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A fuzzy approach to Long-Term Care benefit eligibility; an Italian case-study

Ludovico Carrino¹[0000-0002-5082-5508] and Silvio Giove²[0000-0003-2951-5350]

¹ Department of Global Health and Social Medicine, King's College London, Aldwych 40, UK

² Department of Economics, Ca' Foscari University Venezia, Cannaregio 873, Italia
ludovico.carrino@kcl.ac.uk; sgiove@unive.it

Abstract

We propose a fuzzy approach to quantify a cash-benefit for older people in need of *long-term* care, e.g., affected by limitations in daily-living activities. Many approaches exist at national or regional level in Europe, and most legislation determine eligibility to public care-programs using rule-based approaches which aggregate basic health-outcomes into main pillars and then into eligibility categories. Population ageing and improvements in longevity make access to care a crucial problem for Western economies. In this paper we focus on Italy, where public-care eligibility is decentralized at regional level and often based on check-lists, and in particular on the Toscana region. We investigate the extent to which the existing legislation violates basic properties of monotonicity and continuity, thus potentially increasing inequity in care access. We then propose the introduction of a fuzzy approach to the eligibility determination, which allows for smoother results and reduced inequality.

Keywords: Long term care, eligibility, inequality, membership functions

1 Introduction

While both longevity and health conditions have largely improved in the last century in many developed countries, disease-free life-expectancy indicators have increased at a much lower pace and a significant degree of health inequality is emerging among different socioeconomic groups (1). As a result, the rate of older people in need of Long-Term Care has risen due to a higher prevalence of conditions and to a higher number of disorders limiting the autonomy of individuals (2-4). In order to postpone the onset of severe disability and reduce social exclusion in older age, policy makers have focused on implementing proactive and inclusive programs of care (3).¹

¹ *Formal-care* includes all care services that are provided in the context of formal regulations, such as through contracted services, mostly by trained care workers, that can be paid out of pocket or through reimbursement by public (or, less often, by private) institutions. What characterizes formal care-provision is its acknowledgment by the Social or Health departments at the proper governmental level. *Informal-care* is, conversely, a term that refers to the unpaid

Governments have thus developed forms of public formal care for older people, which vary greatly across OECD countries in terms of the services offered (in cash, in-kind; domiciliary-care vs institutional-care), in order to provide accessible, equal, and adequate care coverage (5). Crucially, the literature has highlighted that a crucial determinant of (in)equality in care-access and coverage is played by eligibility rules, which are policy tools defining the target population in ‘need-of-care’: they represent a compulsory gateway to receive home-care benefits, either in-kind or in-cash (6-8). However, although recent evidence highlighted the extent to which eligibility rules impact the coverage of care systems and potentially care expenditure (7, 9), the literature has overlooked the role of eligibility algorithms in determining horizontal equity in care-access (people with similar needs should receive similar amounts of allowance) and vertical equity in care-access (people with different needs should receive different amounts of care support).

This paper investigates how a rule-based approach which determines eligibility for cash-for-care schemes may inadvertently impact equity in care-access. Moreover, we are among the first to simulate the implementation of a Fuzzy Inference System (FIS) as an eligibility Decision System, and discuss the benefits of this approach. We select Italy’s Toscana region as a case study, due to its comprehensive design (it accounts for several dimensions of loss-of-autonomy such as cognitive, functional and mental health) and its eligibility algorithm which is particularly suitable for a FIS application. We show that the existing legislation introduces sharp discontinuities in the relationship between the cash-allowance and the individual health status, which can in turn result in a failure of both horizontal and vertical equity. Indeed, the existing eligibility rules imply that a marginal change in health conditions may result in large changes in the allowance. Moreover, as the evaluation classifies individual in five large need-of-care categories, a worsening in health condition may not result in an increase in care-allowance.

We then show that implementing a FIS decision system allows for an increased granularity and smoothness in the eligibility determination, and reduce the undesired properties of the current legislation.

Our contribution is relevant under several perspectives. First, this is the among the first analysis that explicitly investigates how eligibility algorithms affect equity in access to care. This is particularly important given the ongoing policy debate on the trade-off between public budget sustainability and adequate care-provision (10). Second, we introduce a novel strategy adopting a more flexible fuzzy system in the field of Long-Term Care eligibility determination. Third, although our case-study is necessarily restricted to a specific European region (Italy’s Toscana), we pave the road for a larger investigation on how the equality embedded by European care-legislations might be enhanced by the adoption of a FIS approach.

assistance provided by partners, adult children and other relatives, friends or neighbors who hold a significant personal relationship with the care recipient.

