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Differentiating Interhospital Transfer Types: Varied Impacts and Diverging Coordination Strategies

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Interhospital transfer (IHT) is common in care delivery. As a form of care transition, IHT faces coordination challenges and can negatively affect care outcomes. Understanding the underlying reasons and the associated operational challenges of different IHT types can help hospital managers design mitigation mechanisms to improve the IHT care outcomes. We conceptually and empirically differentiate between clinical and non-clinical transfers based on their unique characteristics and compare their respective impacts on care outcomes, including length of stay (LOS), readmission, and mortality. Non-clinical transfers are found to have worse care outcomes than clinical transfers and largely accounts for the inferior care outcomes of IHT compared with direct admissions, perhaps due to inadequate care coordination. Since poor coordination between hospitals is frequently cited as a root cause of care quality problems, we investigate whether two coordination mechanisms, namely hospital system affiliation and transfer routinization, can mitigate the potential negative effects of IHT on care outcomes. Our analyses suggest that the two coordination mechanisms are associated with improved IHT outcomes, and both seem to have stronger effects for non-clinical transfers. Specifically, system affiliation and transfer routinization can reduce LOS and readmission for non-clinical transfers. The results offer valuable insights to hospital managers for improving IHT care outcomes.

Key words: coordination mechanism; destination choice strategy; hospital operations management; interhospital transfer types
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1. Introduction

In the United States, about two million emergency department (ED) patients are transferred to another acute care hospital annually (Kindermann et al. 2014). Patient transfers between hospitals are becoming more common as a result of increasingly specialized healthcare services and diversified healthcare resources. In fact, the growth rate of transferred patients exceeds that of directly admitted patients (Hernandez-Boussard et al. 2014). IHT inherently involves care coordination. To arrange a transfer, the sending hospital needs to negotiate with potential receiving hospitals (Bosk et al. 2011). Interhospital transfer (IHT) can cause operational problems because of inefficient coordination during the transfer process (Ong et al. 2011, Riesenberg et al. 2009). Coordinating IHT involves a considerable amount of efforts (Iwashyna 2012), such as identifying a hospital that accepts the patient and managing patient transportation and handoff. The overwhelming efforts may lead to incomplete, late, or even missing patient information (Harl et al. 2017, Herrigel et al. 2016), resulting in procedure delays, medical errors, and clinical complications (Ayabakan et al. 2017). These problems not only introduce risks to patients but also increase costs to hospitals. Several studies report that IHTs may have unfavorable impacts on care outcomes compared with direct admissions, such as longer length of stay (LOS) and higher odds of mortality (Flabouiris et al. 2008, Wiggers et al. 2011, Sokol-Hessner et al. 2016). However, it is unclear what drives the unfavorable IHT outcomes and whether certain IHT cases are more inclined to have poor outcomes than the others. Quality management principles suggest identifying root causes of problems before developing strategies and tactics to solve the problems (Percarpio et al. 2008). Thus, prior to evaluating and attempting to improve care outcomes of transferred patients, it is critical to understand the underlying reasons and inherent nature of IHTs.

The underlying reasons for IHT is an understudied topic. Little is known about whether patients and physicians even agree on the reasons for transfers (Wagner et al. 2013). Our study seeks to fill this gap by differentiating IHT types and estimating their effects on care outcomes. Moreover, we evaluate alternate coordination mechanisms that can mitigate unfavorable care outcomes of IHT.

Interhospital transfer of patients can occur for various reasons. For instance, about 44% of patients with acute myocardial infarction (AMI) need to be transferred to another hospital with Percutaneous Coronary Intervention (PCI) service (a treatment for patients with AMI) because almost two thirds of community hospitals in the United States cannot offer PCI. Patients can be transferred to a receiving hospital for specific diagnoses, procedures, or physician expertise not available at the sending hospital. Such clinically necessary transfers, which we denote *clinical transfers*, are justified by a strategic healthcare network design that matches patients to scarce healthcare resources and hence provides optimal care. Besides clinical necessity, patients may be transferred to another hospital for non-clinical reasons, such as capacity shortage, insurance, or convenience (Wagner et al. 2013). We refer to these transfers as *non-clinical transfers*. Since non-clinical transfers are driven by the variability of operational factors or patients' preferences, they tend to be unpredictable and ad hoc, and hence are likely to be a "pain point" of hospital operations. From the hospital decision makers' perspective, understanding the underlying reasons and the associated operational challenges of different IHT types can allow them to identify the IHT types with unfavorable outcomes and accordingly focus their efforts on designing mitigation mechanisms to improve care outcomes of these IHT types.

Clinical and non-clinical transfers are inherently different from an operational decision-making perspective. Clinical transfer is determined by the hospital's service scope, and transferring is the only option for out-of-scope conditions, and hence the hospital is more likely to pre-plan the course of actions and standardize the process, because the same process is executed for all patients with the same condition. Clinical transfer is typically governed by established interhospital protocols and strategic partnerships. For example, transfer protocols are prevalent in regionalized cares for trauma, STEMI, stroke, and cardiac arrest (Feazel et al. 2015, Kindermann et al. 2015). These characteristics of clinical transfer typically lead to relatively sufficient coordination between the sending hospital (i.e., "sender") and the receiving hospital (i.e., "receiver"). Non-clinical transfer, however, is often based on ad hoc decisions. Hospitals need to make decisions on the fly based on bed availability or patient's preferences. Hospitals often evaluate the possibility of retaining the patient first. Therefore, it is difficult to create standardized procedures, and consequently, non-clinical transfer tends to lack effective coordination. The stark difference between clinical and non-clinical transfers suggests that it is important to study the impacts of the two IHT types on care outcomes. The comparison can allow for proper evaluation of IHT and lead to managerial insights and better decision-making for IHT.

IHT faces a great deal of coordination challenges since the sender and the receiver need to exchange a large amount of information and collaborate on a series of tasks during the transfer (Ong et al. 2011, Riesenberg et al. 2009). Although poor coordination between hospitals is frequently cited as a root cause of adverse events associated with transitions of care (Ayabakan et al. 2017, Herrigel et al. 2016, Usher et al. 2016), there is little coordination guideline among providers for IHT (Green 2012), possibly because of the diverse IHT types. Different IHT types may require different coordination efforts. For example, negotiation with the receiving hospital is generally a time-consuming process (Bosk et al. 2011, Rosenberg et al. 2003), but it tends to be much more straightforward for clinical transfer, since it is a "must-transfer" situation, whereas for non-clinical transfer, the receiving hospital may view the transfer as patient dumping (Bosk et al. 2011) and refuse to accept the transfer. The different coordination requirements between IHT types indicate that hospital managers may need to consider diverse coordination mechanisms. Literature differentiates between formal and informal coordination mechanisms (Martinez and Jarillo 1989). The former is characterized by formal organizational structures resulting in centralized decision-making and financial control, whereas the latter is associated with informal lateral relationships (Agarwal 1982). Drawing on the literature, we investigate two coordination mechanisms: hospital system affiliation and transfer routinization. Hospital system affiliation refers to whether the sending and the receiving hospitals are within the same hospital system, and it can be regarded as a formal mechanism. In contrast, transfer routinization is defined as a repetitive and recognizable pattern of IHT workflows that are largely developed from repetition of transfers rather than imposed by formal organizational structures. We investigate the mitigation effects of these two coordination mechanisms on care outcomes for different IHT types and offer hospital managers important insight into coordination strategies tailored to each IHT type.

Our study makes three important contributions. First, we differentiate between clinical and non-clinical transfers. Our proposed dichotomy of IHT is based on a robust data-driven approach and can be easily adopted by other studies. We scrutinize many potential transfer reasons by analyzing the hospitals' capabilities in terms of diagnoses and procedures, physician availability, comorbidities, and patient ages, as well as patients' insurance coverage and distance to the referring (sending) and referred (receiving) hospitals. The empirical analysis suggests that non-clinical transfer is associated with worse care outcomes than clinical transfer and hence hospital managers should focus on improving the outcomes of non-clinical transfer. Second, we show the different effects of two interhospital coordination mechanisms, namely system affiliation and transfer routinization, on the care outcomes of the two IHT types. Non-clinical transfer between affiliated hospitals or with better routinization tends to be associated with better care outcomes. However, clinical transfer between affiliated hospitals results in higher odds of readmission and mortality. Collectively, these findings suggest that the two coordination mechanisms benefit non-clinical transfer to a greater extent. Third, our study provides hospital managers with a destination choice guideline based on transfer types. For non-clinical transfer, the sending hospital may prioritize choosing hospitals within the same hospital system as transfer destinations. However, clinical transfer decisions should consider out-of-system destinations to a greater extent. Since non-clinical transfer is less coordinated by nature, the sending hospital, which makes the transfer decision, can seek to increase routinization by establishing long-term partnerships with a small number of hospitals. In contrast, for clinical transfer, the sending hospital should consider a broader set of receiving hospitals to better utilize healthcare resources.

2. Hypothesis Development and Related Literature

IHT admissions are prevalent in practice and account for an increasing percentage of overall hospital admissions and healthcare costs in the United States. However, the findings in medical literature (see Table 1) are somewhat inconsistent on the impacts of IHT on patient care outcomes. While many studies find that IHT has unfavorable effects on care outcomes, several studies report neutral or even favorable impacts of IHT on length of stay (LOS), readmission, and mortality (Duke and Green 2001, Garwe et al. 2010, Nathens et al. 2003, Russell et al. 2015, Selevan et al. 1999). The discrepancy is likely due to a lack of understanding of the underlying reasons of IHT since the scopes of these studies are usually limited to a single-hospital setting or a single-disease category. Therefore, it is difficult to discern the varying effects of different IHT types on care outcomes and design specific strategy and tactics to minimize the potential negative consequences.

