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Policy Perspectives

The Value of Vaccines in Maintaining Health System Capacity in England

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ABSTRACT

Objectives: In situations of excess demand for healthcare, treating one patient means losing the opportunity to treat another. Therefore, each decision bears an opportunity cost. Nevertheless, when assessing the value of health technologies, these opportunity costs are not always fully considered. We present a pragmatic approach for conceptualizing vaccines' health system capacity value when considering opportunity costs.

Methods: Our approach proxies opportunity costs through the net monetary benefit forgone as scarce healthcare resources are used to treat a vaccine-preventable disease instead of a patient from the waiting list. We apply this approach to cost the resource "hospital beds" for 3 different scenarios of excess demand. Empirically, we estimate the opportunity costs saved for 4 selected vaccination programs from the national schedule in England during a hypothetical scenario of long-lasting excess demand induced by the pandemic.

Results: The opportunity cost avoided through vaccination rises with excess demand for treatment. When treating an acute vaccine-preventable outcome is a suboptimal choice compared with treating elective patients, preventing a vaccine-preventable disease from blocking a hospital bed generates opportunity cost savings of approximately twice the direct costs saved by avoiding vaccine-preventable hospitalizations.

Conclusions: Policy makers should be aware that, in addition to preventing the outcome of interest, vaccines and other preventative health technologies deliver value in maintaining regular healthcare services and clearing the pent-up demand from the pandemic. Therefore, health system capacity value should be a key-value element in health technology assessment. Existing and potential future vaccination programs deliver more value than hitherto quantified.

Keywords: broader value of vaccination, health system capacity value, health system pressure.

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Introduction

In the global context of health systems dealing with COVID-19, the value of vaccines—including non-COVID-19 vaccines such as flu and pneumococcal—in preventing hospitalizations and intensive care unit admissions has received much attention.[1] By alleviating the burden on the health system during pandemics and the winter season, vaccines contribute to preventing health system pressure, which occurs when demand for a particular service or resource exceeds its available supply. Resources in this context include but are not limited to hospital beds, healthcare staff, medical equipment, single-use materials, and infrastructure. When the health system pressure is large, elective surgeries may be paused, thus increasing waiting lists and waiting times. Excessive longer waiting times mean potentially poorer clinical outcomes, increased costs, inequality, patient anxiety, and dissatisfaction.[2,3]

The value of vaccines in mitigating excess demand for scarce healthcare resources can be considered their "health system capacity" value. It was identified as a critical value element during a round table discussion of senior health economists and policy makers held in 2020 and recommended for further research.[4] In theory, a health technology's cost offset to the healthcare system should capture this value if the total opportunity costs of affected resources are measured and valued correctly. Nevertheless, although economists agree to value opportunity costs with the second-best alternative forgone,[5] opportunity costing is rarely done this way. For pragmatic reasons, reference costs or average accounting expenditures of the chosen alternative are conventionally used in economic evaluations to approximate the opportunity cost of a resource. As such, explicit consideration of the second-best option is often dropped, which would only be adequate in the unlikely circumstance of perfect competition and the absence of any excess demand for bed days.

Therefore, we present a method to quantify the health system capacity value based on the concept of opportunity costs and considering different levels of health system pressure. We then apply that concept to estimate the health system capacity for a hypothetical scenario in which COVID-19 restrictions are eased, prepandemic non-COVID-19 disease patterns are observed, and a long-lasting excess demand induced by the pandemic remains.

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We consider 4 vaccination programs in the UK, focusing on hospital bed days as a key resource.

Methods

Concept of Measuring Health System Capacity Value of Vaccines

Our concept of measuring vaccines' health system capacity value is based on the concept suggested by Sandmann et al,[5] which involves calculating the opportunity cost in terms of health forgone for the second-best patient and expressing them monetarily. We focus on the hospital setting and assume that beds are the key resource facilitating access to hospital treatment, subject to excess demand. We then expand this approach to show how the opportunity cost of hospital beds varies further depending on patients' waiting times.

Our approach requires that—given a constrained budget—a health maximizer such as the National Health Service (NHS) prioritizes elective treatments according to their maximum achievable net monetary benefit (NMB). This implies that the NHS's 18-week target for elective surgery reflects a point in time where the NMB would be maximum for most treatments. Hence, the achievable NMB from treating patients waiting $<$ 18 weeks may, on average, be stagnant or grow over time until it reaches a maximum at the target. This assumes that any deteriorating health because of waiting for care can be fully reversed by treatment, whereas the associated costs stay stagnant or grow less relative to the health loss.

