Chapter 13
An Agent-Based Approach for Patient Satisfaction and Collateral Health Effects

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Abstract The purpose of this study is to clarify the collateral health effects of health care, especially the relationship between patients and their families, using agent-based simulation. To this end we describe the general appearance of our simulation model and the simulation settings. The results of six model scenarios, each involving differing combinations of patient agents, patient's family agents, doctor agents, a government agent, and nonprofit organization (NPO) agents, are then explained and discussed. We conclude with a summary that touches on the tasks that lie ahead, including an appropriate subset of health care policies that involve the participation of NPO agents.

Keywords Agent based simulation • Patient satisfaction • Social cost

13.1 Introduction

According to the World Health Organization (WHO) and the Organization for Economic Cooperation and Development (OECD), Japan enjoys the highest medical level, as measured by life expectancy at birth, probability of dying under age 5, probability of dying between ages 15 and 60, and a low health expenditure as

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a share of gross domestic product (GDP).[1] However, according to the Cabinet Office of the Government of Japan, as well as other sources, patient satisfaction in Japan is low compared with that in other countries.[2] What is more, Japan is now facing various social problems related to health insurance, pensions, and taxation because the population is rapidly aging at an unprecedented pace. To curb the huge and rapidly expanding costs of medical treatment and to increase patient satisfaction, an increase in financial support to patients' families is needed, since family support inevitably entails substantial financial and mental burdens.

In the United States patient-centered and family-centered care has been promoted since the middle of the twentieth century. The Institute for Patient- and Family-Centered Care "serves as an information resource center for patient and family leaders, clinicians, administrators, educators, researchers, and facility designers who are interested in advancing the practice of patient- and family-centered care."[3] In Japan we have, for example, the Patient/Family Support Center at Asahikawa Red Cross Hospital.[4] Thus, in the field of health care service and medical care, it is increasingly important to provide care services not only to patients but also to their family members.

The purpose of this study is to clarify the collateral health effects of health care by means of an agent-based simulation. To this end we describe our simulation model in Sect. 13.2 and the simulation settings in Sect. 13.3. The results of the simulation are discussed in Sect. 13.4, and in Sect. 13.5 we summarize our research results and note the tasks that remain.

13.2 General Form of Our Simulation Model

13.2.1 Basic Characteristics of the Model

There are many studies that deal with patient satisfaction, but very few focus on the relationships between patient satisfaction and the financial and mental burdens of their families. One of the few that does is [6]; it points out the importance of studying collateral health effects, in contrast with conventional views on medical care.

As shown in Fig. 13.1, on the basis of Christakis's research, our simulation model makes use of a social network model in which patients are mutually linked with their families and doctors. We also include a government health care resource. In Japan, the cost of health insurance is approximately 10% of one's income, so in our model each agent pays 10% of their income for health insurance. The total amount of

[1] For example, see [1] and [2].

[2] See Ref. [3].

[3] Quoted from Ref. [4].

[4] See Ref. [5].