2.1. Care Outcomes under Different Transfer Types

There are various underlying reasons for IHT cases. Some cases are mandatory since such cases may be beyond the treatment capability of the hospital that provides the initial care for the transferred patients. Other cases are at the discretion of the hospital, which is capable of providing care but may still considers

Table 1 Recent Studies of the Effect of IHT on Care Outcomes

	IHT type differentiation		Effect of IHT on care quality		
	Conceptual	Empirical	Readmission	Mortality	LOS
Bernard et al. (1996)	No	No			–
Gordon and Rosenthal (1996)	No	No		–	–
Selevan et al. (1999)	No	No	0	0	0
Duke and Green (2001)	Yes	No		0	–
Rosenberg et al. (2003)	No	No		–	–
Nathens et al. (2003)	No	No		0	0
Combes et al. (2005)	No	No		–	–
Stolte et al. (2006)	Yes	No			–
Golestanian et al. (2007)	No	No		–	–
Flabouiris et al. (2008)	No	No		–	–
Odetola et al. (2009a)	No	No		–	–
Odetola et al. (2009b)	Yes	No		–	–
Garwe et al. (2010)	No	No		+	
Wiggers et al. (2011)	No	No	–	–	–
Barratt et al. (2012)	Yes	No			–
Hernandez-Boussard et al. (2014)	Yes	No		–	–
Russell et al. (2015)	Yes	No	+	+	+
Sokol-Hessner et al. (2016)	No	No		–	–

Notes: + Positive care outcomes, – negative care outcomes, 0 no effect.

transferring patients due to capacity constraint or other non-clinical reasons. Duke and Green (2001) categorize transfer for specialty care or higher levels of care as Category A transfer and those due to a hospital's temporary unavailability of beds as Category B transfer. Gray et al. (2003) differentiate between transfer for specialty care and transfer for non-clinical reasons. Stolte et al. (2006) recognize the difference between transfer due to the need for capacity and transfer due to the need for specialty services. Russell et al. (2015) label transfer for specialty care as "up-transfer," those for convalescence and rehabilitation as "down-transfer," and those to equivalent-service hospitals as "lateral-transfer." The different reasons underlying IHT can lead to different care outcomes since the associated decision-making and operational procedures can vary considerably. However, the existing studies only differentiate IHT conceptually. No study provides a generic empirical approach to differentiating transfer types. Our study attempts to fill this gap by differentiating IHT both conceptually and empirically.

We differentiate between two IHT types: clinical and non-clinical transfer. Clinical transfer is required for patients who need to receive higher level care in the form of specific diagnoses, procedures, or physician expertise at the receiving hospital, and non-clinical transfer is due to other, non-clinical reasons. Clinical transfer is the result of a hospital's limited service scope, which is determined by the hospital's long-term strategic plan and does not change in the short- to medium-term because any changes will impact a wide range of business activities. Hence hospital managers often have a plan for clinical transfer and execute the pre-planned process when patients' conditions demand IHT. In this case, the clinical staff typically has a standard IHT protocol to follow. Those plans for clinical transfer are relatively stable, and the same decision and procedure are executed time after time. The operational stability and repetition facilitate cross-functional coordination. For example, Bosk et al. (2011, p. 3) document a nurse's description of the transfer process for STEMI patients:

> If they (the patients) walk in the door up front and they're complaining of chest pain, we immediately take them by wheelchair to [a room]. Usually have 2–3 staff that will come in [to] immediately get them set up for an EKG. Everybody is simultaneously putting them on oxygen, getting aspirin, monitoring [the patient] and getting the EKG in the doctor's hands within ten minutes. Once the doctor's seen the EKG, they usually are on the phone to get them transferred straight to the Cath lab [at another hospital].

The description captures the essential characteristics of a clinical transfer: physicians and nurses follow standardized procedures, and the transfer decision is made by clinical staffs with little ambiguity.

Non-clinical transfer, in contrast, tends to be optional and ad hoc. The transfer decision is made after tactically evaluating several operational factors such as the hospital's available resources, capacity utilization, and the patient's preference. When a hospital has the capability to provide the needed care, it tends to be reluctant to transfer patients for non-clinical reasons, since these patients are potential sources of revenue (Veinot et al. 2012). Hence, each non-clinical transfer case needs to be evaluated individually and independently based on the specific operational situations and patient preferences. Creating a transfer protocol that encompasses all scenarios of non-clinical transfer can be quite complex. As a result, the transfer decisions tend to be arbitrary and at the discretion of the attending physicians (and in some cases, patients and families), leading to variable and inconsistent transfer practices (Mueller 2019).

The different operational natures between clinical and non-clinical transfer suggest that clinical transfer tends to be better coordinated than non-clinical transfer (Bosk et al. 2011), resulting in reduced communication breakdowns, care delays, and medical errors (Risser et al. 1999). Thus, we hypothesize the following:

HYPOTHESIS 1. *Clinical transfer is associated with better patient care outcomes (shorter LOS, lower odds of readmission, and lower odds of mortality) than non-clinical transfer.*

2.2. Interhospital Coordination Mechanisms

IHT is a complex process that involves multiple providers working interdependently. Thus, care coordination is critical to effectively managing IHT. Inadequate coordination can lead to medical errors and inefficiency. For example, nearly half of the preventable readmissions may be attributed to inter-provider coordination problems (Fluitman et al. 2016). Thus, it is important to evaluate alternate coordination mechanisms and their effects on different transfer types in order to inform effective management of IHT.

Galbraith (1974) proposes several coordination mechanisms, and Martinez and Jarillo (1989) categorize those mechanisms into formal and informal ones. In general, formal mechanisms include departmentalization of organizational units, centralization of decision-making through formal hierarchy, strategic planning, and output control such as establishing financial performance goals. Informal mechanisms include lateral relationships such as working relationships, personal relationships, and socialization through culture building. Gittell (2002) views coordination in the healthcare context as a relational process and finds that the inter-provider relationship improves the effectiveness of interorganizational coordination and relational coordination mechanisms are increasingly effective under high uncertainty. The effectiveness of relational coordination is studied in nursing homes (Gittell et al. 2008), pediatric care (Pfefferle et al. 2006), chronic illness care (Noël et al. 2013), and outpatient surgical care (Gittell et al. 2020). We contribute to this stream of literature by investigating coordination mechanisms in IHT. Following the literature on coordination mechanisms, we study system affiliation and transfer routinization. System affiliation is a formal coordination mechanism capturing the formal structure and relationship between the sending and the receiving hospitals, and transfer routinization is an informal coordination mechanism associated with interrelated nature of tasks in the IHT workflows. We investigate the joint effects between each of the two coordination mechanisms and transfer types on care outcomes and provide insights into which coordination mechanisms can facilitate specific transfer types.

2.2.1. Hospital System Affiliation. Hospital system affiliation is considered a form of formal hospital relationship in Lu and Lu (2018), which finds that hospital relationship plays a dominant role over distance and quality in determining transfer destination choices for the cardiovascular patients. Bosk et al. (2011) and Veinot et al. (2012) suggest that hospitals prefer transferring patients to destinations within their own system because they strive to retain the revenue and market share. In addition to sharing common financial interests, a hospital system can facilitate system-wide coordination. Hospitals in the same hospital system typically have shared goals and knowledge and established procedures for performing interhospital tasks (Gittell 2002). A hospital system can centralize transfer management to better coordinate IHT within the system (Kistler et al. 2020). Affiliated hospitals normally have common process design and information systems. With explicitly defined roles, rules, and responsibilities, transfer protocols can be established. Through these protocols, the sending and the receiving hospitals can break the communication barriers so that the sending hospital can timely transmit patients' information, receive quick response from the receiving hospital, and closely track patients' clinical conditions.

HYPOTHESIS 2A. *Hospital system affiliation improves patient care outcomes (shorter LOS, lower odds of readmission, and lower odds of mortality) for IHT.*

The benefits of a coordination platform are especially valuable to non-clinical transfer considering its ad hoc nature. System affiliation can facilitate the creation of a common transfer guidelines and ease the concerns on the potential revenue loss. Such a formal organizational structure also increases the receiving hospital's sense of responsibility to coordinate with the sending hospital and promotes collaborative efforts in patient transfer. However, clinical transfer may benefit less from system affiliation compared with non-clinical transfer since clinical transfer tends to be better coordinated by design. In clinical transfer, the sending hospital automatically initiates the transfer once the need for transfer is established, and the clinical staff follows the established protocols in transfer negotiation and patient handoff procedures. Even without system affiliation, clinical transfer is likely to be executed smoothly. Therefore, we hypothesize:

HYPOTHESIS 2B. *Hospital system affiliation has greater benefits to patient care outcomes for non-clinical transfer than for clinical transfer.*

2.2.2. Transfer Routinization. Routinization refers to repetitive and recognizable patterns of interdependent actions that involve multiple actors (Cohen and Bacdayan 1994). In the healthcare setting, routinization typically refers to clinical pathways that define the activities and responsibilities of different care providers and reflect the established patterns of transfer decisions and operations processes (De Bleser et al. 2006, Hoffer Gittell 2002). Standardized processes may emerge over time through routinization (Bosk et al. 2011, Kindermann et al. 2015, Veinot et al. 2012). Veinot et al. (2012) point out that routinization between care providers enhances coordination and improves efficiency and reduces uncertainty. Following the organizational routines literature, we define transfer routinization as the repetition and concentration of the transfer between the sending and the receiving hospitals. Repetition captures the recurrence of transfer between the sending and the receiving hospitals over time. Concentration captures the extent to which transfer between the sending and the receiving hospitals accounts for their total transfer volume associated with the sending hospital.

We argue that transfer routinization facilitates IHT coordination and hence improves patient care outcomes. Routinization enables standard communication and interaction between clinical staffs in the sending and the receiving hospitals (Feldman and

Rafaeli 2002). Through routinized practices, physicians, nurses, and administrative staff in the two hospitals repeatedly work with each other. As they collaboratively work on the IHT operational details, they develop a mutual understanding of each other's capabilities, processes, and cultures (Zollo et al. 2002). The cognitive consonance stimulates the development of transfer guidelines and protocols. With the increased routinization level, communication breakdowns may be reduced, leading to streamlined transfer processes and hence better patient care outcomes.