Although the prioritization approach based on waiting time targets might have been the default with the NHS over the past 20 years, today, many patients fail to meet the 18-week target. There are several ways in which waiting might affect the achievable health gain and costs associated with treatment.[6,7] For some patients, the achievable NMB might even grow further, as health is lost but can be regained cost-effectively. Nevertheless, with today's unprecedented demand from patients who waited excessively long because of disruptions to hospital activity during the pandemic, the likelihood of treating patients with suboptimal NMB is high, as excessively long waiting increases the associated treatment costs or the patient's health has deteriorated irreversibly.

Therefore, we use NHS England's waiting time classification rules[8] to distinguish between a "regular-elective" patient (waiting time $<$ 18 weeks and waiting does not lower the maximum achievable NMB) and an "urgent-elective-elective" patient (waiting time $>$ 18 weeks and the related achievable NMB might have increased or decreased).

To illustrate how the opportunity cost of a bed day changes depending on the patients waiting for treatment, we look at 3 hypothetical scenarios of excess demand for hospital beds:

1. No excess demand. This is a rather unrealistic scenario in the UK, given that there is always some excess demand for a healthcare system resource like a hospital bed.
2. Excess demand for elective hospitalizations of "regular-elective" patients. Elective patients are "regular" because we expect that the severity of their condition is not significantly affected by the waiting period given that their procedures are generally performed within the accepted waiting time target of 18 weeks. This scenario proxies a situation like the pre-COVID-19 period when excess demand was present but waiting time targets for elective procedures were met (in fact the operational standard of treating 92% of all patients waiting for elective care within 18 weeks was last met in February 2016,[9] suggesting that scenario 3 has become the status quo well before the COVID-19 pandemic).
3. Excess demand for elective hospitalizations of a mix of "regular-elective" and "urgent-elective-elective" patients. We assume that many patients wait $>$ 18 weeks for their treatment in this scenario. It proxies a situation like the (post-)COVID-19 period when nonpharmaceutical interventions have been relaxed, and prepandemic disease patterns (eg, influenza) can be observed. The only difference to pre-COVID-19 times is the substantial increase in patients waiting $>$ 18 weeks because of reduced elective activity during the pandemic.

Suppose a hospital bed is used to treat the optimal patient (ie, with the highest achievable NMB). In that case, the opportunity cost of this choice equals the NMB of the forgone second-best alternative. Nevertheless, suppose decision makers do not use the bed day for the optimal patient, as suggested by Sandmann et al,[5] we then proxy the opportunity cost of this bed day as the sum of the highest NMB forgone plus the expenditure incurred.

When treating an acute vaccine-preventable disease is a suboptimal choice compared with the average elective treatment, the opportunity cost for the hospital bed day when treating the acute patient i (and having patient j as the next-best alternative to patient i) is

$$OC_i = LOS_i * \left(\frac{C_i}{LOS_i} + \frac{B_j * \lambda - C_j}{LOS_j} \right) \quad (1)$$