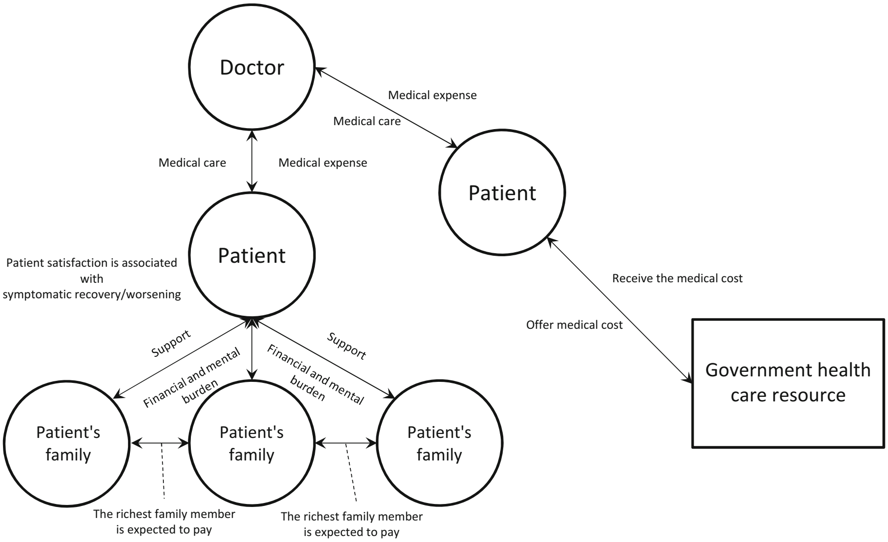

Fig. 13.1 Simulation model

health insurance paid by each agent goes into a government fund that constitutes the health care resource. In our model patients interact with doctors through medical treatments. At such times patients make use of the government health care resource only if they do not have family support. Patients also interact with members of their family through their support and the financial and mental burdens of the family. In this instance, the family's financial and mental burdens equal the social cost[5] that is derived from patient care. If a patient cannot pay medical expenses, his family covers it. In addition, symptomatic worsening of patients affects the satisfaction of patients and their families, while symptomatic recovery and/or increased patient satisfaction will ease the mental burden of the family. Thus, the symptomatic recovery or worsening of a patient is associated with patient satisfaction. We include these mechanisms in our simulation model.

13.2.2 Patient Satisfaction Scale

Based on the agent-based simulation model described above, we need to evaluate patient satisfaction using some kind of "patient satisfaction scale." There is considerable research on the enhancement of patient satisfaction in the field of medical care.

[5]Social cost is generally defined in economics as "the cost to society as a whole from an event." Here we narrowly define social cost as the financial and mental cost incurred by a patient's family in supporting that patient.

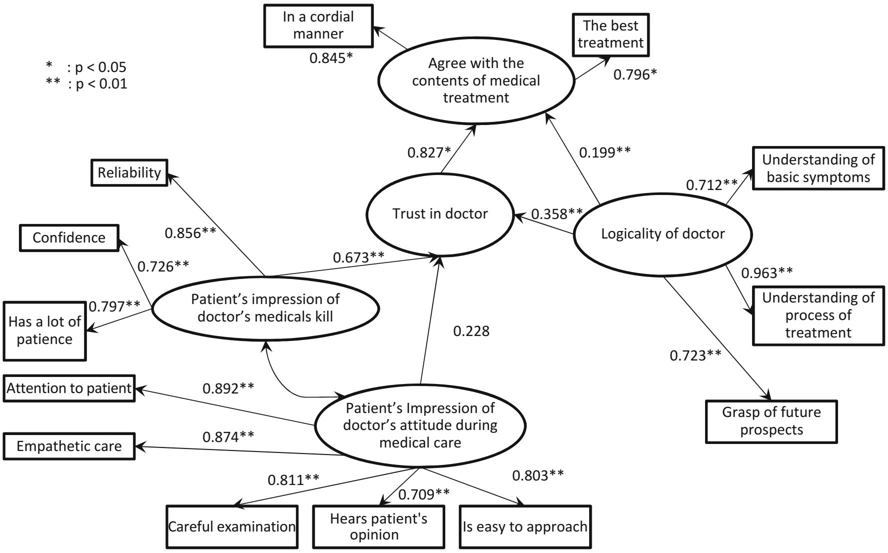

Fig. 13.2 Path diagram for measuring patient satisfaction (*Source*: [10, p. 202])

Nevertheless, more research is needed in regard to a patient satisfaction scale. A scale based on SERVQUAL (see [7]), which is a kind of customer satisfaction measurement, has been developed and used in several studies.[6] In recent years, in order to develop a more useful patient satisfaction scale, some studies have used a structural equation model, but there is no unified methodology for constructing a patient satisfaction scale, and each study uses a different data-gathering process to construct its patient satisfaction scale (for example, see [10–13]). Given this situation, we focus on an idea from study [10] and make use of its basic structure in our simulation model.[7] We have adopted this particular study because it probes into the psychological makeup of patients using a structural equation model. In addition, the clinical department in which the 145 patients in this study were seen is not restricted.

