

Evaluation of Network Public Opinion on the Doctor-Patient Relationship Based on Evolutionary Game Theory

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ABSTRACT Effective management of public opinion on the doctor-patient relationship network is an important element of maintaining social harmony and stability. In this paper, a new tripartite evolutionary game is proposed, the purpose of which is to examine the behavioral strategies of doctors, governments and netizens in the evolution of public opinion on the doctor-patient relationship network. Secondly, we further propose evolutionary replication dynamics equations in order to study the evolutionary stable strategies of participants. Select Shaanxi “Yulin puerpera fall from a building” as a case study, the applicability of the method was demonstrated and the main factors affecting the behavior of participants were found. Finally, we put forward suggestions on the management and control of public opinion on the doctor-patient relationship network from the four perspectives of doctors, government, media, and netizens. Research shows that the development of public opinion on the doctor-patient relationship network is the result of the joint action of multiple participants.

INDEX TERMS Network public opinion, doctor-patient relationship, evolutionary game.

I. INTRODUCTION

At present, China's medical and health system reform has entered an important stage. The complexity of interest adjustment makes the contradictions within the system increasingly prominent. With the rapid development and popularization of the Internet, medical and health incidents closely related to people's lives and health have gradually become a hot topic of online public opinion. Specifically, the online public opinion of the doctor-patient relationship is combined with complicated doctor-patient interests and contradictions. Such public opinions have caught the attention of all sectors of society because they involve many subjects and are often difficult to properly resolve. Therefore, using the method of game theory, this thesis explores the main body of public opinion and its mutual relations, as well as the stable strategy of multiple parties participating in the main body in the evolution of public opinion. Also, game theory can reveal the causes and evolution of public opinion on the doctor-patient relationship network, and then formulate strategies to deal with public opinion crises. This not only expands the

research field of online public opinion, but also supplements the current theoretical research on the online public opinion of the doctor-patient relationship. In general, it is the ultimate goal of this paper to dig out the causes and evolutionary dynamics of medical online public opinion, and to provide medical and government with scientific and reasonable guidance and reference in the response and guidance of online public opinion.

Internet information dissemination has the characteristics of fast speed and wide influence, and it has become the “fourth media” after newspapers, radio and television. The public gradually regards the Internet as the main channel for expressing needs. However, due to the exposing, virtual and rapid nature of the Internet, highly sensitive medical and health incidents are easily discussed by netizens. Once relevant discussions quickly evolve into online public opinion, a public opinion crisis may arise. Furthermore, medical online public opinion not only damages the image of hospitals, governments, and health management departments, it also exacerbates the current tense doctor-patient relationship, disrupts the normal working order of treatment institutions, and even threatens the stability of the medical and health service system. Effective management of Internet

The associate editor coordinating the review of this manuscript and approving it for publication was Nilanjan Dey.

public opinion helps maintain social harmony and stability, and is conducive to creating a good public opinion environment for the reform and development of the Chinese system. Today, health care issues that are closely related to people's lives and health have gradually become the focus of attention of the whole society. Therefore, China urgently needs to improve the ability of hospitals to respond to public opinion on the doctor-patient relationship network.

The innovation of this paper is to study the behavior of doctors, patients, media, Internet users and government in the evolutionary game model under the background of modern network public opinion. Through case analysis, this paper establishes the evolutionary game model of public crisis of doctor-patient contradiction to analyze the behavior changes of doctors, patients, media, Internet users and the government and the relationship between these behaviors when the public crisis of doctor-patient contradiction breaks out. According to the equilibrium solution and the evolutionary stability strategy obtained by simulation analysis, this paper puts forward some suggestions on how to eliminate their adverse effects, how to optimize the game path, and how to guide multi-agent to participate in crisis management.

This paper divides the evolution process of public opinion into stages, constructs the evolutionary game model of participants in each stage, and identifies the main factors that affect the behavior of participants. Based on the relationship between the participants and the main factors that affect the behavior of the participants, this paper explores the relationship between the participants and reveals the network structure characteristics and evolution law of public opinion. This paper puts forward suggestions from the perspective of the four participants, namely, the doctor, the patient, the media and the government, so as to guide the positive development of the public opinion on the medical network, build a harmonious public opinion environment and maintain social stability.

The rest of this article is arranged as follows: The literature on Internet public opinion related to the doctor-patient relationship and the evolutionary game is provided in Section 2. In Section 3, collect online opinion data and conduct empirical research. In Section 4, complete the game equilibrium analysis of the evolutionary process of public opinion on the doctor-patient relationship network. The conclusions are given and we make future research suggestions in Section 6.

II. LITERATURE

The concept of "public opinion" was expounded by scholar Allport. He believed that public opinion is the will of the people, and public opinion is the opinion of most people, and the views of a small number of people can be regarded as public opinion [1]. Price explained the inner content, influencing factors, communication channels and harmfulness of public opinion [2]. After that, Internet public opinion is generated by the stimulation of various events, which are the sum of people's expressed beliefs, attitudes, opinions and emotions [3], [4]. Network public opinion directly reflects

the development trend of social public perspective and affects social harmony [5]. The generation of Internet public opinion was affected by the individual factors of the public and the media of information dissemination [6]. Some scholars have done research on online public opinion. For example, Gil Garcia conducted tracking and information mining on hot Internet topics, and found that text clustering can provide timely and effective Internet public opinion early warning, which was of great help in the monitoring and control of Internet public opinion [7]. The correspondence theory was introduced into the study of Internet public opinion by branchlet Birgit [8], taking "Moluccan" incident in Indonesia as an example, it was concluded that the contradiction and opposition between the two parties in the Internet is very easy to cause internet public opinion. Moluccas' Sullivan and Garduno Hernandez conducted a large number of analyses on topics related to Irish marriage referendum in 2015 to twitter, and conducted a study on the relationship between social structure and public opinion [9]. In addition, it was noted that social structure can be successfully combined with public opinion to understand and analyze the way Internet media users deal with controversial or polarized issues.