HYPOTHESIS 3A. *Routinization improves patient care outcomes (shorter LOS, lower odds of readmission, and lower odds of mortality) for IHT.*

Clinical transfer and non-clinical transfer inherently are associated with different levels of routinization due to their distinct operational characteristics. Since clinical transfer is pre-planned, the sending hospital follows a well-established protocol to initiate clinical transfer and coordinate with the receiving hospital to execute the transfer process. As a case in point, the Emergency Medical Treatment and Labor Act (EMTALA) mandates that "when a patient requires a higher level of care other than that provided or available at the transferring facility, a hospital with the capability and capacity to provide a higher level of care may not refuse any request for transfer" (American College of Emergency Physicians et al. 2009). This suggests that initiation of clinical transfer and the acceptance of transfer request should be quite standard. Other aspects of clinical transfer also tend to be more routinized than non-clinical transfer, such as identifying receiving hospitals (only clinically capable hospitals are eligible candidates) and transfer negotiation (there is no concern for "patient dumping"). Since clinical transfer is already relatively routinized, coordination mechanisms that can facilitate IHT coordination likely will have smaller effects for clinical transfer. Hence, we argue that routinization should have stronger effects in improving care outcomes for non-clinical transfer than for clinical transfer. Routinization results in naturally evolved transfer protocols (as opposed to protocols defined by formal rules, roles, and responsibilities) and makes up for the lack of standardization in non-clinical transfer. A salient concern among receiving hospitals about non-clinical transfer is that sending hospitals are trying to dump the patients they do not want to treat in the receiving hospitals (Bosk et al. 2011). Transfer routinization mitigates such concerns as it develops trust through repeated interaction between the sending and the receiving hospitals (Zollo et al. 2002). Thus, we hypothesize the following:

HYPOTHESIS 3B. *Routinization has greater benefits to patient outcomes for non-clinical transfer than for clinical transfer.*

3. Data and Methods

We employ three patient datasets. The 2014 Florida State Emergency Department Databases (FL-SEDD) and State Inpatient Databases (FL-SID) are obtained from the Healthcare Cost and Utilization Project (HCUP) of the Agency for Healthcare Research and Quality (AHRQ). The FL-SID and FL-SEDD comprise more than 2 million hospitalizations and 6 million ED visits at about 300 hospitals. The data allow us to retrospectively examine patients' historical visits to hospitals. We obtain hospital characteristics from the 2014 American Hospital Association (AHA) Annual Survey data and supplement it with the hospital-wide readmission rate from the Centers for Medicare & Medicaid Services (CMS).

3.1. Transfer Definition and Classification

In our analysis, we consider patients transferred from one hospital's ED to another hospital's inpatient department with emergent admission. The restriction allows us to focus on time-sensitive transfer that is critical to patients. Because emergent transfer requires quick decisions, typically within a few hours, it is less likely to be affected by unobserved endogenous factors during the transfer arrangement time. For example, patients and their families would have less influence on the transfer decisions.

We identify IHT records from the HCUP FL-SID and FL-SEDD data following the same procedures used by Lu and Lu (2018). To be considered a valid transfer, the transfer must involve two consecutive visits of the patient to different hospitals, and the time difference between the discharge from the first hospital and the admission to the second hospital must be less than one day. The criterion is well established in the literature (e.g., Iwashyna et al. 2009b, Kindermann et al. 2015) for identifying ED transfers because most transfers occur within one day after the initial ED arrival. We also require the condition that the patient is discharged to another short-term hospital (i.e., the variable *DISPuniform* = 2). Following the procedure, we identified 17,161 transfers.

In our datasets, treatments for patients are represented by detailed diagnosis and procedure (DX and PR) codes. Altogether, there are 11,424 DX codes and 3335 PR codes. From the data, we identified all DX and PR codes associated with all patients for each hospital. The list of all DX codes and PR codes for each hospital represents the diagnoses and procedures that the hospital can perform and thus indicate the service scope of the hospital. Because the service scope of a hospital is usually stable within a short period of time, we define the capability of a hospital as all DX and PR codes that the hospital performed in the focal year. For a transfer, if at least one diagnosis or procedure (represented by a DX or PR code) performed by the receiver is not performed by the sender, we consider that the transfer occurred due to the *capability* reason. Such a transfer is clinically necessary because the sender does not offer the specialty care or higher level of care needed for the patients, but the receiver does.

In addition, many physicians provide services in multiple hospitals. Patients may be transferred to follow the physician's work arrangement, and this is also a clinically necessary transfer situation in which the clinical capability moves between hospitals following the physician's movement. Our definition of the capability of a hospital based on the procedures or diagnosis performed over the year does not capture this temporally changing clinical capability and therefore can overlook transfer due to this clinical reason. For example, a physician *M* performs a particular procedure at both hospitals *A* and *B*. Then, a patient is admitted to hospital *A* initially but is required to have her procedure done by physician *M* in hospital *B*. In this case, the patient will need to be transferred from hospital *A* to *B*. This transfer is clinically necessary but will not be identified as a clinical transfer if we only examine the diagnosis and procedure capabilities defined by the service scope discussed above. Since our datasets provide the hospital ID and up to three physician IDs for each patient visit, we are able to identify transfer for which a patient was attended by a physician in the receiver who also sees patients in the sender. We view this type of transfer as clinical transfer due to *physician* reason.

We consider a transfer as clinical transfer if it is due to the *capability* or *physician* reasons since both cases result from clinical necessity. There are 10,155 clinical transfers among all 17,161 transfers. A total of 8518 clinical transfers are due to the capability reason and 2932 clinical transfers are due to the physician reason. Besides these two major reasons for clinical transfer that we identify, an IHT may occur for other clinical reasons. For example, a patient may be transferred because the sender does not treat certain comorbidity (beyond the main diagnosis or procedure codes) or because the sender does not provide specialty care for patients younger than 16 years old who may need to be transferred to a children's hospital. These types of transfer should not be viewed as non-clinical transfer. Among all 7006 (=17,161 – 10,155) transfers that are not due to hospital capability or physician reasons, there are only 18 transfers for which the sender cannot treat one or more comorbidities of the transferred patients. These transfers are excluded from our analysis. There is no transfer due to young patients seeking specialty children's care in our sample.

Besides clinical transfer, IHT may occur due to operational reasons, such as the sender's capacity constraints or patient preferences. For example, a patient wants to be transferred to a hospital that accepts the patient's insurance or is close to the patient's home. If the expense of the visit to the sender is already covered by the patient's medical insurance (i.e., the payer type variable is Medicare, Medicaid, or private insurance), then the insurance coverage is less likely be a main reason for transferring the patient. Among all 7006 transfers that are not identified as clinical transfers, 498 transfers could be due to insurance reasons since no insurance coverage is recorded in the sending hospital, and 1122 transfers may be due to distance reason since the receiver's location is closer to patient's home zip code than the sender's. Further, 69 transfers could be due to both insurance and distance reasons. To make a clean sample, we excluded all the transfers that may be due to insurance or distance reasons or both from our analyses. It is quite challenging, if not impossible, to have a perfect classification of transfer types. By scrutinizing the transfer reasons, as well as restricting our samples to emergent admission only, we believe we have a reasonably clean sample of clinical and non-clinical transfer. We carry out multiple robustness checks with regard to different scopes of clinical and non-clinical transfer in Appendix A and the results are all consistent. We summarize our transfer type classifications in Table 2.

3.2. Hospital System Affiliation and Transfer Routinization

We identify two coordination mechanisms associated with IHT: hospital system affiliation and transfer routinization. Our hypotheses center around the different levels of coordination associated with the distinct operational characteristics between clinical and non-clinical transfer. We include a binary variable *affiliation* to indicate whether the chosen receiver belongs to the same hospital system as the sender. Table 3 shows that among all transfers between system-affiliated hospitals in our sample, 38.8% of them are clinical transfers and 39.6% of them are non-clinical transfers. The difference is not significant in a t-test.

Routinization is operationalized through *repetition* and *concentration* of the transfer, which are tested separately. Repetition measures the quarterly repetition of transfers between a pair of sending and receiving hospitals by diagnostic categories. Specifically, given a sender s, a receiver r, and a major diagnostic category (MDC) c, we define repetition$_{src} = 1$ if transfers between s and r for patients within MDC c occur

Table 2 Transfer Classification

Possible transfer reasons	Number of transfers
Total	17,161
Capability	8518
Physician	2932
Capability and physician	1295
Comorbidity	18
Age (≤ 16)	0
Clinical Transfer	10,155
Total *minus* Clinical Transfer	7006
Insurance	498
Distance	1122
Non-Clinical Transfer	5440

Notes: A transfer satisfies the following criteria: (1) The variable VisitLink indicates that the same patient is on two visiting records; (2) Disposition variable DISPuniform = 2 indicates that the patient is transferred out; (3) (DaysToEvent + LOS) of the first visit record = DaysToEvent of the second visit record, where DaysToEvent is a coded variable for admission date; (4) The sending and the receiving hospitals are different.

Table 3 Mean Levels of Hospital System Affiliation and Transfer Routinization

Routine measure	Non-clinical transfer	Clinical transfer	*p*-value
Affiliation	0.396	0.388	0.331
Repetition	0.531	0.580	< 0.001
Outbound concentration	0.661	0.643	< 0.001
Inbound concentration	0.369	0.410	< 0.001

in each quarter, and 0 otherwise. So, IHT between the sender and the receiver has a high routinization level if patients are transferred between them repeatedly through each quarter of the year.

The concentration measure quantifies the percentage of transfers between a sender and a receiver among all the transfers that originate from the sender. It is defined as follows

$$\text{Concentration}_{src} = \frac{\text{number of transfers between } s \text{ and } r \text{ within MDC } c}{\text{number of transfers within MDC } c \text{ originated from the sender} s}.$$

The measure captures the "outbound" concentration since the denominator is the number of transfers from the sender. Similarly, an "inbound" concentration can be constructed where the denominator becomes the number of transfers to the receiver. Because the transfer decision is largely made by the sender, we include the "outbound" concentration in our main analysis and leave the test with the "inbound" concentration in Appendix A for a robustness check. The *t*-test in Table 3 shows clinical transfer has a significantly higher level of repetition than non-clinical transfer, suggesting a higher degree of routinization.