As shown in Fig. 13.2, [10] points out that four potential factors have both a direct and an indirect influence on the patient's assent and satisfaction: the patient's impression of the doctor's medical skill, the patient's impression of the doctor's attitude during medical care, the logicality of the doctor, and the patient's trust in the doctor. These four potential factors affect eleven observed variables: "reliability", "confidence", "has a lot of experience", "attention to patient", "empathetic care",

[6] In the field of medical care, early studies that deal with patient satisfaction are [8] and [9].

[7] Other studies that deal with Japanese patient satisfaction using a structural equation model are [14] and [15]. An example of a study that deals with patient satisfaction in another country is [16].

"careful examination", "hears patient's opinion", "is easy to approach", "grasp of future prospects", "understanding of process of treatment" and "understanding of basic symptoms".[8]

From Fig. 13.2 we see, for example, that if the patient's impression of the doctor's medical skill improves, this directly leads to enhancement of trust in the doctor (0.673). At the same time it indirectly leads to improving the patient's agreement with the contents of the medical treatment (0.673×0.827). In addition, increasing patient satisfaction leads to reducing the mental burden of the patient's family. And finally, the patient's satisfaction is associated with more rapid recovery, so increasing patient satisfaction will also lead to reducing the financial burden of the patient's family. In other words, increasing patient satisfaction leads to reducing the social cost.

Each patient agent has the 11 observed variables as "expectation variables," and these variables are related with each other. Each doctor agent has "ability variables," which are at the same time "perception variables" for the patient agent. If the doctor's professional ability exceed a patient agent's expectation, patient satisfaction is improved. Furthermore, the change of a variable results in alteration of the other variables.

The financial and mental burdens of a patient's family (the social cost) are calculated as follows. If a patient cannot pay her medical fees, the patient's family must pay all of, or shortfalls in, those medical expenses. The mental burden of the patient's family is associated with the patient's satisfaction. The cost is defined as the reciprocal of total patient satisfaction.

According to [10], total patient satisfaction is calculated as follows. Technique, attitude, and logic are three potential factors (out of the four).

```
Function satisfy (technique as double, attitude as
double, logic as double) as double
{
    Dim z as double
    Dim b as double
    Dim a as double

    //The Effect for Satisfaction
    a = technique * 0.673 + attitude * 0.228
    + logic *  0.358
    b = logic * 0.199
    z = a * 0.827 + b
    Return (z)
}
```

[8]According to [10], the goodness-of-fit index (GFI) is 0.861 and the adjusted goodness-of-fit index (AGFI) is 0.781.

Each doctor agent and patient agent has the 11 observed variables described earlier. These variables randomly vary across the simulation steps. Their average is 0 and their standard deviation is 1. For example, if a patient agent's expectation variable "reliability" is lower than that of the doctor's, the function "satisfy" is expressed as satisfy (0.856, 0, 0). The other three potential factors and the 11 observed variables are similarly combined and added up. Because the resultant value is computed by multiplying decimal numbers, it is magnified one hundred times.

13.3 Simulation Settings

In our simulation model the number of patient agents is 1,000. The number of patient family agents is apportioned to each patient agent according to the average number of people per family (average = 2.62, standard deviation = 2) in Japan.[9] If the number of the patient family agent is below one, the patient agent is a home-aloner agent. The number of doctor agents is set at 12 as a trial.

We carried out the above simulation for three models, conducting one-hundred-times simulations. In each model the number of simulation steps was 600. As shown in Table 13.1, in Model 1 there is neither family support nor government health care resources to distribute to patients.[10] In Model 2 there is only family support. In Model 3 there are both government health care resources and family support.

