and 2: Acquisition of knowledge and persuasion

According to Rogers [4], the first stage occurs when parties collect information on ET. During this phase, the manufacturer aims to market their products and the user tries to assess the real impact of the innovation in their context. Once this phase is completed, an opinion is formed towards the technology (Phase 2 of Rogers DoI [4]).

Modern medicine is based on scientific evidence (Evidence-based Medicine, EBM) and, therefore, a technology in healthcare should also be based on EBM [1][11][13]. However, the literature suggests that healthcare professionals have ample autonomy [7] and often disagree on what is the best solution for treatment or diagnosis [14]. This debate is also reflected in the choice and adoption of which innovation should enter their healthcare practice.

As it is difficult for healthcare professionals to understand which technology is best (DoI Phase 1 [4]), it is also challenging for them to take a considerable attitude towards a particular ET (DoI Phase 2 [4]).

In medicine, the acquisition of knowledge and consequently the formation of an opinion towards an ET is still based on the judgment of health professionals and therefore, the process is not objective but marked with a subjective component [15].

Phase 3: Decision

Six factors appear predominant in influencing the decision to adopt an ET in healthcare.

I. The technology is more likely to be adopted if the decision-maker on the acquisition is influenced by respected colleagues (peers) who have a positive attitude about that specific ET [13][14][18].

II. The relative advantage, defined as an individual's perception of the benefit deriving from the use of the ET [3][35][15], is hardly understood in the same way by all parties involved in the decision-making process. This is due to the different specialisations possessed by the vast number of professionals called to decide on an innovation in medicine (e.g., economists, healthcare professionals, lawyers, etc.) [2,20].

III. Adoption is facilitated by honest, collaborative and two-way communication between parties [16][3].

IV. The ET producer or supplier aims to influence the adoption of innovation through a very different set of techniques. The main ones are:

   a. Influencing the perception of relative advantage through marketing [19].

   b. Having their own innovation champions [22].

   c. Give the buyer the opportunity to use the technology (provability [4]).

V. Innovation Champions are individuals who appear to be effective in accelerating the process of adopting an ET [3][16]. In the healthcare sector, Innovation Champions are likely to have an appropriate status within the organisation [23].

VI. Every healthcare professional, as well as every individual, has his or her own personal propensity to adopt new technologies [3,7]. According to Rogers, only 16% of the adopting population, defined as innovators and early adopters, are willing to take the inherent risks of using innovation. Between these two categories and the third, defined as the early majority, there is a significant change of mentality called the "*chasm*" [24][26]. This is because the initial majority prefers to analyse the possible benefits in more detail than the other two categories, taking a longer time to decide on which ET to adopt. This conservative approach can undermine an innovation by not allowing it to "*cross the chasm*" and reach the masses. If an ET manages to reach the third group, representing 36% of the adopting population, it will easily reach the fourth (late majority) and fifth (laggards). This principle appears to be valid also in the medical field [15][20][27].

Phase 4: Implementation

Once the decision to adopt a specific ET is taken, resources are allocated and the implementation phase begins [3]. As innovation in medicine can threaten human health, its development is highly regulated and closely monitored [6].

Adapting an ET to a specific healthcare setting may take a significant amount of time and therefore this phase can be exceptionally long [3].

Literary evidence suggests that the adoption rate depends on norms, roles, professional networking and communication [4]. In healthcare, these factors are even more accentuated by the vast number of stakeholders (e.g., governments, patients, producers, healthcare institutions and professionals).

Although all stakeholders view ET positively, each of them has different interests, priorities, objectives and agendas preventing innovation from being implemented in a timely manner [2].

Step 5: Confirmation

Rogers' last stage is confirmation. This phase is not always present, lasts an indefinite amount of time [3] and has only two possible consequences: the innovation is confirmed and therefore kept or replaced.

Rogers mainly considers this phase from an individual's point of view. Other studies suggest that this decision-making process when applied to organisations follows other dynamics: once the decision to adopt an ET has been taken, the confirmation phase is incorporated into the implementation phase [28][29].

In light of the evidence, this step would not provide any additional value to the decision-making model when applied in organisations. In fact, if an ET is accepted during the decision phase, it continues in its implementation. If an ET is rejected, the process ends.

