Matching Hospital Resources with Patients in Need

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Hospitals provide care for the most urgent and most severe sub-population. In the U.S., hospitals contribute to over 30% of total national healthcare expenditure[1]. However, how care is delivered in hospitals largely remains a black box in the economics literature. This chapter provides a few examples to demonstrate the complexity of allocating hospital resources to patients and the needs for more studies in this area using market design tools.

At a high level, matching hospital resources to patients in need is a complex problem to analyze for several reasons. First, the allocation involves multiple parties including patients and their families, physicians and nurses from potentially multiple units of the hospital and different specialized areas of care, and hospital management and administration teams. Coordinating these parties to reach a decision in a timely fashion is non-trivial. Second, these parties might have different preferences, incentives, and sometimes competing objectives when faced with allocation decisions of hospital resources. Patients and their families are likely to focus on their own health outcomes subject to financial constraints. Physicians, as the primary decision makers, are responsible for their assigned patients only, instead of the greater patient population. Some physicians might have their own practice and, therefore, face

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[1] https://www.cms.gov/files/document/highlights.pdf

distorted incentives. Management and administration staff might have the hospital's overall objective in mind. Hospitals might also have their own preferences when allocating medical resources. For instance, many hospitals in the U.S. prioritize surgical patients when allocating ICU beds (Kim et al., 2015; Shen et al., 2020). Hospitals also reserve some beds in inpatient units for high revenue generating patients (Song et al., 2020; Dong et al., 2019). Policy makers also influence the allocation of medical resources in hospitals. Designs of payment schemes can significantly affect hospital's and physician's patient admission and discharge decisions (Einav et al., 2018). Since multiple parties with potentially conflicts in their interests are involved when allocating hospital resources to patients, and that their incentives are not necessarily aligned with that of the social planner, the market design perspective is particular valuable to derive realistic models and useful insights. Third, given the complex and often stressful environment of hospitals, the behavioral aspect of the decision making, or sometimes human errors, can not be ignored in this context. In addition, patient outcomes unfold over time, which brings additional complexity to those decisions. Finally, hospital resources are interconnected instead of isolated, the allocation decision of one resource might affect that of the other, generating chain effects for the entire system. Understanding the complexity of the allocation problem and designing desirable mechanisms in this market can potentially have significant impact on patient outcomes as well as hospital performance and the overall healthcare expenditures.

In this chapter, I use three examples to demonstrate some of the complexity of the resource allocation problem in hospitals and the needs for more work in this area, especially from the market design aspect.

The first example is physician's decision about which patients to admit into the intensive care unit (ICU) in the hospital. ICUs are specialized inpatient units which provide the highest level of care to the patients with most severe conditions. ICUs are also one of the most expensive medical resources in a hospital and are estimated to be 15% to 40% of total hospital cost in the U.S. (Halpern and Pastores,

2015) In addition, ICUs often operate near full capacity (Coopersmith et al., 2012; Halpern and Pastores, 2010), which makes physician's decision of how to allocate such scare resource crucial for its efficient utilization. Moreover, access to ICU bed has been shown to have significant impact on patient outcomes and healthcare expenditures. Kim et al. (2015) find that access to ICU bed reduces adverse patient outcomes, including hospital readmission and length of stay (LOS) by 30%-75% for high severity patients admitted through the emergency department.

Shen et al. (2020) study one behavioral aspect of physician's ICU bed allocation decision. They use data from 24 Kaiser hospitals and detailed patient level information to study whether physicians are forward-looking when they allocate ICU beds. When each physician, or intensivist, decides whether to allocate an ICU bed for the current patient, there are several factors they might take into account. First, the patient's own severity and needs. Second, the current number of ICU beds available, which depends on the number of other ICU patients such as surgical patients, which many hospitals prioritize. Finally, the decision made by the physician for the current patient has intertemporal externalities on future patients. In other words, an ICU bed allocated to the current patient is one less bed available for future patients who might need ICU care. Shen et al. (2020) extend the standard dynamic discrete choice model (Rust, 1994) to estimate whether physicians take the intertemporal externalities of their ICU admission decision into connsideration. Shen et al. (2020) find that, on average, the discount factor over a two-hour period is 0.3, suggesting that physicians barely take into account bed availability for patients arriving two hours later. Shen et al. (2020) also find that there is large heterogeneity across hospitals within the same hospital system, where the estimated discount factor varies between 0.1 and 0.9. Similar findings of large heterogeneity in phyisician's behavior have been shown in the literature for other diagnostic settings (Abaluck et al., 2016; Mullainathan and Obermeyer, 2022). Using counterfactual analysis, Shen et al. (2020) show that more forward-looking in physician's decision making can substantially reduce the congestion in high-occupancy ICUs with the magnitude of the effect equivalent to adding one ICU bed or $1.1 million savings per year in ICU operating cost.

This study highlights the importance of taking into account physician behavior in matching medical resources with patients in need. It also provides interesting directions for future research in this area. For instance, it calls attention for researchers to identify effective mechanisms to facilitate more informed decision-making by physicians, perhaps through providing real-time patient census information or forecasting patient demand in the future. In addition, the large behavioral heterogeneity across physicians and hospitals also show that more work is needed for designing guidelines and incentives to potentially reduce such heterogeneity and improve the efficiency of medical resource allocation. The role of artificial intelligence (AI) in assisting physician's diagnostic decision-making is another exciting area for future research. Given many medical resources such as ICUs in the hospital are shared across different types of patients (e.g. medical vs. surgical), how such resources should be shared across different departments in the hospital is another under-studied area. More broadly, incorporating incentives and behaviors of all parties involved in hospital's resource allocation will also be valuable for future research. In other words, market design tools robust to behavioral distortion and human error will be particularly useful in this area of research.