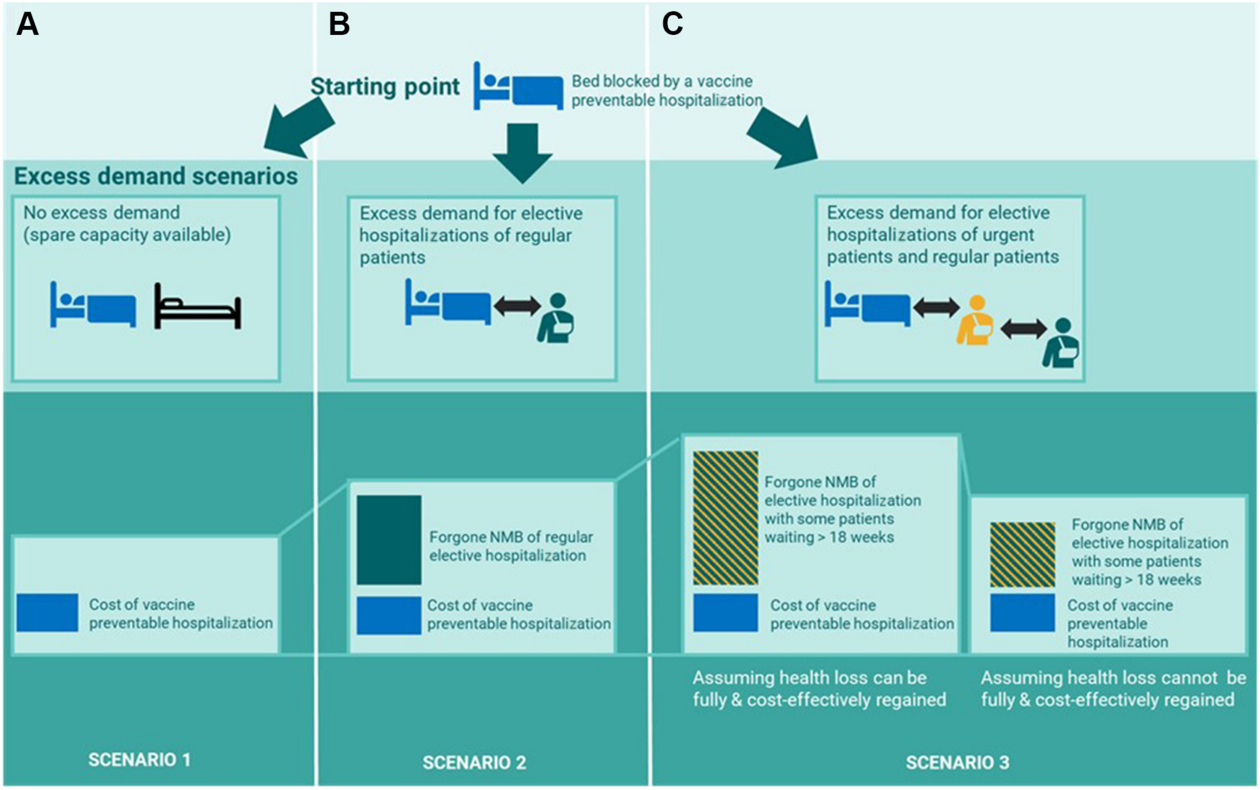
where C_i is the cost incurred for the alternative chosen and $B_j * \lambda - C_j$ is the NMB of the next-best alternative based on the (health) benefit gained per second-best patient B_j, the monetary value assigned to quality-adjusted life-years in local cost-effectiveness thresholds λ, and the expenditure incurred per second-best patient C_j. LOS is the length of stay of patient i or j, respectively.

Equation 1 can be applied to estimate the opportunity costs from the payer's perspective of a bed occupied by a vaccine-preventable disease when health system pressure is present. Treating patients with a vaccine-preventable illness generates opportunity costs in the form of forgone NMBs as long as the demand for elective treatment cannot be supplied because of a shortage of hospital beds. We assume that these opportunity costs drop to zero as soon as the backlog with the respective patients is resolved.

Empirical Approach

We tested our conceptual approach empirically following previous work suggested by Sandmann et al[10] and using publicly available data for England. Our model estimates the health system capacity value within the same year for a hypothetical scenario of excess demand induced by the pandemic but where vaccine-preventable disease patterns (such as influenza) are back to prepandemic levels. This scenario is based on prevented hospitalizations by 4 vaccination programs in 2018/19. It considers the backlog composition of excess demand for regular-elective treatments and the demand for treatments from urgent-elective patients because of long delays in March 2021. We selected 4 immunization programs from the English immunization schedule known to be associated with a significant number of prevented hospitalizations each year: the annual flu vaccination and vaccination against meningococcal type B disease, rotavirus, and pneumococcal disease, respectively.

Figure 1. Visualization of health system capacity value of vaccines at different levels of health system pressure.



NMB indicates net monetary benefit.

First, we estimated the hospitalizations prevented by 4 vaccination programs within specific age groups in the financial year 2018/19 (pre-COVID-19 period). Second, we calculated the opportunity costs of a blocked hospital bed day. In the third and final step, we aggregated the results of steps 1 and 2 to estimate the savings stemming from avoiding vaccine-preventable hospitalizations and savings on opportunity costs of a blocked hospital bed. We provide the details of the model within the Appendix in Supplemental Materials found at https://doi.org/10.1016/j.jval.2022.06.018. We report all monetary values in 2020 GBP.

Results

Conceptual Method to Estimate Opportunity Costs of Hospital Bed Days for Different Levels of Health System Pressure

Scenario 1: no excess demand

There is no excess demand for the hospital bed (Fig. 1, panel A). Hence, the bed occupied by a patient with a vaccine-preventable disease, who either did not choose to vaccinate or where the vaccine failed to protect the patient against severe disease requiring hospitalization, carries no opportunity cost because spare bed capacity is available, and there is no alternative, immediate use of the same bed.

From a payer's perspective, the value of vaccines is simply the avoidable economic costs to hospitalize and treat a patient because of a vaccine-preventable disease as the costs and benefits with patient j in Eq. (1) are zero. This is equal to the value of vaccines when resources are valued according to the traditional reference cost method.

