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Cemented vs uncemented hip replacement: implications for operating theatre productivity

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Introduction

The National Health Service (NHS) is struggling to meet elective surgery recovery targets set by the UK government. Increasing productivity by maximising the number of cases performed through current operating list capacity will be crucial to reduce waiting times.

Methods

This is a retrospective analysis of total hip replacement (THR) procedures performed in a single NHS general hospital using cemented or uncemented prostheses. Data were collected routinely between August 2007 and May 2009. A probabilistic analysis using the Monte Carlo simulation approach was conducted to estimate the probability of completing four cemented or four uncemented THR surgeries within a standard 8-h operating list, and if there was a 15- or a 30-min start delay.

Results

There were 236 surgeries with a cemented prosthesis (mean surgical case time 117.96min) and 333 using an uncemented prosthesis (mean surgical case time 101.54min). For the standard operating list duration of 8h, the probability of completing four cemented hip replacements was approximately 63%, compared with 96% for uncemented procedures. Delayed starts of 15 and 30min resulted in significant reductions in the probability of completing four cemented procedures, decreasing to 44% and 26%, respectively. Uncemented procedures were less affected by these delays, with probabilities of 93% and 87%, respectively.

Conclusions

The use of uncemented prostheses, where clinically suitable, may contribute to increased theatre throughput within current NHS operating list capacity.

Keywords: Arthroplasty; Replacement; Hip; Total hip replacement; Hip prosthesis; Operative time

Introduction

The National Health Service (NHS) is struggling to meet the elective recovery targets set by the government, with the waiting list reduced year-on-year by just 134,000 patient pathways to the end of November 2024.[1,2] This is far below the required reduction of 1 million annually to restore the 18-week referral-to-treatment standard by March 2029.[2] The plan to expand outpatient and diagnostic capacity to address this substantial backlog has merit, with 6.3 million of 7.5 million patients awaiting diagnosis and decision, but will inevitably increase demand for inpatient and day-case treatments. Therefore, increasing productivity by maximising the number of cases performed through current operating list capacity will be crucial to reduce waiting times, because the backlog for diagnosis and treatment will create a domino effect. If diagnostic and outpatient waiting times are cut without increasing surgical capacity, the surge in patients requiring inpatient care will continue to overwhelm available resources.

This challenge in addressing surgical backlogs and optimising productivity in operating theatres is particularly pertinent for elective procedures such as total hip replacements (THR), where demand continues to rise because of an ageing population and an increasing prevalence of osteoarthritis. The NHS has implemented various initiatives, including the Getting It Right First Time (GIRFT) programme, which emphasises efficiency, standardisation and reduction of unwarranted variation in surgical practice.[3] In the context of THRs, GIRFT recommends ensuring that surgical teams can complete four primary cemented THRs in a single operating session, and this is considered a benchmark for efficiency. However, this requires precise scheduling, minimal delays and effective time management. Variability in operative times for procedures, as well as delays in list start times, can significantly impact the ability to meet

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these targets. This study aims to quantify the probability of completing four primary THRs under different conditions to inform decision making and enhance theatre productivity.

Methods

This is a retrospective analysis of THR procedures performed in a single NHS English district general hospital and is reported using the observational routinely collected health data (RECORD) checklist.[4] The analysis was performed using hospital data collected routinely between 6 August 2007 and 29 May 2009. Data from this time were chosen for analysis because at that time the operating theatre had highly standardised practices,[5] and clinical outcomes from this time were excellent and have been reported previously.[5] This highly standardised environment reduced variability from wider operational factors such as theatre set-up, staffing workflows and perioperative processes, thereby allowing clear assessment of operative time variability between prosthesis types. In accordance with NHS Health Research Authority guidance, NHS ethical approval was not required for this service evaluation, although approval was obtained from the hospital.[6] All primary THR procedures using cemented (CPT-ZCA) or uncemented (CORAIL-Duraloc) prostheses at the hospital were included.[7–10] Data on prosthesis type, surgeon, anaesthetist, time admitted to and departure time from the operating theatre were collected by hospital staff during the surgery and entered on to the hospital record system. The primary outcome measure (surgical case time) was the difference in time between admission to and departure from the operating theatre.