3.3. Patient Care Outcomes Variables
To compare clinical and non-clinical IHT, we focus on four patient outcome measures, which are length of stay (LOS) at the sender, LOS at the receiver, readmission, and inhospital mortality. Since LOS at the sender (ED) is generally short, we measure LOS in hours. We calculate LOS in hours using each patient's LOS in days and the hours of admission and discharge. We also perform a logarithmic transformation on the LOS in hours.

We use 30-day all-cause readmission in our analysis. For each transfer, the readmission variable is assigned a value of 1 if a patient is admitted to any hospital for inpatient care within 30 days of discharge from the receiver of the transfer, and 0 otherwise. We exclude a readmission if the previous discharge is against medical advice, because in this case the hospital has limited opportunities to provide high-level care. Inhospital mortality is available from the HCUP data as a binary variable which has value of 1 if the patient died during hospitalization and 0 otherwise.

3.4. Control Variables
We control for both patient-level and hospital-level variables to measure care outcomes of clinical and non-clinical transfers. The patient-level control variables include patient demographics (age, race, and gender), patient medical conditions (MDC, comorbidity, the count of diagnosis, and the count of procedures), and payer types. We also include the count of current procedural terminology (CPT, a type of medical procedure and service code used in ED care) in the sender and the count of inpatient chronic conditions (ICC) in the receiver. In addition, we include total charge to control for the amount of care delivered to the patient, and we include LOS to control for the process quality (Oh et al. 2018) when the dependent variable is readmission or mortality. The workload in a hospital can be a potential driver of non-clinical transfer decisions. If a transfer happens during a hospital's high workload time period, then the transfer may not be arranged timely, and the patient may experience adverse outcomes. There is ample recent evidence in the operations management literature that suggests

such adverse workload-related outcomes (e.g., Freeman et al. 2017, Kim et al. 2015, Kuntz et al. 2015, Lu and Lu 2017, Tan and Netessine 2014 and reference therein). Therefore, to minimize the potential workload-related effects on transfer due to time-of-day or seasonality, we include two more variables, *aweekend* and *admission count*. The former is a binary variable that takes a value 1 if the patient is admitted on a weekend and 0 otherwise. The latter is calculated as the number of patients who are admitted to the same hospital within the same quarter, the same hour, and the same MDC as the focal IHT.

Tables 4–6 report descriptive statistics of patient characteristics, where the second and third columns compare clinical and non-clinical transfer, and the last column shows the *p*-value of the *t*-test. For the number of treatments and total medical charges, we report descriptive statistics in both the sender and the receiver. Table 4 indicates that clinical transfer is generally associated with elderly patients, more treatments, and higher medical charges than non-clinical transfer. Table 4 also indicates possible healthcare inequality due to race and payer type that may be interesting for future research. Tables 5 and 6 show the percentage of the clinical and non-clinical transfer in each MDC (or comorbidity category) against the total number transfers.

The hospital-level control variables include the number of beds in a hospital, hospital ownership type (government, non-profit, or private), and teaching status (a binary variable that has a value 1 if the hospital is a teaching hospital and 0 otherwise), which are available from the AHA annual survey data. In addition, we include hospital system affiliation (variable *affiliation*, which is 1 if the receiver belongs to the same hospital system as the sender and 0 otherwise) and the geographical distance between the sender and the receiver. We include distance because it may affect the choice of transfer destination. Table 7 shows that most IHTs are originated from private hospitals. Among all the clinical (non-clinical) transfers, 49.7% (55.7%) of the senders are private hospitals. However, most of the receivers of IHT are non-profit hospitals. Among all the clinical (non-clinical) transfers, 52.0% (50.9%) of the receivers are non-profit hospitals. Table 7 suggests that the receivers in clinical transfer are more likely to be teaching hospitals, and the receivers in non-clinical transfer are more likely to be hospitals with a larger number of beds. The result is reasonable since the receivers need to have a larger service scope (as in teaching hospitals) for clinical transfer or a larger capacity (measured by the number of hospital beds) for non-clinical transfer. As Table 7 shows, LOS in the receiver (inpatient) is much longer than in the sender (ED), suggesting that the receiver plays a more important role in IHT care outcomes.

3.5. Econometric Models

Generalized linear models are utilized to estimate the hypothesized relationships between the transfer-related variables and patient care outcomes. To estimate the effects of different transfer types and the two coordination mechanisms, we use OLS regression models for the LOS in the sender and the receiver and use logistic regression models for the readmission and mortality. In the result tables, we report parameter estimates for the OLS regressions and odds ratios for the logistic regressions. We also report the goodness of fit as R-squared for the OLS regressions and the area under the ROC curve (AUC) for the logistic regressions. For a given sender s, receiver r, and

Table 4 Patient Characteristics

Patient characteristics	Non-clinical transfer		Clinical transfer		*p*-value	
Age	53.050		57.224		< 0.001	
Female	0.498		0.486		0.146	
Race						
White	0.710		0.739		< 0.001	
Black	0.164		0.150		0.025	
Hispanic	0.113		0.102		0.033	
Others	0.013		0.009		0.018	
Payer type						
Medicare	0.476		0.489		0.124	
Medicaid	0.246		0.152		< 0.001	
Private	0.198		0.196		0.753	
Others	0.080		0.163		< 0.001	
	Sender	**Receiver**	**Sender**	**Receiver**	**Sender**	**Receiver**
Number of Treatments						
ED CPT codes	12.365		13.804		< 0.001	
Inpatient chronic conditions		4.543		5.776		< 0.001
Diagnoses	4.392	9.331	4.424	12.017	0.467	< 0.001
Procedures	0.138	0.891	0.174	2.747	< 0.001	< 0.001
Total charge ($1000)	11.043	44.331	10.251	88.553	< 0.001	< 0.001

Table 5 Transfers by the Major Diagnostic Category (MDC)

MDC	Non-clinical transfer	Clinical transfer	p-value
Diseases and Disorders of the Nervous System	0.206	0.197	0.185
Diseases and Disorders of the Endocrine, Nutritional, and Metabolic System	0.026	0.019	0.003
Diseases and Disorders of the Kidney and Urinary Tract	0.051	0.040	0.002
Diseases and Disorders of the Male Reproductive System	0.003	0.003	0.821
Diseases and Disorders of the Female Reproductive System	0.007	0.010	0.042
Pregnancy, Childbirth, and Puerperium	0.023	0.023	0.988
Newborn and Other Neonates (Perinatal Period)	0.000	0.001	0.529
Diseases and Disorders of the Blood and Blood-Forming Organs and Immunological Disorders	0.017	0.011	0.007
Myeloproliferative DDs (Poorly Differentiated Neoplasms)	0.002	0.005	< 0.001
Infectious and Parasitic DDs (Systemic or unspecified sites)	0.048	0.056	0.027
Mental Diseases and Disorders	0.033	0.020	< 0.001
Diseases and Disorders of the Eye	0.006	0.010	0.014
Alcohol/Drug Use or Induced Mental Disorders	0.004	0.003	0.440
Injuries, Poison, and Toxic Effect of Drugs	0.028	0.027	0.749
Burns	0.009	0.012	0.130
Factors Influencing Health Status and Other Contacts with Health Services	0.004	0.002	0.057
Multiple Significant Trauma	0.007	0.010	0.032
Human Immunodeficiency Virus Infection	0.001	0.002	0.011
Diseases and Disorders of the Ear, Nose, Mouth, and Throat	0.033	0.037	0.178
Diseases and Disorders of the Respiratory System	0.094	0.077	< 0.001
Diseases and Disorders of the Circulatory System	0.110	0.206	< 0.001
Diseases and Disorders of the Digestive System	0.114	0.070	< 0.001
Diseases and Disorders of the Hepatobiliary System and Pancreas	0.027	0.035	0.004
Diseases and Disorders of the Musculoskeletal System and Connective Tissue	0.104	0.104	0.978
Diseases and Disorders of the Skin, Subcutaneous Tissue, and Breast	0.044	0.021	< 0.001

Table 6 Comorbidity by Transfer Types

Comorbidity	Non-clinical transfer	Clinical transfer	p-value
Acquired immune deficiency syndrome	0.002	0.002	0.857
Alcohol abuse	0.053	0.079	< 0.001
Deficiency anemias	0.145	0.198	< 0.001
Rheumatoid arthritis/collagen vascular diseases	0.022	0.026	0.140
Chronic blood loss anemia	0.010	0.014	0.008
Congestive heart failure	0.071	0.084	0.005
Chronic pulmonary disease	0.189	0.218	< 0.001
Coagulopathy	0.050	0.076	< 0.001
Depression	0.089	0.096	0.163
Diabetes, uncomplicated	0.189	0.215	< 0.001
Diabetes with chronic complications	0.031	0.048	< 0.001
Drug abuse	0.045	0.057	0.001
Hypertension (combine uncomplicated and complicated)	0.502	0.578	< 0.001
Hypothyroidism	0.107	0.110	0.543
Liver disease	0.026	0.037	< 0.001
Lymphoma	0.004	0.006	0.262
Fluid and electrolyte disorders	0.220	0.298	< 0.001
Metastatic cancer	0.013	0.024	< 0.001
Other neurological disorders	0.069	0.080	0.008
Obesity	0.101	0.136	< 0.001
Paralysis	0.020	0.040	< 0.001
Peripheral vascular disorders	0.052	0.081	< 0.001
Psychoses	0.037	0.050	< 0.001
Pulmonary circulation disorders	0.018	0.024	0.008
Renal failure	0.096	0.144	< 0.001
Solid tumor without metastasis	0.017	0.021	0.071
Peptic ulcer disease excluding bleeding	0.000	0.000	0.282
Valvular disease	0.032	0.039	0.028
Weight loss	0.036	0.062	< 0.001

patient k, the general structure of our models is:

$$Outcome_{srk} = \beta_0 + \alpha_1 Clinical\ transfer + \alpha_2 Affiliation + \alpha_3 \mathrm{R}epetition(Concentartation) + \boldsymbol{\beta_1 P_k} + \boldsymbol{\beta_2 H_s} + \boldsymbol{\beta_3 H_r} + \beta_4 d_{sr} + \varepsilon_{srk},$$

where $Outcome_{srk}$ represents one of the patient outcome measures (i.e., LOS at the sender, LOS at the receiver, readmission, or mortality) for the transfer of patient k from sender s to receiver r, *clinical transfer* is 1 for a clinical transfer and 0 for a non-clinical transfer, $\boldsymbol{P_k}$ represents the vector of patient characteristics, $\boldsymbol{H_s}$ $(\boldsymbol{H_r})$ represent the vector of hospital characteristics for the sender s (the receiver r), d_{sr} represents the distance between the sender and the receiver. We estimate LOS at both the sender and the receiver because both hospitals contribute to the length of stay. However, readmission and mortality are only estimated for the receiver because the receiver completes the care and hence the measures are tied primarily to the receiver's care outcomes.

