An environmental impact assessment of THA surgery

High-Level Care Pathway Appraisal

Total Hip Arthroplasty (THA) Surgery: Balancing Implant Efficacy with Environmental Responsibility

Title	
Organisation	Johnson & Johnson / DePuy Synthes
Organisation's role	Johnson & Johnson initiated this work but was not involved in collecting and analysing the data.
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Completion date	December 2025
Assurance	Internal assurance
Supporting information	Care pathway mapping discussed with Mr Jonathan Evans
Data gathering and analysis contact	Sam Holmes (sam@shcoalition.org)
Conformance to 'Care Pathways: Guidance on Appraising Sustainability'[1]	Adheres to the Guidance for a high-level appraisal
Care pathway description	THA surgical pathway in the UK
Environmental issues appraised	Global warming potential (IPCC, CO_2e, 100-year)

Summary

- This case study mapped the care pathway for THA to allow a care pathway carbon footprint to be estimated for both primary and revision procedures. It indicates that efficiency savings and improved outcomes through implant choices can reduce the overall carbon footprint of the delivery of THA surgery.
- Clinical performance of implants, including whether rates of revision increase or decrease, must be considered for implications on cost, resource use, patient outcomes, as well as environmental impact.
- The CORAIL™ collared stem with PINNACLE™ Cup demonstrated a significantly lower rate of revision at 10 years post-op, compared to the CORAIL™ collarless stem with PINNACLE™ Cup. Assuming CORAIL stems are representative of cementless stems generally, if all cementless THA surgeries recorded in the National Joint Registry in 2024 had used the collared implants, then that lower revision rate would have resulted in 598 tCO_2e savings.
- When looking to decarbonise THA surgery, appraising the entire care pathway would allow a more comprehensive understanding of hotspots and downstream impact of product choices than considering product level footprint analysis alone.

Introduction

Healthcare systems globally are increasingly committing to decarbonisation, often to be delivered through meeting the ambition of 'net zero' emissions,[2] and this inevitably means that high resource and carbon intense clinical specialities such as orthopaedics are coming under scrutiny.

116,901 primary THA surgeries were recorded as being performed in the UK-based National Joint Registry (NJR) during 2024 and demand for THA surgery continues to grow.[3] With such a high volume of procedures being delivered, even small sustainability improvements can have large-scale impact. Alongside clinical choices on implants and surgical processes, patient's length of stay, overall readmission rates and re-operation rates can each have contributory significance to sustainability and performance measures.

This case study uses a high-level care pathway appraisal approach to show how an objective understanding of products, assessed in the context of the care pathway they support, can have a positive sustainability impact.[4]

"There is the potential to reduce carbon emissions by changing the way we provide healthcare, [and] shortening inpatient stays, reducing the number of outpatient appointments, reducing emergency readmissions, and reducing re-operation rates may all help to contribute to reducing carbon emissions associated with patients undergoing Total Hip Replacement."

Koris et al. [5]

Environmental impact of THA – literature data

There are currently few studies looking at the carbon footprint of THA care pathways, and estimates vary significantly. Eidman *et al*., who reported 81.6 $kgCO_2e$ per patient for primary THA, looked at Scope 1, 2 and 3 emissions within the surgical setting, but excluded the implant footprint due to lack of data.[6] Kodumuri *et al*., using a similar operational boundary (anaesthetic room to recovery room), reported 100.02 $kgCO_2e$ for a cementless THA procedure and 104.89 $kgCO_2e$ for a hybrid (using both cemented and cementless components) THA procedure, per patient. However, the study was limited due to omission of perioperative stages and exclusion of Scope 3 emissions (including implants).[7]

A study by Koris *et al*. found a 25% reduction in carbon footprint per patient across the THA pathway from 2014-2022, attributable to reductions in length of hospital stay (169.1 $kgCO_2e$ to 117.6 $kgCO_2e$ per patient), emergency readmissions (10.8 $kgCO_2e$ to 9.2 $kgCO_2e$ per patient), and revisions (2.9 $kgCO_2e$ to 1.5 $kgCO_2e$ per patient), and when shifting from in-person (22.0 $kgCO_2e$) to virtual (0.1 $kgCO_2e$) outpatient appointments.[5] Length of hospital stay was reduced due to initiatives such as enhanced recovery programmes, which also improve patient outcomes and experiences, and reduce overall costs. These improvements are attributable to macro changes in clinical practice, which were not purely driven by sustainability initiatives.