Attitude Decision and Implementation Model (ADI)

Integrating Rogers' model with literary evidence, the acquisition of knowledge and the formation of an attitude towards an ET (stages 1 and 2 of Rogers' DoI) appear so closely related that they can be simplified into a single phase. Through a collection of information, both the producer and the adopter of ET establish a position towards an innovation and this attitude (A) is the central concept of this stage.

The decision phase (D) (stage 3 of DoI) finds its limits in healthcare, because the decision to adopt an ET is not taken by a single individual in a single moment but goes through a series of confirmation (or negation) from various professionals over a long period of time.

This process is influenced by the professionals' attitude towards technology (A) and continues during the next stage. This incessant interaction collides with the linearity of DoI, and the literacy evidence suggests that the second stage decision (D) overlaps with the previous and following stages.

The third stage Implementation (I), corresponding at stage 4 and 5 of DoI, involves all the actions and decisions (the overlap from the previous stage) involved with the installation, training, usage and follow-up of the ET.

It is also likely that new information is generated during the implementation of ET. This new knowledge for both the adopter and producer influences each of their attitudes towards the innovation resulting in a restarting of stage A. This principle would suggest a cyclic shape of the model with overlaps among all the three phases [30][31].

The resulting framework, ADI, could more accurately describe the decision-making process related to the adoption of ET in medicine and is illustrated in Figure 3.

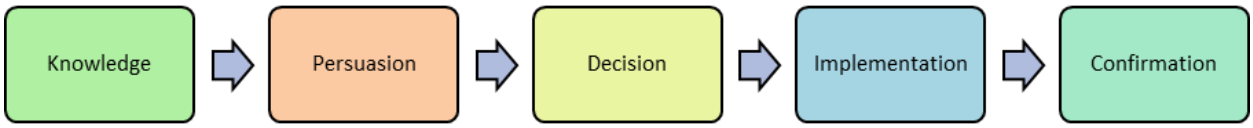

Figure 1 – Rogers' decision-making process of adopting innovation (2003)

Figure 2 – Cyclical adoption and implementation model for complex and evolving technologies (Adapted from Roger, 1995, Ferlie et al., 2005 and Van de Ven et al., 1999)

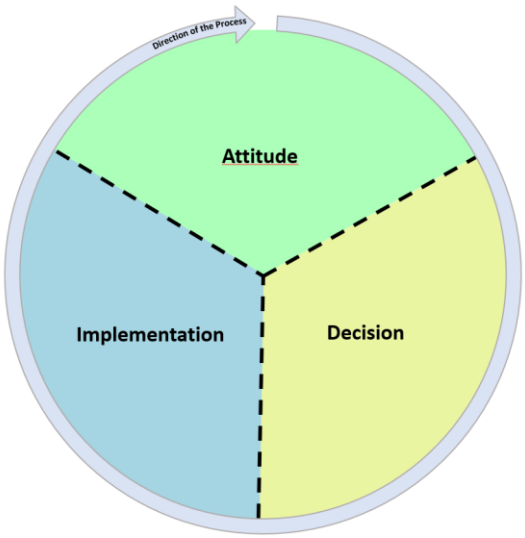

Figure 3 – Attitude, Decision and Implementation (ADI) Model based on Rogers' DoI and integrated with literacy evidence and contextualised to healthcare. Dashed lines suggested the absence of precise moment of transition among phases.

METHODS

The objectives of the study are to understand the main limitations and facilitations for the adoption of ET in healthcare and the creation of a decision-making model that describes this process.

A case study is the research methodology chosen to shed light on the objectives. Through the use of this method, it is possible to have an accurate understanding of the context and related processes [32] from the point of view of the professionals involved in adopting ET (adopter) and producing innovation (producers).

Study sampling is a non-probabilistic purposive approach because respondents are particularly informative: each professional has a particular area of expertise in adopting ET in healthcare [33].

Area	Method	Explanation
Research Philosophy	Interpretive	This sheds light on the adoption of ET in healthcare from the point of view of the interviewees.
Research Approach	Inductive	The creation of new theories or modification of existing ones is achieved through the analysis of primary and secondary data.
Research Strategy	Single Case Study	A case study allows a rich understanding of a specific context. The relationship between a teaching hospital and an ET producer is studied to understand the adoption of ET in healthcare.
Research Choices	Thematic Analysis	Semi-structured interviews are the only primary data. They are analysed for the identification of themes. The themes are integrated with evidence for the delineation of a model.
Time Horizons	Cross-Sectional	From May 2020 to October 2020. This solution provides a "picture" of the actual process, which can be used for future comparisons.
Data Collection Methods	Semi-structured interviews	The interviews were conducted in person or remotely. They have been recorded and transcribed.
Sampling Technique	Non-probability Purposive Approach	Nine professionals with experience in the adoption of ET in healthcare. Six belongs to the adopter and three to the producer.