4. Main Analysis and Results

Critically ill patients tend to have significant complications and increased risk of adverse events. Interhospital transfer can exacerbate patient risks. In this

Table 7 Hospital Characteristics

Hospital characteristics	Non-clinical transfer		Clinical transfer		p-value	
Distance (miles)	50.04		50.83		0.289	
Affiliation	0.396		0.388		0.331	
	Sender	**Receiver**	**Sender**	**Receiver**	**Sender**	**Receiver**
Number of hospital beds	218.6	629.0	143.6	576.7	< 0.001	< 0.001
Hospital ownership						
Government	0.094	0.088	0.105	0.111	0.020	< 0.001
Non-profit	0.349	0.509	0.398	0.520	< 0.001	0.205
Private	0.557	0.403	0.497	0.370	< 0.001	< 0.001
Teaching hospital	0.306	0.812	0.227	0.773	< 0.001	< 0.001
Hourly LOS	5.212	98.756	4.580	152.906	< 0.001	< 0.001

Table 8 Patient Outcomes under Different Transfer Types

Variable	ln(Sender's HLOS)	ln(Receiver's HLOS)	Readmission	Mortality
Clinical transfer	–0.100(0.010)***[1]		–0.048(0.010)*** [1]	0.778(0.126)** [1]
Affiliation	–0.035(0.011)***	–0.037(0.011)***	1.086(0.055)	1.180(0.120)
Aweekend	–0.037(0.010)***	0.014(0.010)	1.081(0.050)	0.980(0.111)
Patient characteristics				
Age	–0.001(0.000)***	–0.001(0.000)***	1.000(0.002)	1.030(0.004)***
Female	–0.054(0.010)***	–0.029(0.010)***	0.954(0.049)	1.004(0.105)
Race	Omitted for brevity and variables are listed in Table 4			
Payer type	Omitted for brevity and variables are listed in Table 4			
Number of treatments	Omitted for brevity and variables are listed in Table 4			
MDC	Omitted for brevity and categories are listed in Table 5			
Comorbidity	Omitted for brevity and categories are listed in Table 6			
ln(total charge)	0.198(0.008)***	0.712(0.007)***		
Admission count	0.004(0.001)***	–0.028(0.017)*	0.892(0.087)	1.062(0.197)
Hospital characteristics	Sender	Receiver	Receiver	Receiver
Hospital beds	0.004(0.003)	0.003(0.003)	0.110(0.010)	0.090(0.023)
Hospital ownership	Omitted for brevity and categories are listed in Table 7			
Teaching hospital	–0.020(0.012)*	–0.029(0.013)**	0.981(0.068)	1.074(0.158)
ln(Receiver's HLOS)			1.452(0.046)***	0.24(0.062)***
Distance	0.135(0.012)***	0.027(0.011)**	1.060(0.057)	1.202(0.116)
R^2 or AUC	0.16	0.64	0.67	0.91
N	15,595	15,595	15,595	15,595

[1]: Support Hypothesis H1.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$ (Standard errors).

section, we first measure LOS and odds of readmission and mortality under different transfer types, then estimate the effects of the coordination mechanisms, namely hospital system affiliation and routinization, on patient care outcomes.

4.1. Patient Care Outcomes under Different Transfer Types

Length of stay (LOS) is an important indicator of care efficiency in hospital management. Reducing LOS can result in lower risk of infection, fewer medication side effects, and increased hospital profit. CMS emphasizes shorter patient stay where possible and offers financial incentives to reduce the time patients spend in hospitals for each episode of care.

Table 8 presents a comparison of LOS between different transfer types at the sender and the receiver. Average LOS for clinical transfer is 10% and 4.8% shorter than that for non-clinical transfer at the sender and the receiver, respectively. Since the average LOS at the sender (receiver) is 4.8 (134) hours, the results imply that LOS in clinical transfer is about 30 minutes (6.4 hours) shorter on average at the sender (receiver), compared with non-clinical transfer. The finding indicates that there is ample room for improving LOS in non-clinical transfer. Since the LOS at the sender is for ED visits, considering the ED crowding (Stolte et al. 2006) and the surging ED visit cost, our findings suggest that hospital managers should focus on improving LOS for non-clinical transfer.

The last two columns in Table 8 report the effects of different transfer types on the odds of readmission and mortality. Since logistic regressions are performed for readmission and mortality, we report odds ratios for the estimated parameters in Table 8 and all the following tables. The odds ratios of readmission and mortality for *clinical transfer* versus *non-clinical transfer* are 0.81 and 0.78, respectively. Thus, the odds of being readmitted (deceased) for clinical transfer is 19% (22%) less than those for non-clinical transfer. These results support our hypothesis H1 and suggest that clinical transfer has better patient care outcomes than non-clinical transfer.

4.2. Effects of Hospital System Affiliation

To estimate the effects of hospital system affiliation and the potentially different effects between different IHT types, we perform regression analyses with LOS, readmission, and mortality as the dependent variables and include an interaction term, *affiliation* × *clinical transfer*, to the model. The results are reported in Table 9.

We find that clinical transfer is consistently associated with better patient care outcomes, in both the main and the marginal effect. The main effect of *affiliation* shows that hospital system affiliation reduces the LOS by 3.4% and 3.5% at the sender and the receiver, respectively, and it has no significant effect on readmission or mortality. The findings support our hypothesis H2A and suggest that system affiliation helps improve patient care outcomes of transferred patients. However, the benefit of system affiliation depends on transfer types as shown in Table 9.

For non-clinical transfer, transferring patients to an affiliated hospital within the same hospital system is associated with an average 3.0% shorter sender's LOS and 2.9% shorter receiver's LOS but no significant effect on readmission or mortality. However, for clinical transfer, within-system destinations are associated with 17% higher odds of readmission and 30% higher odds of mortality (odds ratios 1.17 and 1.30, respectively) than out-of-system destinations. The results support our hypotheses H2B that system affiliation has more benefits to non-clinical transfer than to clinical transfer.

To the best of our knowledge, Lu and Lu (2018) is the first to show that transferring heart attack patients, a typical clinical transfer case, between affiliated hospitals is associated with significantly worse patient care outcomes. Our finding is consistent with the literature and extends the effect of system affiliation to general clinical transfer cases. We find that the effects of affiliation on different transfer types vary considerably, suggesting different decision criteria for choosing receiving hospitals between clinical and non-clinical transfer. For non-clinical transfer, the sending hospital should prioritize choosing hospitals within the same hospital system, which could result in about 3% shorter LOSs (about 9 minutes of ED LOS and 4 hours LOS in the receiver). However, the same strategy may not be readily applicable to clinical transfer. For clinical transfer, decisions based on affiliation may require reevaluation, and the sending hospital should prioritize out-of-system destinations with the needed clinical capability to a greater extent.

4.3. Effects of Transfer Routinization

Because hospitals are inclined to transfer patients within their own system (Bosk et al. 2011, Lu and Lu 2018, Veinot et al. 2012), transfer between affiliated hospitals tends to have higher routinization. Therefore, to properly estimate the effects of transfer routinization on different transfer types, we need to control for potential confounding effect of system affiliation. To account for this potential confounding effect, we introduce a three-way interaction, involving *routinization*, *affiliation*, and *clinical transfer*, to the model and use two different routinization measures, *repetition* and *concentration*, separately to ensure robust results.

The marginal effects of *repetition* and *concentration* are reported in Table 10 and 11, respectively, under different affiliation status. The results show that higher routinization is associated with shorter

Table 9 Hospital System Affiliation

Variable	ln(Sender's HLOS)	ln(Receiver's HLOS)	Readmission	Mortality
Affiliation	−0.03(0.017)*	−0.029(0.017)*	0.941(0.086)	0.887(0.217)
Clinical transfer	−0.097(0.013)***	−0.043(0.013)***	0.746(0.065)***	0.673(0.153)***
Affiliation × Clinical transfer	−0.008(0.020)	−0.011(0.019)	1.246(0.100)**	1.467(0.240)
Control variables	Listed in Table 8			
R^2 or AUC	0.16	0.64	0.67	0.91
N	15,595	15,595	15,595	15,595
Marginal effects[2]				
Affiliation	−0.034(0.011)***	−0.035(0.011)***	1.051(0.057)	1.074(0.135)
Within system at non-clinical transfer	−0.030(0.017)*	−0.029(0.017)*	0.941(0.086)	0.887(0.217)
Within system at clinical transfer	−0.038(0.013)***	−0.040(0.013)***	1.173(0.065)**	1.301(0.134)**

Non-clinical transfer is the base case.
[2]: Support Hypothesis H2A and H2B.
$*p < 0.1$, $**p < 0.05$, $***p < 0.01$ (Standard errors in parentheses).