2 Care eligibility: the Italian case study

Long Term Care (LTC) is defined as a range of services required by persons who cannot cope with basic Activities of Daily Living (ADL) and instrumental Activities of Daily Living (iADL) due to a reduced physical and/or cognitive capacity (8).

In European countries, eligibility for LTC is largely determined based on the evaluation of functional (ADL and iADL), cognitive and mental health limitations. Legislations define an eligibility algorithm which summarizes single health outcomes into an index of need of care. Such algorithm is often highly nonlinear, and its characteristics vary greatly across countries (for a review, see Brugiavini, Carrino (7)). The Italian public LTC is based on in-kind or in-cash programs which are mostly region-based and not harmonized, in terms of both the services provided and the eligibility rules (7).² In 2006, the Italian government established a National Fund to be allocated to regions in order to provide in-cash or in-kind LTC support (FNNA, *Fondo Nazionale Non Autosufficienza*). Moreover, several Regions chose to complement the FNNA with a similar Regional Fund for LTC (FRNA, *Fondo Regionale per la Non Autosufficienza*).

2.1 A case study: Italy's Toscana

Toscana's main regional Long-term Care programme PAC (*Progetto per l'assistenza continua alla persona non autosufficiente*, Long-term care for non-autonomous individuals) was introduced in 2010 with the regional law D.G.R. n.370 (March 22, 2010). The PAC is financed by the FRNA fund (regional law 66/2008) and encompasses both benefits in-cash (aimed at sharing the costs of hiring a private professional caregiver) and in-kind (nursing-care by public medical professionals) for adults aged 65 or higher. The programme is means-tested, since the household income is taken into account when defining the amount-of-care to be supplied/reimbursed or the cash-benefit to be allocated (7). The PAC is managed at the district level, where a Multi-disciplinary Evaluation Unit (*Unità di Valutazione Multidisciplinare*, UVM), composed of a doctor, a nurse and a social assistant, is responsible for the assessment-of-need of the elderly applicants and for the definition of a Personalized Plan of Assistance, which regulates the care-services to be supplied.

In Toscana, need of care is assessed through a multi-dimensional approach in three main domains: Functional limitations, Cognition, Behavior/depression disorders. Within each domain, the loss-of-autonomy is categorized as either Light, Medium or Severe. Depending on the combination of the scores obtained in the domains, an individual is assigned in one of five eligibility classes, which correspond to a specific cash-allowance. This makes it an ideal case study for a Fuzzy Inference System application, as we will discuss later. Similar eligibility algorithms are implemented, to various extents, in several European countries (see, for example, the existing legislation in France, for the APA programme (7)). However, the Toscana system is a better example for a

² A nation-wide cash benefit, the *Indennità di Accompagnamento* (IA), is available to individuals classified as *invalid*. Yet, there is no nationwide guideline as to how to assess and evaluate such outcome.

case-study, as the eligibility algorithm is more transparent and relatively simpler with respect to the French one.

Functional impairment assessment

Functional autonomy is evaluated through the Basic Activities of Daily Living scale (BADL), a Katz-adapted list of activities-of-daily-living included in the Minimum Data Set for Home Care (MDS-HC) assessment method (11). The BADL has seven items, each evaluated on a five-step scale, from 0 (independence) to 4 (full assistance required) according to the need of care required in the last seven days. The BADL score ranges from 0 to 24. The degree of functional limitation is determined as follows:

Table 1. Definition of functional dependency, Toscana's PAC

Dependency in BADL	description	BADL scale
Light	Full dependency in 2 BADL <i>or</i> light/heavy dependency in 3 BADL	8-14
Moderate	Full dependency in 3 BADL <i>or</i> light/heavy dependency in 4+ BADL	15-20
Severe	Heavy dependency in roughly all BADL	21-24