The second example is in the context of allocating operating rooms (ORs) to cardiac surgeons. In most U.S. hospitals, cardiac OR schedule is organized by blocks–i.e., one OR is assigned to one surgeon for an entire day. One of the reasons to this allocation scheme is that surgeons prefer block schedules as it allows them to spend other days teaching and seeing patients. Such block schedules are typically fixed months in advance. As a result, when an urgent surgical patient arrives, the surgeons with OR blocks on that day are more likely to perform the surgery. However, such practice might also significantly increase surgeon's daily workload. Using detailed cardiac surgery data from Columbia Hospital, Shen et al. (2021)

find that adding one more case to surgeon's daily workload increases OR time by 27 minutes per surgery and post-surgery ICU time by 21%, on average. In other words, inefficient OR allocation leads to surgeon fatigue, inefficient use of ORs, and poor post-surgery patient outcomes. The authors also show that a simple optimization with limited changes to surgeon's schedules which smooth out their daily workload leads to substantial improvement in patient's post-surgery outcomes.

These findings give rise to a series of follow-up research questions on the allocation of ORs in hospitals. Given the commonly adopted block schedule in most hospitals, designing mechanisms to incentivize surgeons not in schedule to share the workload when the number of cases is high can be one possible way to mitigate the negative impact of surgeon's daily workload. More accurate forecast of OR time by surgeon might be used to better allocate ORs to surgeons and surgeries. The matching of ORs and surgeons is also closely dependent on the matching between surgeons and patients which have not been studied much in the literature. In addition, coordinating the schedules of specialists and staff members needed for each surgery and across surgeries is another opportunity to improve the overall matching efficiency. More broadly, coordinating the provision of care pre-surgery and post-surgery with the allocation of ORs might further improve the matching outcomes.

The third example considers the allocation of inpatient unit beds to patients admitted into the hospital. In most U.S. hospitals, inpatient units are organized by medical specialties. For instance, a certain number of inpatient beds might be dedicated for cardiology unit which accepts cardiology patients who are admitted to the hospital. However, in practice, a cardiology patient might be admitted to a gastroenterology unit if the demand for cardiology beds is high. With high levels and fluctuations of demand for hospital resources, such off-service placements are common in most hospitals' daily operations (Song et al., 2020; Dong et al., 2019). Such practice brings up the important role which network structure plays when studying the allocation of hospital resources: Hospitals are complex interconnected systems where resources are shared across different care teams and medical specialties (Dong et al., 2023). Studies have also shown that some interconnection across units established by practices such as off-service placements can have significant negative impact on patient outcomes (Song et al., 2020), which further complicates the design of mechanisms to match hospital beds to patients.

To summarize, the examples in this chapter demonstrate the complexity and the needs for more market design works in the area of matching hospital resources to patients in need. The multiple parties with potentially competing objectives involved, the importance of behavioral aspects in the decision making, and the interconnections among multiple hospital resources make the problem particularly challenging and exciting for market design researchers.

References

J. Abaluck, L. Agha, C. Kabrhel, A. Raja, and A. Venkatesh. The determinants of productivity in medical testing: Intensity and allocation of care. *American Economic Review*, 106(12):3730–3764, 2016.

C. M. Coopersmith, H. Wunsch, M. P. Fink, W. T. Linde-Zwirble, K. M. Olsen, M. S. Sommers, K. J. Anand, K. M. Tchorz, D. C. Angus, and C. S. Deutschman. A comparison of critical care research funding and the financial burden of critical illness in the united states. *Critical Care Medicine*, 40(4): 1072–1079, 2012.

J. Dong, P. Shi, F. Zheng, and X. Jin. Off-service placement in inpatient ward network: Resource pooling versus service slowdown. *Columbia Business School Research Paper*, 2019.

J. Dong, P. Shi, F. Zheng, and X. Jin. Capacity management in networks: A structural estimation approach for hospital inpatient wards. *Columbia Business School Research Paper*, 2023.

L. Einav, A. Finkelstein, and N. Mahoney. Provider incentives and healthcare costs: Evidence from long-term care hospitals. *Econometrica*, 86(6):2161–2219, 2018.

N. A. Halpern and S. M. Pastores. Critical care medicine in the united states 2000–2005: an analysis of bed numbers, occupancy rates, payer mix, and costs. *Critical Care Medicine*, 38(1):65–71, 2010.

N. A. Halpern and S. M. Pastores. Critical care medicine beds, use, occupancy and costs in the united states: a methodological review. *Critical Care Medicine*, 43(11):2452, 2015.

S.-H. Kim, C. W. Chan, M. Olivares, and G. Escobar. ICU admission control: An empirical study of capacity allocation and its implication for patient outcomes. *Management Science*, 61(1):19–38, 2015.

S. Mullainathan and Z. Obermeyer. Diagnosing physician error: A machine learning approach to low-value health care. *The Quarterly Journal of Economics*, 137(2):679–727, 2022.

J. Rust. Structural estimation of markov decision processes. *Handbook of Econometrics*, 4:3081–3143, 1994.

Y. Shen, C. Chan, F. Zheng, and G. J. Escobar. Structural estimation of intertemporal externalities on icu admission decisions. *Available at SSRN 3564776*, 2020.

Y. Shen, C. W. Chan, F. Zheng, M. Argenziano, and P. Kurlansky. The impact of surgeon daily workload and its implications for operating room scheduling. *Columbia Business School Research Paper*, 2021.

H. Song, A. L. Tucker, R. Graue, S. Moravick, and J. J. Yang. Capacity pooling in hospitals: The hidden consequences of off-service placement. *Management Science*, 66(9):3825–3842, 2020.