Table 10 Transfer Routinization: Repetition

Variable		ln(Sender's HLOS)	ln(Receiver's HLOS)	Readmission	Mortality
Affiliation		–0.027(0.025)	0.015(0.025)	0.914(0.128)	0.725(0.391)
Repetition		–0.061(0.021)***	0.024(0.02)	0.833(0.103)*	1.078(0.254)
Clinical transfer		–0.101(0.018)***	–0.054(0.017)***	0.712(0.087)***	0.685(0.218)*
Affiliation × Repetition		0.012(0.033)	–0.08(0.032)**	1.118(0.166)	1.274(0.467)
Affiliation × Clinical transfer		–0.006(0.032)	–0.021(0.031)	1.352(0.159)*	2.16(0.439)*
Repetition × Clinical transfer		0.009(0.025)	0.019(0.024)	1.128(0.125)	0.961(0.293)
Affiliation × Repetition × Clinical transfer		–0.005(0.041)	0.016(0.04)	0.846(0.207)	0.596(0.528)
Control variables		Listed in Table 8			
R^2 or AUC		0.16	0.64	0.67	0.91
N		15,595	15,595	15,595	15,595
Marginal Effects[3]					
Affiliation Status	**Variable**				
Out-of-system	Repetition	–0.057(0.013)***	0.034(0.013)***	0.885(0.067)*	1.057(0.154)
	Repetition at non-clinical transfer	–0.061(0.021)***	0.024(0.02)	0.833(0.103)*	1.078(0.254)
	Repetition at clinical transfer	–0.052(0.015)***	0.043(0.015)***	0.94(0.079)	1.036(0.159)
Within system	Repetition	–0.047(0.017)***	–0.038(0.017)**	0.91(0.085)	1.04(0.226)
	Repetition at non-clinical transfer	–0.049(0.026)*	–0.055(0.026)**	0.931(0.134)	1.374(0.398)
	Repetition at clinical transfer	–0.046(0.02)**	–0.02(0.02)	0.889(0.101)	0.787(0.202)

[3]: Support Hypothesis H3A and H3B.
$*p < 0.1$, $**p < 0.05$, $***p < 0.01$ (Standard errors in parentheses).

Table 11 Transfer Routinization: Concentration

Variable		ln(Sender's HLOS)	ln(Receiver' HLOS)	Readmission	Mortality
Affiliation		0.069(0.042)*	–0.018(0.041)	1.095(0.202)	0.768(0.534)
Concentration		–0.057(0.032)*	0.029(0.031)	0.771(0.155)*	0.756(0.387)
Clinical transfer		–0.101(0.027)***	–0.049(0.026)*	0.667(0.131)***	0.473(0.302)**
Affiliation × Concentration		–0.13(0.055)**	–0.021(0.054)	0.855(0.272)	1.271(0.726)
Affiliation × Clinical transfer		–0.02(0.052)	0.02(0.052)	0.981(0.256)	2.363(0.623)
Concentration × Clinical transfer		0.006(0.039)	0.012(0.039)	1.204(0.196)	1.848(0.458)
Affiliation × Concentration × Clinical transfer		0.019(0.069)	–0.046(0.068)	1.343(0.345)	0.46(0.844)
Control variables		Listed in Table 8			
R^2 or AUC		0.16	0.64	0.67	0.91
N		15,595	15,595	15,595	15,595
Marginal Effects[3]					
Affiliation Status	**Variable**				
Out-of-system	Concentration	–0.054(0.02)***	0.034(0.02)*	0.846(0.102)	1.027(0.237)
	Concentration at non-clinical transfer	–0.057(0.032)*	0.029(0.031)	0.771(0.155)*	0.756(0.387)
	Concentration at clinical transfer	–0.051(0.024)**	0.04(0.024)*	0.928(0.126)	1.396(0.26)
Within system	Concentration	–0.175(0.029)***	–0.01(0.029)	0.838(0.145)	0.886(0.361)
	Concentration at non-clinical transfer	–0.187(0.046)***	0.007(0.045)	0.659(0.225)*	0.961(0.617)
	Concentration at clinical transfer	–0.163(0.036)***	–0.027(0.035)	1.066(0.178)	0.816(0.363)

[3]: Support Hypothesis H3A and H3B.
$*p < 0.1$, $**p < 0.05$, $***p < 0.01$ (Standard errors in parentheses).

sender's LOS and lower readmission. For out-of-system transfer, the repetition measure is associated with 5.7% shorter sender's LOS and 11.5% lower odds of readmission, and the concentration measure is associated with 5.4% shorter sender's LOS. For within-system transfer, the repetition and concentration measures are associated with 4.7% and 17.5% shorter sender's LOS, respectively. The results support our hypothesis H3A.

The magnitudes of the marginal effects on different transfer types show that routinization is associated with better patient care outcomes for non-clinical transfer than for clinical transfer in terms of LOS and readmission. Comparing out-of-system transfers under different transfer types (non-clinical vs. clinical), routinization is associated with shorter sender's LOS (–6.1% vs. –5.2% for repetition, –5.7% vs. –5.1% for concentration), shorter receiver's LOS (no effect vs. 4.3% for repetition, no effect vs. 4% for concentration), and lower odds of readmission (0.883 vs. no effect for repetition, 0.771 vs. no effect for concentration) for non-clinical transfer than for clinical transfer. The results for within-system transfer are qualitatively consistent. Hence, our findings support hypothesis H3B.

We note that routinization may increase the receiver's LOS for out-of-system clinical transfer. The effect is not unexpected, since clinical transfer occurs when patients require higher level, specialty care at the receiver, where the specialty care resources are also in demand from other hospitals in the region that do not provide the specialty care patients need.

Our findings suggest that increasing repetition and concentration in IHTs can be an effective means of improving patient care outcomes for non-clinical transfer regardless of affiliation status, but it is not as effective for clinical transfer. Patient care outcomes of non-clinical transfer can be significantly improved with better coordination enabled by transfer routinization. The sending hospital can increase repetition or concentration of transfer by building long-term relationships with a limited number of hospitals. This is especially important for hospitals not affiliated with a hospital system.

In the following, we quantify the benefits of routinization using the transfer concentration measure since it is continuous and allows us to estimate the benefits at different levels of concentration. In our sample, the median level and the 75th percentile of concentration at the MDC level are 0.63 and 0.83, respectively, a 0.20 difference. For non-clinical transfer within system, the increase from median to 75th percentile concentration level is associated with 3.74% (=18.7% × 0.20) or 11 minutes shorter ED LOS (recall that average ED LOS is 4.8 hours), and 6.82% (=34.1% × 0.20) lower odds of readmission.

Since the median number of transfers at the MDC level is 6, our estimation suggests a total of 66 minutes (11 minutes × 6 patients) shorter ED LOS at the MDC level, and 1650 minutes shorter ED LOS at the hospital level (66 minutes × 25 MDC) if the concentration level increases from median to 75th percentile. The average 150 patients (6 patients × 25 MDCs) transferred across all MDCs between a sender and a receiver on average has 6.82% lower odds of readmission. Note that these quantified benefits are at the relationship level (a transfer relationship between a sender and a receiver), and a sender typically has multiple transfer relationships with various receivers, and therefore the benefits can be multiple times the above quantified benefits.

For clinical transfer, although routinization is associated with shorter ED LOS, it may increase the LOS in the receiver for out-of-system transfer. Because clinical transfer requires high level of cares that are available in relatively few hospitals, we suggest hospital managers consider diversifying transfer destination choices to better utilize limited healthcare resources. Our findings highlight the importance of differentiating IHT types and tailoring destination choice strategies to each IHT type.

5. Robustness Checks and Post Hoc Analysis

We perform a number of analyses to check the robustness of our results and conduct a post hoc analysis to understand the spillover effect of transfer routinization.

5.1. Propensity Score Matching

The sender's choice of transfer destination may be affected by the characteristics of patients. Thus, it is possible that patients transferred within the same hospital system (or transferred to a hospital with higher repetition) may be systematically different from those transferred out of the system (or transferred to a hospital with lower repetition). To account for this potential difference, we employ propensity score matching (PSM) methods to find pairs of patients with the same propensity of being transferred to the same type of destination but one is transferred to a system-affiliated hospital (a receiver with which the sender has a high transfer repetition), while the other to an out-of-system hospital (a receiver with which the sender has a lower transfer repetition). The propensity score is defined by Rosenbaum and Rubin (1983) as the probability of assignment to the treatment group conditioning on a set of observed baseline covariates. The PSM procedure matches each treated unit with one control unit (in exact match) that has a similar value of propensity score to minimize the effects of confounding. In our analyses, if two patients with very similar propensity scores are transferred to destinations with different affiliation status or repetition levels, then the different care outcomes are likely a result of the different transfer destination choices.

We perform two PSM analyses. In the first analysis, we match patient pairs based on the propensity score of system affiliation with covariates including patient-level characteristics, the sending hospital's characteristics, and the receiving hospital's characteristics. The matching procedures are performed separately for non-clinical and clinical transfer. We obtain 1135 and 2309 matched pairs for non-clinical and clinical transfer, respectively. Then, the matched samples are used to estimate patient outcomes. The results are presented in Table 12. For the non-clinical transfer group, system affiliation is associated with 5.5% shorter sender's LOS and lower odds of mortality (odds ratio 0.496). For the clinical transfer group, system affiliation is associated with 3.9% shorter sender's LOS and 5.0% shorter receiver's LOS. However, clinical transfer between affiliated hospitals is associated with higher odds of readmission (odds ratio 1.175). The results support our findings that on average it is more favorable for non-clinical transfer cases to remain

Table 12 PSM Analysis on System Affiliation

	Variable	ln(Sender's HLOS)	ln(Receiver's HLOS)	Readmission	Mortality
Non-clinical Transfers	Affiliation	–0.055(0.023)**	–0.026(0.025)	1.096(0.129)	0.496(0.374)*
	Propensity matched pairs	1135			
Clinical Transfers	Affiliation	–0.039(0.017)**	–0.05(0.016)***	1.175(0.086)*	1.212(0.193)
	Propensity matched pairs	2309			

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$ (Standard errors in parentheses).

Table 13 PSM Analysis on Repetition

Affiliation status	Transfer type	Variable	ln(Sender's HLOS)	ln(Receiver's HLOS)	Readmission	Mortality
Out-of-system	Non-clinical	Repetition	–0.078(0.025)***	0.013(0.026)	0.749(0.139)**	0.826(0.406)
		Propensity matched pairs	905			
	Clinical	Repetition	–0.069(0.018)***	0.034(0.019)*	1.038(0.1)	1.156(0.192)
		Propensity matched pairs	1820			
within system	Non-clinical	Repetition	–0.004(0.036)	–0.078(0.039)**	0.92(0.206)	1.315(5.012)
		Propensity matched pairs	494			
	Clinical	Repetition	–0.011(0.03)	–0.009(0.028)	0.751(0.15)*	0.413(0.381)**
		Propensity matched pairs	827			

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$ (Standard errors in parentheses).

within the same hospital system since doing so tends to lead to better patient care outcomes. The qualitatively consistent results suggest that the findings from our main analyses on system affiliation (H2B) are not significantly biased by potential sample selection bias.