Table 1 - Summary of the methodology (36).

A thematic analysis is used for the elaboration of primary data. This technique allows the identification, analysis and correlation of meanings (themes) within the data [34]. Interviews are the source of primary qualitative data and the information obtained through this process is analysed to find meanings beyond the explicit words (34). These meanings, defined as themes, are named and linked to the raw data through a coding process [24]. The codified themes, with the support of secondary data and literary evidence, can outline a Model [34].

Nine semi-structured interviews were conducted with innovation management professionals at the Cambridge University Hospital (CUH), as an adopter of innovation, and at GE Healthcare as a producer of ET (refer to Table 5 for a description of the sample). The two entities were chosen for accessibility reasons.

This research was approved through an ethical review process by the Social Sciences & Arts Cross-Schools Research Ethics Committee (C-REC) of the University of Sussex. The ethical review application number is ER/MC771/1.

The interviews lasted between thirty-five minutes to one hour and were performed face-to-face, video call or call, depending on the interviewees' needs or preference. The author kept the interview informal to make the participants free to express their opinion while being guided in touching the objectives of the study and preventing them from going off topic. With this approach, the respondents' true point of view is more likely to emerge [37].

The questionnaire, see Table 3, is structured in twelve main questions (primary), six of which evolved into more detailed queries (secondary questions). The structure of the questionnaire reflects the objectives of this study and is derived from the evidence emerging from the state of the art as summarized in Table 2.

Correlation with literary evidence	Question
Diversity in training and background of the decision-making professionals involved in the adoption of ET in Healthcare.	**1, 3, 2**
Absence of a single definition of ET in the health sector.	**2**
Verify the involvement of professionals during the process.	**3, 4, 10**
Lack of a shared model.	**4, 5, 9, 10, 11**
Limiting factors for the adoption of ET in healthcare.	**5, 6, 7, 8, 10, 11**
Facilitating factors for the adoption of ET in healthcare.	**12**
Lack of clear delineation between phases.	**4, 5, 9, 10, 11**

Table 2 - Correlation of the questions in the questionnaire with the literary evidence.

Primary Question
1. What is your background in healthcare and your current role in the organisation?
2. What type of technology would you consider to be an innovative and potentially useful technology for your role?
3. Have you been involved in adopting new technologies in your past roles?
4. What were the main issues that you had in bringing this technology into your organisation and using it in your day-to-day role?
5. What steps does a new technology need to pass through before being used in medicine?
6. Have you experienced difficulties in training the adopter's staff?
7. Have you found resistance in the usage by the users?
8. Which are the most common issues you encountered after the adoption?
9. Does your company have meetings to follow up on the process of adoption?
10. What about the relationship between adopter and supplier?
11. Does your company have any KPIs in the adoption of new technology?
12. What do you think can be done from the parties to ease the process?

Table 3A – Questionnaire: primary questions

Secondary Question
3a) Is the user of the new technology involved in this phase?
4a) Does your organisation have a particular procedure for implementation and testing? 4b) Did you experience problems in certification, standards, patents, safety in the development?
5a) Do you think this process is clearly defined? 5b) Do you think there are specific moments or meetings that are decisive for the adoption? 5c) Which are the most common issues in the process? 5d) Does your organisation have a particular procedure for the adoption? 5e) Which are the most common or significant barriers for the adoption? 5f) Which are the most common or significant facilitators for the adoption?
10a) Are you involved in this relationship? 10b) Which are the most common issues? 10c) Which are the key figures that are more relevant for the adoption of new technology? 10d) How is the interaction between these professionals? 10e) How is the relationship between producer and adopter once the technology is used daily?
11a) Are they financial or non-financial? 11b) Can you provide some KPI's in this area? 11c) Can you describe how they are generally achieved?
12a) At the development and improvement stage? 12b) At the adoption stage? 12c) At the usage stage? 12d) In the relationship?

Table 3B – Questionnaire: secondary questions

RESULTS

The following table summarizes the main themes that emerged in the analysis of the primary data.

