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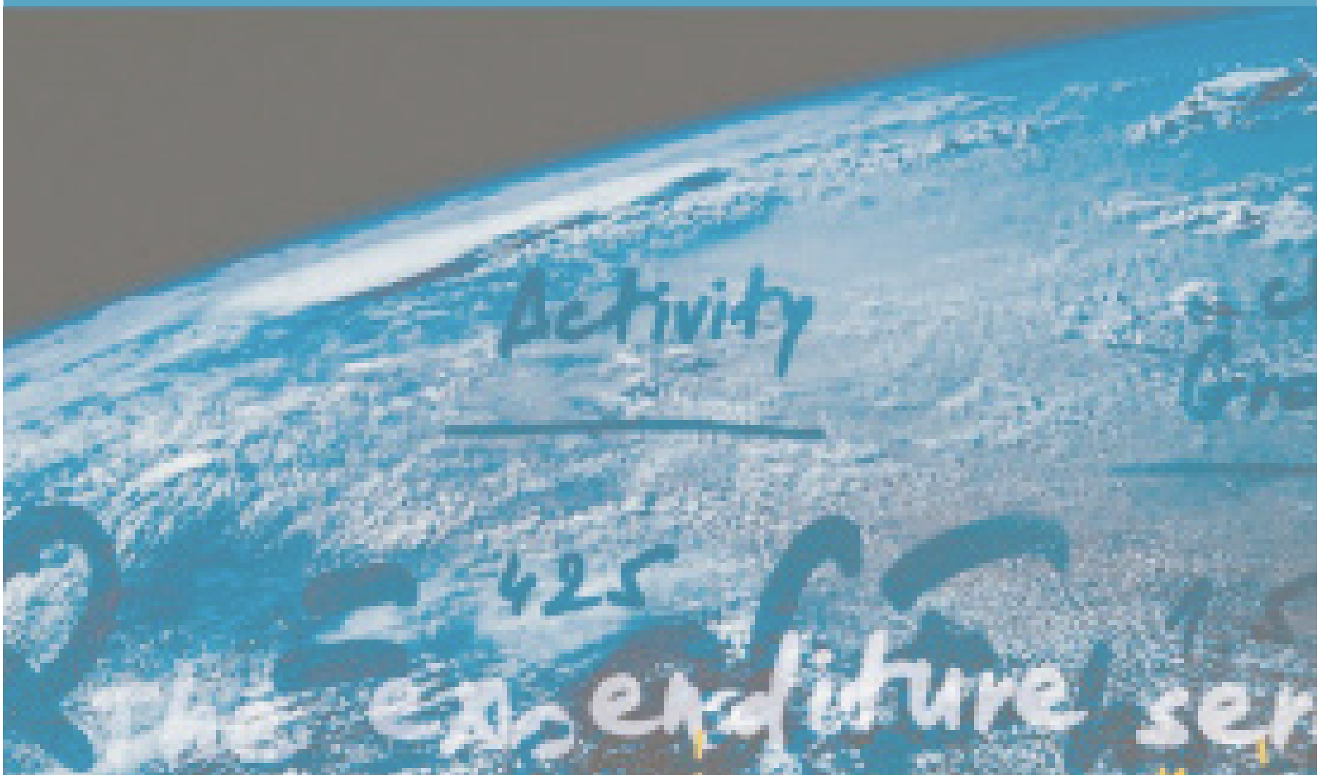

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Panagiotis Kasteridis
Luigi Siciliani
Peter Sivey

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Corresponding Author
Luigi Siciliani, Department of Economics and Related Studies, University of York.
Luigi.Siciliani@york.ac.uk

Centre for Health Economics
Alcuin College
University of York
York
YO10 5DD
UK

york.ac.uk/che

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Panos Kasteridis Luigi Siciliani Peter Sivey

Abstract

Waiting times for planned healthcare treatments have been slowly increasing in England in the last decade, and increased sharply during the COVID-19 pandemic. One policy to reduce the impact of waiting times on patients' health is for doctors to prioritise patients according to need. This study uses hospital administrative data in 2015-2021 on hip replacements in England to investigate the extent to which publicly-funded patients with higher need, measured by pre-operative health, are prioritised on the list by public and private providers. Our results provide evidence of inpatient waiting-time prioritisation (from specialist addition to list to admission for surgery) based on pre-operative health with a difference of at least 12 days between patients with lowest and highest pre-operative health depending on the year. The gradient becomes steeper as waiting times increase, and much steeper during COVID-19. While outpatient waiting times (from referral to specialist visit) comprise a substantial proportion of total time waited (inpatient plus outpatient), we find limited evidence of outpatient waiting time prioritisation. Differences in inpatient waiting-time prioritisation between public and private providers are mostly due to different casemix and shorter average waiting times by private providers. We also show that prioritisation policies that further reduce inpatient waiting times for patients with low pre-operative health by 20% while simultaneously increasing it for those with high pre-operative health can generate health gains of 188 QALYs in a given year. We conclude that there is scope for improving prioritisation of patients on the waiting list.

Keywords: prioritisation, health care, waiting times, provider behaviour, capacity constraints.

Introduction

Long waiting times for hospital care are a major health policy issue in many countries (OECD 2020). Waiting times for non-emergency care have been exacerbated by the COVID-19 pandemic, which disrupted the provision of healthcare services and created backlogs therefore increasing waiting times. In the UK, approximately 34% of elective care was cancelled in 2020 (Burn et al 2021), with only a slow recovery to pre-pandemic levels in 2021 and 2022 (Morris and Reed 2022). The UK, like other OECD countries, specifies maximum waiting times for elective surgery, with the main target of 18 weeks in recent years. Performance against this waiting time target has been gradually worsening over the past decade, with a dramatic fall in the percentage of patients treated within the target time since the onset of the pandemic (NHS England 2022).

Prior to the COVID-19 pandemic, only a few OECD countries engaged in explicit prioritisation of patients waiting for elective care (OECD 2020). Countries can differ in their approach with some countries using more formalised tools with more explicit criteria to support doctors to prioritise patients on the list (for example, in New Zealand) while others have generic descriptors to prioritise patients on the list based on their degree of urgency across a range of treatments and surgical procedures (OECD 2013 2020).

Health professionals are used to prioritising patients based on urgency, need, and ability to benefit. There is evidence across a range of countries suggesting that patients wait longer for less urgent surgical procedures such as hip and knee replacement or cataract relative to more urgent ones, such as coronary bypass, angioplasty, hysterectomy and prostatectomy (OECD 2013). The extent to which patients are prioritised within a treatment is less clear. The English NHS did not explicitly prioritise patients, although evidence suggests that hip replacement patients with worse pain and mobility did wait less during the early 2010s (Gutacker et al 2016). After the onset of the pandemic, guidelines were introduced to prioritise patients within specialties, including for hip replacement surgery (Federation of Specialty Surgical Associations 2021).

We investigate the extent to which doctors prioritise patients on the waiting list. We focus on patients in need of hip replacement in public hospitals. More precisely, we test the extent to which patients with worse pre-operative health (who are in more pain or less mobile) wait less than patients with relatively better pre-operative health. We also investigate if higher socioeconomic status, which should not affect prioritisation, reduces waiting times. We look at a period when mean waiting times for public providers have gradually increased over time by 34% between 2015/16 and 2019/20 (from 90 to 121 days) before rising to 219 days in 2020/21 during COVID-19. This time frame allows us to test whether prioritisation is more pronounced as waiting times increase, and at what point prioritisation becomes more explicitly encouraged by guidelines. We test for prioritisation both for the inpatient waiting time, from specialist addition to list to treatment, and outpatient waiting time, from referral (for example, from a GP) to specialist visit. Our analysis measures pre-operative health through patient-reported outcome measures based on the Oxford Hip Score, which is a condition-specific instrument comprising a range of questions related to pain, joint movement and ease of undertaking normal domestic activities such as walking or climbing stairs. We also control for an extensive range of patient characteristics that could be correlated with pain and mobility.

A significant proportion of publicly-funded patients are treated by private hospitals (known as Independent Sector providers in England), about 25% in 2015/16 and 37% in 2020/21. We therefore compare waiting time prioritisation between public and private hospitals. Private providers tend to have shorter waiting times and treat less complex patients, which could also affect prioritisation. We therefore use matching techniques to compare prioritisation between public and private providers with similar casemix and waiting times. Last, we quantify potential health gains that would arise from making the waiting time prioritisation steeper by further reducing waiting time for patients with lower pre-operative health while simultaneously increasing it for those with higher pre-operative health.

Our key findings are as follows. Our results provide evidence of prioritisation based on pre-operative health. The difference in inpatient waiting times between patients with lowest and highest pre-operative health is at least 12 days depending on the year. The gradient becomes somewhat steeper as waiting times increase with a difference that is less than 22 days up to 2019/20, and much steeper in 2020 with a difference of about 47 days. We also find some inequalities in waiting times by income deprivation in the pre-pandemic years: patients in the most deprived quintile waited four days longer in 2018/19 and 2019/20. This difference increased to 20 days in 2020/21.

While outpatient waiting times comprise a substantial proportion of total time waited (inpatient plus outpatient), we find limited evidence of outpatient waiting time prioritisation. Patients with highest pre-operative health wait at most 13 days longer than those with middle pre-operative health, for a given number of appointments. When general practitioners (GPs) are the source of referrals to specialist care and patients have one outpatient appointment from GP referral to addition to the list we find no evidence of outpatient waiting time prioritisation. Patients with higher pre-operative health are more likely to have multiple outpatient appointments and this translates into longer waiting times for this group.

When comparing prioritisation between public and private providers, we find that patients treated by private providers with *highest* pre-operative health also tend to wait longer than patients with middle pre-operative health (by 8-14 days in the pre-pandemic years), and this is despite the much shorter inpatient waiting times of private hospitals (for example 52 days for private providers and 109 days for public providers in 2017/18). Instead, patients treated by private providers with *low* pre-operative health tend to wait similarly relative to patients with middle pre-operative health, which is in contrast to the results for public providers. However, differences in inpatient wait prioritisation are somewhat attenuated when public and private providers are matched on patient characteristics: differences in waiting times for public providers for patients with low pre-operative health are smaller for the matched sample. When comparing public and private hospitals with similar average waiting times, we do not find systematic differences in inpatient wait prioritisation between public and private providers.

Last, we show there is scope for enhancing waiting-time prioritisation. For example, prioritisation policies that reduce inpatient waiting times for patients with low pre-operative health by 20% while simultaneously increasing it for those with high pre-operative health can generate health gains of 188 QALYs for patients having hip replacements in one year of our sample. Similarly, a policy that would reduce waiting times by 40% for those with worst health would increase health gains by 351 QALYs.

We make several contributions to the literature. First, in addition to the inpatient waiting time (Gutacker et al 2016), we also test for prioritisation and inequalities in outpatient waiting time, the waiting time for the outpatient appointment at which the patient is added to the list. This approach captures more accurately the full patient experience, as the outpatient wait accounts for a substantial proportion of total wait from referral to treatment (more than one third in our data). Moreover, it captures differences in prioritisation between healthcare professionals working in different segments of the health system along the patient pathway. For example, GPs are responsible for referring the patient and can influence the outpatient wait while specialists are responsible for the inpatient wait.

Second, we compare waiting time prioritisation before and after the onset of the COVID-19 pandemic. With the increase in waiting time following the pandemic, there is a stronger rationale to prioritise patients with highest need, greater capacity to benefit, those who suffer most while waiting or whose health benefit may reduce more quickly while waiting. We also look at whether differences in waiting times by socio-economic status and patient complexity changed following the pandemic.

