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ORIGINAL ARTICLES AND REVIEWS

Does exceeding maximum waiting times of total hip replacement patients affect resource consumption? Evidence from a highly specialized orthopedic Italian hospital

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ABSTRACT

Background. Long waiting times for elective surgeries are a common issue in publicly funded healthcare systems, raising concerns about their impact on patient outcomes. In Italy, the National Health System assigns priority classes to regulate waiting times, with class C patients expected to undergo surgery within 180 days. This study investigates whether exceeding this threshold affects surgical and hospitalization outcomes for patients undergoing total hip replacement (THR).

Methods. We conducted a retrospective observational study on 1,872 class C patients who underwent THR between 2019 and 2022 at the Rizzoli Orthopedic Institute and affiliated centers. Patients were categorized based on adherence to the 180-day waiting threshold. The study analyzed differences in surgical time, length of hospital stays and touch time. Additional analyses considered patient characteristics such as the American Society of Anesthesiologists (ASA) classification and Body Mass Index (BMI). Independent t-tests were used to assess statistical significance.

Results. Patients exceeding the 180-day waiting limit did not show significantly longer hospital stays or surgical times compared to those operated on time ($p>0.05$). However, ASA classification and BMI influenced hospital stay duration, with high ASA (3-4) patients staying 1.7 days longer on average and obese patients (BMI ≥30) staying 0.4 days longer.

Conclusions. The findings suggest that exceeding the maximum waiting time does not negatively impact surgical outcomes or hospital stay duration. However, clinical characteristics such as ASA and BMI play a significant role in postoperative recovery. Further research is needed to refine prioritization criteria to ensure optimal patient outcomes.

Key words
- waiting times
- total hip replacement
- length of stay
- surgical time
- public health

INTRODUCTION

The increasing pressure on healthcare systems highlights the need to move away from linear models and respond flexibly to emerging challenges [1]. Growing demand, driven by an aging population and advances in medical technology [2], has outpaced supply, creating a gap between needed services and available resources.

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This imbalance results in worse access, longer waiting times, and larger waiting lists. Addressing long wait times is a priority for Italy's National Health System to ensure timely, quality care for all patients [3].

Hospitalization days and operating room time are key indicators of hospital efficiency [4], with prolonged durations signalling worsening patient conditions [5-7]. In elective cases, non-urgent patients are expected to remain stable while waiting, but excessive delays can worsen clinical outcomes. Long waiting times, common in publicly funded healthcare systems, are influenced by factors like system capacity, patient volume, and emergency arrivals, creating a complex interplay of demand and supply.

In elective treatments, maximum waiting times are commonly used to align healthcare supply with demand. Governments set these limits to establish targets or guarantees for treatment within a certain timeframe [8]. If not met, providers may face penalties or patients can seek care elsewhere. In Italy, the National Health System classifies waiting times by pathology priority, introduced in the 2006 National Plan for the containment of waiting times. This plan established four priority classes for elective surgeries and admissions, with specific waiting time guarantees for each class:

- A-hospitalization within 30 days;
- B-hospitalization within 60 days;
- C-hospitalization within 180 days;
- D-hospitalization without the maximum defined wait, at least within 12 months.

The purpose of the study is to investigate whether there is a difference in operating on time or out of maximum time, allowed by current regulations, patients placed on the class C waiting list for total hip replacement (THR) surgery, in terms of surgical time and hospitalization time.

For the research, the American Society of Anesthesiologists (ASA) classification and Body Mass Index (BMI) were considered as clinical parameters to be considered in defining variation in consuming the surgery resources.

In particular: "The ASA physical status classification system was introduced in 1941 to provide perioperative clinicians with a standardized method to evaluate a patient's medical comorbidities and help predict perioperative risk" [9].

For what concern BMI, defined as body weight in kilograms divided by the square of height in meters (kg/m^2), is a simple and widely used proxy for body fatness in adults" [10].

For descriptive completeness, THR is a routine major orthopaedic surgery performed to replace a damaged hip joint with an artificial implant. It is primarily indicated to relieve hip pain and stiffness caused by hip arthritis. This procedure may also be used in the treatment of injuries such as hip fractures, improperly developing hips, and other degenerative conditions of the joint [11, 12].