Research Theme	Participant Code									
	1	2	3	4	5	6	7	8	9	Total
Barriers to adoption										
Budget constraints	✓	✓	✓	✓	✓		✓	✓	✓	8
Time constraints	✓	✓	✓	✓	✓		✓	✓	✓	8
Training	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Involvement of appropriate professionals	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Understanding relative advantage	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Communication	✓	✓		✓	✓	✓	✓	✓	✓	9
Clinician's resistance	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Lack of a shared model	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Facilitators to the adoption										
Innovation Champions	✓	✓		✓		✓	✓	✓	✓	7
Appropriate marketing	✓	✓	✓	✓	✓		✓	✓	✓	8
Conferences	✓	✓	✓	✓	✓		✓	✓	✓	8
Process of the adoption of ET in Healthcare										
Lack of standardisation	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Phases overlapping	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Decision	✓	✓	✓	✓			✓	✓	✓	7
Installation			✓	✓		✓		✓	✓	5
Daily usage			✓	✓	✓	✓	✓	✓	✓	7
Follow up	✓	✓	✓			✓	✓	✓	✓	7
Facilitating the process										
Communication	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Time management	✓	✓	✓	✓	✓	✓	✓	✓		8
Engagement with Clinicians	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Knowledge	✓	✓	✓	✓	✓	✓	✓	✓		8
✓ = concept present during the interview			Blank = theme absent during the interview							

Tab. 4 – Summary of the results.

	Participant Code	Job Role	Organisation
1	SMI-A	Senior Manager in Innovation	Adopter (A)
2	SMCE-A	Senior Manager in Clinical Engineering	Adopter (A)
3	COM-A	Clinical Operations Manager	Adopter (A)
4	SCS-A	Senior Clinical Scientists	Adopter (A)
5	FU1-A	Final User 1 (Senior Role)	Adopter (A)
6	FU2-A	Final User 2 (Senior Role)	Adopter (A)
7	SMM-P	Senior Modality Manager	Producer (P)
8	SCAS-P	Senior Clinical Application Specialist	Producer (P)
9	SAM-P	Senior Account Manager	Producer (P)

Table 5 - Description of the Participant Code relating to the professional's role in the organisation to which they belong.

DISCUSSION – Main limitations

In the next part, the factors that limit the adoption of ET in healthcare emerged from the thematic analysis of the primary data will be related to the literary evidence.

Financial resources

All the interviewees suggest that it is quite challenging to justify the allocation of large sums to technology. It appears even more challenging when a technology is complex to understand and the benefits are seen by very few stakeholders. This point is also largely supported in the literature [38,39].

"*Price is a big [barrier] because it might be the best product in the world, but you need to convince who is at the top of the pyramid that [it] is good*" Final User 1 – Adopter.

Healthcare professionals' time constraints

The analysis of primary data and literary evidence [2] confirm that healthcare professionals are busy in daily work activities and have little free time for innovation.

- Clinicians do not have free time to be exposed to new technologies.
- Time constraints are present during the installation resulting in miscommunication and poor tailoring of the ET to the adopter's needs. As a consequence, they have a negative impact on the clinicians' opposition.
- Time limitations affect training, which often means users being not entirely confident with the usage of the ET, resulting in opposition to the usage.

"*At the end of the day [clinicians] wants to go home on time*" Senior Application Specialist – Producer.

Professionals' skills and know-how

The process of adoption is vast and passes through many disciplines involving a considerable number of professionals. These individuals generally have an area of expertise but they have difficulties seeing the bigger picture and understanding all the implications that an ET involves [40].

This specialisation is also present from an educational point of view: there are courses related to parts of the process, but no schools offer a general understanding of the process. Companies, both adopters and producers, have to train professionals involved in this discipline internally, making the training long, complicated and heavily based on direct experience. This lack of standardisation results in long training and the skills and know-how needed are difficult to pass to the next generation of professionals.

"*The expertise is essential: it is essential to have the right skills with the right roles. Unfortunately, we need know-how that is not provided by any school because in this field there are many facets of the same principle*" Modality Manager – Producer.

Identification of the appropriate professionals

Most of the interviewees agree that one of the most common issues is interfacing with the wrong people. It appears that those who have the power to make a decision about a technology (e.g., bureaucrats) do not fully understand the implications of the ET, and as a result, they base their decisions on misleading parameters resulting in wrong assessment or less efficient processes.