Third, we are the first to compare waiting time prioritisation between public and private hospitals treating publicly-funded patients. Private providers differ in patient casemix, have shorter waiting times and are more likely to give a higher weight to profit considerations (Brekke et al 2012), all of which may affect incentives to prioritise patients.

Fourth, we simulate the effect of different wait prioritisation policies and show that further redistributing waiting times from patients with high to low pre-operative health can generate significant health gains, which is in line with theoretical predictions (Gravelle and Siciliani 2008).

Related Literature

Our study is most closely related to Gutacker et al (2016) who investigate waiting time prioritisation for hip and knee replacement in 2009-14 in England, when waiting times for publicly-funded patients were at the lowest level at 82 days for hip replacement across the sample period (Nuffield Trust 2022). It shows a 20 days difference between patients with high and low pre-operative health, and the relationship is approximately linear. They find no differences by socioeconomic status. Although not the primary focus of their paper, Nikolova et al (2016) run regressions of waiting time on patient characteristics including PROMS such as the Oxford Hip Score (OHS) with data from 2009/10. Using a linear continuous specification of the OHS, their coefficients suggest approximately 4-5 days difference in waiting time between patients in the best and worst pre-operative health. They also use another variable collected in PROMS: symptom duration prior to the procedure, and find that longer symptom duration is associated with a small increase in waiting time (1.6 days increase in wait from the shortest to the longest symptom duration). Lau et al (2020) investigate symptom duration in more detail and find that the extreme values (<1 year or >10 years) are associated with poorer pre-operative health, and the longer durations with poorer health gain from surgery.

Our study also relates to the literature on socioeconomic inequalities in waiting times for publicly-funded patients using administrative data. For hip replacement, Laudicella, Siciliani and Cookson (2012) find that in 2001 patients in the fourth and fifth most income-deprived quintiles waited about 7% longer than patients in the least deprived quintile, though it reduced by 2010 (Moscelli et al 2022). Also for hip replacement in 2000-03, Monstad, Engesæter and Espehaug (2014) find that in Norway men in the highest income group waited 14% less relative to those with lowest income. Women with the highest education waited 7% less relative to those with lowest education. Simonsen et al (2020) find a socio-economic waiting time gradient for hernia (8-17 days) and cataract surgery (4-5 days) using data from Denmark. For coronary bypass in England, Moscelli et al (2018) found up to 35% (43 days) difference in waiting time between patients in the most and least deprived quintiles, and that only up to 12% of these waiting time inequalities can be attributed to patients' choices of hospital and type of treatment (heart bypass versus stent). Johar et al (2013) find that in Australia (New South Wales) more deprived patients in need of elective treatment wait 16-24% longer. Sharma et al (2013) find that in Australia (Victoria), patients living in areas in the highest income decile wait overall 12% less.

Marques et al (2014) uses data from the UK from 2006 to 2009 on both inpatient and outpatient waiting times (which they label the "official" and "work-up" waiting time). They find very high outpatient waiting times (mean 429-532 days compared to 88-157 days for inpatient waits) and that patients living in the least deprived 20% of areas experience shorter outpatient waits but no difference in inpatient waiting time.

Institutional setting

The English National Health Service (NHS) provides universal access to healthcare, which is free at the point of use. The normal care pathway for patients requiring hip replacement surgery is for them to first visit their general practitioner (GP) with symptoms of hip osteoarthritis and subsequently they may be referred for specialist treatment either at an intermediate musculoskeletal hub/clinic or directly with an orthopaedic surgeon (McHugh et al 2011; Dakin et al 2020). There are two components of the waiting time, the outpatient waiting time for a specialist appointment with a consultant orthopaedic surgeon and the inpatient wait for subsequent surgery if deemed appropriate. Waiting times for care are the focus of targets, maximum waiting time guarantees and policies in the NHS, in line with other OECD countries (OECD 2020).

The NHS in England completed approximately 126,000 elective hip replacements per year prior to the pandemic (Krelle et al 2021) with about 25% of these and similar treatments provided in independent sector providers (Peytrignet et al 2022). There are approximately 30,000 privately-funded hip replacements per year in the UK (or approximately 25,000 per year in England) which are not included in this study (PHIN 2022). The NHS has an 18-week target (NHS England 2019) for any type of elective surgery, including hip replacement. Recent years have seen overall performance of nearly 90% of patients admitted within-target in the early 2010s, falling to about 70% prior to the pandemic in 2019.

During the COVID-19 pandemic, elective care, including joint replacement surgery, was severely disrupted. In the first months of the pandemic (March and April 2020) elective hip replacements fell to almost zero before beginning to recover unevenly across the country (Krelle et al 2021). The Health Foundation has estimated that 58,000 fewer people had a hip replacement in 2020 compared to normal. The number of elective patients meeting the target waiting time of 18 weeks fell (from 70% prior to the pandemic) to 59% by early 2022. For Trauma and Orthopaedics patients (including elective hip replacements) the figure fell to 56% (NHS England 2022).

Unlike other countries, such as Australia (VAHI 2022), Portugal, Norway or New Zealand (OECD 2020), prior to the COVID-19 pandemic there was no formal process for prioritisation of patients waiting for elective surgery in the English NHS. However, during the pandemic, the Federation of Specialty Surgical Associations produced a document "Clinical guide to surgical prioritisation during the coronavirus pandemic" (FSSA 2022). In these guidelines, arthroplasty procedures (including joint replacement) were listed as prioritised first if there was "risk of serious adverse consequences of delay", second, in "any site where an extended wait will prejudice outcome" and third "not otherwise specified" (i.e., all others). It is unknown how these guidelines affected waiting time prioritisation in England in practice.

Data

Our sample consists of patients aged 18 or over who underwent a hip replacement surgery in an acute NHS hospital between April 2015 and March 2021, and for whom a) we have information on their pre-operative health and b) we can measure both their inpatient and outpatient waiting times. All data is presented and analysed according to UK financial years (for example, for 2015/16 the financial year is between 1 April 2015 and 31 March 2016).

Our final regression sample is based on the following criteria (see Appendix A for details). We initially identify all hip replacement surgeries that took place during the study period using the procedure codes recorded in the Hospital Episodes Statistics (HES) inpatient data. The identification algorithm includes all types of hip replacements but excludes bilateral operations and revisions[1]. Over 70,000 hip replacements (excluding revisions) took place each year between 2015/16 and 2019/20 but the volume dropped dramatically to about 30,000 in 2020/21. We obtain information on pre-operative health by linking hip replacement procedures identified in HES with PROMs data.

PROMs data have been collected nationally since 2009. Hip replacement is one of the four elective surgical procedures covered by the PROMs programme (NHS Digital 2022)[2]. All providers of NHS-funded unilateral hip replacements are expected to invite patients undergoing these procedures to complete a pre-operative PROMs questionnaire and a post-operative questionnaire following their operation to report their health status and health related quality of life.

Completion of the pre-operative PROMs questionnaire is voluntary for the patient and is administered by the hospital between the last outpatient appointment preceding admission and the surgery[3]. The post-operative questionnaire is posted to patients at least six months after surgery. The pre-operative and the post-operative PROMs data are commonly used to determine the outcome of the surgery as perceived by patients in terms of its impact on their self-reported symptoms and functional status. We only use questionnaires on health prior to surgery.

Each pre-operative questionnaire includes a mixture of generic and condition-specific questions. The Oxford Hip Score (OHS) is a condition-specific instrument comprising 12 questions designed to assess a patient's experience of pain, ease of joint movement and ease of

[1] The procedure codes for the various types of hip replacements are defined in the PROMs guide (NHS Digital, 2017). They are also listed in Appendix B.

[2] Collection of PROMS data for two procedures (varicose vein and groin hernia) ceased in 2017, while the collection continued for hip and knee replacements. The last finalised (provisional) data for these two procedures were available for April 2020 - March 2021 (April 2021 - March 2022).

[3] There is significant local discretion as to when the pre-operative questionnaire is administered over this time interval.

undertaking normal domestic activities such as walking or climbing stairs (Appendix C). Each question scores on a five-point scale, ranging from zero (severe problems) to four (no problems). Individual scores are added together to provide an overall score with zero indicating the worst possible score and 48 indicating the best possible score.

We link hip replacement procedures identified in HES with PROM records that have a completed pre-operative OHS and are linkable with HES[4]. For 2015/16-2019/20, a pre-operative questionnaire was completed for 60-67% of hip replacement surgeries. In 2020/21, the response rate fell dramatically to 38%. Of the procedures with pre-operative OHS, we exclude records with missing values on waiting times and patient characteristics (11%) and 56 records with age younger than 18.

Inpatient waiting time is defined as the number of days between the specialist's decision to add a patient to the waiting list and the date the patient is admitted to hospital for surgery. We exclude inpatient waiting times longer than three standard deviations from each year's mean (1%).[5] We analyse separately hip replacements performed by independent sector (private) providers treating NHS-funded patients (25% in 2015/16 and 37% in 2020/21). This is because waiting times for private providers are much shorter, which could have a significant impact on prioritisation[6].

We use the outpatient HES database to identify outpatient appointments associated with the decision to add a patient to the inpatient waiting list. The identification process involves the following steps. The outpatient data provide information on the date of attendance of an appointment and the outpatient consultant's specialty, allowing us to identify relevant appointments as all outpatient appointments that a) took place prior to the addition of the patient to the inpatient waiting list and b) were led by a consultant whose specialty during the period of care was Orthopaedics[7].

We organised the relevant outpatient appointments in spells as follows: an outpatient spell is defined as the set of a patient's outpatient appointments for which a referral (from a GP or other

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[4] Not all PROM questionnaires can be linked to HES. Unlinked questionnaires occur because: a) patient details on the questionnaire are poorly completed, b) clinical coding in the episode may be missing or poorly completed failing to identify the episode as a hip replacement and making it ineligible for matching, c) there are provider mapping issues, d) patient died before the operation, e) patient cancelled the operation.

[5] Some patients had more than one hip replacement in the same year and therefore submitted more than one questionnaire. We only use records related to the first questionnaire submitted by the patient.

[6] We exclude privately-funded patients treated in NHS and private hospitals.

[7] There are some outpatient appointments for which the consultant's specialty is not "Orthopaedics" but matches the specialty of the consultant responsible for the inpatient admission. These appointments are also included.

source) was received on the same date. A hip replacement record may be linked to one or more outpatient spells[8]. Less than 0.5% of the outpatient appointments identified belong to spells with more than 10 appointments and are dropped from the sample as outliers.

We consider the outpatient appointment that is nearest to the date of addition to the inpatient waiting list. If this appointment has taken place up to three days prior to the addition to the list, it is considered a match. Patients who do not have matched appointments are removed from the sample. We were able to match about 80% of hip replacements with an outpatient appointment (Appendix A).

For the matched sample, we define the outpatient waiting time as the number of days between the referral date and the day the patient was added to the inpatient waiting list. We exclude outpatient waiting times that are longer than three standard deviations from each year's mean (Appendix A).

The final regression sample consists of 21,192 hip replacement admissions in 2015/16, 24,059 in 2016/17, 22,166 in 2017/18, 23,233 in 2018/19, 18,956 in 2019/20 and 4,414 in 2020/21. The OHS enters our econometric specifications (described in the next section) in two ways. In the main specification, we split the OHS into nine groups coded as 0-4, 5-8, 9-12, 13-16, 17-20, 21-24, 25-28, 29-32, 33-48 (to allow for a non-linear relationship between pre-operative health and waiting times). In a sensitivity analysis, we recode the 12 OHS questions as binary variables indicating difficulties in each domain, to assess the role of the individual domains comprising the OHS (Appendix C). We control for various patient characteristics including patients' gender, age, ethnicity, rurality, and deprivation. We construct six age groups: 18–44 years old, 45–54, 55–64, 65–74, 75–84 and 85 years or above. Rurality is captured by a binary variable indicating whether a patients' output area (average population of 300 residents) falls within towns, villages, hamlets and isolated dwelling. To proxy socioeconomic status, we use the 2019 Index of Multiple Deprivation (IMD) quintile for the patient's area of residence (Lower Super Output Area with average population of 1,500 inhabitants) as an indicator of area-level deprivation.