Furthermore, the network public opinion of the doctor-patient relationship refers to the sum of all emotions, attitudes, opinions and follow-up influence of the public on medical and health hot events formed in the Internet space [10]. The network public opinion of the doctor-patient relationship is generally triggered by sudden medical and health events. Specifically, the highly sensitive medical and health events can be roughly divided into four categories: medical reform, medical quality and safety, medical accidents and disputes, and hospital staff receiving red envelopes and kickbacks, among them, the frequency of medical accidents and disputes causing network public opinion is the first [11]. Then, the online public opinion of the doctor-patient relationship has the characteristics of general online public opinion, such as negative topics, information distortion, difficult to control, and public opinion showing "medical weakness" [12], [13].

Scholars initially studied the problem of doctor-patient communication, then, gradually paid attention to the influence of online public opinion on the doctor-patient relationship. Hayes Bautista believes that communication between doctors and patients is necessary in the process of diagnosis and treatment. In this process, as a doctor, we do not simply dictate in our own capacity, nor do patients blindly follow the doctor's instructions mechanically and undoubtedly [14]. Gupta and Arora set up a decision-making system to improve the smoothness of communication [15]. Many follow-up researchers have also further realized the extreme importance of doctor-patient communication and cooperation, and put forward their respective solutions. However, due to the differences between doctors and patients in status, education, vocational training and other aspects, some communication barriers still exist. In this way, conflicts between doctors and patients cannot be completely avoided [16].

Susanne and other scholars mainly focused on the impact of health information on the power relationship between doctors and patients on the Internet, aiming to explore whether patients' access to information on the Internet will change patients' participation in doctors' decision-making [17]. Gerber mainly focused on the role of online medical information on the relationship between doctors and patients and health outcomes, and explored whether the decision-making process would be improved if the network information shared the knowledge [18], [19]. Marta and other scholars mainly focused on the impact of medical information on the public and Internet users' cognition of the doctor-patient relationship [20]–[22].

Most of the sources of online public opinion crises caused by doctor-patient relations are medical accidents. At present, the research on doctor-patient disputes has been relatively mature. Mainly from the following four aspects: first, pay attention to the social roles of both doctors and patients. According to the severity of the patient's condition, Sion Taylor divided the roles of both doctors and patients in the medical process into three types: guidance and cooperation, active and passive, and mutual participation [23]. Second, to explore the phenomenon of medical information cognitive asymmetry between doctors and patients. For example, Gerber believed that patients lack of information in medical treatment, resulting in no alternative opportunities, and was in a weak position in the doctor-patient relationship [24]. Thirdly, discuss the process of doctor-patient communication. Starr pointed out that the interaction between TCM and the patient during medical treatment is not a process that the doctor orders and the patient follow mechanically, but the result of parties negotiates [25]. Fourth, the health care system. Benedetti combed the evolution history of the doctor-patient relationship in the United States. He found that the ideal doctor-patient trust was undermined by the medical insurance system, which was manifested in the decrease in doctor-patient interaction. Patients did not trust doctors, and doctors expressed outrage and injustice when faced with patients' doubts [26]. What's more, Claus Wendt proposed that public opinion and doctors' preference was the key to understand the potential of medical system reform [27].

Moreover, evolutionary game is a method of studying multi-participant decision-making. With the deepening of research, it has been widely used in the fields of international relations, public choice, economic management, complex networks and other fields [28]. Evolutionary game theory is a theory that combines game theory analysis and dynamic evolutionary process analysis. It takes the limited rationality hypothesis of behavior characteristics as the basis and group as the research object. Also, this theory believes that the behavior of participants is a dynamic adjustment process under the influence of internal and external factors such as the environment and resources, and as internal and external factors change, the behavioral strategies and game results of the participants will show different states [29]. The basic concept of this theory, evolutionary stability strategy, was presented

by Maynard Smith in the 1880's, and then it has attracted the general attention of the academic community [30]. Weibull systematically summarized the evolutionary game theory, which was typically used in the fields of economy, society and management at present. He explained and predicted the group behavior of participants by constructing a game model to describe the interaction between individuals with strategies and benefits [31]. Evolutionary game theory simulates the adjustment process of game players' strategies by constructing replication dynamic equation. Therefore, replication dynamic equation is also known as imitator dynamic equation. In fact, it is a dynamic differential equation that describes the probability that a specific strategy is enacted in a participant. Li Yuqiao used evolutionary game theory to study the evolution and propagation of public opinion, and used complex networks to simulate the interaction between members of the multi-agent system [32]. Khaled applied automata to game theory [33]. Abram studied the Nash equilibrium of the game, and made static and dynamic evolution analysis [34]. Hendrik Richter introduced a framework to describe the dynamics of coevolutionary game with landscape model, and concluded that coevolutionary game can stimulate dynamic landscape [35]. Satoshi Uchida combined prospect theory with evolutionary game theory, and proposed peering punishment as a theoretical approach to solve the dilemma [36]. Ayong proposed an evolutionary game model to study the permission request strategy of bounded rational application providers, and conducted a detailed simulation study on the proposed evolutionary game model [37].