In the second analysis, we conduct a one-to-one matching based on the propensity score of repetition with the same covariates used in the first analysis. The matching procedures are performed for each combination of transfer types and system affiliation status. The results presented in Table 13 are qualitatively consistent with the main analysis. For out-of-system transfer, repetition is associated with 7.8% shorter sender's LOS and 25.1% lower odds of readmission for non-clinical transfer and 6.9% shorter sender's LOS and 3.4% longer receiver's LOS for clinical transfer. For within-system transfer, repetition is associated with 7.8% shorter receiver's LOS for non-clinical transfer and 24.9% lower odds of readmission and 58.7% lower odds of mortality for clinical transfers. In summary, we find that repetition benefits non-clinical transfer regardless of affiliation, but for clinical transfer, the benefit depends on system affiliation.

5.2. Comparison with Direct Admission

Our literature review suggests that most studies find that IHT as a whole is associated with worse care outcomes (LOS and mortality) compared with direct admissions (see Table 1). To further understand the difference between IHT types, we compare care outcomes of clinical and non-clinical transfer to direct admission. Since direct readmission can only be identified from inpatient discharges, we compare the patient care outcomes at the receiver in our analysis. Table 14 presents the results of our regression analysis and the related PSM for robustness check.

Our findings resonate with the literature that both clinical and non-clinical transfers are associated with longer LOS and higher mortality, compared with direct admission, but non-clinical transfer appears to be much worse. Specifically, non-clinical transfer is associated with 12.7% longer LOS and 127.2% higher odds of mortality than direct admission, while clinical transfer is associated with 3.5% longer receiver's LOS and 52.5% higher odds of mortality than direct admission. Similar to Russell et al. (2015), we find that transferred patients tend to experience lower odds of readmission. However, we suggest interpreting the lower odds of readmission with caution because of higher mortality.

Considering that transferred patients may have quite different medical conditions compared with direct admission, we conduct a PSM to mitigate sample selection bias. The matching procedure resembles the matching procedure used for system affiliation analysis in Section 5.1. We match patients one-on-one based on the propensity score of transfer with covariates including both patient- and hospital-level characteristics. Each matched pair (including one IHT and one direct admission) has similar propensity scores of being a transfer case. We obtain 15,590 matched pairs where, among all transferred patients, there are 5440 non-clinical transfer cases and 10,150 clinical transfer cases. The results are qualitatively consistent and show that IHT is associated with worse care outcomes, especially for non-clinical transfer.

Table 14 IHT versus Direct Admission

Variable	ln(Receiver's HLOS)	Readmission	Mortality
Non-clinical transfer	0.127(0.008)***	0.89(0.039)***	2.272(0.097)***
Clinical transfer	0.035(0.006)***	0.8(0.029)***	1.525(0.057)***
Control variables		Listed in Table 8	
R^2 or AUC	0.56	0.65	0.91
N	1,460,314	1,460,314	1,460,314
Propensity Score Matching			
Non-clinical transfer	0.099(0.009)***	0.932(0.045)	1.9(0.117)***
Clinical transfer	0.025(0.007)***	0.783(0.036)***	1.388(0.081)***
Control variables		Listed in Table 8	
R^2 or AUC	0.62	0.66	0.91
N	31,180	31,180	31,180

Direct admission is the base case.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$ (Standard errors in parentheses).

5.3. Selection Bias

Since the transfer decision is made by the sender, potential selection bias at the sender may bias our results if non-trivial relevant decision factors are not accounted for in our model. We conduct a Heckman two-stage regression to address the selection bias concern. The dataset used to estimate the selection model includes both interhospital and direct admission from ED to the same hospital.

The dependent variable in the first-stage selection model is the transfer decision which is 0 for direct admission and 1 for IHT. The second-stage selection model has the sender's LOS as the dependent variable because the sender makes the transfer decision. Both stages contain the list of independent variables for the sender's LOS model shown in Table 8. The limitation of this test is that we can only examine one of the dependent variables of interest in the outcome model. We include the receiver's characteristics (teaching status and ownership) as predictors of transfer because these variables affect the transfer decision by the sender but not likely the sender's LOS for IHTs, thus meeting the exclusion restriction (Wolfolds and Siegel 2019). The outcome model uses only the selected IHTs, and it includes the computed inverse Mills ratio for correcting potential sample selection bias.

The parameter estimates are shown in Table 15 and indicate a strong effect of the characteristics of the receiver on treatment selection. The estimate on *rho* indicates that treatment selection bias has no effect on the outcome. The test shows that clinical transfer has 9.7% shorter LOS at the sender than non-clinical transfer and is qualitatively consistent with our findings in Table 8.

5.4. Spillover Effect of Transfer Routinization

Our routinization measures are defined at the MDC level. The medical professionals of different MDCs within the same hospital may share medical resources (such as nurses, operating rooms, and equipment) and knowledge and best practices in IHT. Therefore, the effect of transfer routinization at one MDC may spill over to other MDCs, and the care outcomes of IHT can be affected by the routinization level of both the focal MDC and other MDCs.

Following the study of the spillover effect of health IT investments (e.g., Atasoy et al. 2018), for each transfer pair of sender s and receiver r at a focal MDC c, we define the average routinization level of other MDCs as.

$$\text{routine}'_{src} = \frac{\sum_{i \in \text{MDCs}} \text{routine}_{sri} - \text{routine}_{src}}{\text{total number of MDCs having transfer excluding MDC}\, c},$$

which is the total amount of transfer routinization of all MDCs excluding the focal MDC over the total number of MDCs having transfer minus one (the focal MDC). We set the value to 0 if the number of MDCs transferred between sender s and receiver r is 1. The interaction term, $cln\_trans \times routine'$, is included in the model to estimate the spillover effect. We check the spillover effects using both *repetition* and *concentration* as the transfer routinization measurement.

The results are presented in Table 16. For clinical transfer, the high level of routinization at other MDCs may have negative effects on patient care outcomes of the focal MDC, such as longer LOS in the receiver and higher mortality. Since clinical transfer requires specialty care, a high level of routinization at other MDCs may suggest that patients competing for limited medical resources, and hence result in poor care outcomes. However, for non-clinical transfer, the high level of routinization at other MDCs can have positive

Table 15 Robustness Check on Selection Bias

Variable	Selection model
Control variables	Listed in Table 8 for ln(Sender's HLOS)
Instruments (receiver)	
Teaching hospital	2.132(0.018)***
Hospital ownership (base: private)	
Government	–0.053(0.038)
Non-profit	0.562(0.024)***
Rho	–0.008(0.012)
	Outcome Model
Clinical transfer	–0.097(0.010)***
Control variables	Listed in Table 8 for ln(Sender's HLOS)

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$ (Standard errors in parentheses).

effects on patient care outcomes of the focal MDC, such as shorter LOS in the sender and lower odds of readmission. Since non-clinical transfer is less coordinated by nature and requires less specialty care, routinization across all MDCs can benefit the focal MDC through shared experience and best practices in IHT.

6. Conclusion and Discussion

With the trend of hospital service specialization, regionalization of specialty care, and imbalance of care resources, a growing number of ED patients are being transferred to another acute care hospital for further care. Transferring patients with time-sensitive conditions to another hospital can allow the patients to receive timely care and mitigate hospital congestion (Iwashyna et al. 2009a, Russell et al. 2015). Timely transferring patients out of the ED is especially important to alleviating ED workload because EDs are getting increasingly crowded. However, transferring ED patients to another hospital can present potential clinical risks since many patients admitted to the ED are severely ill and in unstable conditions.

Our study aims to understand the underlying transfer reasons and offers hospital managers relevant insights into approaches to improve patient transfer outcomes. In particular, we elaborate the distinct natures of clinical and non-clinical transfer from the coordination perspective. Clinical transfer is necessary for patients who require higher level care in the form of specific diagnoses, procedures, or physician expertise at the referred hospital. This type of IHT is determined by hospitals' service scope intentionally designed to match patients to scarce healthcare resources within a regional care provider network. Since clinically necessary transfer is built into the configuration of a hospital's service scope and supposedly aligned with the distinct capabilities of a region's care provider network, this type of transfer is likely better coordinated through pre-planned decision criteria and standardized processes. Non-clinical transfer, however, is triggered by reasons other than clinical or physician capabilities, such as capacity shortage, patient insurance, or family convenience. Since non-clinical transfer is typically based on stochastic factors, this type of transfer tends to be ad hoc in nature and lacks effective coordination compared with clinical transfer.

Our transfer type classification allows us to uncover the varying impacts of clinical and non-clinical transfer on patient care outcomes. We find that non-clinical transfer in general is associated with worse outcomes than clinical transfer. As such, non-clinical transfer largely accounts for the overall worse care outcomes of IHT than direct admission. This finding is important since hospital managers can now focus on improving non-clinical transfer rather than attempt to improve all types of transfer indiscriminately, which can be much more costly and harder to manage.

To offer managerial insights into improving patient care outcomes for IHT, especially non-clinical transfer, we investigate two coordination mechanisms: hospital system affiliation and transfer routinization, which serve as a formal and an informal coordination mechanism, respectively. While coordination can improve patient care outcomes of all IHT types, our analysis suggests that the two coordination mechanisms have considerably different effects on the care outcomes of clinical and non-clinical transfer.

Table 16 Spillover Effect of Transfer Routinization

Transfer type	Variable	ln(Sender's HLOS)	ln(Receiver's HLOS)	Readmission	Mortality
Clinical	Repetition	–0.056(0.014)***	–0.005(0.014)	1.003(0.073)	0.77(0.149)*
	Repetition′	0.025(0.033)	0.111(0.032)***	0.725(0.164)**	2.5(0.338)***
Non-clinical	Repetition	–0.051(0.019)***	–0.011(0.019)	1.009(0.095)	1.11(0.24)
	Repetition′	–0.024(0.044)	0.02(0.042)	0.468(0.222)***	0.783(0.572)
Clinical	Concentration	–0.095(0.027)***	–0.018(0.027)	1.079(0.141)	0.985(0.297)
	Concentration′	0.016(0.03)	0.058(0.03)*	0.882(0.157)	1.423(0.34)
Non-clinical	Concentration	–0.012(0.034)	0.035(0.033)	0.776(0.17)	0.568(0.473)
	Concentration′	–0.142(0.037)***	–0.019(0.037)	0.856(0.187)	1.537(0.545)
	Control variables	Listed in Table 8			

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$ (Standard errors in parentheses).