[8] As an example, consider the case of a hypothetical patient that was added to the hip replacement waiting list on 1st July 2017. For this individual, we identify two spells: the first outpatient spell consists of a single appointment that has a referral request date on the 15th May 2017 and was attended on the 20th June 2017; the second spell consists of three appointments that had the same referral request date of 1st February 2017 and they were attended on 1st April, 15th May and 1st July of the same year.

We account for prior healthcare utilisation by including a categorical variable indicating whether a patient had zero, one, or more than one emergency admissions in the year prior to their joint replacement surgery. To account for the complexity of a patients' condition, we include dummy variables indicating the type of primary diagnosis at admission. Specifically, we include dummies for the 10 most frequent primary diagnoses (using the International Classification of Diseases (ICD) version 10 codes) and a dummy indicating any other primary diagnosis. The most common primary diagnoses are different types of coxarthrosis. As well as the primary diagnosis for the admission, we create dummy variables indicating the presence of each of the conditions of the Elixhauser index recorded in any of the admissions in the previous year (including as secondary diagnoses in the current admission). This results in 30 dummy variables, which allow us to control for the complexity of a patient's health status. To capture symptom duration we include information about whether patients experienced problems with their hip for less than a year, 1 to 5 years, 6 to 10 years, and more than 10 years.

Finally, for the analysis of outpatient waiting times we construct two additional variables: dummy variables indicating the source of referral (GP, responsible outpatient consultant, other) and the number of appointments in the outpatient spell (1, 2, 3, 4 or more).

Methods

Our regression model of waiting times is:

$$WT_{ij} = c + \boldsymbol{S}'_{ij}\boldsymbol{\beta} + \boldsymbol{X}'_{ij}\boldsymbol{\gamma} + \boldsymbol{h}_{\boldsymbol{j}} + u_{ij} \qquad (1)$$

where WT_{ij} is the inpatient or outpatient waiting time of patient i in hospital j; $\boldsymbol{S}_{ij}$ is a vector of indicators of pre-operative health as measured by the Oxford Hip Score; $\boldsymbol{X}_{ij}$ is a vector of patient characteristics (for example age, sex, ethnicity, primary and secondary diagnosis, year of admission, etc.); $\boldsymbol{h}_{\boldsymbol{j}}$ are hospital fixed effects that control for differences in waiting times across hospitals which arise from unobserved supply factors (for example, availability of beds, staffing, infrastructure, management and organisation, and quality) and unobserved demand factors such as overall health of the population of the catchment area around the hospital. Finally, u_{ij} is an idiosyncratic error term.

We estimate the linear model in (1) using OLS with standard errors clustered at the hospital level[9]. We interpret the estimates of the coefficient vector $\boldsymbol{\beta}$ as evidence of waiting time prioritisation by pre-operative health status, conditional on patient and hospital characteristics. Including patient characteristics is important to control for factors that may also influence waiting times and be correlated with the Oxford Hip Score, which captures pre-operative health related to pain and lack of mobility due to problems with the hip. Variation in waiting time according to other patient characteristics can be interpreted as other forms of prioritisation (for example, age), inequalities (for example, deprivation), or clinical factors that can slow down patient's journey (for example, co-morbidities which preclude treatment in certain types of facilities). Including hospital fixed effects implies that the estimated $\boldsymbol{\beta}$ measures the degree of prioritisation *within hospitals,* while controlling for any correlation between pre-operative health and waiting times at the hospital level. For instance, if more severely ill patients are treated in hospitals with low waiting times, this is accounted for by the hospital fixed effects.

To assess whether patients treated by private providers are prioritised differently from patients treated by public providers, we match NHS providers with private providers and we run the regression analysis separately for the matched NHS and private provider matched samples. We perform coarsened exact matching (CEM), which involves the following steps: a) each matching variable is coarsened into substantively meaningful groups; b) coarsened covariate patterns (strata) are created representing unique combinations of values across all coarsened covariates; c) each treated and control unit is assigned into one of the strata based on their coarsened values (exact matching on the coarsened variables); d) any stratum that does not contain at least one treated and one control unit is pruned; e) the original (uncoarsened) variables of the matched samples are used in separate regression analyses to determine the effects on waiting times.

We perform three types of matching: a) we match at patient level on selected patient characteristics (OHS group, gender, age, deprivation, the three most frequent primary diagnoses, and the six most frequent Elixhauser conditions) using k:m matching which allows unequal number of treated and control units within strata. In this case, matching weights are used in the regressions to account for the differential strata sizes; b) we match at patient level on the same selected patient characteristics using k:k matching which prunes observations from

[9] As robustness checks, we estimate models with a logged dependent variable and count data models, such as Poisson or negative binomial (Gutacker et al 2016, Siciliani and Verzulli 2009).

each stratum so that the same number of treated and controls are contained in all strata; c) we match at provider level on average waiting times. The regressions on the matched NHS and private provider samples are carried out at patient level.

For all three types of matching, we assess the balance achieved by the matching using unidimensional measures of imbalance such as differences in means and percentiles for each variable as well as the multivariate L1 distance statistic (Iacus, King, and Poro 2009) that measures the balance of the joint distribution of variables (global balance).

Results

Descriptive statistics

Table 1 provides summary statistics for our regression sample. Inpatient waiting times increased gradually from 90 days in 2015/16 to 121 days in 2019/20, and then sharply to 219 days in 2020/21 after the onset of COVID-19. Outpatient waiting times varied little between 2015/16 and 2019/20 with a mean of 108-111 days but increased to 131 days in 2020/21. The median outpatient waiting time is roughly half of the mean outpatient waiting time throughout the period 2015/16 to 2020/21, suggesting that most patients experience relatively low outpatient waiting time while a small proportion of patients experience a very long wait.

The patient composition was generally stable across years, even in 2020/21 where the sample size is much smaller due to the pandemic which reduced the number of procedures and the PROMS response rates. About 52% of patients have a pre-operative OHS between 9 and 20 points, 40% are male, and 35% are between 65 and 74 years old. 85% have white ethnicity in 2020/21, about 2-4 percentage points lower than the pre-pandemic period. Less than 30% of patients reside in rural areas. At least 90% of patients have no emergency admissions in the year prior to surgery, and about 2% have more than one.

Different types of arthritis of the hip account for more than 90% of admissions (unspecified coxarthrosis 74-77%; other primary coxarthrosis 8-10% and polyarthrosis for 6-7%). For at least 44% of patients, hypertension is recorded as the most common co-morbidity. The second most common morbidity is obesity whose prevalence increases from 15% in 2015/16 to 25% in 2020/21. Other common morbidities are chronic pulmonary disease (16%-18%), diabetes (10%-11%), and cardiac arrhythmias (9%-11%).

Less than 16% of patients are in the most deprived quintile in 2015/16 and this percentage drops to 11% in 2020/21. In that year almost 50% of the sample are in the first two (least deprived) quintiles. The referral source from a GP was at least 73% of the outpatient appointments. For 34% of patients in 2015/16, the outpatient spell consists of two or more appointments.

Regression results. Inpatient waiting times

Table 2 provides the main regression results for the inpatient waiting times. There is evidence of waiting time prioritisation. Patients with better pre-operative health (larger values of OHS) wait longer. In 2015/16, relative to the reference group (13-16 OHS points), patients achieving 29-32 (33-48) points on the OHS scale wait about 4 (7) days longer and patients with 5-8 (0-4) points wait about 3 (6) days less.

The gradient becomes generally steeper every year in the pre-pandemic period. Patients with the worst pre-operative health wait less relative to the reference group by 7 days in 2016/17, 6 days in 2017/18, and 10 days in 2018/19 and 2019/20. In 2020/21, waiting time prioritisation is even steeper. Patients with the worst pre-operative health wait 22 days less, while those with 29-32 points wait 25 days longer compared to the reference group.

Several other patient characteristics are also associated with waiting time. For given pre-operative health, younger patients tend to wait longer. Patients in the 18-44 age group wait 7-13 days longer than patients in the 65-74 age group in 2015/16-2017/18. The effect of gender on waiting times is either small or statistically insignificant.

Patients who had been admitted to hospital as an emergency within the last year wait significantly less than those who had not. The magnitude of the effect is much larger in 2020/21: waiting time for patients with one emergency admission (relative to no admission) is four days shorter in 2018/19 but 22 days shorter in 2020/21. Those with more than one emergency admission had 10 days shorter waiting times in 2018/19 but 54 days shorter in 2020/21. Patients with previous emergency admissions were prioritised more heavily during the pandemic.

Longer symptom duration is associated with longer waiting time. In 2015/16 patients who experienced symptoms for more than 10 years waited 5 days longer than those whose symptoms had lasted only 1-5 years (the reference group), who waited nearly 12 days longer than those experiencing symptoms only in the past year. As with the gradient on pre-operative health, these effects grow over time. By 2019, patients with the longest symptom duration wait 9 days longer than those with a symptom duration of 1 to 5 years, and those with the most recent symptom onset wait 21 days less than the base category. The beginning of the pandemic sees even larger effects with patients with the most recent symptom onset waiting 85 days less than those in the base category in 2020-21.

Relative to the most frequent primary diagnosis, which is unspecified coxarthrosis, patients with osteonecrosis have a shorter waiting time, with the difference gradually growing from 5 days in 2015 to 23 days in 2020/21. Amongst the secondary diagnoses, having cardiac arrhythmia is associated with a longer wait by 4-7 days up to 2019/20 and increased to 19 days in 2020/21. Similar results hold for diabetes.[10]

There is a deprivation gradient with patients in the most deprived quintile waiting up to four days longer for admission than those in the least deprived quintile pre-pandemic. The deprivation gradient becomes remarkably steeper in 2020/21 with those in the most deprived quintile waiting more than 20 days longer compared to those in the least deprived quintile. We generally find no differences in waiting times by ethnicity, except for black patients who in 2018/19 waited eight days longer than the base category (white).

Outpatient waiting times

Table 3 provides the estimates for the outpatient waiting times. This model contains the same control variables as for inpatient waiting times in Table 2, but also controls for source of outpatient referral (GP vs responsible consultant vs other) and number of outpatient appointments.

The results provide some evidence of prioritisation in outpatient waiting time with respect to pre-operative health, though this is less pronounced relative to inpatient waiting time and it is concentrated amongst patients with higher pre-operative health. In 2016/17-2018/19, patients

[10] On the contrary, patients with metastatic cancer (not reported in the table) had waiting times up to 27 days shorter compared to patients without metastatic cancer diagnosis pre-pandemic. The difference in waiting times increased to 60 days in 2020/21 implying that patients with metastatic cancer were prioritised more heavily during the pandemic.

with higher OHS (33-48) wait at least 10 days longer than the reference group (13-16 OHS). This effect is less pronounced in 2015/16 and 2019/20, and absent in 2020/21.

In contrast, patients with low pre-operative health do not generally differ in outpatient waiting time relative to the reference group. The only exception is patients with 5-8 OHS scores who wait 5 days less in 2015-16.

Patients with multiple outpatient appointments have much longer outpatient waiting times than patients with only a single GP appointment. For example, in 2015-16 patients with two outpatient appointments waited 87 days longer relative to those with one appointment; those with three outpatient appointments waited 193 days longer, and those with four appointments or more waited almost a year longer. Differences in waiting times based on referral source are also noticeable. Relative to patients referred by the GP, patients referred by a consultant wait 21 days longer. Patients with symptom duration less than a year wait less than those whose symptoms last 1-5 years by about 15-20 days depending on the year.