To sum up, at present, the research on doctor-patient relationship network public opinion is still in its infancy. Related research is mainly carried out from two aspects: network public opinion and doctor-patient dispute. Most scholars analyze or discuss the specific medical problems from the perspective of both doctors and patients, but seldom study the interaction between TCM hospitals, patients and netizens. Research on network public opinion of the doctor-patient relationship focuses on practice and lacks basic theory. This leads to the lack of a unified theoretical standard in practice. Therefore, the network public opinion theory of the doctor-patient relationship needs to be further strengthened. In addition, existing network public opinion game research pays too much attention to the construction and solution of the evolutionary game model, and ignores the information of public opinion itself. As a result, the model is only suitable for individual cases, and the specific application scope is not clear. Therefore, it is necessary to model from the perspective of public opinion theme, divide the network public opinion into several categories according to certain topical classification standards, and construct the network public opinion game model of each topic. As far as the participants of network public opinion are concerned, we must consider factors from all aspects. In other words, it is necessary to adjust the number of participants in the public opinion game so that the game model constructed can be as close to the actual situation as possible. By combing and summarizing the

relevant literature, this paper takes Shaanxi “Yulin puerpera fall from a building” as an example, and tries to introduce the evolutionary game theory to analyze the dynamic evolution of network public opinion of the doctor-patient relationship.

III. CASE SELECTION AND EVOLUTION OF PUBLIC OPINION

At 20:00 on August 31, 2017, on the 5th floor of the inpatient department of Suide District, the first hospital of Yulin City, Shaanxi Province, a pregnant woman waiting for childbirth fell to death. The matter came into public view after being reported by the media. The hospital and maternal family members have repeatedly expressed their opinions on the rights and responsibilities of the incident through the media platform, saying that the accident was caused by the other party. The event continued to ferment, causing heated discussion among netizens and social concern. In this paper, the event data is organized and filtered by sina.com’s “hot news ranking list” and “people’s public opinion channel”. In the development process of the “maternal fall” event in Yulin, Shaanxi Province, the game involving multiple parties has been fully reflected. This is a representative and typical network public opinion doctor-patient relationship perspective event, which is suitable for the empirical case analysis of this study.

In order to monitor and collect the relevant information of the “maternal fall incident”, we study the network public opinion transmission process of the event. This paper uses the Baidu Index (Internet social hotspot aggregation platform, which has data reserves covering tens of billions of microbiology, WeChat, and news media sites) to enter the keyword “maternal fall”. This leads to the overall trend chart of the search index and the overall trend chart of the eventual development of “maternal crash” in Yulin, Shaanxi Province. The public opinion of the incident began to spread on September 4, 2017, and the amount of public opinion reached its peak on September 6, until the heat gradually lowered on September 16, and the spread of public opinion gradually disappeared. The public opinion of the incident lasted more than ten days from the beginning to the end. Although the duration is short, the evolutionary process is ups and downs. This incident was widely disseminated on multiple Internet channels such as Weibo, WeChat and new media websites, and it had an impact that could not be ignored for the entire society.

According to the overall development trend of the “maternal falling into the building incident” network public opinion spread, combined with life cycle theory [38], this paper sets out the evolutionary process of this event. The stage of public opinion is divided in the formation of public opinion and the subsidence of public opinion, and analysis of the game between its participating subjects. The affected party believed that the medical accident should be primarily the responsibility of the medical party, so he defended his rights through the media and the media. The medical side responds through its own official Internet platform. Netizens began

to call attention to the incident, and public opinion on the Internet came into being. As netizens discussed the incident, information about the incident spreads widely on the Internet. Both doctors and patients further develop their voices and responses to defend their respective rights. In many responses from both sides, netizens gradually questioned the truth of the incident from the initial shock and sympathy, and finally discussed the attribution of responsibility and reflection on the current lack of trust between doctors and patients. Public opinion has repeatedly reversed. Because of the incident, netizens have paid great attention to and discussed it hotly. The relevant government departments of the hospital had to attract attention and respond. Due to multiple pressures such as media follow-up reports, continued attention from netizens, and official government intervention, the doctors and patients finally reached an agreement to properly resolve the incident. As a result, the sentiment of netizens has eased, and online public opinion has gradually subsided. The figure 1 shows the analysis results of the evolutionary process of network public opinion of the doctor-patient relationship.

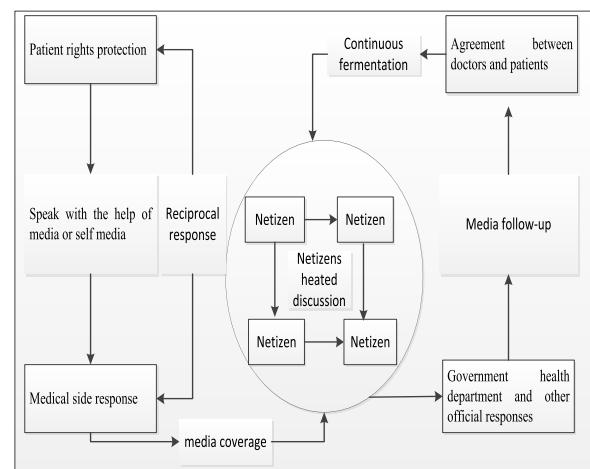


FIGURE 1. The evolution process of network public opinion on the doctor-patient relationship.

IV. GAME EQUILIBRIUM ANALYSIS

In the same living environment, the tripartite game model is a stable state realized by the tripartite players for the utilization of a certain kind of common resources. This is an evolutionary game relationship due to the dynamics and persistence of the game among populations. Referring to the tripartite game method of scholars, the game model of this paper is designed [39].