MATERIALS AND METHODS

The starting sample consisted of all scheduled surgical patients, of priority class C, that presenting minimal pain, dysfunction, or disability, and do not show a tendency to worsen nor can cause serious damage to the prognosis, subjected to THR surgery in the Rizzoli Orthopedic Institute (ROI) and its external platforms. It numbered 3,205 patients operated from 2019-2022. BMI and ASA grades were extracted from ROI workflow software used to manage and document all aspects of clinical care. Exclusion criteria are reported as follows. Ten patients whose operating time was less than 30 minutes were excluded from the sample as it was considered a mistake made while reporting the time. The patients operated at external accredited hospitals, in 2019, also had to be excluded from the sample, as the production tool was not available, therefore it was not possible to access the operating room time. Concerning BMI and ASA, it was apparent that there was no corresponding data for all patients, so those who did not have data on BMI and ASA did not make part of the research, which significantly reduced the sample size to 1,882 patients.

It was subsequently decided to exclude 10 patients whose main diagnoses were – tumor and special joint disorders – as their worse outcomes could be due to the severity of the disease and not the factors considered in this study, which could make the result of the analysis biased.

This made a final sample number, 1,872 patients of waiting who satisfied all the criteria and had all the necessary data for the analysis. Patients included have been operated on between 2019-2022 and have the following characteristics:

- main intervention: THR;
- priority class: C;
- main diagnosis: primary, secondary, and post-traumatic arthrosis; aseptic necrosis of the head and the neck of the femur; other mechanical complications of the joint prosthesis implantation.

The statistical analysis started with dividing the sample into 2 groups based on their waiting time. Patients who waited more than 180 days – expired, and the patients who waited less or equal to 180 days – non-expired. The means were calculated of each groups' length of stay (LOS), surgical and touch time. Then, descriptive statistics were provided.

The mean or average value is a measure of central tendency used to describe the average or typical value of a set of numbers or data points. To calculate the mean value, all values in a dataset are added up and then divided by the number of values.

Next, the same sample was divided in 4 different groups depending on patients' level of ASA and BMI as follows:

- low ASA (1, 2) and high ASA (3, 4);
- obese patients (BMI ≥30) and non-obese patients (BMI <30).

The means of all the outcome variables were calculated for each of these groups.

In the end the t-tests were performed to understand if there are statistically significant differences in means.

RESULTS

The research hypothesis is to question the fact that patients undergoing THR over 180 days, although these are cases in which the pathological and general health condition should not worsen while waiting, have longer hospitalization and intervention times. To examine this, first the sample were separated in 2 groups – patients operated before 180 days (≤180) and patients operated after 180 days – a dummy variable "threshold" was created, representing a value of 1 for the patients who exceeded the 180 days threshold of maximum waiting, and 0 for patients who did not.

Out of a total of 1,872, 906 (48.4%) were called on time and did not exceed the threshold of 180 days, while 966 (51.6%) patients waited longer than predicted for their priority class.

From this threshold, the results of the analysis are reported in relation to the outcome and clinical parameters as follows below.

Waiting time

It is the time spent on the waiting list until the procedure is performed. The unit of measurement is days, and they are calculated from the date of insertion in the waiting list until the day of the intervention. In the study, a likewise distribution was found with a mean waiting time for patients being 243.8 days and a median of 187 days.

95% of patients received the treatment in 579.2 days, 75% in 339.8 days and 50% of them in 187 days. The 50^{th} percentile is the median value, and it presents the point where half of the waiting times are less than or equal to that value, and the other half are greater.

This variable is used to make a division between patients who waited more and less than a maximum waiting time.

Next, the hospitalization days variable is described with the descriptive statistics of the hospitalization days with respect to the 180-day threshold. The same is done for the variables used to measure time in the OR-surgical time and touch time.

Length of stay in the hospital

LOS, also called days of hospitalization or hospitalization days, is a measure of the length of time a patient requires in-hospital care, so they refer to the number of days a patient spends in a hospital as an inpatient for medical treatment, in this study THR surgery. These days include both the day of admission and the day of discharge. The mean of the LOS in the sample is 7.7 days, which tells us that the patients in the study undergoing THR surgery on average stay 7.7 days in the hospital until their discharge. This period does not consider their outpatient recovery. The median value is quite similar to 7.4 days. The standard deviation is 2.9 showing us that data points are relatively close to the mean. The minimum value in the sample is 1.8 and the maximum is 30.5, representing the minimum and the maximum number of days a patient stayed in the hospital.

Next it is calculated the distribution of the LOS over binary variable threshold, which represents patients who exceeded the threshold of maximum waiting time of 180 days (threshold=1), and those who were operated in time(threshold=0). The distribution of the 2 groups seemed not to differ largely. Standard deviation is larger for the expired patients 3.9 and with respect to 2.7 and it also has a bigger maximum value of 30.5 days. However, this does not seem to significantly influence the means of the two groups since both are close to the mean of the entire sample -7.7.