Cognitive impairment assessment

Cognitive impairment is measured through the application of Eric Pfeiffer's Short Portable Mental Status Questionnaire (12). The questionnaire includes questions on, for example, time orientation (current day of the week, current date in full), space orientation (name of the current location, phone number), age and birthdate, knowledge of the current and former Pope or President of the Republic, own mother's maiden name, numeric questions. The answers are then recorded and an overall score is attributed, depending on the number of mistakes, so that individuals are classified as "non-impaired or lightly impaired", "moderately impaired" and "severely impaired", as follows (13):

Table 2. Definition of cognitive dependency, Toscana's PAC

Cognitive Dependency	Short Portable Mental Score
Light	0-4
Moderate	5-7
Severe	8-10

Behavioral/depression disorders

Depression- and Behavior-assessment follow the guidelines from MDS-HC. Depression (mood) assessment consists in a list of questions about whether the patient exhibits: (i) a feeling of sadness depression or death-wishes; (ii) persistent anger with self or

others; (iii) expressions of what appears to be unrealistic fears; (iv) repetitive health complaints (obsessive concerns); (v) repetitive anxious complaints; (vi) sad, pained, worried facial expressions; (vii) recurrent crying, tearfulness; (viii) withdrawal from activities of interest; (ix) reduced social interaction; Instances when client exhibited behavioral symptoms. Behavior-assessment deals with the occurrence of: (i) wandering; (ii) verbally abusive behavioral symptoms; (iii) physically abusive behavioral symptoms; (iv) other behavioral symptoms; (v) resisting care/taking medications/injections/ADL assistance/eating/changes in position. The assessment results in a score between 0 (low behavioral/depression risk) and 12 (high risk). Individuals are then categorized as “lightly disturbed”, “moderately disturbed”, “severely disturbed”, as follows:

Table 3. Definition of behavioral/depressive issues, Toscana's PAC

Behavioral/Depression risk	Short Portable Mental Score
Light	0-3
Moderate	4-7
Severe	8-12

Eligibility rules

By combining the functional, cognitive and the behavioral/depression scores, individuals are categorized in 5 ISO-groups, representing five homogeneous levels of need-of-care (see Profili, Razzanelli (13)). Group 5 corresponds to the most severe profiles, while group 1 gathers individuals who have at most a light deficit in the three domains.

The following Table explains in details the eligibility rules, i.e. how the ISO-groups are defined (see Profili, Razzanelli (13) and Visca, Profili (14)).

Table 4. ISO-eligibility groups, Toscana

ISO-GROUP	functional deficit								
	light			moderate			severe		
	Behav. deficit			Behav. deficit			Behav. deficit		
cognitive deficit	L	M	S	L	M	S	L	M	S
L	1	2	3	2	3	4	4	4	5
M	2	2	3	3	3	4	4	4	5
S	3	3	4	3	4	5	4	5	5

The eligibility rules are as follows:

- Age should be at least 65 years
- Yearly household income should be lower than € 25000³

³ See, e.g., the regulation of the Casentino district, at

- ISO-GROUP should be 3 or higher⁴

For those eligible, the amount of the in-kind or the in-cash allowance ranges between a minimum and a maximum depending on individuals' income (ISEE). As we are interested in a representative individual, we will consider the average benefit amount, as follows

- ISO-GROUP 3: € 140 [€80-€200]
- ISO-GROUP 4: €240 [€170 – €310]
- ISO-GROUP 5: €355 [€260 – €450]

For instance, an average-earning individual (satisfying age and income constraints above defined) with moderate functional deficit, medium cognitive limitations, and low behavioral/depression issues respectively, would be classified in the ISO-GROUP 3, with a monthly allowance of €140.

3 The proposed modified fuzzy approach

As many other LTC systems in Europe, the Toscana system allocates individuals in five eligibility classes (ISO-GROUP). Subdivision in classes is a popular strategy in welfare-benefit systems, as it can be useful for practical purposes. However, it suffers from some undesired drawbacks. Namely, the *crisp* border between contiguous classes implies sharp discontinuities (“jumps”) in the output: a small marginal change in one basic health-indicator can shift an individual to the next ISO-GROUP, with a significant variation in the cash-benefit (e.g., switching from ISO3 to ISO4 increases the monthly benefit from €140 to €240 for an average-earning individual). Such a sharp discontinuity in the benefit allocation has no clear economic justification, and may be perceived as a driver of inequity in care-access. Moreover, it can incentivize strategic and, in extreme cases, illegal behaviors.