We were able to ascertain the differences in patient satisfaction, in the burdens of family members, and in the amount of government health care resources in each model.[11]

Table 13.1 Summary of each model

	Family support	Health care resources
Model 1		
Model 2	√	
Model 3	√	√

[9]The average number of people per family is based on [17, p. 3].

[10]In order to analyze the rate of decrease in health care resources in our other models, we implement the mechanism of a government health care system in Models 1 and 2, although in these models no government health care resources are distributed to patients.

[11]In our simulation model we use artisoc 3.0, which is produced by Kozo Keikaku Engineering, Inc.

13.4 Simulation Results

13.4.1 Basic Simulation

The simulation results are shown in Table 13.2 and the increase-decrease rate of each scale is shown in Table 13.3. As these tables show, with the introduction of family support the average patient satisfaction (through all steps) is increased by 71.4% compared with that of Model 1. At the same time, it drives up the social cost (comparing Model 2 with Model 1). When government health care resources are introduced, average patient satisfaction (through all steps) is increased by 16.7%. On the other hand, we see that the social cost in Model 3 is slightly lower than in Model 2 (by −1.1%), and that government health care resources in Model 3 are nearly 40% lower than those given in Model 2.

Note that, in a Model 1 scenario, patients unable to pay out-of-pocket medical costs cannot be under the care of a doctor, because of the absence of both family support and government health care resources. In a Model 2 scenario, some patients, especially live-alone agents, cannot be treated until full recovery, because they cannot get support from their family. In a Model 3 scenario, patients who cannot receive adequate treatment in Models 1 and 2 are given adequate treatment. The social cost is offset by government health care resources to some extent, but the degree of reduced health care resources is exceptionally high.

From Table 13.2 it would seem that there is little difference between the average patient satisfaction (through all steps) in Model 2 and that in Model 3. However, as shown in Fig. 13.3, the difference between the maximum value of the step-by-step average patient satisfaction in Models 2 and 3 is very high.

Table 13.2 Simulation results

	Model 1	Model 2	Model 3
Average patient satisfaction (through all steps)	0.70	1.20	1.40
Social cost (unit: 10,000 yen)	0.000	1,142.469	1,130.465
Health care resources (unit: 10,000 yen)	48,440.567	48,376.330	29,238.571

Table 13.3 Increase-decrease rate of each scale

	Model 1 to Model 2	Model 2 to Model 3
Average patient satisfaction (through all STEPS)	71.4%	16.7%
Social cost (unit: 10,000 yen)	–	−1.1%
Health care resources (unit: 10,000 yen)	−0.1%	−39.6%

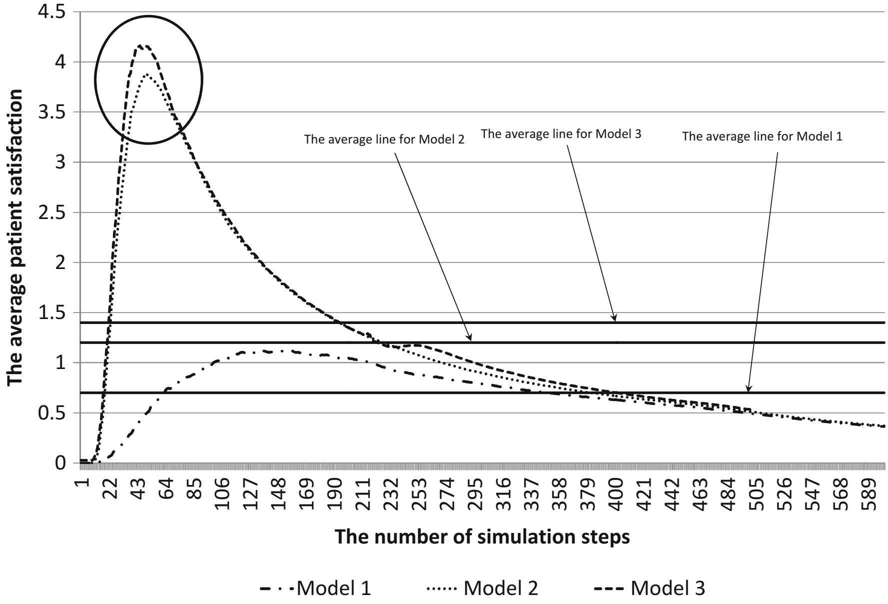

Fig. 13.3 The time series variation of average patient satisfaction and its average line through all steps

