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PERSPECTIVE

Applying Game Theory Models to Inpatient Medicine: Opportunities to Improve Care

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Abstract

Inpatient hospital costs have been increasing exponentially in the United States. Part of this increase is attributed to over and undertreatment, leading to higher costs and potential patient harm. Research improving clinician−patient interactions can help minimize and optimize the costs. Game theory has the ability improve clinician−patient interaction by modeling outcomes. Using variations of game theory, the bad doctor bad patient stigma can reframed to incentives. We believe the use of different models (prisoner dilemma, centipede game, assurance game, and chicken game) can outline the challenges faced during common inpatient scenarios, including end of life conversations and aggressive procedures. Applying game theory to multiple inpatient scenarios may also assist with analysis during morbidity and mortality conferences and quality improvement projects.

Keywords: Game theory, Prisoner's dilemma, Inpatient medicine, Patient−doctor interactions, Decision-making

1. Introduction

Healthcare spending is on the rise in the United States, with inpatient hospital costs constituting one-third of healthcare spending.[1] Inpatient clinicians make impactful decisions daily with limited information known about each patient. They make treatment recommendations, and the patient decides whether to follow those recommendations. Clinicians, about 42% of the time, will either overtreat or undertreat a condition, leading to increased healthcare spending or patient harm.[2] We believe these are not the result of "bad doctors" or "bad patients", but instead due to the inherent incentive structures that make these decisions predictable. Game theory has great potential in understanding the clinician−patient interactions[2,3] and describes the individual and collective incentives for competition and cooperation. This framework has been demonstrated in offering end-of-life chemotherapy, prescription of antibiotics and opiates, and administration of vaccines.[4-7] In this paper, we introduce several game structures in the context of inpatient clinical scenarios to demonstrate the broader impact of game theory. The paper focuses primarily on the inpatient setting, but may also be extrapolated to other interactions and similar outpatient scenarios.

2. Game theory models and applications

2.1. The Prisoner's dilemma

The Prisoner's Dilemma is a standard model involving trust and betrayal. The game scenario is described as two players having to independently choose to betray or to remain silent (Fig. 1). If both players remain silent, then each player will receive the minimal sentence. If one betrays while the other remains silent, then the former gets a lighter sentence and latter will receive the full sentence. If both players choose betrayal, then both will share the full sentence. The best collective outcome is when both players remain silent, and the worst collective outcome is when both betray. However, a rational player will always betray because the individual outcomes are always better with betrayal than silence. If Player One chooses to remain silent, then Player Two would betray to receive a lighter sentence, since this is the better outcome for Player

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		Player 2	
		Trust	Betray
Player 1	Trust	P1 1 year P2 1 year	P1 10 years P2 1 year
	Betray	P1 1 year P2 10 years	P1 5 years P2 5 years

Fig. 1. ***Prisoner's Dilemma.*** *Players choose a strategy to trust or betray. Numbers in each cell represent individual outcomes. Although the best collective strategy is to trust, the most rational individual strategy is to betray, thus yielding the worst collective outcome.*

Two. If Player One betrays, then Player Two would betray as well, since remaining silent would mean that Player Two gets the full sentence, the worst individual outcome. Regardless of Player One's choice, the best outcome for Player Two would be to betray. Similarly, Player One would reach the same conclusion and would betray, therefore, leading to the worst collective outcome and both will remain in prison. In this scenario, betrayal is the logical choice and the dominant strategy. Both players pursued their best individual strategies but paradoxically arrived at the worst collective outcome.

A clinical example involves the practice of prescribing opiates for patients with sickle cell during acute pain episode. A clinician can either titrate opiates rapidly or slowly to control pain and the patient would either endorse or deny pain to guide titration. The best collective interest for both the clinician and patient is when pain is controlled and the patient is comfortable, resulting in timely discharge for the patient. However, clinicians are often hesitant to increase opiates fearing opiate overdose and contributing to opiate dependence. Consequently, patients may endorse pain more frequently, leading the clinician to falsely believe that the patient is exhibiting drug-seeking behaviors, consistent with a stigma sickle cell patients carry.[8] The end result is uncontrolled pain for the patient and frustration for the clinician, leading to global dissatisfaction. Despite both the clinician and patient making rational decisions, the worst possible outcome (longer hospital stay and readmission) becomes the common product.[9]