Surgical time

Surgical time is calculated as the difference between the event of the end of the surgical procedure, the last suture, and the beginning of the surgical procedure, the beginning of the surgical incision. Our Descriptive statistics analysis of Surgical time variable (min) showed that the sample, the mean value, or the average time for performing the surgery is 77.3 minutes, the median was 73 minutes. The standard deviation that measures variability or spread from the mean and had the same unit as the data, was 25.5 min. The minimum in the sample was 31 min and the maximum was 275 min. The remaining descriptive statistics were later summarized.

Surgical time of the patients who exceeded the threshold waiting time has been analyzed and those who did not. From our results, the mean surgical time of patients admitted in time was 78 minutes, while patients who exceeded the threshold had on average a shorter surgical time, 76.7 minutes. Thus, patients who waited longer for the surgery on average did not have longer surgical time. The analysis shows quite the opposite, longer surgical time for non-expired patients. This difference, however, is less than 2 minutes.

ASA

ASA classification is represented by a grade, from 1 to 5 or 6, in this sample it ranges from 1 to 4. Proportions estimation was reported as a proportion or percentage of a categorical variable that belongs to each group (1-4). We found 25.34% of patients with grade ASA 1; 55.10% of them had ASA 2; 19.23% with ASA 3 and only 0.26% of patients with ASA 4. This is because, for the purpose of the analysis, only patients whose health should not deteriorate over time were included, so multimorbid patients with severe conditions are not present in the sample. There are only 5 patients with ASA 4.

For further analysis, we defined 1,2 as a low level of ASA and 3,4 as a high level of ASA and created dummy variables levelasa=0 for the low level of ASA and levelasa=1 for a high level of ASA.

It is possible to see the proportion of patients with high ASA and low ASA in the *Table 1*, 80.5% of patients had low ASA and 19.5% had high ASA. This proportion is expected in the present sample since it contains only patients of the C category, non-urgent whose health should not deteriorate while waiting.

It has been also calculated the distribution of hospitalization days for high and low levels of ASA. The mean length of stay for the patients with low ASA was 7.3 days and for those with high levels of ASA 9.1. The assumed differences in LOS between these groups are expected as patients with high ASA could have more complications and they could need longer recovery, surveillance of the health workers, additional tests, and consequentially longer length of stay.

Table 1
Proportion estimation of high (levelasa=1) and low (levelasa=0) ASA variable

Proportion estimation — Number of obs = 1,872

	Proportion	Std. err.	Logit [95% conf. interval]	
levelasa				
0	.8050214	.0091568	.7864343	.8223561
1	.1949786	.0091568	.1776439	.2135657

ASA: American Society of Anesthesiologists; obs: observation; std err: standard error; logit: logistic regression; conf. interval: confidence interval.

As showed in *Table 2*, surgical time is calculated for patients with low ASA (levelasa=0) and patients with high ASA (levelasa=1). It is possible to see that high ASA patients do not have significantly longer surgical time (77.6 min) in respect to low ASA patients (77.2 min).

BMI

It provides a numerical value that categorizes individuals into different weight categories. From the descriptive statistics analysis the mean value was 27, which the BMI scale classifies as overweight. The median was 26.6, so that half of the dataset has BMI values below 26.6, and the other half has values above this value. Skewness and kurtosis are quite low, indicating that distribution can be close to normal.

We also calculated the summary statistics of hospitalization days for non-obese patients with dummy variable levelbmi=0 and obese patients with dummy variable levelbmi=0. From the results it can be observed that their means were slightly different, being 7.6 days for non-obese and 8 days of hospitalization for obese patients. This gave additional reason to test for the differences between these 2 groups. The groups were different in size, with 1,430 not-obese patients and 442 obese patients with BMI larger than 30.

Obese patients had on average longer surgical time (80 minutes) than non-obese patients (76.4 minutes).

In our sample, the difference between these 2 groups was 1.8 days of hospitalization. To investigate if this difference was significant, a t-test for independent samples assuming equal variances was used. In this inferential statistic, the null hypothesis states that the difference in the means between the two groups is 0. Observing the test, p-value was really close to 0 and less than the significance level of 0.05, therefore, the decision is to reject the null hypothesis and accept the alternative one. There was a difference in the days of hospitalization for patients with low and high ASA. Patients with high ASA tend to have longer hospitalization than patients with low ASA, in this sample they on average stay 1.8 days longer in the hospital.