THR cases were divided into cemented and uncemented prosthesis combinations, and a probabilistic analysis was conducted to estimate the likelihood of completing four cemented or four uncemented primary hip replacements within a standard 8-h, all-day NHS operating theatre list.[3]

Probabilities were calculated for the following scenarios (target time limits):

- 8h (480min): an ideal operating list duration
- 7h 45min (465min): assuming a 15-min start delay
- 7h 30min (450min): assuming a 30-min start delay

To determine the probability that four consecutive operative case time events of a given class (in this case cemented and uncemented prostheses) could fit within the target time limits (T) two probability estimation approaches were considered:

- normal distribution cumulative distribution function (CDF) approach
- Monte Carlo stochastic simulation approach[11]

The CDF approach assumes normality, whereas Monte Carlo simulations execute stochastic sampling from the empirical experimental data. Subsequently, Monte Carlo simulations are more computationally expensive. A normality test was conducted to determine the appropriate method programmatically via the Python SciPy library for Shapiro–Wilk test, kurtosis and skewness.[12–15] Both methods were executed such that their outcomes could be compared, and full details on the methods and results from each method can be found in the Supplementary Information.

To assess bias in the study, anaesthesiologist–surgeon combinations were assessed to check diversity for both types of prosthesis. Entropy was examined to give an indication as to the tendency of combinations to favour specific surgeries. Full details on the methodology can be found in the Supplementary Information.

Results

There were 236 THR surgeries using a cemented prosthesis and 333 using an uncemented prosthesis. Surgery with a cemented prosthesis had a mean surgical case time of 117.96min with a standard deviation (sd) of 16.11min and median of 115.50min. Surgery with an uncemented prosthesis had a mean surgical case time of 101.54min with an sd of 19.13min and a median of 98.00min.

Surgery case times for both cemented and uncemented procedures were determined to be normal distributions according to Shapiro–Wilk test. With kurtosis values of 0.28 and 1.82 for cemented and uncemented, respectively, the closer to 0 kurtosis value for cemented procedures suggested a more normal distribution. Skewness was 0.63 and 1.09, respectively, where normality would have corresponded to a value of 0. Distribution graphs are given in the Supplementary Information. The Monte Carlo simulation approach was considered as the recommended method.

The probabilities of completing four cemented or uncemented THRs within the given time constraints for the Monte Carlo approach are summarised in Table 1.

The CDF approach produced very similar probabilities to the Monte Carlo approach, and therefore each method validated the other as they were completely independent algorithms. (Supplementary Information).

Regarding potential bias in the medical staff undertaking the surgeries, there were 178 unique combinations of anaesthesiologist and surgeon across 569 surgical procedures, with 44 unique anaesthesiologists and 19 surgeons. There were 119 combinations in cemented procedures and 126 combinations in uncemented, with 67 (37.6%) of the unique staff combinations performing both cemented and uncemented operations. Some 57.9% of surgeons performed both types of operation.

Overall, there was a considerable diversity of teams contributing to both types of surgery, as well as teams overlapping both modalities, therefore providing satisfactory low staffing bias in this study. A weighted entropy assessment (Supplementary Information) demonstrated low bias with an entropy score of 0.67 regarding the tendency of teams to operate in only a single modality (cemented or uncemented). This relatively high entropy, along with the large number of surgeon–anaesthesiologist combinations (178), quantified the acceptably low bias and team diversity towards each of the two surgical modalities. Figure 1 demonstrates the overlap in staffing between the cemented and uncemented prosthesis surgeries.

Interpretation

Given that the data were found to be non-normal, the Monte Carlo results were interpreted. For the ideal operating list duration of 8h, the probability of completing four cemented hip replacements was approximately 63%, compared with 96% for uncemented procedures. Delayed starts of 15 and 30min resulted in significant reductions in the probability of completing four cemented procedures, decreasing to 44% and 26%, respectively. Uncemented procedures were less affected by these delays, with probabilities of 93% and 87%, respectively. This analysis highlights the impact of operative time variability and delays on achieving optimum productivity in NHS operating theatres.