In addition, it seems that the day-to-day user of the technology is it not often involved in the decision-making process until the very final moment where he or she is called to use a particular technology, highlighting a top-down decision-making process [41].

"*The question is about who is defined as the user [because], it depends on the job role [...] and understanding the unmet clinical needs*" Senior Manager Clinical Engineering – Adopter.

Understanding the relative advantage

Producers tend to use marketing techniques to increase the perception of the relative advantage of an ET [4][19]. The adopters try to see through the manufacturer's marketing campaigns to understand the real impact of the ET on its organisation.

For the adopter, the ability to assess the ET correctly is costly, in terms of time and energy, and it involves the collaboration of many professionals with specific knowledge. If the producer bases its strategy on advertising instead of scientific evidence, it causes frustration for the adopter with possible deterioration of the relationship.

"*Probably over-exaggeration of capabilities by the vendors who will tell you that it is a revolution*" Senior Clinical Scientist – Adopter.

Communication

Scholars highlight the importance of effective communication [3][16] and all the interviewees agree that honest, open and two-way communication is essential to build a trustworthy relationship which has positive implications throughout the entire process. Unfortunately, it emerges from the primary data that often the communication between adopter and user is not clear because the two organisations "speak different languages" due to a significant difference in background, knowledge and professional agenda.

"*Communication is the big problem. If there is an issue and it is not flagged up, the producer cannot do anything. Also, if there are a lot of problems and you tell them to the supplier and [they don't get back to you], these are also problems*" Senior Final User 2 - Adopter.

Clinician resistance

It is well documented in the literature the resistance that clinicians oppose to the adoption of new technology [7,42] and the interviewees agree on this point. The main reasons for this opposition are:

- Healthcare professionals' time constraints (see previous point).
- Nature of the individuals: it appears that resistance is a natural component of human personality because changes involve a certain degree of effort [2].
- Confidence: the healthcare professionals' confidence in performing a procedure is of major importance. The healthcare professionals would prefer to use an old technique that is mastered instead of a new one because they can predict possible complications [43]. In this regard, the role of training is essential.
- "*When I ask [whether we can] change something [in order] to improve it, often clinicians reply [that] they have been doing this for 35 years [and] how dare I question whether they are competent. [..] If it was bad, they would have changed already*" Senior Manager Clinical Engineering – Adopter.
- Pride: some technologies are developed in competitors' sites, and this increases the clinician resistance.
- "*A secondary reason might be some clinicians are reluctant to adopt practices which have been developed in other [hospitals]*" Senior Manager in Innovation – Adopter
- Lack of Trialability: the absence of the possibility of trying an ET before the acquisition is a factor that creates opposition as highlighted by Rogers [3].
- Availability of human resources: the chronic lack of healthcare professionals in healthcare

inevitably affects the pace of adoption [44].

Lack of a standardised and shared model

From the literature [45,46] and the primary data, it appears that there is no standard model for the adoption of ET in healthcare and every producer has its own one. The same is true on the adopter's side, with the aggravation that a written procedure is not often present and the adoption is mainly based on professional experience.

In addition, when both parties have a formal procedure, it is written in a "language" difficult to understand by the counterpart and mainly internally focused, resulting in misinterpretation and frictions between parties.

"Our company has clear and defined procedures. Issues appear when we deal with the adopters because they have different guidelines. It takes effort to adjust [the producer's] procedures to the adopter's one." Account Manager - Producer

The ADI Model can be used as a shared framework between the adopter and the ET producer as it is written with a shared and understandable terminology. It can be a point of reference for understanding where the parties are in the adoption process and what and who is needed at any given time. This model, therefore, could be used as a basis for building a win-win relationship in the long term.

Furthermore, having a shared framework would break the boundaries in obtaining know-how and skills mainly through personal experience. This would improve the transmission of knowledge through the codification of the steps and the standardisation of the skills and responsibilities of the actors involved in the process.

DISCUSSION – Facilitating factors

In the following part, the facilitating factors highlighted by the thematic analysis of the primary data will be associated with literary evidence.

Innovation Champions

In the healthcare institutions, Innovation Champions are generally healthcare professionals who have a substantial interest in working with cutting-edge innovations and have a personal interest in technology. From the analysis of the interviews, it appears that manufacturers can identify these individuals and expose them to ET.

In doing so, the champions will begin to exert pressure within the health institution. It should be noted that the Innovation Champions must have a genuine interest in innovation and not be sponsored by the manufacturer.