(1) Definition of game related content

There are three participants A , B and C , and each has two optional behavior strategies $A(A(P_1)\bar{A})$, $B(B(P_2)\bar{B})$, $C(C(P_3)\bar{C})$. P_1 , P_2 and P_3 is the probability that the three parties choose the first behavior strategy. Thus, eight kinds of game strategy combination can be generated, and the strategy combination and income are shown in Table 1.

TABLE 1. Tripartite game strategy combination.

Strategy combination	A	B	C
(A, B, C)	a_1	b_1	c_1
(A, B, \bar{C})	a_2	b_2	c_2
(A, \bar{B}, C)	a_3	b_3	c_3
(A, \bar{B}, \bar{C})	a_4	b_4	c_4
(\bar{A}, B, C)	a_5	b_5	c_5
(\bar{A}, B, \bar{C})	a_6	b_6	c_6
(\bar{A}, \bar{B}, C)	a_7	b_7	c_7
$(\bar{A}, \bar{B}, \bar{C})$	a_8	b_8	c_8

(2) Copy dynamic equation

$$U_A = P_2P_3a_1 + P_2(1 - P_3)a_2 + (1 - P_2)P_3a_3 + (1 - P_2)P_3a_3 + (1 - P_2)(1 - P_3)a_4$$

$$U_{\bar{A}} = P_2P_3a_5 + P_2(1 - P_3)a_6 + (1 - P_2)P_3a_7 \times (1 - P_2)(1 - P_3)a_8$$

$$\bar{U}_{\bar{A}} = P_1U_A + (1 - P_1)U_{\bar{A}}$$

$$U_{\bar{A}} = P_2P_3a_5 + P_2(1 - P_3)a_6 + (1 - P_2)P_3a_7F(P_1)$$

$$= \frac{dp_1}{dt} = P_1(U_A - \bar{U}) = P_1(1 - P_1)(U_A - \bar{U}_{\bar{A}})$$

U_A represents the expected benefits of participant A choice of strategy A.

$\bar{U}_{\bar{A}}$ represents the expected return of strategy \bar{A} selected by participant A.

$\bar{U}_{\bar{A}}$ represents the average return of participant A.

The dynamic differential equation $F(P_1)$ is the replicator dynamic equation. Let $F(P_1) = 0$, the stable state of the participants can be obtained by solving the function equation, and then the evolutionary stability strategy can be obtained.

The formation of network public opinion on the doctor patient-relationship is rapid and short-lived. The affected party voiced its rights on the Internet through various channels. The medical side responds through the official platform or decides to be silent. After receiving relevant information, netizens expressed their attitudes towards both doctors and patients through comments and reposts, so that public opinion quickly spread, and network public opinion of the doctor-patient relationship was formed.

(1) Based on the evolutionary game model of the formation stage of network public opinion on the doctor-patient relationship, this paper gives the following basic assumptions:

Hypothesis 1: suppose that there are three rational subjects: patients, doctors and netizens. Each strategy is reciprocally exclusive. Each entity in the tripartite evolutionary game model is bounded rational and always wants to maximize its utility.

Hypothesis 2: If the probability of the right protection is P_1 the probability of excessive rights protection is $1 - P_1$. If the probability of the response is P_2 , the probability of not responding is $1 - P_2$. If the probability of Internet users choosing to support the patient is P_3 , the probability of choosing to support the doctor is $1 - P_3$.

(2) Suppose that the normal income of the patient is I_{11} . The additional income of the patient to obtain public opinion support of netizens is I_{12} . Additional benefits from excessive rights protection of patients I_{13} . The cost of the patient's voice is C_{11} . The risk of public opinion pressure denounced by netizens is R_{11} .

Suppose that the normal income of the medical side receiving the support of Internet users is I_{21} . The positive image income of the response from the medical side was I_{22} . When the patients are defending their rights, the additional income of the medical side is I_{23} . The fixed cost of response is C_{21} . When the doctor does not respond, the additional compensation paid by the doctor to the patient is μ_{21} . The risk of being questioned and denounced by netizens is R_{21} . The risk of adverse effect caused by the inherent thinking of the public is R_{22} . When patients' rights are over protected, the actual loss of Internet users' support is e_{21} . The negative impact on hospital reputation caused by the expansion of the incident was a_{21} .

The normal income of netizens to support the legitimate rights protection of patients is I_{31} . When the patients' rights are over protected, the normal income of netizens supporting the medical side is I_{32} . The income of netizens from the medical response was I_{33} . When the medical side does not respond, the cost of Internet users looking for favorable information to support the medical side is C_{31} . The actual loss caused by Internet users' support for patients' excessive rights protection is e_{31} . The negative impact of netizens' support for patients' excessive rights protection on social stability is a_{31} . When patients are defending their rights, the negative impact of netizens' support on social stability is a_{32} .

(3) The combination of game strategy: the patient's tactical choice for defending rights is legitimate or excessive. The medical party can choose to respond to or not to respond to the patient's voice. The behavior strategy choice of Internet users is to assist patients or doctors. The game strategy combination and corresponding benefits of the affected party, medical party and netizen are shown in Table 2.

The evolutionary game equilibrium solution process of public opinion formation stage of doctor-patient relationship is as follows:

(1) The replication dynamic equation of the proper strategy was selected by the patients to protect their rights.

Suppose that the right protection of the patient is U_{11} , the excessive rights protection right is U_{12} , and the average return is, so:

$$U_{11} = P_2P_3(I_{11} + I_{12} - C_{11} - C_{12}) + P_2(1 - P_3) \times (I_{11} - C_{11} - C_{12}) + (1 - P_2)P_3(I_{11} + I_{12} - C_{11}) + (1 - P_2)(1 - P_3)(I_{11} - C_{11}) = P_3I_{12} + I_{11} - C_{11} - P_2C_{12}$$

TABLE 2. Income Matrix of patients, doctors and netizens.