Another example is aggressive treatment/interventions (such as dialysis or tracheostomy) near the end-of-life. The best collective outcome is pursuing comfort-oriented measures and minimizing additional risks to the patient. The worst collective outcome is pursuing aggressive interventions for small health benefits, while risking complications and expending resources. Families of patients with poor clinical prognosis often accept these aggressive interventions to maintain control. They are reluctant to give up hope without exploring all options, regardless of the possible negative impact.[10] Clinicians may choose to not offer any interventions as it would not meaningfully change the patient's clinical outcome. However, clinicians often have difficulty discussing end-of-life options. They experience emotional distress, failure, guilt, and disappointment if they do not offer their patients or family any interventions. Furthermore, the clinician's decision is influenced heavily by the patient/family's preferences, especially in cases when outcomes are unpredictable which could lead to giving false hope that defies statistical expectations.[11]

Perhaps more common is treating patients with vague complaints. The clinician may choose to expend lengthy time understanding the nature of the complaint and providing recommendations. On the other hand, the clinician may simply write a prescription and complete the encounter in a fraction on the time. Almost 38% of the time, physicians overtreat due to inadequate time spent with patients.[12] This scenario is particularly challenging in patients with psychosomatic features when the clinician is unfamiliar with the patient's chronic history. This "over-treat" strategy becomes dominant because it is time efficient and satisfies the patient. However, this may result in a poorer societal outcome from unexpected side effects and polypharmacy, and can potentially masquerade a serious illness.

2.2. Centipede game

The centipede game is designed to model the sequential iteration of the Prisoner's Dilemma, adding a temporal component. In this game, both players benefit with successive interactions, building mutual trust and cooperation, leading to the best collective outcome. However, if a player decides to defect at any point, then the game terminates (Fig. 2). The main distinction with this game is that reciprocal cooperation develops over time. A player is willing to risk a lower payoff if they can trust the other player to cooperate. In contrast to the Prisoner's Dilemma, the outcome of reciprocal cooperation is that both players would pursue a strategy

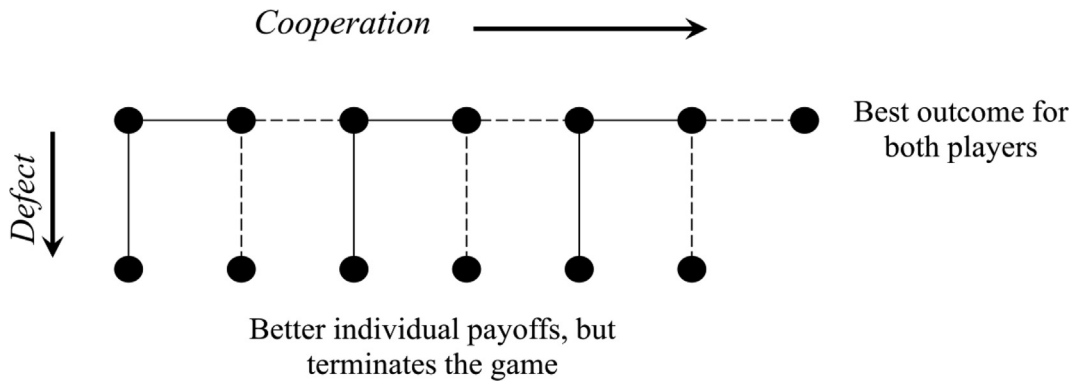

Fig. 2. ***Centipede model.*** *Each player takes turn to decide to cooperate, thus continuing the game, or defect, thus terminating the game. The best collective outcome is to reach the last node; however, the incentive to defect is greater than to proceed to the next node. Hence, mutual cooperation involves taking mutual risks. Dashed lines are clinician's move, while solid lines are patient's move.*

towards the best collective outcome, rather than pursuing the best individual strategy.

One fitting example of the game model is caring for patients with opiate use disorder. A patient with chronic intravenous opioid use is admitted to the hospital for endocarditis. The best outcome for both players would be to complete the medical work up and necessary treatment such that the patient can be discharged without readmission. During each patient–clinician interaction, the patient may either cooperate with the clinician's management or defect and self-discharge from the hospital. The incentives for patients to leave stem from lack of respect, inadequate pain control, inadequate withdrawal control, psychological distress, visitor restriction, or unwillingness to be physically confined to an institution.[13] Leaving against medical advice puts a bigger risk on the clinician as the patient can be readmitted with worse prognosis and higher mortality.[14,15] The clinician, at each step, decides whether or not to comply with the patient's requests such that the medical work up and the treatment continue. If the clinician defects, the clinician and staff can dedicate more time to other patients, whereas the patient would suffer more, leading to dissatisfaction and mutual defect. As the sequence of interactions progress without defection, the motivation to cooperate increases, emphasizing that cooperation within the first handful of interactions is key to developing mutual cooperation. This is especially relevant to the inpatient settings as trust needs to be rapidly established from the start.