Appropriate marketing

ET manufacturers use generalist marketing when approaching healthcare institutions. From the primary data, it is essential that the manufacturer adapts the products to the needs of those who will use the ET.

From the perspective of the healthcare institution, a feeling of frustration arises when the manufacturer provides solutions that are neither aligned with the mission and vision of the healthcare institution nor directly aimed at improving the problem for which ET is considered.

From the manufacturer's point of view, an adequate segmentation of the offer, the ability to listen to the adopter's needs and consequently tailor the technology to these factors are necessary actions to facilitate its adoption.

Conferences

All the respondents supported the view that conferences and fairs are among the best way to be exposed to ET. Thanks to these events, clinicians are informed about innovation, and once they are back "home" they spread the information to colleagues and contact producers to gain further information. This approach is also supported in the literature as an effective method to spread innovation [47].

ADI MODEL – PROCESS OF ADOPTION OF ET IN HEALTHCARE

The first objective of this study is to understand the limiting and facilitating factors in the process, the second is to create a decision-making model for the adoption of ET in healthcare. The ADI framework, previously contextualised in medicine through literary evidence, is now correlated and verified with primary evidence.

Phases

The following section analyses the primary data through the three phases of the ADI Model.

Phase I - Attitude (A)

The thematic analysis highlights that from the very moment that a healthcare professional is exposed to an ET, they immediately begin to have an opinion about it. This evidence supports the ADI Model which considers the first two phases of Rogers' DoI (4) (the acquisition of knowledge and the formulation of an attitude) as a single stage and not as two separate stages.

"*It can be particularly challenging to identify all of the benefits when something is very new. [Because such ET] has not landed in the clinical environment for very long, the benefits and evidence are based on lab tests and theories, and this can be a bit of an obstacle for assessing an early technology*" Clinical Operations Manager – Adopter.

To facilitate this phase, the ET producer and adopter should clearly identify which needs the innovation should address. The two sides should also involve professionals who will use innovation in their daily activities and understand their needs and motivations.

Also involving the decision-making professionals to express judgment (managers, economists, etc.) about the adoption of an ET in this early stage could speed up the subsequent stages.

The healthcare institution should allocate time for the professionals involved in the adoption process, to let them understand and experience the ET. The manufacturer should adapt the explanation of the possible benefits to the specific needs of health institution. This can be done only by listening to the problems of the professionals involved in the process.

It is essential to avoid pure marketing which advertises and promises "*revolutionary*" solutions because healthcare institutions would receive this approach in a negative way, making it more difficult to build a positive long-term relationship.

Phase II – Decision (D)

This stage is not just a mere signature on a contract but a complex interaction between professionals from both sides. The primary data and the literacy evidence [4][17] suggests that the process of decision starts in the previous stage (Phase I) because the manufacturer aims to influence the decisions of health professionals practically from the initial moment, they are exposed to it.

"*What I do is I sit down with the customer, I go through a script [and] in the script I tell [them] about what they are going to get [and] the benefit of it [for their] system. I will make sure that even before I get the technology on-site, I buy in the site*" Senior Application Specialist – Producer.

Phase II also overlaps with Phase III because the decision of adopting occurs even during the implementation: the final users need to be convinced to use the technology once it reaches the healthcare institution.

The main problem of this phase is the large number of professionals present [5]. Getting the appropriate professionals involved is the key to a better transition to the third stage. Since the decision of adopting an ET has already started in the Attitude phase (A), involving the same professionals can speed up the process.

Creating a business case is also a key component of this stage. The analysis of primary data, with literary evidence, supports the idea that the difference in education (e.g., economists vs clinicians) and respective agendas (e.g., spending limits vs improvement of care) between parties, results in a very complicated negotiation that inevitably slows down the adoption process [2][5].

The business plan is analysed by the adopter's finance office as it is essential that the benefits of the ET are quantitatively assessed to help economists understand its impact. If the data is qualitative, where possible, convert them into numerical terms.

Phase III – Implementation (I)

The implementation of an ET goes through various sub-phases.

Installation

The producer tailors the ET to the healthcare institution needs. From the analysis and the literature [3], the critical factors for the success of this part are a clear, honest and bidirectional communication among parties and the involvement of the final user.

"*We are not involved in the installation*" Senior Final User 1 – Adopter.