Non-clinical transfer benefits from these coordination mechanisms to much greater extents. Given these findings, transfer type differentiation should be a prerequisite for hospital managers to adopt appropriate coordination mechanisms to improve IHT care outcomes.

We suggest that the sending hospitals prioritize non-clinical transfer to hospitals within the same hospital system. However, clinical transfer decisions should consider out-of-system destinations to a greater extent to utilize the higher level, specialty care capabilities from other hospitals in the region. We find that transfer routinization improves patient care outcomes, more so for non-clinical transfer than for clinical transfer. Our findings suggest that the sending hospital should build long-term partnerships with a limited number of receiving hospitals for non-clinical transfer. However, overly concentrating clinical transfer on a few receiving hospitals may limit the sending hospital's choice of transfer destinations. Since the high-level specialty care of the receiving hospitals is relatively limited and tend to be in high demand, it is advised that for clinical transfer, the sending hospital consider a large set of transfer destinations when possible. Our managerial implications can also apply to the receiving hospital since transfer coordination involves both the sending and the receiving hospitals and can improve the care outcomes at both hospitals. The receiving hospital needs to proactively coordinate with the sending hospital on activities such as capacity planning, transfer handoff, and process standardization that directly affect IHT.

IHTs are prevalent in practice and account for a significant amount of healthcare costs in the United States. It is important yet challenging to differentiate patient transfer types and uncover specific ways to improve each transfer type. While we have attempted to address the challenge to the best we can, several limitations remain, each providing opportunities for future research. First, we do not have real-time resource utilization information of the hospitals at the time of transfer. Hence, our transfer type classification is a retrospective analysis based on transfers already completed instead of the transfer decision process. The retrospective analysis allows us to classify transfers using objective treatment information, but it is possible that the differences in the transfer outcomes may be due to systematic differences between hospitals that have the capacity to treat patients of a specific condition. Although we have strived to overcome this limitation by including a rich list of relevant control variables, we believe real-time resource utilization information can help improve non-clinical transfer decisions even further. For example, the sending hospital can pre-plan for non-clinical transfer if the hospital foresees an upcoming event that may consume a large amount of hospital capacity. Second, the robustness of our analysis to sample selection bias is only tested using the sender's LOS as the outcome variable, mainly due to the difficulty in finding proper predictor variables of the transfer decision. Nonetheless, the receiver's characteristics appear to be appropriate predictor variables for the sender's LOS since they should meet the exclusion restriction. We hope to perform more thorough robustness checks in future research using data on the sender's operations details, should such data become available. Third, our analysis demonstrates the importance of adopting different strategies to manage different transfer types. The simple effects of system affiliation and transfer routinization on different transfer types provide insights into coordination approaches to improve care outcomes of transferred patients. However, it would be interesting to predict counterfactuals and compare the estimated care outcome measures to provide a better sense of opportunities for improvement. Finally, sharing patient information is important to IHT, and the use of electronic health records systems, telemedicine, and teletherapy may affect IHT coordination. But few studies have investigated whether and how health IT facilitates IHT. Future studies are needed to understand how health IT facilitates patient transfer and how the effects may differ between clinical and non-clinical transfer.

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Appendix

Alternative Transfer Type Classifications

Our transfer type classifications are based on retrospective analyses. Since the decisions to transfer emergent patients are complex, we adopt alternative transfer type classifications for robustness check. In particular, we consider three classifications: (i) excluding transfers due to the physician reason from clinical transfer; (ii) including transfers due to insurance into non-clinical transfer; and (iii) including transfers due to distance into non-clinical transfer. Table A1 provides the scope of the clinical and non-clinical transfer for these three alternative classifications compared with the one used in our main analysis.

Next, we investigate the effect of different transfer types on patient care outcomes under the different scopes of transfer type classification. In all three cases, clinical transfer is associated with significantly better patient care outcomes than non-clinical transfer. The results in Table A2 are qualitatively consistent to our main analyses. The robustness check confirms our main results and supports H1.

Table A1 Alternative Transfer Classifications

Possible transfer reasons	Number of transfers			
	Main	Robustness 1	Robustness 2	Robustness 3
Total	17,161			
Capability	8518			
Physician	2932	Excluded		
Capability and physician	1295			
Comorbidity	18			
Age ($\leq$ 16)	0			
Clinical Transfer	10,155	8158	10,155	10,155
Total *minus* Clinical Transfer	7006			
Insurance	498		Included	
Distance	1122			Included
Non-Clinical Transfer	5440	5440	5869	6493

A.1. Robustness to Hospital Clustering

The standard errors reported in Table 8 are derived from OLS. One concern is that the IHT observations may correlate within clusters, where each cluster is defined by the same sender and receiver pair. Table A3 reports the robust standard error estimates after clustering by sending and receiving hospital pairs. The standard error of the variable *clinical transfer* in each model only increases a small amount compared with the results in Table 8 and the effects remain significant.

A.2. Transfers on Weekdays and Weekends

Recall that the variable *aweekend* has a value 1 if the patient is admitted on weekends and 0 otherwise. We included *aweekend* in our analysis to control for the potentially different workload of a hospital on weekdays versus weekends. In the robustness check, we estimate the simple effects of different transfer types on patient care outcomes on weekdays versus weekends by including an interaction term *aweekend* × *clinical transfer*. Table A4 shows that clinical transfer has significantly better patient care outcomes than non-clinical transfer no matter if a patient is admitted on weekdays or weekends. Since we also control for the variable *admission count* for the hospitals' workload, the result suggests that the effect of *clinical transfer* is likely due to the different natures of clinical versus non-clinical transfer rather than due to the timing of transfer.

A.3. Alternative Concentration Measure

Although the transfer decision is largely made by the sender, the receiver may also be part of the routinization mechanism. To check the robustness of our concentration measure, we define the "inbound" concentration as follows:

Table A2 Robustness Check on Alternative Transfer Classification

Classification	Variable	ln(Sender's HLOS)	ln(Receiver's HLOS)	Readmission	Mortality
Robustness 1	Clinical transfer	−0.112(0.011)***	−0.062(0.011)***	0.798(0.056)***	0.779(0.131)*
Robustness 2	Clinical transfer	−0.098(0.010)***	−0.051(0.010)***	0.818(0.051)***	0.765(0.123)**
Robustness 3	Clinical transfer	−0.097(0.010)***	−0.042(0.010)***	0.815(0.050)***	0.785(0.119)**

Other variables (listed in Table 8) are omitted for brevity.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$ estimate or odds ratio (Standard errors).

$$\text{Concentration}_{src} = \frac{\text{number of transfers between } s \text{ and } r \text{ within MDC } c}{\text{number of transfers to the receiver } r \text{ within MDC } c}.$$

The results based on the "inbound" concentration measure are reported in Table A5 and qualitatively consistent with our main analysis in Section 4.3.

Table A3 Robustness Check on Standard Errors

	Variable	ln(Sender's HLOS)	ln(Receiver's HLOS)	Readmission	Mortality
Hospital clustering	Clinical transfer	–0.100(0.014)***	–0.048(0.015)***	0.813(0.056)***	0.778(0.129)*

Other variables (listed in Table 8) are omitted for brevity.
$^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$ estimate or odds ratio (Standard errors).

Table A4 Robustness Check on Transfer Types in Weekday and Weekend

Variable	ln(Sender's HLOS)	ln(Receiver's HLOS)	Readmission	Mortality
Clinical transfer at weekday	–0.102(0.012)***	–0.047(0.012)***	0.835(0.062)***	0.853(0.146)
Clinical transfer at weekend	–0.097(0.018)***	–0.050(0.018)***	0.764(0.089)***	0.616(0.217)**

$^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$ (Standard errors in parentheses).

Table A5 Alternative Concentration Measure

Variable		ln(Sender's HLOS)	ln(Receiver's HLOS)	Readmission	Mortality
Affiliation		–0.012(0.03)	0.02(0.029)	0.941(0.154)	0.671(0.392)
Concentration		0.011(0.04)	0.004(0.039)	1.041(0.198)	0.973(0.481)
Clinical transfer		–0.071(0.018)***	–0.074(0.018)***	0.683(0.091)***	0.657(0.211)**
Affiliation × Concentration		–0.041(0.057)	–0.084(0.056)	1.001(0.29)	1.69(0.729)
Affiliation × Clinical transfer		–0.068(0.037)*	–0.059(0.037)	1.383(0.19)*	2.305(0.449)*
Concentration × Clinical transfer		–0.087(0.046)*	0.097(0.046)**	1.298(0.23)	1.079(0.541)
Affiliation × Concentration × Clinical transfer		0.148(0.069)**	0.043(0.068)	0.746(0.352)	0.414(0.843)
Control variables		Listed in Table 8			
R^2 or AUC		0.16	0.64	0.67	0.91
N		15,595	15,595	15,595	15,595
Marginal Effects					
Affiliation status	**Variable**				
Out-of-system	Concentration	–0.033(0.025)	0.052(0.024)**	1.186(0.123)	1.011(0.289)
	Concentration at non-clinical transfer	0.011(0.04)	0.004(0.039)	1.041(0.198)	0.973(0.481)
	Concentration at clinical transfer	–0.076(0.026)***	0.101(0.026)***	1.351(0.132)**	1.05(0.286)
Within system	Concentration	0.001(0.028)	–0.011(0.027)	1.026(0.14)	1.099(0.337)
	Concentration at non-clinical transfer	–0.03(0.042)	–0.081(0.041)*	1.043(0.219)	1.645(0.566)
	Concentration at clinical transfer	0.031(0.033)	0.059(0.032)*	1.01(0.163)	0.734(0.337)

$^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$ (Standard errors in parentheses).