The combination of strategies	The patients	The doctors	The netizens
(Right protection,respond,support the patient)	$I_{11} + I_{12} - C_{11} - C_{12}$	$I_{22} - C_{21} - R_{22} - a_{21}$	$I_{31} + I_{33}$
(Right protection,respond,support the doctors)	$I_{11} - C_{11} - C_{12}$	$I_{21} + I_{22} + I_{23} - C_{21}$	$I_{33} - a_{32}$
(Right protection,not respond,support the patient)	$I_{11} + I_{12} - C_{11}$	$-\mu_{21} - R_{21}$	I_{31}
(Right protection,not respond,support the doctors)	$I_{11} - C_{11}$	$I_{21} + I_{23}$	$-C_{31} - a_{32}$
(Excessive rights protection,respond,support the doctors)	$I_{11} + I_{13} - C_{11} - C_{12} - R_{11}$	$I_{21} + I_{22} - C_{21}$	$I_{32} + I_{33}$
(Excessive rights protection,respond,support the patient)	$I_{11} + I_{12} + I_{13} - C_{11} - C_{12}$	$I_{22} - C_{21} - R_{22} - a_{21}$	$I_{33} - e_{31} - a_{31}$
(Excessive rights protection,not respond,support the doctors)	$I_{11} + I_{13} - C_{11} - R_{11}$	I_{21}	$I_{32} - C_{31}$
(Excessive rights protection,not respond,support the patient)	$I_{11} + I_{12} + I_{13} - C_{11}$	$-\mu_{21} - R_{21} - e_{21}$	$-e_{31} - a_{31}$

$$\begin{aligned}
 U_{12} &= P_2 P_3 (I_{11} + I_{12} + I_{13} - C_{11} - C_{12}) \\
 &+ P_2 (1 - P_3) (I_{11} + I_{13} - C_{11} - C_{12} - R_{11}) \\
 &+ (1 - P_2) P_3 (I_{11} + I_{12} + I_{13} - C_{11}) \\
 &+ (1 - P_2) (1 - P_3) (I_{11} + I_{13} - C_{11} - R_{11}) \\
 &= P_3 I_{12} + P_3 R_{11} + I_{11} + I_{13} - P_2 C_{12} - C_{11} - R_{11} \\
 \bar{U} &= P_1 U_{11} + (1 + P_1) U_{12}
 \end{aligned}$$

Thus, the replication dynamic equation of choosing the proper strategy for defending the rights of the affected party is obtained as follows:

$$\begin{aligned}
 (P_1) &= \frac{dP_1}{dt} = P_1 (1 - P_1) (U_{11} - \bar{U}_1) \\
 &= P_1 (1 - P_1)^2 (R_{11} - P_3 R_{11} - I_{13}) \quad (1)
 \end{aligned}$$

When $F(P_1) = 0$, the equilibrium point of three party games is $P_1 = 0, 1, P_3 = \frac{R_{11} - I_{13}}{R_{11}}$, when $P_3 = \frac{R_{11} - I_{13}}{R_{11}}, F(P_1) = 0$, at this time, regardless of the value of P_1 , the interests of the three parties can reach the maximum, and all points are dynamic equilibrium points; When $P_3 > \frac{R_{11} - I_{13}}{R_{11}}, \left. \frac{\partial F(P_1)}{\partial P_1} \right|_{x=1} < 0, \left. \frac{\partial F(P_1)}{\partial P_1} \right|_{x=0} > 0, P_1 = 1$, the equilibrium point is reached. The patient's right protection is the strategy of evolution and stability; when

$P_3 < \frac{R_{11} - I_{13}}{R_{11}}, \left. \frac{\partial F(P_1)}{\partial P_1} \right|_{x=1} > 0, \left. \frac{\partial F(P_1)}{\partial P_1} \right|_{x=0} < 0, P_1 = 0$, the equilibrium point is reached, the patient's choice of over safeguarding rights is an evolutionary and stable strategy.

Similarly, the replication dynamic equation of hospital selection response strategy is as follows:

$$\begin{aligned}
 F(P_2) &= \frac{dP_2}{dt} = P_2 (1 - P_2) (U_{21} - \bar{U}_2) \\
 &= P_2 (1 - P_2) (P_3 \mu_{21} + P_3 R_{21} + P_3 e_{21} \\
 &+ I_{22} - P_3 R_{22} - P_3 a_{21} - P_1 P_3 e_{21} - C_{21}) \quad (2)
 \end{aligned}$$

In the same way, the replication dynamic equation of netizens selection response strategy is as follows:

$$\begin{aligned}
 F(P_3) &= \frac{dP_3}{dt} \\
 &= P_3 (1 - P_3) (U_{31} - \bar{U}_3) \\
 &= P_3 (1 - P_3) (P_1 I_{31} + P_1 e_{31} + P_1 a_{31} + P_1 I_{32} \\
 &+ C_{31} - P_1 a_{32} - P_2 C_{31} - I_{32} - e_{31} - a_{31}) \quad (3)
 \end{aligned}$$

According to the detailed steps of the tripartite agent evolutionary game model [40], [41], this paper uses equations (1), (2) and (3) to solve the evolutionary equilibrium state of tripartite subject game in the formation stage of public opinion of the doctor-patient relationship, as shown in Table 3.

TABLE 3. The evolutionary equilibrium solution of patients, doctors and netizens.