It appears that the final user of the technology may oppose the new ET dependent on personal characteristics and background. It is important to have the involvement of the final user during the installation stage because a small flaw could result in fierce opposition. This inaccuracy can be not related to the ET per se, but with the environment where the innovation is used (e.g., installed too far from the room entrance). Flaws are generally connected with an increment of "*effort*" required by the final user if compared with the current solution.

"*Complaints arise when people compare what they were used to do [with the new technology]. It might be that something new does not look as good as the previous one until the point you actually learn how to use it properly*" Senior Final User – Adopter.

Testing

Once installed, the ET is thoroughly tested to ensure that the users of the ET would not incur any unnecessary issues. However, from the primary data and the literature [5] it appears that the adopter would almost always create opposition, independent of how well the ET works.

"*When you talk about something as complex as an [ET, there can be] a mismatch between [the] expectations [of the user] and services offered [by the producer]*" Modality Manager – Producer.

Training & day-to-day usage

There are no certainties that users will work with this technology on a daily basis: if the ET is too complicated or too laborious compared to the current technology in use, users will either be against adoption or stop using it.

"*One of the most common issues is that new technology is not used properly and therefore it cannot accomplish the purpose it was designed [for] or [be used to] its full potential*" Account Manager – Producer.

Training plays a significant role in the use of an ET and healthcare professionals will only use the technology if they achieve a good degree of trust and confidence in it. For the health institution, it is crucial to allocate sufficient time for training. In the event that an ET involves direct contact with patients, more time per patient should be allocated than with the current solution. The manufacturer expects resistance from healthcare professionals and to overcome this limitation it is essential that the healthcare practitioners feel confident in experimenting. Innovation Champions can contribute to this stage because they are well respected in the healthcare institution and can guide, inspire or influence end users.

Follow-ups

Once the training is over, it is advisable to maintain close contact between the parties in order to ensure a smooth transition. Since an ET is new, the manufacturer wants feedback in real, day-to-day use and therefore the healthcare institution should devote time to healthcare professionals to provide feedback to the manufacturer.

Shape of the Model and Cyclicality

Rogers' DoI theory is based on five steps with a linear approach: a stage must finish for the following one to start. Other scholars [31,48] suggested that there are overlaps among phases and the Model follows a cyclical pattern: once the last stage is concluded, the first one starts again. The analysis of primary data seems to support this second approach: all the interviewees agree that there is a continuous process of interaction, communication and feedback between the producer and the adopter from the very moment the ET is known to the moment is used routinely.

"*There is always an overlap among stages because you simply cannot pass from one to the other in just one day*" Final User 1 – Adopter.

Once Phase III is accomplished, Phase I starts over because new knowledge, based on the feedback of the day-to-day use, is obtained and a new attitude is formed. The consequential decision of continuing using the ET or implementing it is taken and the process carries on. The ADI Model, therefore, can be considered as a cycle of repetitive interaction between parties during the process of adoption.

"*The sell never stops*" Modality Manager – Producer.

LIMITATIONS AND FURTHER RESEARCH

The methodology used is a qualitative thematic analysis based on a case study dependent on the quality of the survey carried out. Therefore, its generalisation in other contexts can be problematic [36,37].

The results of this study are intrinsically connected with the small sample of participants and with the short time used for sampling.The ADI Model should be verified in other organisations in

order to reach further insights. First, it could be tested in environments similar to the Cambridge University Hospital, characterised by a strong relationship between academia, health institutions and technology producers, and subsequently verified in district hospitals.

The radiopharmaceuticals currently available must be known for their respective specifications by the radiographer, in order to guarantee their correct acquisition and compliance with the timing.