Some other patient characteristics are also associated with outpatient waiting time. Younger patients generally wait longer. Patients with more emergency admissions experience shorter waits by at most 18 days if they have two admissions or more. Similar to the inpatient results, patients with osteonecrosis as a primary diagnosis wait less than patients with coxarthrosis. There is no consistent pattern on the effects of co-morbidities (secondary diagnoses) on outpatient waiting time.

Ethnicity is generally not statistically significant at 5% level, except for black patients who in 2018-19 waited 17 days longer and Asian patients who in 2020-21 waited 27 days shorter than white patients. With a few exceptions, local area deprivation is not statistically significant with no clear pattern.

Alternative specifications for outpatient waiting times

Table 4 presents the coefficients for pre-operative health of two alternative specifications. These models differ in how they deal with patients with multiple outpatient appointments and source of referral of the outpatient appointment. The first panel of Table 4 repeats the baseline model in Table 3 to facilitate comparison.

The second panel in Table 4 (partial adjustment) removes the number of outpatient appointments in the spell and source of referral. The coefficients of pre-operative health on outpatient waiting times are larger once omitting these variables. There is a difference of 20-35 days between patients with the highest OHS and the reference category (OHS of 13-16) across all years except 2020-21. This is because patients with better pre-operative health (higher OHS) are more likely to have multiple outpatient appointments and more appointments are associated with longer outpatient waiting times (patients with more than one appointment wait at least 80 days longer).

The third panel in Table 4 (restricted sample) includes only patients with a single outpatient appointment prior to joining the waiting list, and who are referred by a GP. This restriction reduces the sample by 50% and provides a more homogenous sample where only the GP had the opportunity to prioritise the outpatient waiting time, and differences in waiting time are not due to differing number of outpatient appointments before adding the patient to the list. The results suggest that GPs do not prioritise patients according to their OHS for outpatient appointments: the coefficients are quantitatively small and only occasionally statistically significant at 5% level.

Private providers

In this section, we test whether patients treated by private providers are prioritised differently from patients treated by public providers. In our samples, private providers treated 25% of patients in 2015/16 increasing to 37% in 2020/21. Waiting times are generally shorter for private providers, for both the inpatient and outpatient component. For example, in 2018/19 (2019/20), inpatient waiting time was on average 59.1 (66.7) days for private providers and 120.5 (120.8) days for public providers. In 2020/21 the wait increased to 129.4 days for private providers and 219.5 days for public providers. Therefore, waiting time prioritisation could be smaller (in absolute level). Moreover, private providers treat generally less complex patients, which could also affect the comparison. Appendix D provides descriptive statistics for the sample of private providers.

Table 5.a provides estimates of inpatient waiting time prioritisation for private providers. It suggests that patients with higher pre-operative health wait generally longer. For example, patients with an OHS of 25-28 wait 4-7 days longer than the reference group between 2015/16 and 2019/20. Patients with an OHS of 33-48 wait at least 8 days longer each year, and this

increases to 24 days in 2020-21. Instead, patients with lower OHS do not tend to differ in inpatient waiting time relative to the reference group. To facilitate comparison, Table 5.a also provides the estimates of prioritisation by public providers from Table 2. Prioritisation for patients with high pre-operative health (above the reference group) appears comparable between public and private providers. Prioritisation differs instead for patients with low pre-operative health. This is because patients with low pre-operative health have shorter waiting times than the reference group within public providers but this is not the case for private providers where differences are limited and less systematic. This comparison however does not take into account the different casemix between types of provider and the longer average waiting times by public providers.

Given that patient casemix can differ between public and private providers, differences in wait prioritisation could reflect differences in casemix. We use three matching approaches (see Methods) to compare prioritisation across matched samples. **Table 5.b** presents the results for the regressions estimated on the samples created by carrying out a "k-to-m" coarsened exact matching on patient characteristics. Prioritisation by private providers is similar to Table 5.a. Prioritisation by public providers is also similar to Table 5.a, but with fewer statistically significant effects, possibly due to the smaller sample. However, it is still the case that patients with an OHS of 5-8 wait less by at least five days in three financial years and by 37 days in 2020/21. **Table 5.c** presents the results using samples with a 1:1 coarsened exact matching on patient characteristics[11]. The results are qualitatively similar to Table 5.b. Wait prioritisation is comparable between private and public providers for patients with an OHS above 16 points. This is perhaps surprising given that private providers have much shorter waiting times than public providers.

While the above matching approaches produce matched samples that are balanced in terms of patient characteristics, waiting times for private providers remain significantly shorter compared to public providers (matching does not reduce imbalance in waiting times). This motivates the third matching approach where we match each private provider with one public provider based on the average waiting time (coarsened) of each provider. This approach implicitly excludes private providers with short average waiting times that have no match with

[11] The sample size is identical across the matched samples and smaller than in table 5.b because not all patients treated by private providers have a match in the sample of public providers and vice versa.

a public provider, and public providers with long average waiting times that have no match with a private provider.

Table 6.a compares average waiting times between public and private providers before and after matching. The average waiting time after matching grows from 76 days to 95 days in the pre-pandemic years and to 205 days in 2020-21. **Table 6.b** presents the results for the regressions on the matched samples. In the pre-pandemic years, patients with higher pre-operative health (above the reference group) tend to wait longer in both public and private providers, but whether the effect is larger for public or private providers depends on the year. Patients with lower pre-operative health (below the reference group) also wait less when treated by private providers while the effect for public providers is attenuated. These results suggest that wait prioritisation by public and private providers is more similar when restricting the comparison to hospitals with similar average waiting times.

In Table 7, we compare outpatient wait prioritisation between public and private providers. This comparison is more tentative as outpatient waiting time by a private provider can be preceded by outpatient appointments in a public provider, which is not measured in our database. The unmatched sample in **Table 7.a** suggests that there is some prioritisation in private providers, but generally less pronounced relative to public providers. **Table 7.b** presents the comparison when each patient treated by private providers is matched with at least one patient from public providers. The results are similar to the unmatched sample.

Prioritisation on different dimensions of health

We have so far focused on prioritisation based on the pre-operative Oxford Hip Score. **Table 8** provides evidence of prioritisation on 12 individual domains on which the OHS is based. While each of the 12 questions has five possible answers, we create dummy variables that indicate the presence of serious or very serious health issues in each domain. Details on how these variables are constructed and descriptive statistics are in Appendix C. The results show that it is mostly the pain dimensions that reduce inpatient waiting times. Patients experiencing severe pain (relative to moderate, mild, very mild or no pain) have shorter inpatient waiting times by 4 days in 2015/16-2019/20 and by 7 days in 2020/21. Mobility and ability to carry out daily activities do not generally affect waiting times.

Simulation of health effects of increased prioritisation

Our findings provide some evidence of waiting time prioritisation across patients with differing pre-operative health along the inpatient component of the patient pathway. In this section, we explore the health gain that could be attained by making prioritisation of patients more pronounced (Gravelle and Siciliani 2008) and redistributing waiting times across patients, for example by shortening the waiting times for patients with higher pain and reduced mobility and increasing it for the other patients.

Table 9 presents the mean pre- and post-operative health-related quality of life (HRQoL) from the PROMS dataset for NHS providers in 2019/20 for each category of OHS. The HRQoL scores are provided by the PROMs dataset from the EQ-5D component of the PROMS surveys with the three levels of each of the five dimensions of health valued according to the results from Dolan (1997) with a score of 1 representing full health and zero representing death. The mean HRQoL gain is highest for patients in the lowest OHS score category (0.69) and lowest for patients in the highest OHS score category (0.16). Therefore, as expected, patients with highest pain and lowest mobility have the largest health gain six months following hip replacement surgery, which is well documented in the literature (eg Jenkins et al 2013, Fordham et al 2012). We also show the mean waiting time for each OHS category in our estimation sample (123 vs 115 days between the top and bottom group). Multiplying the mean HRQoL gain with the total number of patients in each OHS category we obtain an estimate of the total health gain measured in quality-adjusted life years (QALYs) for the patient group in the first year following surgery.

Table 10 presents a simulation of the potential health effects of additional prioritisation (see Appendix E for a more formal presentation of the effect of a change in prioritisation). We simulate a reduction in waiting time of 20% for the bottom three OHS categories (7,022 patients in total) and an increase in waiting time of 20% for the top four OHS categories (6,713 patients in total). To ensure that the total number of days waited by patients is approximately the same, we increase the waiting time for 2,783 out of the 2,829 patients in the 21-24 OHS group. Therefore, the total waiting time in the top three groups reduces by 165,035 days and this is compensated by an increase in the total waiting time for the bottom four groups by 165,042 days (with a very small seven days difference due to rounding up of waiting times in days).

We then calculate the health gains and losses associated with this additional prioritisation in each OHS group. We do so by multiplying for each OHS group i) the number of patients in each group, ii) the HRQoL gain for each OHS group, and iii) the fraction of the year experienced in improved or reduced health. For example, for patients with a 0-4 OHS who have a shorter waiting time by 23 days, the health gain is equal to 901 patients x 0.69 HRQoL x (23/365 years) = 39.17 QALYs. For patients with 33-48 OHS who wait 25 days longer, the health loss is equal to: 932 patients x 0.16 HRQoL x (25/365 years) = 10.21 QALYs.

For the lowest three OHS groups, patients wait less, receive the gain in HRQoL associated with the procedure earlier, and therefore experience a gain in health associated with a longer time spent in improved health. For the highest three OHS groups, the reverse holds: their health gain from treatment is delayed further and therefore there is a net loss in health for these groups from the additional prioritisation. However, since the health gain from the lowest OHS groups is larger, it more than offsets the loss of health gain from the higher OHS groups, therefore leading to a net increase in health from this change in prioritisation of 186.45 QALYs. To gauge order of magnitude, this is equal to 1.9% of the QALY gain from hip replacements in our sample in the first year, or 0.19% if those gains are extrapolated simply over 10 years without any decline over time or discounting applied.

Table 11 simulates a larger reduction in waiting time of 40% for the bottom three OHS categories and an increase in waiting time of 40% for the top three OHS categories. The total waiting time in the top three groups reduces by 333,555 days and this is compensated by an increase in the total waiting time for the bottom four groups by 333,329 days (slightly below the reduction in the top groups). The net increase in health from this change in prioritisation is now given by 351.97 QALYs, which is a little less than double relative to the previous simulation.

This simple approach makes a number of assumptions: we do not model the length of the health gain from treatment and any subsequent differences according to patients treated earlier as a result of prioritisation. For example, our approach assumes that patients receiving treatment earlier do not suffer an earlier decline in their hip function as the implant ages. While this is a limitation, it is unlikely to make a large difference to our results given that the health gain from hip replacement treatment only declines slowly over time (Fordham et al 2012) and differences in health gain far into the future are likely to be less important due to discounting. We also do not allow for any heterogeneity in patients' health gain from treatment (apart from in respect of pre-operative OHS), and assume each patient receives the average health gain associated with their OHS category.

Discussion and conclusion

This study provides evidence of waiting time prioritisation based on pre-operative health for hip replacement patients in England. Between 2015/16 and 2019/20, the difference in inpatient waiting time between those with the lowest and highest pre-operative health prior to surgery was approximately 13-21 days. This suggests that doctors prioritise patients even in the absence of explicit guidelines to reduce the disutility from waiting (Gutacker et al 2016, Gravelle and Siciliani 2008).