On the other hand, as this method pools together many individuals in the same ISO-GROUP (assigning them the same benefit), it neglects the fact that, even within the same group, some profiles may be characterized by more severe limitations than others.

For such reasons, we claim that ISO-GROUP clustering does not allow for an adequate degree of granularity and smoothness, to guarantee (i) *strong monotonicity* of benefit-eligibility to health; and (ii) *pseudo-continuity* of benefit-eligibility to health.

Let us clarify the previous points with an example of three hypothetical individuals:

- individual A, with a score of 15 in the physical scale (medium), 0 in the cognitive scale (low), and 4 in the behavioral/depression scale (medium);
- individual B, with a score of 20 in the physical scale (medium), 7 in the cognitive (medium) scale and 7 in the behavioral/depression scale (medium);

<http://www.uc.casentino.toscana.it/regolamenti/disposizioni-attuative-anno-2013.pdf>

⁴ The UVM can, in principle, decide to allow some benefit for individuals in groups 1 and 2 (Regional law D.G.R. n.370, Attachment A)

- individual C with a score of 20 in the physical scale (medium), 7 in the cognitive scale (medium), and 8 in the behavioral/depression scale (severe).

Individuals A and B would both be classified in the ISO-GROUP 3, and would thus get the same monetary amount, Nevertheless, individual A has a lower need-of-care, as she has no cognitive impairment, and she lies at the lower bound of the “medium dependency” category for both Functioning and Behavior/depression dimensions. Conversely, individual B fares much worse than A, lying at the upper bound of the “medium dependency” category in all the dimensions. Albeit A and B are characterized by different degrees of loss-of-autonomy, the eligibility rule is insensitive to such a worsening in health conditions. Thus, the legislation does not satisfy the (strong) *monotonicity* assumption, and risks to inadvertently contribute to care-access inequality.

Consider now individual C, who has the same clinical profile as B, but has a worse behavior/depression score by just one point. This marginal increase makes C eligible for ISO-GROUP-4 benefits, which means an average monthly allowance of €250. As a marginal increment in one dimension causes a large change in the monetary outcome, the eligibility rules violate the *pseudo-continuity* property.

It is important to note that such issues would arise, to different extents, for most LTC programs in Europe, as most of them allocate people in classes based on the score they fare in several health dimensions (7).

We argue that a Fuzzy-Logic Inference System (FIS) can enhance both the *granularity* and the *smoothness* of the eligibility rules, basing on the existing ISO-GROUP clustering (see Kukolj (15), Takagi and Sugeno (16) for further details). This way, a personalized benefit can be assigned *ad-hoc* to each eligible person.

Pseudo-continuity is linked to granularity, while monotonicity to smoothness. Through a FIS, monotonicity can be obtained by using a Sugeno-type with L-R type and unimodal fuzzy numbers (17, 18), as *triangular* fuzzy numbers, with MIN t-norm, defined on the universe set of each of the 3 ISO-GROUP class. Pseudo-continuity can be obtained by differentiating together the output of each rule, this increasing its granularity. That is, instead of the (discrete and natural) score between 0 and 5, each cell of the rule block will be directly assigned the economic benefit⁵. By assigning a specific monetary amount to each cell, we would realize the highest granularity.

3.1 Structure of the proposed FIS

We hereby describe an example of a FIS tailored for this type of problem, whose parameters are inspired by the Toscana legislation. In order to enhance granularity and smoothness in the eligibility rules, corresponding to monotonicity and pseudo-continuity, are desirable properties, we make use of a *zero-order* Sugeno model (aka as TSK, Takagi-Sugeno-Kang model) with MIN t-norm and trapezoidal/triangular membership (19).

⁵ The exact monetary value of the benefit in each cell needs to be determined by the Public Authority. This phase will require participatory decision methods (focus group, brainstorming, questionnaires). In this paper, the values allocated to each cell are purely indicative.

