

# Matching Hospital Resources with Patients in Need

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August 2024

Hospitals provide care for the most urgent and most severe sub-populations. In the U.S., hospitals contribute to over 30% of total national healthcare expenditures<sup>1</sup>. However, how care is delivered in hospitals largely remains a black box in the economics literature. This chapter provides several examples to demonstrate the complexity of allocating hospital resources to patients and highlights the need 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 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, as well as 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 making allocation decisions regarding hospital resources. Patients and their families are likely to focus on their own health outcomes subject to their financial constraints. Physicians, as the primary decision makers, are responsible for their assigned patients only, rather than the broader patient population. Some physicians might have their own practices and, therefore, face

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<sup>1</sup><https://www.cms.gov/files/document/highlights.pdf>

distorted incentives. Management and administration staff might prioritize the hospital's overall objective. 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. The 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 conflicting interests are involved when allocating hospital resources to patients, and that their incentives are not necessarily aligned with that of the social planner, a market design perspective is particularly valuable for deriving realistic models and useful insights. Third, given the complex and often stressful environment of hospitals, the behavioral aspect of the decision-making, including the potential for human errors, can not be ignored in this context. In addition, patient outcomes unfold over time, which brings additional complexity to these decisions. Finally, hospital resources are interconnected instead of isolated; the allocation decision of one resource might affect others, generating chain effects throughout the entire system. Understanding the complexity of the allocation problem and designing desirable mechanisms in this market can potentially have significant impacts 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 need for more work in this area, especially from the market design aspect.

The first example is physician's decision regarding 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 the most severe conditions. They are also one of the most expensive medical resources in a hospital, accounting for an estimated 15% to 40% of total hospital costs 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 scarce resource crucial for its efficient utilization. Moreover, access to ICU beds has been shown to have significant impacts on patient outcomes and healthcare expenditures. Kim et al. (2015) find that access to ICU beds 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, several factors might be taken into consideration. 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, including surgical patients whom 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 consideration. 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, with the estimated discount factor varying between 0.1 and 0.9. Similar findings of large heterogeneity in physician’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 behavior in physician’s decision-making can substantially reduce

congestion in high-occupancy ICUs, with the magnitude of the effect equivalent to adding one ICU bed or saving \$1.1 million per year in ICU operating costs.

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 hospitals are shared across different types of patients (e.g. medical vs. surgical), how such resources should be shared across different departments and different types of patients 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 a 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 schedules in most hospitals, designing mechanisms to incentivize surgeons not in schedule to share the workload when the number of urgent 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. These are all interesting directions for future research.

The third example considers the allocation of inpatient ward (floor unit) beds to patients admitted into the hospital. In most U.S. hospitals, inpatient floor 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). This practice highlights the important role

that network structure plays in 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 a significant negative impact on patient outcomes (Song et al., 2020), further complicating the design of mechanisms to match floor unit beds to patients.

To summarize, the examples in this chapter demonstrate the complexity and the need for more market design works in the area of matching hospital resources to patients in need. The involvement of multiple parties with potentially competing objectives, the importance of behavioral aspects in decision-making, and the interconnections among various hospital resources make this problem particularly challenging and exciting for market design researchers. As discussed in this chapter, future research should focus on developing allocation schemes that account for behavioral factors, incentive distortions, and human errors when matching medical resources to patients in need. Additionally, incorporating real-time patient data, system data, and AI assistance into the decision-making process are important avenues for further exploration. Finally, another promising direction for future research is enhancing decision-making processes by considering the interconnected nature of hospital resources. Understanding and leveraging the complex network of interdependencies between different units, teams, and resources within a hospital can lead to more efficient and effective allocation strategies. By addressing these network dynamics, researchers can develop more robust models that better reflect the real-world complexities of resource management in healthcare settings.

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