This finding is further corroborated by how prioritisation changed over time. Inpatient wait prioritisation became steeper when waiting times were longer. In 2018/19, when waiting times were on average 120 days, the difference between the lowest and highest pre-operative health was 21 days, while in 2015/16 when waiting times were on average 90 days the difference between the two groups was 13 days. As the waiting time increases, doctors further differentiate between patients with differing levels of health (mostly related to pain of the joint and mobility).

The onset of the COVID-19 pandemic reduced elective care volume and increased average waiting times to 219 days in 2020/21. During this period we document a further increase in prioritisation with a difference of up to 47 days in waiting time between those in the highest and lowest pre-operative health in 2020/21. The steeper gradient may also reflect the introduction of guidance by the surgical specialty association recommending prioritising patients for whom long delays could affect health outcomes (FSSA 2022).[12]

We show that outpatient waiting times, between the referral of a general practitioner or other sources and the specialist visit, comprise a substantial proportion of total time waited (from referral to surgery). Therefore, outpatient waiting times constitute another opportunity to prioritise along the patient pathway. In contrast to the findings on inpatient wait prioritisation, we find mixed and more limited evidence of outpatient waiting time prioritisation. Patients

[12] In line with Nikolova et al (2016), we also find that symptom duration is associated with longer waiting times, with patients with recent symptoms having much shorter waiting time. This may capture an association between symptom duration and perceived severity, with evidence suggesting that short symptom duration prior to surgery is associated with lower pre-operative health and a larger health gain (Lau et al 2020).

with highest pre-operative health wait at most 13 days longer than patients with middle pre-operative health, for a given number of appointments, but patients with lowest pre-operative health generally wait the same as the middle group. Therefore, prioritisation is less pronounced than for inpatient waiting time. Moreover, patients with better pre-operative health have more outpatient appointments and this contributes to a longer overall outpatient waiting time for these patients.

When we look only at patients who have a single outpatient appointment after being referred by a GP, we find no evidence of outpatient waiting time prioritisation by pre-operative health. This suggests that there is scope for developing policies that encourage GPs to indicate the degree of priority in their referral to the specialist. There have been several initiatives across countries to improve the coordination between primary and secondary care to ensure appropriate and timely referrals, for example in Canada, Italy and Finland (OECD 2020). Some evidence from Italy suggests that GPs and specialists may however disagree in the assessment of patient priority. GPs tend to assign a higher priority than specialists, though agreement between GPs and specialists can be facilitated by electronic referral management tools (Mariotti et al 2022).

Private providers have shorter inpatient waiting times and a lighter casemix of patients (Street et al 2010). We find that patients with low pre-operative health tend to wait similarly relative to patients with middle health while those with high pre-operative health tend to wait longer. This is in contrast to public providers that prioritise with a shorter wait patients with low pre-operative health. Our analysis shows however that these differences can be mostly explained by the different casemix and the shorter waiting times, as the comparison between public and private providers does not systematically differ when comparing hospitals with similar casemix and average waiting times. This suggests that private hospitals do not generally differ in the prioritisation of patients. Although this is reassuring in terms of equity implications, it remains the case that private providers have much shorter waiting times, and this can create inequalities in waiting times based on the geographical distribution of private providers.

Our simulation of different wait prioritisation policies shows that more pronounced prioritisation that increased (decreased) waiting times for patients with high (low) pre-operative health could generate significant health gains (as per Gravelle and Siciliani, 2008). We show that increasing waiting times by a further 20% for patients with the best pre-operative health (who have the smallest health gains) and decreasing waiting times by an equivalent amount for patients with the worse pre-operative health (who have the largest health gains), can increase overall health by 1.9% of the first year of health gain experienced by hip replacement patients post procedure. While this is a modest improvement, it could be achieved for zero additional cost to the health budget, and greater gains could be achieved with stronger prioritisation.

Last, our analysis shows that patients living in more deprived areas face higher inpatient waits, but the effect is relatively modest in the pre-COVID period, at most 4 days for patients in the most deprived quintile. However, these inequalities are much more pronounced in the COVID-19 year, with patients in the most deprived quintile waiting 20 days longer than those in the least deprived one. This suggests that inequalities are likely to arise when waiting times increase. We did not find evidence of inequalities in outpatient waiting times by income deprivation.[13]

Overall, our analysis suggests that there is scope for improving prioritisation of the patients on the list along the patient pathway both in the inpatient and the outpatient component. This is especially important when waiting times are high, as in England in recent years and in particular post-pandemic. Waiting time prioritisation can become more salient through further informal or formal guidance (FSSA 2020), and there is a widespread debate about how to prioritise patients to improve the equity of outcomes at a local level (Shenoy 2023). Policymakers at a national level could further develop robust frameworks and criteria for waiting time prioritisation to ensure equity and efficiency goals are being achieved.

[13] An earlier study by Marques et al. (2014) found evidence of socioeconomic differences in outpatient waiting times but they used older data (prior to 2009) and a different measure of outpatient waiting time.

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Table 1. Summary statistics. Public providers (NHS Trusts)

N. of observations	2015/16 (21,192)	2016/17 (24,059)	2017/18 (22,166)	2018/19 (23,233)	2019/20 (18,956)	2020/21 (4,414)
Inpatient waiting time (mean, days)	90.120	103.846	109.362	120.487	120.798	219.466
Inpatient waiting time (median)	82	95	97	106	106	227
Outpatient waiting time (mean, days)	107.932	107.994	111.721	110.492	108.112	131.420
Outpatient waiting time (median)	48	50	51	48	49	70.5
Pre-operative Oxford hip score						
0-4	0.041	0.045	0.051	0.054	0.052	0.056
5-8	0.124	0.128	0.137	0.142	0.138	0.156
9-12	0.164	0.164	0.179	0.178	0.176	0.195
13-16 (reference group)	0.184	0.188	0.190	0.186	0.184	0.189
17-20	0.175	0.168	0.164	0.164	0.165	0.144
21-24	0.132	0.132	0.129	0.120	0.127	0.112
25-28	0.092	0.090	0.077	0.083	0.079	0.076
29-32	0.051	0.051	0.045	0.043	0.046	0.039
33-48	0.038	0.035	0.029	0.031	0.033	0.033
Symptoms duration						
Less than a year	0.127	0.122	0.107	0.104	0.099	0.059
1-5 years (ref. group)	0.690	0.692	0.697	0.704	0.708	0.751
6-10 years	0.115	0.117	0.124	0.121	0.125	0.116
>10 years	0.069	0.069	0.072	0.070	0.069	0.075
Male	0.404	0.402	0.402	0.407	0.400	0.390
Age						
18-44	0.031	0.030	0.030	0.029	0.028	0.039
45-54	0.085	0.087	0.090	0.083	0.082	0.093
55-64 (ref. group)	0.205	0.203	0.200	0.205	0.215	0.220
65-74	0.353	0.357	0.360	0.353	0.346	0.355
75-84	0.277	0.270	0.267	0.277	0.276	0.249
>=85	0.048	0.053	0.052	0.053	0.052	0.045
Ethnicity						
White (ref. group)	0.892	0.890	0.882	0.881	0.878	0.849
Mixed	0.002	0.002	0.002	0.002	0.002	0.001
Asian	0.005	0.005	0.006	0.005	0.005	0.009
Black	0.007	0.006	0.007	0.007	0.007	0.007
Other ethnicity	0.004	0.005	0.005	0.004	0.005	0.003
Missing Ethnicity	0.090	0.092	0.099	0.101	0.104	0.130
Rural (ref group: urban)	0.253	0.270	0.274	0.278	0.274	0.294
Emergency admissions^						
0 (ref. group)	0.919	0.913	0.910	0.907	0.903	0.922
1	0.064	0.068	0.072	0.075	0.076	0.059
>=2	0.017	0.019	0.018	0.018	0.022	0.018
Primary diagnosis^^						
Coxarthr., unsp. (ref. group)	0.740	0.755	0.768	0.766	0.773	0.750
Other primary coxarthrosis	0.107	0.095	0.079	0.084	0.084	0.101

Polyarthrosis, unspecified	0.061	0.067	0.073	0.073	0.070	0.061
Osteonecrosis, unspecified	0.010	0.011	0.011	0.011	0.009	0.012
Primary coxarthrosis, bilateral	0.017	0.010	0.007	0.007	0.007	0.007
Secondary diagnosis^^^						
Hypertension, uncomplicated	0.482	0.481	0.493	0.492	0.489	0.440
Obesity	0.154	0.173	0.200	0.227	0.256	0.249
Chronic pulmonary disease	0.162	0.167	0.172	0.178	0.179	0.169
Diabetes, uncomplicated	0.109	0.110	0.111	0.112	0.111	0.100
Cardiac arrhythmias	0.092	0.097	0.107	0.109	0.109	0.094
Hypothyroidism	0.080	0.088	0.089	0.094	0.101	0.089
Depression	0.060	0.066	0.077	0.081	0.086	0.096
Renal failure	0.068	0.072	0.077	0.079	0.085	0.071
Rheumatoid arthritis	0.055	0.061	0.065	0.065	0.066	0.073
Valvular disease	0.028	0.032	0.036	0.038	0.042	0.029
Index of Multiple Deprivation (IMD) quintile						
1 (ref. group - least deprived)	0.221	0.225	0.227	0.228	0.229	0.250
2	0.227	0.233	0.232	0.231	0.228	0.245
3	0.211	0.214	0.216	0.218	0.213	0.227
4	0.185	0.180	0.182	0.176	0.184	0.167
5 (most deprived)	0.155	0.148	0.144	0.147	0.146	0.111
Referral source						
GP referral (ref. group)	0.773	0.774	0.755	0.749	0.740	0.732
Responsible consultant	0.033	0.029	0.028	0.027	0.025	0.026
Other	0.194	0.197	0.217	0.224	0.235	0.243
Number of outpatient appointments						
1 (ref. group)	0.661	0.657	0.653	0.639	0.644	0.580
2	0.153	0.154	0.155	0.165	0.160	0.189
3	0.076	0.077	0.075	0.080	0.077	0.089
>3	0.110	0.113	0.117	0.117	0.119	0.142

Notes. Mean values for all listed variables (except for the two labelled "median") over six financial years.
^ Emergency admissions in the year preceding a hip replacement surgery.
^^ Indicators for the most frequent primary diagnosis at admission and an indicator for any other primary diagnosis. We only show the most common five primary diagnoses; other diagnoses included in the models are: other secondary coxarthrosis, other dyspalstic coxarthrosis, gonarthrosis (unspecified), arthritis (unspecified), other post-traumatic coxarth., other.
^^^ Indicators for each of the Elixhauser morbidities recorded in the year preceding the hip replacement surgery. We only show the most common ten secondary diagnoses; other diagnoses included: fluid & electrolyte disorder, alcohol abuse, other neurological disorder, congenital heart failure, peripheral vascular disorder, deficiency anaemia, solid tumour w/o met., liver disease, coagulopathy, diabetes complicated, peptic ulcer, weight loss, pulmonary circulation disorder, metastatic cancer, lymphoma, drug abuse, paralysis, psychoses, hypertension (complicated), blood loss anaemia.