Published data on manufacturing emissions for THA implants is currently lacking. A titanium alloy (Ti_6Al_4V) femoral stem implant, such as the CORAIL™, was estimated by Cappucci *et al*. to be 56.4 $kgCO_2e$.[8] An equivalent estimate for a stainless-steel implant is not available.

Revision rates for collared versus collarless implants

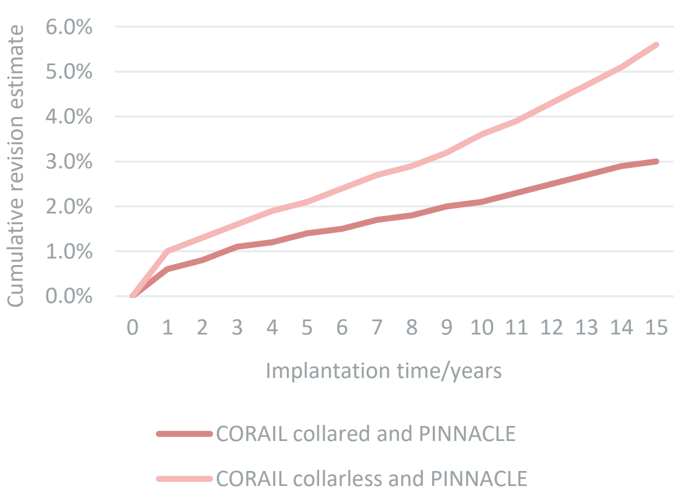
A bespoke report analysis conducted by the NJR into cementless hip implants observed that the CORAIL™ collared stem with PINNACLE™ Cup was associated with a 42% lower rate of revision at 10 years post primary THA compared to CORAIL™ collarless stem with PINNACLE™ (excluding metal-on-metal).[9, 10]

Table 1: Cumulative revision rates (Jan 2004-Dec 2024)

Period /years	CORAIL collared and PINNACLE*	CORAIL collarless and PINNACLE*
1	0.6% (0.6% - 0.6%)	1.0% (0.9% - 1.0%)
2	0.8% (0.8% - 0.9%)	1.3% (1.2% - 1.4%)
3	1.1% (1.0% - 1.1%)	1.6% (1.5% - 1.7%)
5	1.4% (1.3% - 1.5%)	2.1% (2.0% - 2.2%)
10	2.1% (2.0% - 2.2%)	3.6% (3.4% - 3.7%)

** Excluding metal on metal bearings*

Graph 1: Endpoint all reasons for revision (excl. metal-on-metal)[9,10]



Carbon emissions of primary versus revision THA

The patient care pathways for both a 'primary' THA and 'revision' THA were mapped (figure below) and inputted into the Sustainable Healthcare Coalition's Care Pathway carbon calculator[11]. The mapped pathways included GP and outpatient appointments (pre- and post-operatively), diagnostics, inpatient bed days (low and high intensity) the implant and surgical procedure.

The results indicate that for both primary and revision THA procedures, the biggest contribution to overall footprint is from the provision of inpatient bed days.