Once again, a significant difference in means between 2 groups, obese and non-obese patients, was confirmed. The t-test done to test this hypothesis gave the p-value of 0.02, that is smaller than the significance level (0.05), thus rejecting the null and the alternative was accepted. The obese patients have longer hospitalization than non-obese patients. The obese patients stayed on average 0.4 days longer in the hospital (9.6 hours).

It is possible to confirm that there is a significant difference in means of surgical time between 2 groups, obese and non-obese patients. The t-test done to test this hypothesis gave the p-value of 0.009, that is smaller than the significance level (0.05), thus rejecting the null and the alternative was accepted. The obese patients have longer surgical time than non-obese patients. The operation of the obese patients on average lasted 4 minutes more.

The t-test was applied for each of the investigated hypotheses. In particular, a standard student t-test was performed, and an inferential statistic was used to determine if there was a statistically significant difference between the means of 2 groups.

More in detail, statistical analysis investigated:

- differences in hospitalization days between patients who expired and those who did not expire from the waiting list;
- differences in surgical time between patients who expired and did not expire from the waiting list;
- differences in hospitalization days between patients with low and high ASA;
- differences of hospitalization days between obese and non-obese patients;
- differences in surgical time between obese and non-obese patients.

Only two results highlighted a significant difference in terms of resources consumed. In particular:

- the differences in hospitalization days between patients with low and with high ASA;
- the differences of hospitalization days between obese and non-obese patients.

1) "Null hypothesis": there is no difference in hospitalization days between patients with low and with high ASA.

"Alternative hypothesis": there is difference in days of hospitalization between patients with low and with high ASA.

Here, we questioned if there was a significant difference in means between patients with high and low ASA grades. In our sample, the difference between these 2 groups was 1.8 days of hospitalization. To investigate if this difference was significant, a t-test for indepen-

Table 2
Summary statistics of surgical time of patients with low and high level of ASA-minutes

-> levelasa = 0

Variable	Obs	Mean	Std. dev.	Min	Max
tempochiru~n	1,507	77.25946	25.12637	31	275

-> levelasa = 1

Variable	Obs	Mean	Std. dev.	Min	Max
tempochiru~n	365	77.64658	26.98216	35	264

ASA: American Society of Anesthesiologists; obs: observation; std. dev.: standard deviation; min: minimum; max: maximum.

dent samples assuming equal variances was used. In this inferential statistic, the null hypothesis states that the difference in the means between the 2 groups is 0. Observing the test, the p-value was really close to 0 and less than the significance level of 0.05, therefore, the decision was to reject the null hypothesis and accept the alternative one. There was a difference in the days of hospitalization for patients with low and high ASA. Patients with high ASA tend to have longer hospitalization than patients with low ASA, in this sample they on average stay 1.8 days longer in the *Table 3*.

2) "Null hypothesis": there is no difference in hospitalization days for obese than non-obese patients.

"Alternative hypothesis": there is a difference in hospitalization days for obese than non-obese patients.

Here, a significant difference in means between 2 groups, obese and non-obese patients, is again confirmed. The t-test done to test this hypothesis gave the p-value of 0.02 that is smaller than the significance level (0.05), thus we rejected the null and accepted the alternative. The obese patients have longer hospitalization than non-obese patients. The obese patients stayed on average 0.4 days longer in the hospital (9.6 hours, as showed in *Table 4*.

DISCUSSION

Patient prioritization represents a crucial tool for assuring timely and fair access to health care services. Maximum waiting times can be understood as a form of guarantee or agreement made between the health provider and the patient that assures that treatment will be provided and that this will happen within a specified timeframe.

After performing the t-tests to determine if there is a statistically significant difference between the means of the two groups – patients who exceeded the threshold waiting time and patients who did not – it can be concluded that being operated on after the time limit of 180 days does not result in having worse outcomes, i.e., longer length of stay and surgical time.

All two t-tests showed that the difference in means is irrelevant. Two groups of non-expired and expired patients and similar in size. There are 906 non-expired patients and 966 expired ones in the sample, therefore we do not assume that the difference in the size of the sample could influence the outcomes of the t-tests. The size of the sample is large enough to perform this type of analysis, however, a larger sample size could make the analysis more relevant and precise.

The second research question regarded patients' characteristics that, if high, can define individuals as at-risk patients, ASA and BMI. It was evident that patients with high ASA spent 1.7 days more time in the hospital than patients with low ASA. The same is shown for obese patients who had 0.4 days or 9.6 hours longer stay in the hospital than non-obese patients.