Scenario 2: excess demand for elective hospitalizations of regular-elective patients

With excess demand for elective hospitalizations of regular-elective patients (Fig. 1, panel B), there are alternative uses of the bed in addition to admitting a patient with a vaccine-preventable disease, represented by nonzero costs and benefits associated with treating patient j in Eq. (1).

We assume that vaccine-preventable diseases lead to acute hospitalizations, which, due to their urgency, take priority over elective ones. When treating the vaccine-preventable outcome is, on average, not the intervention with the largest NMB that a hospital can undertake, the opportunity cost of a bed used to treat a patient with a vaccine-preventable disease in scenario 2 is, therefore, the sum of the acute hospitalization cost and the NMB forgone from an elective hospitalization. This sum equals the value of vaccines from the "payer's" perspective in avoiding a vaccine-preventable hospitalization. No further opportunity costs are generated at the margin, where the associated excess demand is resolved.

Scenario 3: excess demand for elective hospitalizations of urgent-elective patients and regular-elective patients

In scenario 3 (Fig. 1, panel C), the opportunity cost of the bed used by a patient with a vaccine-preventable disease, which is not the best alternative, can again be obtained as the sum of the acute hospitalization cost and the NMB forgone from the next-best alternative use of the bed.

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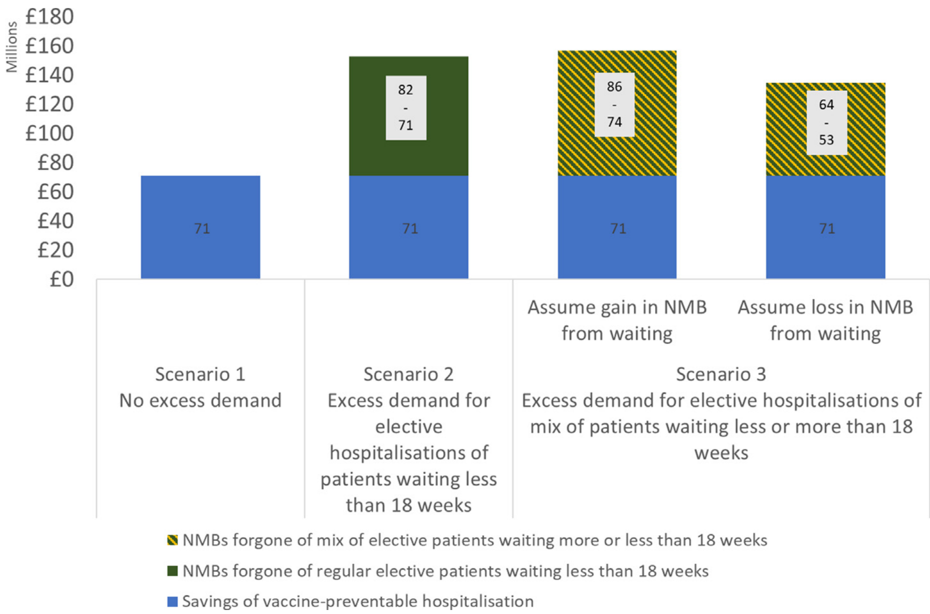
Figure 2. Economic costs saved by 4 vaccination programs under 3 excess demand scenarios.



NMB indicates net monetary benefit.

In this case, the waiting list for elective treatments includes a mix of patients that can be either a regular-elective patient *j* and an urgent-elective patient *k* who waited longer than the 18-week target. Whether the NMB forgone is higher or lower than that in scenario 2 depends on whether we assume that the NMB from treating patient *k* is higher or lower than the NMB from treating patient *j*.

On the one hand, patient *j* might have lost health during waiting that can be restored cost-effectively through hospital treatment, which would increase the NMB by extending the waiting time. On the other hand, there is ample evidence in the field of cancer that each month's delay increases the risk of mortality[3] and leads to higher costs.[11] As a result, the forgone NMB due to a vaccine-preventable hospitalization would likely be lower than in scenario 2.

Empirical Evidence From England

Figure 2 shows the health system capacity value of 4 vaccination programs regarding the economic costs saved on hospital bed days under 3 excess demand scenarios. In case there is no excess demand, the 4 programs save approximately £71 million in direct treatment costs. As soon as there is demand from regular-elective patients waiting $<$ 18 weeks (scenario 2), there is an additional opportunity cost of £71 to £82 million proxied by the NMBs from forgone treatments. In scenario 3, this additional opportunity cost rises to £74 to £86 million when we assume that waiting leads to an increase in NMBs and falls to an additional £53 to £64 million under the assumption that waiting lowers the achievable NMBs.