Discussion

The findings of this study underscore the challenges of achieving optimal productivity in NHS operating theatres, particularly when

Table 1 Probability of cemented vs uncemented prosthesis meeting given target time using Monte Carlo simulation method

Time constraint	Cemented probability (%)	Uncemented probability (%)
Monte Carlo simulation approach		
8h (480min)	62.52	96.05
7.75h (465min)	44.45	92.72
7.5h (450min)	26.48	87.30

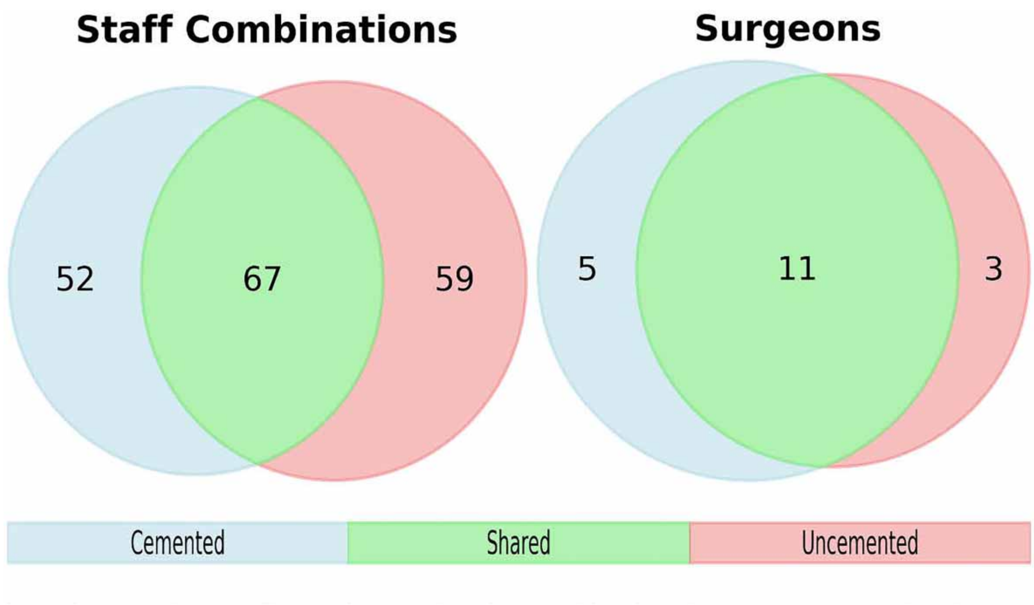

Figure 1 Venn diagram illustrating overlapping combinations between cemented and uncemented for the 178 staff anaesthesiologist–surgeon combinations and 19 surgeons

delays in start time or variability in operative times occur. Although uncemented hip replacements demonstrated a high probability of completion within the standard 8-h list and even under delayed conditions, cemented procedures showed significantly lower probabilities. This variability highlights the impact of procedure type on theatre efficiency, a critical consideration as the NHS strives to address surgical backlogs. However, operating theatre productivity is multifactorial and so may also be influenced by wider perioperative, organisational and workflow-related factors. Adopting uncemented procedures where clinically appropriate could enhance productivity without compromising patient outcomes. However, this must be balanced against clinical considerations, such as patient comorbidities, bone quality and surgeon preference, to ensure that efficiency gains do not negatively affect long-term outcomes. Importantly, prosthesis fixation strategy should be considered as one component within wider theatre optimisation efforts, rather than as a standalone solution to improving operating theatre productivity.

From a clinical perspective, the findings suggest a need for tailored approaches to theatre scheduling and list planning. For lists comprising predominantly cemented hip replacements, realistic scheduling may need to account for higher variability in operative times, and contingency planning should be in place to address potential delays. Efforts to standardise operative techniques and implement measures to reduce variability, such as surgeon training and multidisciplinary team coordination, could improve predictability and efficiency.