Table 2. Regression results: inpatient waiting times

N. of observations	2015/16 (21,192)	2016/17 (24,059)	2017/18 (22,166)	2018/19 (23,233)	2019/20 (18,956)	2020/21 (4,414)
Pre-operative Oxford Hip Score						
0-4	-5.53***	-6.96***	-5.83***	-10.06***	-10.20***	-22.33**
5-8	-2.77***	-2.72**	-2.28*	-4.56***	-7.22***	-24.84***
9-12	-2.22**	-1.88*	-2.75**	-3.19**	-3.03*	-4.39
13-16 (reference group)						
17-20	0.56	1.91	1.26	1.03	1.21	10.84*
21-24	2.30**	2.46**	2.97**	2.02*	1.03	2.17
25-28	4.72***	4.43***	4.76***	3.62**	4.23**	14.50*
29-32	4.26***	4.07**	6.20***	6.30***	4.55**	25.09***
33-48	7.43***	9.56***	13.89***	11.39***	8.11***	11.12
Symptoms duration						
Less than a year	-11.94***	-13.70***	-16.98***	-18.87***	-21.12***	-84.90***
1-5 years (ref. group)						
6-10 years	2.60**	3.29***	4.21***	4.29***	6.43***	15.60***
>10 years	4.82***	7.18***	4.90***	6.05***	9.12***	6.91
Male	-0.55	-0.52	-1.39**	-0.46	-0.49	-4.65
Age						
18-44	12.48***	7.00***	12.89***	6.03*	6.04**	6.19
45-54	5.60***	4.60***	5.92***	3.27**	4.00*	-0.39
55-64	2.72***	1.85**	4.36***	2.38*	0.85	-10.89**
65-74 (ref. group)						
75-84	-0.54	0.05	1.06	0.08	-0.89	0.07
>=85	3.22*	0.72	-1.82	-2.11	-2.78	13.30
Ethnicity						
White (ref. group)						
Mixed	-7.79	3.65	1.24	-0.99	12.64	17.11
Asian	2.07	1.75	1.87	4.67	5.57	-15.53
Black	3.36	-4.87	0.31	8.20**	-8.72*	-4.31
Other	2.86	2.47	12.28*	4.38	-2.18	-33.68
Missing	-2.84**	-2.82*	0.16	-1.23	-2.23	-6.29
Rural (ref group: urban)	-0.11	-0.06	0.25	2.59**	0.01	-6.94*
Emergency admissions^						
0 (ref. group)						
1	-1.63	-3.43***	-4.45***	-4.06**	-4.31**	-21.86**
>=2	-3.44	-7.62**	-4.63	-9.58***	-5.07	-53.54***
Primary diagnosis^^						
Cox. unsp. (ref. group)						
Other primary cox.	-0.14	-1.83	0.13	0.08	8.21**	30.68**
Polyarthrosis unsp.	0.09	1.53	0.52	-2.29	0.87	-16.78**
Osteonecrosis unsp.	-5.44*	-8.02**	-11.86***	-17.66***	-9.22	-23.03
Primary cox., bilateral	3.16	3.20	0.46	2.39	17.69**	12.50
Secondary diagnosis^^^						
Hypertension uncompl.	0.81	0.76	1.38*	0.90	3.54***	7.92*

Obesity	2.60***	1.97*	2.72**	0.11	1.26	12.08***
Chronic pulmonary dis.	1.99**	2.02**	4.10***	3.05***	2.76**	7.65
Diabetes uncompl.	3.13***	2.03*	2.36**	4.71***	4.53***	7.05
Cardiac arrhythmias	6.91***	3.90***	4.30***	5.23***	5.89***	19.31***
Hypothyroidism	1.63	0.91	0.19	1.37	0.70	-2.18
Depression	3.79**	2.39*	1.74	0.86	3.54**	-6.50
Renal failure	1.90	3.57**	1.54	2.26	4.41***	-10.56
Rheumatoid arthritis	-1.52	-1.74	2.34	2.36	-1.23	11.20*
Valvular disease	6.39***	5.40**	7.09***	9.35***	1.68	9.69
Index of Multiple Deprivation (IMD) quintile						
1 (ref. group: least deprived)						
2	-0.85	0.25	1.39	0.29	1.28	6.74
3	0.43	-0.97	1.52	0.58	0.21	11.33*
4	1.13	0.39	1.18	3.32**	-0.17	-0.17
5 (most deprived)	2.38**	-0.59	3.02**	4.29***	4.04**	20.20**

*p<0.1, ** p<0.05, *** p<0.01

Notes. Hospital fixed effects included but not reported.

^ Emergency admissions in the year preceding a hip replacement surgery.

^^ Indicators for the most frequent primary diagnosis at admission and an indicator for any other primary diagnosis. We only show the most common five primary diagnoses; other primary diagnoses included in the models are: other secondary coxarthrosis, other dyspalstic coxarthrosis, gonarthrosis (unspecified), arthritis (unspecified), other post-traumatic coxarth., other.

^^^ Indicators for each of the Elixhauser morbidities recorded in the year preceding a hip replacement surgery. We only show the most common ten secondary diagnoses, others included are: fluid & electrolyte dis, alcohol abuse, other neurological dis., cong. heart failure, peripheral vascular dis., deficiency anaemia, solid tumour w/o met., liver disease, coagulopathy, diabetes complicated, peptic ulcer, weight loss, pulmonary circulation disorder, metastatic cancer, lymphoma, drug abuse, paralysis, psychoses, hypertension (complicated), blood loss anaemia.

Table 3. Regression results: outpatient waiting times

N. of observations	2015/16 (21,192)	2016/17 (24,059)	2017/18 (22,166)	2018/19 (23,233)	2019/20 (18,956)	2020/21 (4,414)
Pre-operative Oxford Hip Score						
0-4	-3.55	1.36	-4.47	-5.06	0.96	-11.70*
5-8	-5.37**	-3.24*	-3.21	-1.99	-1.11	-9.25*
9-12	-2.87	-2.24	2.13	-3.14*	-1.51	-4.09
13-16 (ref. group)						
17-20	3.31*	3.37	4.49**	2.92	3.95**	-4.91
21-24	3.74*	7.95***	6.85***	2.24	3.76	0.71
25-28	2.56	6.37***	6.00**	1.85	4.14	3.36
29-32	3.55	5.61*	7.35**	9.97***	8.77**	-9.18
33-48	7.30*	10.94***	13.08***	10.41**	7.52*	1.00
Symptoms duration						
Less than a year	-16.30***	-17.32***	-17.19***	-18.58***	-19.19***	-14.00*
1-5 years (ref. group)						
6-10 years	4.70**	1.95	4.04*	4.97*	6.74***	7.30
>10 years	-0.52	1.74	2.68	6.04**	2.39	-1.23
Male	-1.42	-1.65	-3.09***	-1.85	0.45	-6.08*
Age						
18-44	17.74***	5.05	8.44	9.26	9.80	26.25*
45-54	6.70***	4.74*	3.56	1.84	3.15	13.10**
55-64	1.17	4.68***	3.54*	0.34	0.95	7.82*
65-74 (ref. group)						
75-84	-2.94*	-3.43***	-1.88	-3.09**	-2.71*	-5.67
>=85	-3.20	-4.67*	-4.54	-7.06**	0.04	-16.22**
Ethnicity						
White (ref. group)						
Mixed	11.65	-10.72	-15.10	8.52	1.89	-12.11
Asian	0.11	-8.14	16.80	6.91	-5.16	-27.21***
Black	18.97	-7.04	2.90	16.68**	10.34	-16.31
Other	3.22	-3.09	-9.69	20.06	-8.86	9.51
Missing	-4.57**	-6.90***	-5.56**	-3.00	-6.21***	-8.09*
Rural (ref group: urban)	-1.48	-0.26	-0.63	0.51	-2.92**	3.38
Emergency admissions^						
0 (ref. group)						
1	-5.25*	-4.65*	-10.64***	-8.94***	-7.93***	3.69
>=2	-18.25***	-6.46	-8.41	-14.03**	-12.06***	-17.02
Primary diagnosis^^						
Cox. unsp. (ref. group)						
Other primary cox.	8.41**	3.89	-1.10	-0.25	2.51	3.21
Polyarthrosis unsp.	2.84	-0.40	0.39	2.79	-2.81	-5.12
Osteonecrosis unsp.	-10.29	-15.86**	-10.30*	-13.17*	-39.54***	-29.93*
Primary cox., bilateral	8.67**	-4.11	-6.86	-14.24**	-4.20	-32.53
Secondary diagnosis^^^						
Hypertension uncompl.	0.26	-0.10	0.50	1.53	-0.59	7.84**

Obesity	1.83	0.03	0.75	2.48	4.95***	-5.84
Chronic pulmonary dis.	3.58**	1.21	2.24	0.90	-2.93	-0.15
Diabetes uncompl.	0.01	0.62	1.92	0.12	5.12**	4.82
Cardiac arrhythmias	2.41	2.71	2.20	0.62	2.26	3.44
Hypothyroidism	2.48	-0.99	-0.35	-2.19	-1.10	9.13
Depression	-2.73	-5.48**	0.13	-0.11	3.07	-10.30**
Renal failure	-1.64	0.10	-4.33*	3.00	1.72	-5.62
Rheumatoid arthritis	-0.29	-2.20	-0.07	0.16	-0.18	6.46
Valvular disease	-5.02	4.97*	-0.46	1.32	6.39*	-9.13
IMD quintile						
1 (ref. group - least deprived)						
2	-1.93	0.04	1.14	-2.08	3.39**	2.19
3	0.27	1.85	0.99	-4.19**	1.08	-0.66
4	-2.04	1.77	2.78	-1.43	-0.09	-0.09
5 (most deprived)	-0.37	4.01**	-2.62	1.12	3.73	1.50
Referral source						
GP referral (ref. group)						
Responsible consultant	20.67***	11.73**	4.51	20.27**	28.96***	2.12
Other	8.44***	3.08	3.98**	4.91*	8.71***	17.58***
N. of outpatient appointments						
1 (ref. group)						
2	87.02***	87.91***	88.72***	89.84***	82.34***	85.12***
3	193.25***	187.16***	191.16***	193.78***	182.61***	178.15***
>=4	357.22***	341.58***	357.83***	355.72***	343.10***	336.17***

*p<0.1, ** p<0.05, *** p<0.01

Notes. Hospital fixed effects included but not presented.

^ Emergency admissions in the year preceding a hip replacement surgery.

^^ Indicators for the most frequent primary diagnosis at admission and an indicator for any other primary diagnosis. We only show the most common five primary diagnoses here, others included in the models are: other secondary coxarthrosis, other dyspalstic coxarthrosis, gonarthrosis (unspecified), arthritis (unspecified), other post-traumatic coxarth., other.

^^^ Indicators for each of the Elixhauser morbidities recorded in the year preceding a hip replacement surgery. We only show the most common ten secondary diagnoses here, others included are: fluid & electrolyte dis, alcohol abuse, other neurological dis., cong. heart failure, peripheral vascular dis., deficiency anaemia, solid tumour w/o met., liver disease, coagulopathy, diabetes complicated, peptic ulcer, weight loss, pulmonary circulation disorder, metastatic cancer, lymphoma, drug abuse, paralysis, psychoses, hypertension (complicated), blood loss anaemia.