	The point of equilibrium is $P_i = 0$	The point of equilibrium is $P_i = 1$
Patients $i = 1$	$P_3 < \frac{R_{11} - I_{13}}{R_{11}}$	$P_3 > \frac{R_{11} - I_{13}}{R_{11}}$
Doctors $i = 2$	$P_1 < \frac{\mu_{21} + R_{21} + e_{21} - R_{22} - a_{21}}{e_{21}} + \frac{I_{21} - C_{21}}{e_{21}} \frac{1}{P_3}$	$P_1 > \frac{\mu_{21} + R_{21} + e_{21} - R_{22} - a_{21}}{e_{21}} + \frac{I_{21} - C_{21}}{e_{21}} \frac{1}{P_3}$
Netizens $i = 3$	$P_2 < \frac{I_{31} + I_{32} + e_{31} + a_{31} - a_{32}}{C_{31}} P_1 + \frac{C_{31} - I_{32} - e_{31} - a_{31}}{C_{31}}$	$P_2 > \frac{I_{31} + I_{32} + e_{31} + a_{31} - a_{32}}{C_{31}} P_1 + \frac{C_{31} - I_{32} - e_{31} - a_{31}}{C_{31}}$

After the occurrence of medical and health events, in order to safeguard their own interests, patients often express their opinions through the convenient and fast network media and create the focus of public opinion, so that the event can enter the public view in a short time, leading to the formation of network public opinion on the doctor-patient relationship. From the evolutionary equilibrium solution of the rights of the patients in Table 3, it can be concluded that when the pressure and risk of excessive rights protection of is high, the patients tend to take the legitimate rights as their own evolutionary stable strategy. And the response of the doctors to the patient’s rights depends on the cost, negative impact, the risk of adverse effect, additional compensation, the actual loss of not responding, the risk of being questioned and condemned by the netizens, and so on. The attitude of netizens to both doctors and patients is determined according to the information provided by both sides. Patients protect their rights according to law, and doctors respond, so that netizens can get full and true information. This is conducive to the rational judgment of netizens, and promotes the healthy development of network public opinion of the doctor-patient relationship.

Game equilibrium analysis of public opinion decline stage in the doctor-patient relationship:

The influence of network public opinion of the doctor-patient relationship has been rapidly expanded. In order to maintain the stability of social, shape the positive image. The government disperses the focus of public opinion by intervening, or being silent to control and appease the public opinion. The media are involved in the whole process of the evolution of the network public opinion of the doctor-patient relationship. Objective reporting can block the development of the network public opinion crisis to a certain extent, and the false reports with obvious tendency are more likely to arouse the attention and discussion of netizens, to promote the development of public opinion crisis. Under the multiple pressures of the government, media and public opinion, the medical and patient parties finally reach an agreement to solve the event. Internet users, as the public, can choose to maintain the public interest and continue to participate in the public opinion after knowing the result of the event, or withdraw from the public

opinion due to the satisfaction of the event results or other objective factors, and the network public opinion of doctor-patient relationship gradually subsides.

(1) Based on the evolutionary game model of network public opinion of the doctor-patient relationship in recession, this paper gives the following basic assumptions:

Hypothesis 1: suppose that there are three rational subjects: Media, government and netizens. Each strategy is mutually exclusive. Each entity in the tripartite evolutionary game model is bounded rational and wants to maximize its utility.

Hypothesis 2: If the probability of media choosing objective report is P_1 , the probability of a false report is $1 - P_1$; if the probability of government choosing control is P_2 , the probability of not controlling is $1 - P_2$; if the probability of netizens choosing to participate is P_3 , the probability of not participating is $1 - P_3$.

(2) Assuming that when netizens participate, the amount of hits and advertising revenue obtained by media reports is I_{11} . When netizens participate, the extra hits and advertising revenue from false media reports are I_{12} . The fixed cost of media coverage is C_{11} . When netizens participate, the cost of tracking report is C_{12} . Under the control of the government, the fine for false media reports is f_{11} . The risk of the decrease of the number of hits and the decrease of the attention caused by the objective media report is R_{11} . The damage of false media reports on their own image and the pressure of public opinion are V_{11} .

Government control can improve the credibility of the government I_{21} . Under the control of the government, the benefits of objective media reports to social stability are I_{22} . When the media reports unreasonably, the fine income obtained by government control is I_{23} . The general cost of government control is C_{21} . When netizens participate, the additional cost of government control is C_{22} . The loss caused by the government’s neglect of control is e_{21} . When netizens participate, the loss caused by the government’s neglect of control is e_{22} . When the government does not control the time, the false media reports bring negative effects to the government e_{23} .

Netizens get the sense of identity and satisfaction when they participate in public opinion, and the potential benefits are I_{31} . The inherent benefit of netizens’ withdrawal from

TABLE 4. Income matrix of media, government and netizens.

Strategy combination	Media	Government	Netizens
(Report objectively, manage and control, participant)	$I_{11} - C_{11} - C_{12} - R_{11}$	$I_{21} + I_{22} - C_{21} - c_{22}$	$I_{31} + I_{33} - C_{31}$
(Report objectively, manage and not participant)	$-C_{11}$	$I_{21} + I_{22} - C_{21}$	$I_{32} + I_{33}$
(Report objectively, not manage and control, participant)	$I_{11} - C_{11} - C_{12} - R_{11}$	$-e_{21} - e_{22}$	$I_{31} - C_{31}$
(Report objectively, not manage and control, not participant)	$-C_{11}$	0	I_{32}
(Report falsely, manage and control, participant)	$I_{11} + I_{12} - C_{11} - C_{12} - f_{11} - V_{11}$	$I_{21} + I_{23} - C_{21} - C_{22}$	$I_{31} + I_{33} - C_{31} - a_{31}$
(Report falsely, manage and control, not participant)	$-C_{11} - f_{11}$	$I_{21} + I_{23} - C_{21}$	$I_{32} + I_{33}$
(Report falsely, not manage and control, participant)	$I_{11} + I_{12} - C_{11} - C_{12} - R_{11}$	$-e_{21} - e_{22} - e_{23}$	$I_{31} - C_{31} - a_{31}$
(Report falsely, not manage and control, not participant)	$-C_{11}$	0	I_{32}

public opinion is I_{32} . The benefits of good social environment from government control are I_{33} . The fixed cost of netizens' participation in public opinion is C_{31} . The negative impact of netizens' participation in public opinion is a_{31} .