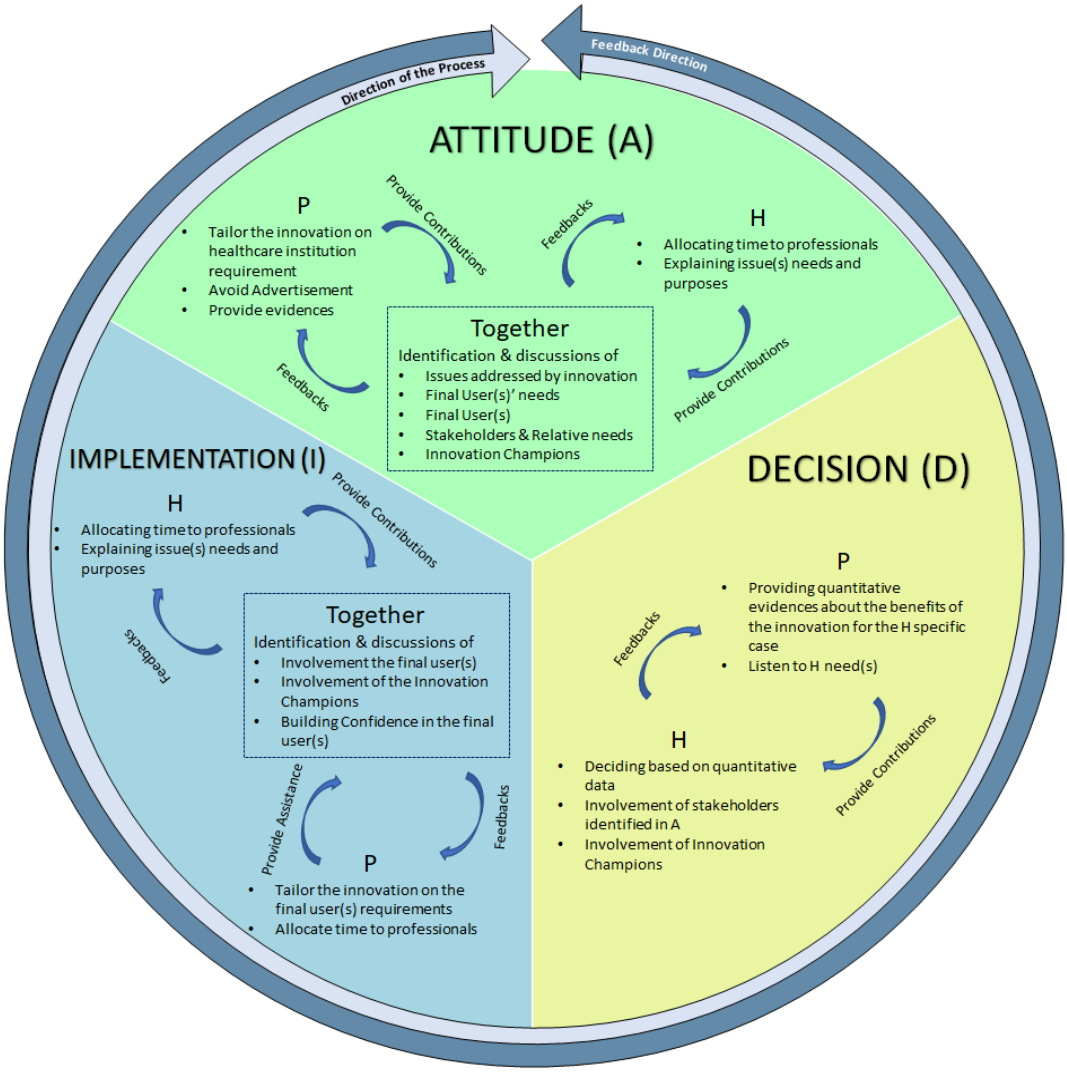

Figure 4 - ADI model integrated with the results of the study. In each phase the key concepts that emerged from the primary data are included and supported by literacy evidence. The dotted line between the phases indicates the absence of a specific moment of transition from one phase to another, highlighting a gradual transition. The clockwise arrow indicates the direction of the ET adoption process in medicine. The counter-clockwise arrow indicates the feedback that is generated during the adoption. P is the producer of innovation; H is the adopter (healthcare institution).

CONCLUSIONS

In conclusion, the adoption of ET innovation in healthcare appears to be a paradox: to improve health, medicine continually pushes for innovation, but at the same time this field creates opposition to its adoption.

There are, in fact, multiple barriers that oppose the rapid adoption of ET in healthcare against a few facilitators. In addition, there is a lack of a shared and codified model for this process.

The ADI model, after being created from literary evidence, was used as a theoretical lens to analyse the adoption process. The analysis of primary data and the literature seem to suggest its validity. The three phases of the ADI: forming an attitude towards the ET on the basis of current or new knowledge (A), deciding to continue the collaboration between the parties (D) and implement the ET in order to adapt the technology to the needs adopter (I) appear accurate in following the path that innovation takes to enter healthcare institutions.

This framework can be used by both parties as it is written with common terminology, encodes the knowledge needed in the process and aims to build a win-win relationship between the parties.

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