Table 4. Outpatient waiting times (base model and alternative models)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
N. of Obs.	(21,192)	(24,059)	(22,166)	(23,233)	(18,956)	(4,414)
Base model^						
Pre-operative Oxford Hip Score						
0-4	-3.55	1.36	-4.47	-5.06	0.96	-11.70*
5-8	-5.37**	-3.24*	-3.21	-1.99	-1.11	-9.25*
9-12	-2.87	-2.24	2.13	-3.14*	-1.51	-4.09
13-16 (ref. group)						
17-20	3.31*	3.37	4.49**	2.92	3.95**	-4.91
21-24	3.74*	7.95***	6.85***	2.24	3.76	0.71
25-28	2.56	6.37***	6.00**	1.85	4.14	3.36
29-32	3.55	5.61*	7.35**	9.97***	8.77**	-9.18
33-48	7.30*	10.94***	13.08***	10.41**	7.52*	1.00
N. of Obs.	(21,192)	(24,059)	(22,166)	(23,233)	(18,956)	(4,414)
Partial adjustment^^						
0-4	-1.69	-0.29	-2.62	-1.74	0.48	-11.95
5-8	-3.45	-3.83	1.14	-1.64	-1.54	-12.75*
9-12	-5.75*	0.08	1.70	-3.12	-3.35	-0.23
13-16 (ref. group)						
17-20	-0.36	2.78	5.81*	3.84	9.46**	-1.98
21-24	4.44	11.08***	10.00***	3.41	5.43	4.76
25-28	8.13*	9.01**	9.60***	10.74***	5.52	11.02
29-32	9.45*	12.44***	14.99***	20.01***	17.23***	-0.04
33-48	20.00***	24.96***	34.52***	26.44***	30.95***	6.39
N. of Obs.	(11,171)	(12,531)	(11,097)	(11,265)	(9,204)	(1,891)
Restricted sample^^^						
0-4	0.11	-2.38	-1.91	-0.83	-1.57	-3.21
5-8	1.90**	-1.30	-0.56	2.12*	-0.52	-7.20*
9-12	-0.00	-0.67	-0.51	0.59	-0.56	-1.12
13-16 (ref. group)						
17-20	1.42*	-0.21	0.26	1.46	0.37	-9.26**
21-24	0.49	0.72	1.31	1.12	-0.93	-0.92
25-28	0.81	1.47*	0.70	0.29	0.86	-7.46*
29-32	-0.20	2.19*	2.30	0.80	-0.33	-7.98*
33-48	1.49	2.50*	1.89	1.28	-0.57	-3.22

Notes. The models control for hospital fixed effects and all patients characteristics listed in Table 3.
^ Patients with any type of referral and any number of outpatient appointments; model controls for source of referral and number of outpatient appointments.
^^ Same as ^ above, but the model does not control for type of referral and number of outpatient appointments.
^^^ Sample includes only referrals from a GP and with a single outpatient appointment.

Table 5a. Inpatient waiting time. Unmatched sample

Private providers (Independent Sector)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
N. of obs.	(7202)	(8598)	(8368)	(11299)	(10258)	(2648)
Mean wait time (days)	52.3	51.1	52.3	59.1	66.7	129.4
Oxford Hip Score						
0-4	-1.60	-2.35	5.25	-0.34	-7.29	-8.47
5-8	-1.84	2.48	-1.70	-2.25	-4.25*	-8.75
9-12	-1.04	2.46	-0.12	0.28	-3.67*	-11.35*
13-16 (ref. group)						
17-20	-0.25	3.89*	2.58	0.09	-1.52	-6.30
21-24	1.82	5.50**	2.85***	4.79***	6.44***	-1.90
25-28	6.19***	6.30***	3.81***	6.58***	5.27***	4.55
29-32	3.97*	6.34***	3.23**	6.83***	3.86*	11.33
33-48	8.01**	12.14***	9.46***	13.12***	14.27***	23.77***

Public providers (NHS Trusts)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
N.	(21192)	(24059)	(22166)	(23233)	(18956)	(4414)
Mean wait time (days)	90.1	103.8	109.4	120.5	120.8	219.5
0-4	-5.53***	-6.96***	-5.83***	-10.06***	-10.20***	-22.33**
5-8	-2.77***	-2.72**	-2.28*	-4.56***	-7.22***	-24.84***
9-12	-2.22**	-1.88*	-2.75**	-3.19**	-3.03*	-4.39
13-16 (ref. group)						
17-20	0.56	1.91	1.26	1.03	1.21	10.84*
21-24	2.30**	2.46**	2.97**	2.02*	1.03	2.17
25-28	4.72***	4.43***	4.76***	3.62**	4.23**	14.50*
29-32	4.26***	4.07**	6.20***	6.30***	4.55**	25.09***
33-48	7.43***	9.56***	13.89***	11.39***	8.11***	11.12

Notes. The models control for hospital fixed effects and all patient characteristics listed in Table 2.

Table 5b. Inpatient waiting time. Matched sample (k:m)

Private providers (Independent Sector)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
N.	(6262)	(7446)	(7020)	(9555)	(8453)	(1651)
Mean wait time (days)	52.1	50.7	51.2	58.4	65.7	126.6
Oxford Hip Score						
0-4	0.74	4.45	11.70*	-10.90*	-7.44	-12.79
5-8	-1.65	2.42	-1.58	-2.02	-3.65	-9.28
9-12	0.31	2.85*	-0.19	0.40	-3.79**	-11.78*
13-16 (ref. group)						
17-20	-0.68	3.31	3.21	-0.59	-0.47	-1.66
21-24	1.88	5.60**	4.65***	4.78***	6.92***	1.31
25-28	6.49***	6.69***	2.78*	7.11***	3.72	1.69
29-32	4.00*	6.86***	4.94**	5.86**	3.03	-13.13
33-48	8.97***	13.05***	9.55**	10.65***	14.42***	14.17

Public providers (NHS Trusts)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
N.	(12995)	(14832)	(13654)	(15086)	(12057)	(2014)
Mean wait time (days)	89.4	104.2	108.9	121.3	120.7	221.6
0-4	-3.09	-2.35	-0.23	-19.56***	-10.62**	-36.18
5-8	-5.72***	-5.41***	0.80	-2.35	-7.44***	-36.90***
9-12	-3.64**	-1.36	0.46	-3.17*	-4.45*	0.92
13-16 (ref. group)						
17-20	-1.05	2.42	3.56**	0.88	0.29	12.89
21-24	0.74	0.57	3.92**	3.18	-0.45	7.39
25-28	3.11*	5.11**	5.43***	6.07***	2.25	11.55
29-32	0.97	5.22**	7.65***	7.65***	4.19	36.92**
33-48	7.37**	9.46***	11.96***	12.45***	13.02***	18.86

Notes. The models control for hospital fixed effects and all patient characteristics listed in Table 2. Coarsened exact k:m matching at patient level (k patients treated by private providers matched to m patients treated by public providers) on the following variables: Oxford Hip Score categories, sex, age categories, Index of Multiple Deprivation quintiles, the most common three primary diagnoses at admission (coxarthrosis unspecified, other primary coxarthrosis, polyarthrosis unspecified), the most common six secondary diagnoses of the Elixhauser morbidities recorded in the year preceding a hip replacement surgery (hypertension uncomplicated, obesity, chronic pulmonary disease, diabetes uncomplicated, cardiac arrhythmias, hypothyroidism).

Table 5c. Inpatient waiting time. Matched sample (k:k)

Private providers (Independent Sector)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
N	(5995)	(7116)	(6576)	(8683)	(7499)	(1388)
Mean wait time (days)	52.0	50.7	51.2	58.2	65.7	127.4
Oxford Hip Score						
0-4	1.16	3.28*	12.86*	-9.25	-8.17	-7.39
5-8	-0.96	1.76	-1.03	-2.02	-3.04	-11.60*
9-12	0.10	2.70*	-0.25	-0.11	-3.82	-9.68
13-16 (ref. group)						
17-20	-0.10	3.05	2.52	-1.25	-0.46	-2.77
21-24	1.28	4.95**	4.35**	3.39*	6.40***	-3.93
25-28	7.04***	6.74***	3.47*	6.25***	3.15	-16.46
29-32	3.60	6.58***	5.83**	7.16**	4.10	-10.87
33-48	8.65**	13.07***	9.89***	10.42***	14.19***	2.20

Public providers (NHS Trusts)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
N.	(5995)	(7116)	(6576)	(8683)	(7499)	(1388)
Mean wait time (days)	89.4	104.1	108.7	121.0	121.2	220.9
0-4	-12.18*	-2.78	2.91	-20.98***	-13.04**	-23.30
5-8	-7.43***	-5.46*	0.99	-0.47	-10.35***	-44.15***
9-12	-3.64*	-3.02*	1.38	-3.60	-3.19	-4.15
13-16 (ref. group)						
17-20	0.12	2.44	5.05**	1.49	1.48	16.15
21-24	-0.01	0.62	3.13	3.54	1.00	14.52
25-28	3.93**	4.89**	4.74*	5.98**	3.98	15.96
29-32	-0.38	5.56**	9.13***	7.58**	2.32	39.40***
33-48	4.95	8.31***	15.48***	10.21**	12.65***	4.48

Notes. The models control for hospital fixed effects and all patient characteristics listed in Table 2. Coarsened exact k:k matching at patient level (k patients treated by private providers matched to k patients treated by public providers) on the following variables: Oxford Hip Score categories, sex, age categories, Index of Multiple Deprivation quintiles, the most common three primary diagnoses at admission (coxarthrosis unspecified, other primary coxarthrosis, polyarthrosis unspecified), the most common six secondary diagnoses of the Elixhauser morbidities recorded in the year preceding a hip replacement surgery (hypertension uncomplicated, obesity, chronic pulmonary disease, diabetes uncomplicated, cardiac arrhythmias, hypothyroidism).

Table 6.a Average inpatient waiting time (days) for public and private providers

	N	2015/16 mean wait time	N	2016/17 mean wait time	N	2017/18 mean wait time	N	2018/19 mean wait time	N	2019/20 mean wait time	N	2020/21 mean wait time
Unbalanced sample												
Public providers	129	92.8	131	106.5	128	115.1	127	125	122	127.6	104	229.2
Private providers	105	57.7	135	60.3	139	60.3	148	65	144	70.6	115	146.1
Balanced sample												
Public providers	49	76	56	82.4	47	85.6	47	93.1	49	95.4	56	204.8
Private providers	49	76.1	56	81.3	47	84.5	47	92.9	49	95.1	56	204.7

Notes: N denotes the number of providers.

Table 6.b Inpatient waiting time prioritisation for public and private providers.
Matched sample based on average waiting time by provider

Private providers (Independent Sector)

	2015/16 (2493)	2016/17 (2814)	2017/18 (2024)	2018/19 (3189)	2019/20 (3084)	2020/21 (973)
Pre-operative Oxford Hip Score						
0-4	4.96	-13.41**	11.72	-14.23***	-10.48	-32.61
5-8	-4.32	-0.41	4.99	-4.99***	-2.27	-28.19**
9-12	0.81	2.33	2.23	-0.74	-1.33	-24.90**
13-16 (ref. group)						
17-20	-0.64	5.33	12.70***	-1.90	6.46	-17.50
21-24	3.10	6.09	8.03***	4.96	7.99*	-14.39
25-28	9.58**	6.15**	8.13***	8.68***	8.26**	-21.38
29-32	3.41	6.79**	5.85	7.74	2.99	-2.92
33-48	7.61	12.01*	18.05***	9.98***	14.04**	11.23

Public providers (NHS Trusts)

	2015/16 (8934)	2016/17 (11151)	2017/18 (9277)	2018/19 (10287)	2019/20 (8504)	2020/21 (2343)
0-4	-4.97	-2.46	-5.08*	-2.31	-4.36	-0.94
5-8	-3.28***	-2.65*	-1.63	-2.48	-2.38	-8.91
9-12	-3.22**	-2.80*	-3.54	-2.25**	-1.75	7.92
13-16 (ref. group)						
17-20	-1.00	0.02	-1.43	1.11	1.28	13.72
21-24	2.84*	-0.31	1.80	3.98**	0.66	1.24
25-28	4.59**	3.35**	3.49*	4.25**	3.04	18.07*
29-32	4.96***	3.89*	7.74***	6.52***	5.68**	24.20*
33-48	6.76***	7.38***	11.65***	10.37***	7.68***	17.75**

Notes. The models control for hospital fixed effects and all patient characteristics listed in Table 2. Coarsened exact k:k matching at provider level (k private providers matched to k public providers on their average inpatient waiting times). Regressions estimated at patient level using all patients from the matched samples.