(3) The combination of game strategy: the strategy choice of the media report is an objective report or false report; the strategy choice of government is control or not control; the strategy choice of netizens is participating, or not to participate. Media, government and netizens of the combination of game strategy and the income of correspondence as shown in Table 4.

The evolutionary game equilibrium solution process of public opinion decline stage of the doctor-patient relationship is as follows:

(1) Replication dynamic equations for media selection of objective reporting strategy.

Suppose that the expected return of objective report is U_{11} , the expected return of false report is U_{12} , and the average return is \bar{U} , so:

$$\begin{aligned}
 U_{11} &= P_2 P_3 (I_{11} - C_{11} - C_{12} - R_{11}) + P_2 (1 - P_3) (-C_{11}) \\
 &\quad + (1 - P_2) P_3 (I_{11} - C_{11} - C_{12} - R_{11}) \\
 &\quad + (1 - P_2) (1 - P_3) (-C_{11}) \\
 &= P_3 I_{11} - P_3 C_{12} - P_3 R_{11} - C_{11} \\
 U_{12} &= P_2 P_3 (I_{11} + I_{12} - C_{11} - C_{12} - f_{11} - V_{11}) \\
 &\quad + P_2 (1 - P_3) (-C_{11} - f_{11}) + (1 - P_2) \\
 &\quad \times P_3 (I_{11} + I_{12} - C_{11} - C_{12} - R_{11}) + (1 - P_2) \\
 &\quad \times (1 - P_3) (-C_{11}) \\
 &= P_3 I_{11} + P_3 I_{12} + P_2 P_3 R_{11} - P_3 C_{12} - P_3 R_{11} \\
 &\quad - P_2 P_3 V_{11} - P_2 f_{11} - C_{11} \\
 \bar{U} &= P_1 U_{11} + (1 - P_1) U_{12}
 \end{aligned}$$

Thus, we can get the dynamic equation which the netizens choose the strategy of supporting the patients is:

$$\begin{aligned}
 F(P_1) &= \frac{dP_1}{dt} = P_1 (1 - P_1) (U_{11} - \bar{U}) \\
 P_1 &= (1 - P_1) (P_2 P_3 V_{11} + P_2 f_{11} - P_2 P_3 R_{11} - P_3) \tag{4}
 \end{aligned}$$

When $F(P_1) = 0$, the equilibrium point of three party game is $P_1 = 0, 1, P_2 = \frac{I_{12}}{P_3(V_{11}-R_{11})+f_{11}} P_3$, when $P_2 = \frac{I_{12}}{P_3(V_{11}-R_{11})+f_{11}} P_3, F(P_1) = 0$, at this time, regardless of the value of P_1 , the interests of the three parties can reach the maximum, and all points are dynamic equilibrium points; when $P_2 > \frac{I_{12}}{P_3(V_{11}-R_{11})+f_{11}} P_3, \frac{\partial F(P_1)}{\partial P_1} \Big|_{x=1} \left(0, \frac{\partial F(P_1)}{\partial P_1} \Big|_{x=0} \right) > 0, P_1 = 1$, the equilibrium point is reached, media's choice of objective report is an evolutionary and stable strategy; When $P_2 < \frac{I_{12}}{P_3(V_{11}-R_{11})+f_{11}} P_3, \frac{\partial F(P_1)}{\partial P_1} \Big|_{x=1} > 0, \frac{\partial F(P_1)}{\partial P_1} \Big|_{x=0} < 0, P_1 = 0$, the equilibrium point is reached, it is an evolutionary stable strategy for the media to choose false reports.

Similarly, the replication dynamic equation of hospital selection response strategy is as follows:

$$\begin{aligned}
 F(P_2) &= \frac{dP_2}{dt} = P_2 (1 - P_2) (U_{21} - \bar{U}) \\
 &= P_2 (1 - P_2) (P_1 I_{22} + P_3 e_{21} + P_3 e_{22} + P_3 e_{23} \\
 &\quad + I_{21} + I_{23} - P_1 P_3 e_{23} - P_3 C_{22} - P_1 I_{23} - C_{21}) \tag{5}
 \end{aligned}$$

In the same way, the replication dynamic equation of netizens' choice of supporting the patient strategy is as follows:

$$\begin{aligned}
 F(P_3) &= \frac{dP_3}{dt} = P_3 (1 - P_3) (U_{31} - \bar{U}_3) \\
 &\quad \times P_3 (1 - P_3) (P_1 a_{31} + I_{31} - I_{32} - C_{31} - a_{31}) \tag{6}
 \end{aligned}$$

TABLE 5. The evolution equilibrium Solution of media, government and netizens.