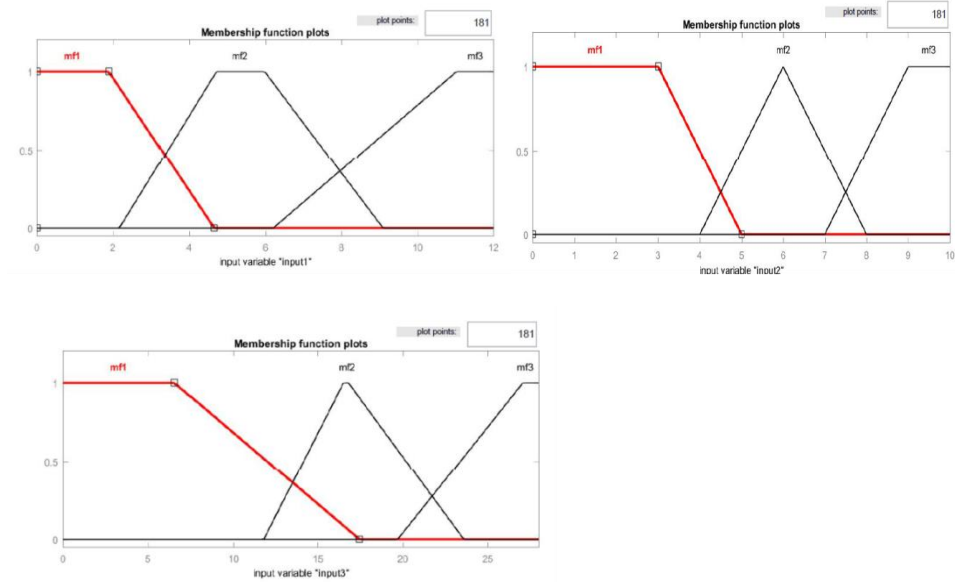


Fig. 1. Membership functions for the three input variables Behav, Cogn, Func. (Input1, Input2, Input3 respectively)

This is realized using trapezoidal fuzzy numbers (rather than triangular). Moreover, in order to avoid a complete departure from the actual legislation, we do not force the maximum granularity, thus some cells of the rule block contain the same level of allowance (for instance, in the first Table, the amount €140 appears in the second row, third column, but also in the third row second column). For each of the three input variables, Functional Deficit (Func), Cognitive Deficit (Cogn) and Behavioral/depression Deficit (Behav) we used three membership functions (trapezoidal fuzzy numbers), corresponding to the linguistic terms-sets Low, Medium and Severe, which corresponds to the actual terms used in the legislation (Table 4), and represented in Fig. 1. Again, to increase the granularity, we modified the values in the Table 4, substituting to the class label (natural numbers 1 up to 5) the direct value of the benefit, inferred from each class from the average values in Table 3, suitably modified to differentiate the elements from classes. The results are reported in Table 6. By way of example, Fig. 2 reports the rule surface corresponding to the second and the third health variables (Cognitive and Behavioral scores).

Table 6. Output of the Sugeno FIS (net average benefit for each class)

ISO-GROUP	functional deficit								
	light			moderate			severe		
	Behav. deficit			Behav. deficit			Behav. deficit		
cognitive deficit	L	M	S	L	M	S	L	M	S
L	0	0	100	0	140	240	200	240	300
M	0	0	140	140	180	280	240	280	355
S	100	140	280	140	280	355	280	355	400

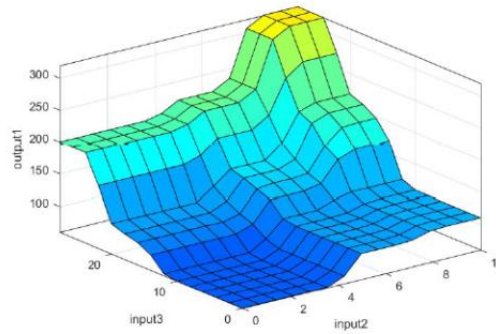


Fig. 2. Output surface for the second and the third variables.

4 A numerical example

The proposed zero-order Sugeno FIS was tested with some simulated cases. To this purpose, we evaluated the system with the 3 hypothetical profiles described above, plus one (case D) characterized by a worse health status. The profiles are characterized by the following scores in the three main variables capturing loss-of-autonomy in the Behavior/Depression, Cognition, and Functioning domains:

1. Case A (4, 0, 15)
2. Case B (7, 7, 20)
3. Case C (8, 7, 20)
4. Case D (8, 7, 22)

The input activation of the Sugeno FIS and the corresponding output for each rule is reported in Fig 3 for case A. Similar results, available on request, are obtained for cases B, C, D.