13.4.2 Additional Simulation

13.4.2.1 The Effect of Including NPO Agents

From the results of our simulation we conclude that a part of health care resources for treatment of a patient should be distributed to the patient's family to keep down the social cost. From Tables 13.2 and 13.3 we see that the difference between Model 2 and Model 3 in our simulation results is that social cost is offset by government health care resources to a small extent and that the degree of reduced health care resources is exceptionally high in Model 3. Given such findings, it is imperative to look for some kind of equilibrium point for cost-effective medical care that is based on an agent-based simulation model. A further direction of our study would be to build mechanisms (such as smoothing community relations) and to include other types of agents, such as nonprofit organizations (NPOs), into our simulation model, to serve as a basis for simulating the effect of interventions that minimize social cost.

We have thus decided to implement a simulation model (Model 4) with NPO agents that will help a patient's family. Eventually they minimize the social cost for the patient's family. When the patient's family agent has a link with an NPO agent, the family's mental burden is reduced. The government agent will release the resources needed for NPO agents' activities, and NPO agents will use money earmarked for their activities. The amount will be a percentage of the health care resources paid to patients in Model 3.

In addition, the intensity of an NPO agent's activity will change in proportion to the amount of funding received. We look at percentages of health care funding ranging between 10 and 40%.

The number of NPO agents is fixed at 50.[12] The budget allotment to an NPO agent is approximately 190 million yen, which is calculated from the average health care funding shown in Model 2 minus that in Model 3 (see Table 13.2). This is then multiplied by the percentage of health care funding mentioned above.

In addition to Model 4, we implement Model 5, which differs from Model 4 only in that the NPO agents take action voluntarily and do not receive government health care funding.

From the simulation results for these models shown in Table 13.4, we see that there is little difference between the average patient satisfaction in Model 3 and that in Model 4. When the percentage of health care funding distribution to NPO agents is 40%, a drastic change occurs: the social cost decreases dramatically. However, although a certain amount of health care funds is redistributed to NPO agents, the funding average is slightly reduced in Model 4. The reason for this is that patients receiving medical assistance have their benefits reduced at a constant rate; since they receive medical assistance more frequently in Model 4, their health care funding is reduced.

Compared with the health care funding in Model 3, that in Model 5 remains virtually unchanged. A percentage of health care funds allocated to an NPO agent in Model 4 can be compensated for by the organizational maturity of the NPO agent in Model 5. The declining rates of social cost seen in Model 5 depend on the intensity of an NPO agent's activity; a high level of organizational maturity drastically reduces social cost and results in a more cost-effective approach than that of Model 4. It can be said that creating conditions in which NPO agents can improve their performance and develop greater autonomy is desirable.

13.4.2.2 Our Simulation's Correspondence with Reality

Now let us look at how our simulation model corresponds with the real world in Japan.

Since 1961 there has been a universal health insurance system in Japan, according to which, when people become sick, they usually go to a hospital and pay 30% of hospital expenses, with the rest being covered by "Health Insurance." So, in a simulation model adapted to suit what happens in Japan, patient agents first expect to receive health care from the government. Next, patient agents and

[12]In 2009 the average number of hospitals per a population of 100,000 was 6.9; on the other hand, the average number of NPOs per a population of 100,000 was 31.3. These numbers are published by each of the administrative districts of Japan. See, for example, the websites of [18] and [19].