Discussion

We extended a novel approach to estimate the opportunity cost of a blocked hospital bed to estimate the health system capacity value of vaccines from the payer's perspective under 2 different levels of excess demand. A complementary empirical model illustrates the magnitude of this value for 4 vaccination programs in England.

The findings add to the understanding of the broader value of vaccines and support the argument made by various health economists, including ourselves, that vaccination programs may be systematically undervalued.[4,12–18] Therefore, we argue to integrate health system capacity value into the existing broader value frameworks.

Traditional value assessment methods consider vaccines (and any other preventative treatments) as if there was no excess demand for the resources in a healthcare system (our "scenario 1"). Nevertheless, there is a long-standing history of excess demand for hospital bed days within the NHS, and therefore, the assumption of no excess demand is unrealistic. Hence, the existing valuation approach does not always consider appropriately the opportunity costs stemming from patients who miss out on their treatment when a patient with a vaccine-preventable disease urgent-electively requires a hospital bed. Consequently, the value of the 4 vaccination programs to a payer is likely almost twice as high when excess demand for elective care from regular-elective patients is considered and treating the vaccine-preventable outcome is a suboptimal choice. With increasing health system pressure, the health benefits forgone and costs associated with longer than acceptable waiting times further increase the value of vaccines (to approximately 2 times the value compared with the scenario of no excess demand).

In England, the size of the backlog of demand for hospital treatments is currently unprecedented. Of the 7 million patients whose diagnosis was missed during the pandemic, 65% to 80% are expected to return to access NHS care over the next year.[19] Hence, vaccines' potential health economic value in preserving the availability of the health system's capacity was never as high as today and is likely to be growing.

The bearer of these costs arising from this excessive backlog of patients is not always the hospital. Assuming that excessive waiting lowers the achievable NMB from treatment, opportunity costs could also decline. Nevertheless, in such a case, the health system would fail its objective to maximize population health, as patients waiting for treatment lose their health irreversibly.

Our results also have important implications for health equity. In patients from lower socioeconomic backgrounds, long waits for surgical procedures are shown to lead to worse outcomes in quality of life[19] than in other patient groups. Hence, preventative interventions that help avoid waits beyond the 18-week target promote health equity as they prevent those patients from internalizing the irreversible loss in health.

A strength of our approach is that it is transferable to any technology preventing excess demand and across different types of resources needed to deliver primary and secondary care. It is based on the assumption that the opportunity costs of imperfectly marketable resources (such as hospital beds) may diverge from the cost derived through conventional costing methods.[5] Therefore, we recommend using this approach in a resource-constrained setting with excess demand for care for any treatment that is expected to deliver exceptionally large health system capacity value as it would be significantly undervalued otherwise.

The presented approach has limitations that require refinement for future application. The conceptual and empirical models rely on several simplifying assumptions. These include the assumption that the increasing severity of long waiting patients reduces the forgone NMB for some patients and that the length of hospital stay is unaffected by the severity of the disease. Furthermore, we assume that the urgency for treatment is the primary determinant of prioritizing patients in the hospital and that triaging leads to allocating all hospital beds freed up by vaccination to urgent-elective elective patients first. Third, we assume that treating an acute vaccine-preventable outcome is always the suboptimal choice, which might not be true in every case. In the absence of empirical evidence, removing the incurred treatment costs when assuming that treating all vaccine-preventable outcomes would be the optimal decision would significantly reduce the opportunity cost. Finally, we assume perfect transferability of hospital beds across hospital departments and treatments.

These limitations introduce uncertainty in the value estimate and limit the generalizability of the results to other vaccination programs. For illustration purposes, we selected vaccination programs that are known to free up relatively large amounts of bed days. It is likely that the empirical estimate reflects a higher bound for the health system capacity value of vaccination programs in general. If programs free up fewer hospital bed days, they will consequently deliver less health system capacity value.

Conclusion

Understanding and considering opportunity costs are crucial to appropriately value any preventative treatment that can free up relevant resources during excess demand for healthcare services. Our results show vaccines can save large opportunity costs when treating the vaccine-preventable outcome is the suboptimal choice in the presence of excess demand for treatment from a mix of elective patients with urgent conditions. Policy makers should be aware that, in addition to preventing the outcome of interest, vaccines may deliver value in maintaining regular healthcare services and clearing the pent-up demand from the pandemic. Therefore, vaccines' health system capacity value should be a key-value element to consider in health technology assessment, and further methodological research should aim to facilitate this.

Supplemental Materials

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.jval.2022.06.018.

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