	The point of equilibrium is $P_i = 0$	The point of equilibrium is $P_i = 1$
Media $i = 1$	$P_2 < \frac{I_{12}}{P_3(V_{11} - R_{11}) + f_{11}} P_3$	$P_2 > \frac{I_{12}}{P_3(V_{11} - R_{11}) + f_{11}} P_3$
Government $i = 2$	$P_3 < \frac{c_{21} - I_{21} - I_{23}}{e_{21} + e_{22} + e_{23} - C_{22} - P_1 e_{23}} - \frac{I_{23} - I_{22}}{e_{21} + e_{22} + e_{23} - C_{22} - P_1 e_{23}} P_1$	$P_3 < \frac{c_{21} - I_{21} - I_{23}}{e_{21} + e_{22} + e_{23} - C_{22} - P_1 e_{23}} - \frac{I_{23} - I_{22}}{e_{21} + e_{22} + e_{23} - C_{22} - P_1 e_{23}} P_1$
Netizens $i = 3$	$P_1 < \frac{I_{32} + C_{31} + a_{31} - I_{31}}{a_{31}}$	$P_1 > \frac{I_{32} + C_{31} + a_{31} - I_{31}}{a_{31}}$

According to the detailed steps of building a tripartite evolutionary game model, the equations (4), (5) and (6) are substituted, and this paper solves the evolutionary equilibrium state of the tripartite game in the decline stage of network public opinion of the doctor-patient relationship, as shown in Table 5.

VI. DISCUSSION

As one of the hot issues, medical and health incidents have gradually attracted the attention of the government. After the development of network public opinion of the doctor-patient relationship to a certain stage, the losses will be caused by the inaction of government, such as the deterioration of the situation, the unrest of the social, the decline of its own credibility, the negative impact, and so on. Therefore, the government is inclined to manage and control by taking timely and effective measures to appease the public opinion in network, and the handling of public opinion events has gradually changed from the traditional way of “chasing and intercepting” to the open and transparent way. In order to protect the right to learn the truth, the government should release the relevant information of public opinion truthfully and encourage the major media to report. However, to prevent the media from making false reports on the public opinion in network for profiteering and malicious propaganda, the government may refer to the evolutionary equilibrium solution of the media in Table 5 to increase the fines that the media should pay for false reports and public opinion pressures. The evolutionary stabilization strategy of the media tends to be objective reporting. Also, after the realization of self-demand and benefits of netizens, the discussion and dissemination of the event will also spontaneously reduce. The negative impact on society will be avoided, and network public opinion of the doctor-patient relationship will gradually decline.

VI. CONCLUSION

This paper takes the “maternal falling into the building incident” in Yulin, Shaanxi as an example. By analyzing the game models of the participants at each stage of the dynamic evolution of network public opinion on the doctor-patient relationship, it is concluded that the development of network public opinion of the doctor-patient relationship is the result

of the joint action of multiple participants. Due to the professionalism of medical knowledge, traditional doctor-patient communication is a two-way asymmetric communication. Vulnerable patients often use “we media”, media and other Internet platforms to continue and realize their rights and interests. In order to gain huge profits and attention, the media habitually conducts trend reports from the perspective of the affected party. The medical side often responds to the affected party’s rights protection only through its own official Weibo. The channel is single, and related information is discussed and disseminated after attracting the attention of netizens. Network public opinion of the doctor-patient relationship quickly formed and was pushed to the next stage. Most netizens quickly stand in the affected party owing to limited knowledge level and psychological factors. After the influence of public opinion reaches a certain level, the government and relevant departments will take action to control the progress of public opinion and ease the relationship between doctors and patients. It can be found that events, netizens, media and government have different influences on the evolution of Internet public opinion on doctor-patient events. The doctor-patient incident directly stimulates netizens to respond to the doctor-patient problem. As a direct actor, the hospital’s negative reaction to public opinion directly expands the risk of network public opinion. The attention of Internet media directly promotes the popularity of network public opinion on doctor-patient events. The weakening of network media and the pursuit of economic benefits can easily lead to the imbalance of discourse in media reports. Instead of clarifying the facts, we should promote the transformation of medical and patient events to the whole people. The openness of official news not only clarifies the facts and responds to concerns, but also reduces the popularity of online public opinion on medical and patient events. The government is the main force to restrain the risk of network public opinion. The improvement of government regulation level can well restrain the development of network public opinion of the doctor-patient event. However, in the process of network public opinion performance of the doctor-patient event, the government public opinion disposal deviates from the process of network public opinion, which expands the risk of network public opinion of the doctor-patient event.

In order to create a healthy public opinion environment and guide the harmonious development of network public opinion of the doctor-patient relationship, this paper makes the following suggestions from the perspective of the medical side, government, media and netizens. First of all, the medical side needs to form strong crisis awareness, pays attention to media communication, and improves communication issues. After the network public opinion of the doctor-patient relationship is formed, it is necessary to proactively and quickly confess the true situation of the incident to the public. Translate professional medical terminology into easy-to-understand words, explain it in simple terms, seize the commanding heights, and continue to publish instant information. Secondly, the government should develop and improve medical systems and laws and regulations related to public opinion on medical-related networks, through appropriate intervention. Guide the affected parties to defend their rights through the Internet, media and other channels, and strengthen the control and punishment of false media reports. Guide the media to carry out objective and true information transmission and public opinion supervision. Thirdly, the media should strengthen their professional ethics. In the report on hot medical and health incidents, we should stand squarely, maintain objective neutrality, correctly guide public opinion, and provide benefits for rebuilding doctor-patient trust and maintaining social stability. Finally, the participation of netizens in the whole process of public opinion evolution of medical-related networks should remain rational and improve their personal quality. Netizens should understand basic medical knowledge, learn to identify the authenticity of information from patients, doctors, and media, reasonably participate in public opinion, and promote the harmonious development of doctor-patient relationships.

ACKNOWLEDGMENT

The author would like to thank the research team of the laboratory. The researchers are very serious and responsible for this study.

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