The data also support the need for optimising preoperative pathways to minimise delays, such as ensuring the availability of instruments, the reduction and utilisation of the surgical tray, preoperative imaging and surgical planning. Initiatives to reduce late starts, including addressing logistical and administrative barriers, could significantly enhance productivity and enable the NHS to meet GIRFT targets.

The practical implications of these findings extend to theatre managers, policymakers and clinicians. Strategies to mitigate delays, reduce variability and optimise list planning include:

- implementing robust start-time management protocols to minimise delays in commencing operating lists;
- enhancing intraoperative efficiency through standardised and simultaneous workflows, optimising staffing and adequate resource allocation;
- using predictive modelling to plan lists based on historical data, incorporating variability in operative times for different procedure types.

Study limitations

Although the data set used in this study was collected more than 15 years ago, several factors strongly mitigate concerns about the data's relevance and accuracy. The first author (TWW) conducted a rigorous daily quality control process during the original data collection period as part of an established operating theatre efficiency programme. TWW verified surgical times daily, and all data were entered contemporaneously by trained staff in the clinical setting, ensuring a high standard of accuracy and reliability.

Moreover, as described, data were collected during a period of highly standardised care in a single NHS hospital that had implemented highly standardised protocols as part of a well-defined enhanced recovery pathway. All operations took place in the same two operating theatres and were performed by the same operating theatre teams, reducing contextual variability. Such a controlled clinical environment supports the internal validity of the findings and allows for a robust comparison of prosthesis types.

Although historical data can sometimes raise concerns regarding generalisability, the stability and transparency of the clinical pathway during this period, combined with a thorough quality assurance process, make this data set particularly valuable. We believe that the completeness, consistency and quality assurance associated with this data set provide important strengths that support its continued value for addressing the present research question. Although contemporary joint replacement pathways continue to evolve, challenges relating to theatre efficiency, delayed starts and operative variability remain highly relevant to current NHS elective practice.

The Monte Carlo simulation method used in our analysis directly samples from the empirical data distribution, enhancing the robustness of probabilistic estimates even when applied to non-normally distributed datasets. Finally, while entropy was used to evaluate potential bias in team distributions across surgical types, alternative measures, such as the Jensen–Shannon divergence (Supplementary Information), could provide complementary perspectives on team assignment bias.[16] Future studies may consider these additional metrics.

Future studies should apply this probabilistic modelling methodology to contemporary arthroplasty data sets to determine whether improvements in theatre processes have altered the probability estimates observed in this study.

Conclusion

This analysis provides evidence-based insights into the feasibility of completing four hip replacements within an operating session under different conditions. Although uncemented procedures are more likely to meet productivity benchmarks in this highly standardised operating environment, achieving the same for cemented procedures requires addressing variability and operational inefficiencies. These findings support the GIRFT recommendations for enhanced planning and standardisation and underscore the importance of addressing logistical barriers to optimise theatre productivity in the NHS. Future research should explore the integration of predictive analytics and innovative technologies to further improve surgical throughput and patient outcomes.

Competing interests

RGM reports receipt of royalties from Zimmer Biomet and Lima, and consultancy fees from Zimmer Biomet. The remaining authors declare no conflict of interest.

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Ethics approval and consent to participate

This study was carried out under the Code of Ethics of the World Medical Association (Declaration of Helsinki). The secondary analysis was done as a service evaluation and NHS ethical approval was not required for this study.[6] Approval for the work was given by the hospital.

Code availability

Upon acceptance the code used in the analysis will be available at https://github.com/RichardMatzko/ORI_Cemented-Uncemented-CDF-Monte-Carlo-Surgical-Times

Author contributions

TW Wainwright: Conceptualisation, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **R Matzko:** Formal analysis, Visualisation, Writing – review & editing. **T Immins:** Data curation, Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing. **RG Middleton:** Conceptualisation, Supervision, Writing – original draft, Writing – review & editing.

Artificial Intelligence

The author/s declare that no AI was used to conduct the study or prepare the manuscript.

Supplementary Information

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