Table 7a. Outpatient waiting time. Unmatched sample

Private providers (Independent Sector)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
N	7202	8598	8368	11299	10258	2648
Mean wait (days)	54.3	58.5	69.6	61.0	56.7	100.7
Oxford Hip Score						
0-4	-9.04	-4.82*	-1.85	-6.69**	-3.40	0.82
5-8	-2.54*	-1.32	1.67	-1.45	-3.82	-20.61
9-12	-0.06	-0.95	1.03	0.34	-4.10**	-12.65*
13-16 (ref. group)						
17-20	0.71	0.50	2.27	1.24	-0.27	-4.04
21-24	0.78	0.79	2.47	0.24	0.51	-6.96*
25-28	3.62**	2.20	2.67**	4.57**	-0.13	0.56
29-32	3.26**	1.94	6.99***	4.23***	3.73	-4.51
33-48	1.47	6.58***	1.73	4.82	1.95	2.53

Public providers (NHS Trusts)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
N	21192	24059	22166	23233	18956	4414
Mean wait (days)	107.9	108.0	111.7	110.5	108.1	131.4
0-4	-3.55	1.36	-4.47	-5.06	0.96	-11.70*
5-8	-5.37**	-3.24*	-3.21	-1.99	-1.11	-9.25*
9-12	-2.87	-2.24	2.13	-3.14*	-1.51	-4.09
13-16 (ref. group)						
17-20	3.31*	3.37	4.49**	2.92	3.95**	-4.91
21-24	3.74*	7.95***	6.85***	2.24	3.76	0.71
25-28	2.56	6.37***	6.00**	1.85	4.14	3.36
29-32	3.55	5.61*	7.35**	9.97***	8.77**	-9.18
33-48	7.30*	10.94***	13.08***	10.41**	7.52*	1.00

Notes. The models control for hospital fixed effects and all patient characteristics listed in Table 2.

Table 7b. Outpatient waiting time. Matched sample (k:m)

Private providers (Independent Sector)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
N	(6262)	(7446)	(7020)	(9555)	(8453)	(1651)
Mean waiting time	53.9	58.1	69.4	60.4	56.6	96.5
Oxford Hip Score						
0-4	-6.34	-5.11	-3.11	-5.53	0.45	1.05
5-8	-2.77**	-2.17	0.52	-1.15	-4.69	-22.58**
9-12	0.00	-1.65	0.56	0.18	-3.66*	-7.26*
13-16 (ref. group)						
17-20	0.47	-0.86	1.84	1.68	0.43	1.48
21-24	0.96	-0.85	1.05	0.44	0.38	-3.75
25-28	3.36*	0.74	2.36	4.59*	-0.04	9.74
29-32	2.88	1.71	5.68*	4.06***	5.89**	-1.06
33-48	1.20	5.48***	-2.13	5.15	3.44	10.97

Public providers (NHS Trusts)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
N. of obs.	(12995)	(14832)	(13654)	(15086)	(12057)	(2014)
Mean waiting time	104.0	105.3	111.9	107.8	104.5	129.0
0-4	1.34	-0.17	-1.77	-5.53	-3.72	-10.92
5-8	-4.74	-1.92	-3.49	-2.40	-1.45	-5.52
9-12	-2.14	-3.52	4.85*	-2.25	-0.29	-11.72
13-16 (ref. group)						
17-20	-0.23	5.72**	3.64	2.95	0.41	-6.65
21-24	1.85	7.79***	8.93***	2.80	6.92**	-4.00
25-28	3.28	7.79**	4.81	3.84	4.11	6.01
29-32	6.08	0.03	7.52	15.18**	3.38	-30.02***
33-48	0.80	8.99**	4.07	18.46***	16.35**	3.80

Notes. The models control for hospital fixed effects and all patient characteristics listed in Table 3.

Table 8. Inpatient waiting times. Individual hip score domains

N	2015/16 (21,192)	2016/17 (24,059)	2017/18 (22,166)	2018/19 (23,233)	2019/20 (18,956)	2020/21 (4,414)
Pain	-4.13***	-3.95***	-4.12***	-3.38***	-3.42***	-7.41
Sudden pain	-1.62**	-1.04	-0.29	-1.92**	-1.81	-11.63***
Night pain	-2.62***	-1.51*	-2.63***	-1.88**	-1.58	-5.39
Washing	-0.73	-1.07	1.20	0.28	0.30	-5.75
Transport	-1.03	-0.74	0.03	-0.50	0.61	0.76
Dressing	0.17	0.66	-0.73	0.68	1.09	-5.01
Shopping	0.40	-0.61	0.15	0.31	-2.70**	-7.27
Walking	0.26	-0.04	0.41	-0.50	-1.26	-3.83
Limping	0.25	-0.96	-1.08	-1.97**	-3.76***	-11.63***
Stairs	0.45	1.86**	-0.99	-0.23	-0.47	12.45***
Standing	0.27	0.00	-1.62*	-0.35	-0.59	6.04
Work	-1.63*	-2.06**	-0.77	-3.21***	0.14	-1.65
Symptoms duration						
Less than a year	-11.88***	-13.67***	-16.87***	-18.69***	-20.74***	-83.83***
1-5 years (ref. group)						
6-10 years	2.55**	3.22***	4.16***	4.15***	6.43***	16.53***
>10 years	5.06***	7.25***	5.03***	5.93***	9.38***	7.32
Male	-0.57	-0.34	-1.41*	-0.27	-0.44	-2.72
Age	12.65***	7.54***	12.81***	6.66*	6.20**	8.27
18-44	5.99***	4.95***	6.08***	3.86**	4.20*	2.02
45-54	2.92***	2.02**	4.40***	2.70**	0.94	-9.29*
55-64						
65-74 (ref. group)	-0.76	-0.12	0.89	-0.06	-0.90	-1.38
75-84	2.67	0.10	-2.30	-2.59	-2.95	11.06
>=85	-0.57	-0.34	-1.41*	-0.27	-0.44	-2.72
Ethnicity						
White (ref. group)						
Mixed	-7.00	3.84	1.51	-1.56	12.78	14.51
Asian	2.28	1.40	1.13	4.09	5.19	-17.63
Black	3.79	-4.92	-0.08	8.16**	-8.62	-4.38
Other	2.45	2.00	11.85*	3.78	-2.88	-32.03
Missing	-2.95**	-2.79*	0.12	-1.35	-2.29	-6.41
Rural (ref group: urban)	-0.05	-0.08	0.28	2.64**	0.04	-6.57
Emergency admissions^						
0 (ref. group)						
1	-1.77	-3.63***	-4.54***	-4.32**	-4.38**	-22.17**
>=2	-3.58	-8.03***	-4.85	-9.93***	-5.47*	-55.52***
Primary diagnosis^^						
Cox. unsp. (ref. group)						

Other primary cox.	-0.03	-1.82	0.28	0.08	8.23**	30.29**
Polyarthrosis unsp.	0.02	1.47	0.57	-2.32	0.72	-18.14***
Osteonecrosis unsp.	-5.66*	-8.32***	-12.29***	-17.80***	-9.17	-21.97
Primary cox., bilateral	3.12	3.25	0.49	1.97	17.52**	10.57
Secondary diagnosis^^^						
Hypertension uncompl.	0.72	0.65	1.23	0.84	3.59***	7.71*
Obesity	2.41***	1.76	2.58**	-0.06	1.04	11.33***
Chronic pulmonary dis.	2.07**	1.92*	4.10***	2.92***	2.69**	7.37
Diabetes uncompl.	3.02***	1.87	2.29**	4.52***	4.29***	6.57
Cardiac arrhythmias	6.85***	3.68***	4.13***	5.09***	5.82***	18.75***
Hypothyroidism	1.62	0.93	0.18	1.29	0.68	-1.97
Depression	3.79**	2.23*	1.49	0.73	3.32**	-7.55
Renal failure	1.94	3.53**	1.50	2.25	4.44***	-11.98
Rheumatoid arthritis	-1.64	-1.85	2.04	2.09	-1.24	8.65
Valvular disease	6.34***	5.55**	7.17***	9.45***	1.65	8.53
IMD quintile						
1 (ref. group-least depr.)						
2	-0.83	0.24	1.41	0.28	1.19	6.88
3	0.43	-0.96	1.51	0.59	0.23	11.76*
4	1.22	0.37	1.25	3.27**	-0.11	-0.26
5 (most deprived)	2.46**	-0.63	2.93*	4.22***	4.12**	20.18**

Notes. *p<0.1, ** p<0.05, *** p<0.01. Hospital fixed effects are included but not presented.

^ Emergency admissions in the year preceding a hip replacement surgery.

^^ Indicators for the most frequent primary diagnosis at admission and an indicator for any other primary diagnosis. We only show the most common five primary diagnoses here, others included in the models are: other secondary coxarthrosis, other dyspalstic coxarthrosis, gonarthrosis (unspecified), arthritis (unspecified), other post-traumatic coxarth., other.

^^^ Indicators for each of the Elixhauser morbidities recorded in the year preceding a hip replacement surgery. We only show the most common ten secondary diagnoses, others included are: fluid & electrolyte dis, alcohol abuse, other neurological dis., cong. heart failure, peripheral vascular dis., deficiency anaemia, solid tumour w/o met., liver disease, coagulopathy, diabetes complicated, peptic ulcer, weight loss, pulmonary circulation disorder, metastatic cancer, lymphoma, drug abuse, paralysis, psychoses, hypertension (complicated), blood loss anaemia.

Table 9. Average HRQoL gain for patients in different OHS categories in 2019/20

OHS category	Number of patients	Mean Pre-operative HRQoL	Mean Post-operative HRQoL	Inpatient Waiting Time	Mean HRQoL gain	Total health gain
0-4	901	-0.13	0.56	115	0.69	624
5-8	2,592	-0.02	0.66	117	0.68	1763
9-12	3,529	0.09	0.74	121	0.65	2278
13-16	3,855	0.25	0.78	122	0.53	2026
17-20	3,515	0.42	0.81	122	0.39	1373
21-24	2,829	0.54	0.84	121	0.30	852
25-28	1,864	0.60	0.86	123	0.26	478
29-32	1,134	0.66	0.87	123	0.21	242
33-48	932	0.73	0.90	123	0.16	153
					TOTAL	**9789**

Notes: HRQoL= health-related quality of life.

Table 10. Simulation of health gain from additional prioritisation

OHS category	Number of patients	Prioritised Waiting Time (-20%, +20%)	Change in waiting time from prioritisation	HRQoL gain per patient	Health (QALY) gain from prioritisation
0-4	901	92	-23	0.69	39.17
5-8	2,592	94	-23	0.68	111.07
9-12	3,529	97	-24	0.65	150.83
13-16	3,855	122	0	0.53	0.00
17-20	3,515	122	0	0.39	0.00
21-24	46	145	0	0.30	0.00
21-24	2,783	145	24	0.30	-54.90
25-28	1,864	148	25	0.26	-33.19
29-32	1,134	148	25	0.21	-16.31
33-48	932	148	25	0.16	-10.21
				TOTAL	**186.45**

Table 11. Simulation of health gain from additional prioritisation

OHS category	Number of patients	Prioritised Waiting Time (-40%, +40%)	Change in waiting time from prioritisation	HRQoL gain per patient	Health (QALY) gain from prioritisation
0-4	901	69	-46	0.69	78.35
5-8	2,592	70	-47	0.68	225.99
9-12	3,529	73	-48	0.65	304.17
13-16	3,855	122	0	0.53	0.00
17-20	3,515	122	0	0.39	0.00
21-24	2,892	169	48	0.30	-115.05
25-28	1,864	172	49	0.26	-75.38
29-32	1,134	172	49	0.21	-39.74
33-48	932	172	49	0.16	-26.38
				TOTAL	**351.97**