2.3. Assurance game

Also known as the stag hunt game, this models the conflict between safety and social cooperation. This scenario describes two hunters deciding to hunt for a stag (larger reward but requires cooperation) or a hare (minimal reward but can hunt alone). If only one hunter chooses to hunt for a stag, then the effort would be wasted, as a stag is too strong for one hunter alone. The dilemma here asks the hunters to give up some autonomy in exchange for cooperation, leading to a larger reward. One analogy involves counseling patients with newly diagnosed heart failure. Providing counseling such as lifestyle modifications on salt and fluid consumption, blood pressure monitoring, daily weights, and anticipatory guidance will help patients better understand their disease with relatively low healthcare cost. However, such counseling is time-consuming and might be deferred if the clinician has no assurance that the patient would follow these instructions. Furthermore, if the clinician is not assured that the patient can achieve good outpatient follow-up, the clinician's strategy may involving keeping the patient in the hospital longer. If the patient has good outpatient follow up and family support, the clinician can discharge the patient once the respiratory status is at baseline, without extensive inpatient testing. This is particular relevant as congestive heart failure was among the top five conditions with the highest readmission rate.[16]

2.4. Chicken game

This game describes a conflict between two drivers on a collision course, where the best outcome occurs if either player yields, consequently obtaining an inferior social status. If neither player yields, the worst outcome occurs. An application of this scenario is when a patient demands to leave to smoke cigarettes and would likely be readmitted. The clinician counsels the patient that there is a risk of developing complications including death. The

patient yields to continue treatment, and the provider offers nicotine replacement therapy. A more impactful example would involve conflict among the care team, such as clinicians and nurses. If neither the clinician nor the nurse agrees to assume responsibility of a task (patient transportation, indwelling catheter insertion/removal, peripheral intravenous access), then a standoff would occur, risking delay in patient care and causing potential patient harm. The conflict could also occur between two medical teams, for instance, infectious disease and cardiology teams disagree on whether a transesophageal echocardiogram will benefit the patient, and thus the patient's treatment plan is stalled.

3. Discussion

This paper introduced a variety of game theory models in the context of common inpatient clinical scenarios and offered insights towards the interplay of the patient-physician interactions. As demonstrated, game theory provides a conceptual framework for how incentive structures impact cooperation and competition. It can minimize the notion of "bad patients" and "bad doctors" by highlighting that the decision-making process is rational and therefore predictable.

Game theory is an emerging concept within the healthcare system as the urgency to reduce costs continues. The misalignment of incentives is particularly useful with at-risk patient populations, such as those with limited access, poor socioeconomic status, and mental health and addiction problems. Realignment of incentives to be patient-centered is key to reducing cost, providing better care, and improving outcomes. We believe that it is not enough to only educate and increase awareness to practitioners, but a top-down approach to action would be more effective. For example, for years, the benefits of early palliative care intervention are well-known, yet referral rates remain low[17,18] Another example is that practitioners have long known about emerging antimicrobial resistance, yet inappropriate prescriptions continue to be written. Coalitions have been seen recently that aim to realign opposing incentives. The National Harm Reduction Coalition is a community that primarily focuses on medical conditions associated with drug use, including infections and drug overdoses. The interventions (providing naloxone and clean needles) and strategies (safer drug use and medication assisted treament) employed specifically targets patients with HIV, Hepatitis C, skin and soft tissue infections, and the ongoing overdose crisis.[19] Another example is antimicrobial stewardship programs, which monitor and advise on the use and misuse of antimicrobials. Antimicrobial stewardship programs use best practice guidelines to balance the individual need to treat with the societal need to conserve. Both of these examples utilize patient-centered strategies to pursue the best individual outcomes without compromising the best collective outcome. In addition to these large scale national movements, interventions can also occur at the institutional or departmental level. The concepts and models from game theory can be incorporated into mortality and morbidity discussions, within the design of quality improvement projects, and in medical education. Understanding the incentive structures behind a root cause will provide a unique perspective on the behaviors around a problem. Thus, we believe game theory offers a new perspective for research and modeling of patient-physician decision-making, and subsequently become another tool to enhance quality of care.

4. Conclusion

The decision making process during a hospitalization is complex and challenging. Game theory models offer insights to the patient-physician interactions. Strategies involving multilevel reform to realign individual interests with collective interests would be necessary to provide better and higher quality patient care. By understanding the different dynamics of the patient-physician interactions, game theory offers a direction for future research to promote better care.

Conflicts of interest statement

The authors declared no conflict of interest.

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