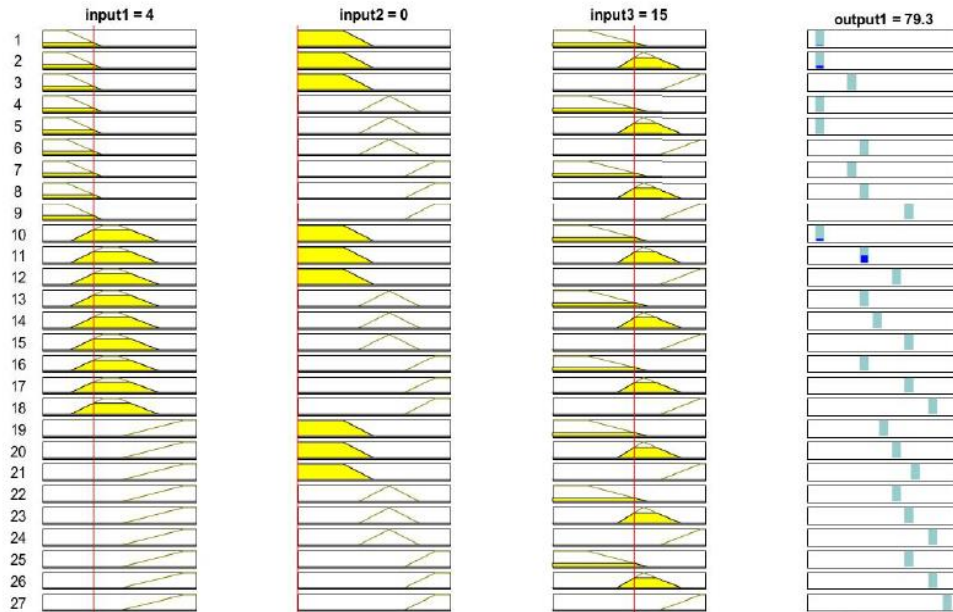


Fig. 3. Activation rules and output for case A.

The FIS then provides the monetary amounts that the four clinical profiles would be eligible to, keeping income constant (at the average level).

Table 5. Monetary amounts assigned to four hypothetical profiles

	Actual legislation	FIS-system
Profile A	€140 (ISO-3)	€79.3
Profile B	€140 (ISO-3)	€ 206.38
Profile C	€240 (ISO-4)	€237.6
Profile D	€355 (ISO-5)	€281.11

Results in Table 5 show that, unlike the original Toscana's legislation, a FIS can implement a set of eligibility rules which allocate care-allowances to different clinical profiles, by satisfying pseudo-continuity and monotonicity. In the original set-rules, individual A would be allocated the same allowance as individual B, although being characterized by a healthier profile. Under the FIS rules, individual B would get a consistently higher allowance than individual A.

Similarly, individual C, who is just marginally different than individual B, is allocated a largely different allowance in the original rules. Conversely, the FIS rules assign her only an increment of around €30 in the cash-benefit.

5 Conclusion and future research

Various approaches are currently being implemented at national or regional level, to ameliorate the wellbeing and need of care for older people in Europe. Concerns related to, on one hand, adequacy of Long-term Care support for dependent individuals and, on the other hand, sustainability of public social-care and health programs are particularly relevant, in light of the population ageing and enhanced longevity. In Italy, most regions have established cash-for-care schemes based on rule-based approaches. Among the most encompassing eligibility algorithms, we focus on the case of the Toscana region, which aggregates basic health indicators into three main pillars, Functioning, Cognition and Behavior/Depression. After having analyzed the system currently in use, we verified how the eligibility rules violate some basic properties, potentially increasing inequality and incentivizing strategic (and even illegal) behaviors. Thus, to increase granularity and smoothness in the Decision System, we introduce a Fuzzy Inference System (FIS), to compensate, at least partially, the undesired characteristics of the currently implemented rules.

The proposed FIS constitutes a prototype which will require, in future analysis, a fine tuning of its parameter. Specifically, this will require to perform a Multi-Person preference elicitation, through participatory methods involving relevant Actors in the field of social- and health care. Suitable methods would include focus groups, brainstorming, and conjoint analysis. Furthermore, as a subsequent research step, we intend to propose a general structure based on a FIS, to be adopted by the Italian National Healthcare System.

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