All these differences were significant in the tests with a p-value smaller than the significance level chosen for this analysis (0.05).

T-tests performed in this analysis confirmed that there is a statistical difference in means between the two groups, but it doesn't determine whether one variable causes the difference in means or if there are other factors at play.

It is evident that the distribution of these variables is proportional in the two groups, patients who exceeded the 180-day waiting limit have on average a very similar BMI (≈27) and ASA (≈1.9) to patients who were surgically treated on time. The groups are balanced; therefore, even if they are aggravating factors, these variables did not cause bias in the results of the analysis of tests done on the impact of waiting time on the outcomes.

Finally, although at-risk patients do have longer LOS, based on our initial analysis, which indicated that adhering to the 180-day threshold does not influence the outcomes, we can assume the same for the at-risk groups, as the variables (age, ASA; BMI) are evenly distributed across both groups. There is no presumption that exceeding maximum waiting times worsens the outcomes: length of stay and surgical time, even for at-risk patients. However, further analysis should be done on the issue.

T-tests, as mentioned before, do not establish causation or explain why that difference exists. To investigate the impact of one variable on another and establish causation it is needed to conduct more complex analyses, such as regression analysis or experimental design. Regression analysis allows us to assess the relationship between variables and can help identify whether changes

Table 3
T-test assuming equal variances of the hospitalization days variable with respect to patients with low ASA and high ASA grade

Two-sample t test with equal variances

Group	Obs	Mean	Std. err.	Std. dev.	[95% conf.	interval]
0	1,507	7.359604	.065006	2.523539	7.232092	7.487116
1	365	9.10941	.2008468	3.837172	8.714445	9.504376
Combined	1,872	7.700779	.06727	2.910544	7.568847	7.832711
diff		-1.749806	.1649494		-2.07331	-1.426302

```
    diff = mean(0) - mean(1)                                      t = -10.6081
H0: diff = 0                                     Degrees of freedom =     1870

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

ASA: American Society of Anesthesiologists; obs: observation; std err: standard error; std. dev.: standard deviation; conf. interval: confidence interval.

Table 4
T-test assuming equal variances of the hospitalization days variable with for obese and non-obese patients

Two-sample t test with equal variances

Group	Obs	Mean	Std. err.	Std. dev.	[95% conf.	interval]
0	1,430	7.606065	.0750941	2.839709	7.458759	7.753372
1	442	8.007205	.1480427	3.112419	7.716248	8.298162
Combined	1,872	7.700779	.06727	2.910544	7.568847	7.832711
diff		-.4011398	.1581679		-.711344	-.0909355

```
    diff = mean(0) - mean(1)                                      t =  -2.5362
H0: diff = 0                                     Degrees of freedom =     1870

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0056         Pr(|T| > |t|) = 0.0113          Pr(T > t) = 0.9944
```

Obs: observation; std err: standard error; std. dev.: standard deviation; conf. interval: confidence interval.

in one variable are associated with changes in another. However, even correlation or regression analyses cannot definitively establish causation; they can only provide evidence of an association or relationship.

At first glance, the results of the analysis can put into question the accuracy of the patient prioritization methods and adherence to the maximum waiting times, given that the patients waiting more than six months do not show worse outcomes in terms of longer hospital stay and longer surgical time. This conclusion holds true for both the overall patient population and at-risk groups defined by ASA, BMI. However, the benefits of adherence to maximum waiting times go beyond the avoidance of further deterioration of patients' health and surgical outcomes.

CONCLUSIONS

In conclusion, the maximum waiting times are the most prevalent approach to deal with the long waiting times and are an indispensable part of regulations and guidelines for the management of the waiting list implemented by the hospitals, including ROI.

According to the literature, for patients undergoing THR, receiving care on time reduces the burden of living with pain or dysfunction that impacts the quality of life.

However, it remains important to state that health care institutions, for organizational reasons and in order to be able to respond efficiently to the health demand of citizens represented by waiting lists, should still consider in organizational planning not only waiting times but also factors such as ASA and BMI, because they could influence the scheduling of interventions and the management of productive resources allocated to planned surgical activity.

It's important to note that while statistical differences were identified, the study does not establish causation. It indicates that certain patient characteristics are associated with longer lengths of stay but it doesn't determine whether these characteristics directly cause the differences. The study acknowledges the need for further analysis to delve deeper into the relationship between these variables.

Authors' contributions

All Authors have contributed significantly to the work and approved the final version.

Conflict of interest statement

There are no competing interests to declare.

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