Table 13.4 The effect of including NPO agents

	Model 3	Model 4						
		The percentage of funding distribution to each NPO						
		10%	15%	20%	25%	30%	35%	40%
Average patient satisfaction (through all steps)	1.40	1.39	1.40	1.39	1.42	1.40	1.40	1.40
Social cost (unit: 10,000 yen)	1,130.465	1,146.8433	1,130.6830	1,072.2897	1,025.2556	921.9023	841.1741	496.0975
Health care funding (unit: 10,000 yen)	29,238.571	28,407.973	27,308.359	26,428.145	25,771.625	21,199.159	22,550.839	23,035.060
		Model 5						
		1.40	1.37	1.40	1.38	1.40	1.41	1.42
		1,150.780	1,138.0328	1,095.5390	1,072.8579	923.6590	836.3567	467.5582
		28,467.097	31,030.115	29,118.527	32,185.348	29,415.603	29,213.902	29,861.349

Table 13.5 Comparison of the results of Model 2 and Model 6

	Model 2	Model 6
Average patient satisfaction (through all steps)	1.20	1.39
Social cost (unit: 10,000 yen)	1,142.469	475.651
Health care funding (unit: 10,000 yen)	48,376.330	27,956.393

their family agents seek help from NPO agents. Last of all, patient agents ask their families for assistance. The results of this simulation model, Model 6, are shown in Table 13.5, where they are compared with the results from Model 2.[13]

From Table 13.5, and comparing it with Table 13.4, we see that in Model 6 average patient satisfaction is slightly lower than in Models 4 and 5. Looking at social cost in Model 6, we see that it is at a level seen in Models 4 and 5. Health care funding, however, is slightly lower in Model 6 than it is in the other two models.

Health care funding is slightly lower because all patient agents, even low-income ones, can first receive health care from the government. However, though almost all patients receive medical services, this fact does not necessarily raise patient agents' satisfaction; the degree of patient satisfaction is not connected with the order in which patients receive health care services. This may explain why average patient satisfaction is at the same level as in Models 4 and 5. After the initial visit to a hospital, before a heavy burden is imposed on patient family agents, patients and their family members may seek help from NPO agents. Note, too, that social cost is at a level close to those shown in Models 4 and 5. Hence, on the basis of our simulation results, it can be said that conditions conducive to improving NPO agents' performance and helping them develop autonomy are desirable in the context of prevailing health care. It is important that an appropriate subset of health care policies be implemented.

13.5 Conclusion and Future Work

From the preceding discussion we can conclude that family support, which entails a high social cost, strongly raises patient satisfaction. However, even if government health care resources are introduced, social cost does not necessarily decrease by much. The results derived from our simulation suggest a need for interventions that minimize the social costs for patients' families. There are many different methods to minimize social cost for a patient's family; for example, smoothing community relations or building a system in which local citizens and NPOs participate willingly.

In addition, we presented a simulation model that takes into account the preferences or choices of an individual patient and/or the patient's family in real life. That is, individual patients first seek to receive health care from the government.

[13] Model 6 is based on Model 4. The number of simulation times is 10.

Then they and their family agents seek some help from NPO agents. Last of all, the patient agents seek assistance from their families. Our simulation results suggest that, in the context of health care as it exists in Japan, conditions need to be created that will improve NPO performance and develop NPO autonomy. For this to happen, an appropriate subset of health care policies must be implemented.

The simulation model used in our study is a very simple agent-to-agent network model. It would be better if we could indicate in our model actual relations among patients, patient families, and doctors; for example, many patients might actually be isolated from any relatives. Also, in our study no statistical test is performed. Our simulation model is still an experimental model, and the amount of data obtained from the simulation is small. Therefore, we hope to develop our model further and obtain enough data so that we can apply statistical methods to test the differences in each model. In addition, a continuous examination and refinement of the patient satisfaction scale would strengthen the proposition set forth in this chapter.

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