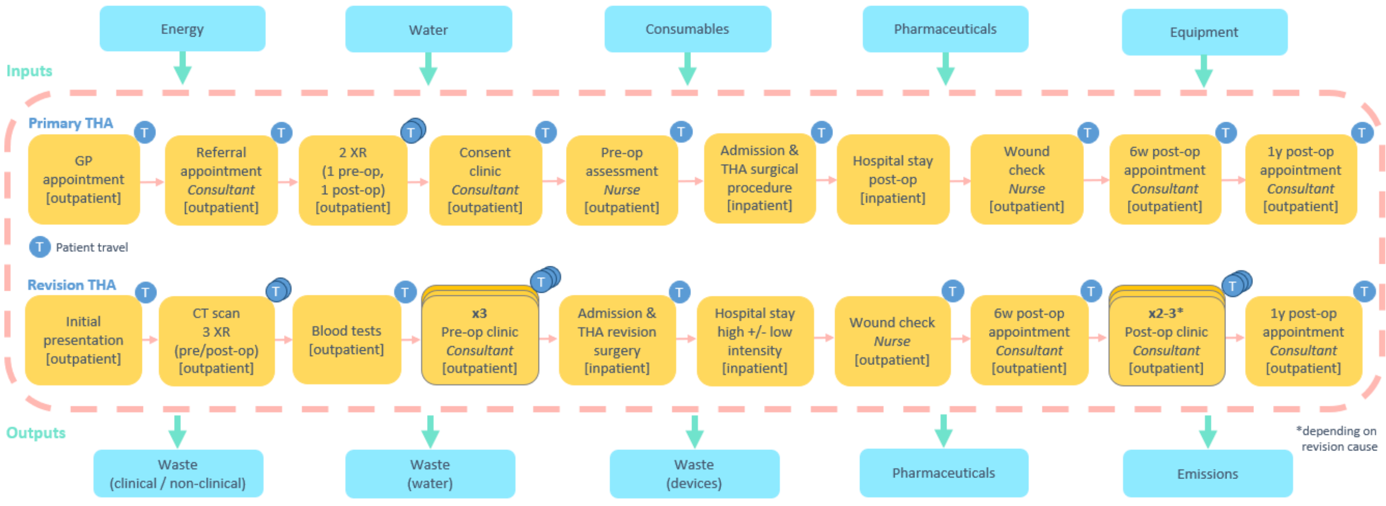
Furthermore, the revision pathway results in almost three-fold emissions per patient compared to primary surgery. This is due to the complexity of the revision procedure which drives up operation time and requires more carbon intensive anaesthesia, an increased number of both high and low intensity bed days, and an increase in outpatient appointments both pre- and post-operatively, including the need for diagnostics.

Table 2: Carbon emissions per patient for primary and revision THA care pathways

Module	Primary THA (kg CO_2e)	Revision THA (kg CO_2e)
GP consultation	2	2
Diagnostics	8[+]	18[*]
Inpatient bed day	130[■]	400[♦]
Surgical procedure	82	310
Implant	56[9]	56[9]
Other	24[⌘]	25-35[¥]
Total	**300[^]**	**810-820[^]**

+ *2 XR*
* *1 CT scan and 3 XR*
■ *3 low intensity bed days*
♦ *7.84 low intensity bed days; 0.56 high intensity bed days*
⌘ *6 outpatient appointments; 1 local anaesthetic*
¥ *8-11 outpatient appointments*
^ *Figures calculated prior to rounding*

Figure 1: THA primary and revision patient care pathways



Findings

Mapping the THA care pathway allows an estimate of the impact of primary versus revision surgery. In the UK in 2024, 48,982 patients underwent cementless THA surgery,[3] equating to 14,793 tCO_2e. When considering 10-year revision rates of cementless CORAIL™ collarless stem with PINNACLE™ Cup (3.6%) versus the CORAIL™ collared stem with PINNACLE™ Cup (2.1%), if all patients received the collared system, an estimated 734 revision procedures could have been avoided over the 10 years following primary surgery. This equates to a saving of 598 tCO_2e, or the average annual footprint of 142 UK households.[12] While revision numbers are relatively low, contribution to the overall carbon footprint across all THA procedures is significant, therefore implant selection in relation to published revision rates should be considered. It must be acknowledged that there is a paucity of data examining THA care pathways and more evidence is needed to support efforts to decarbonise this speciality. This study serves as a screening assessment to identify hotspots. A comprehensive care pathway assessment would require primary data for implants and site-specific resource use, which represents a clear opportunity for future industry-NHS collaboration.

Supplementary information

The following assumptions have been made in producing this case study:

- This case study is based on a comparison of cementless CORAIL™ stem with PINNACLE™ Cup in collared and collarless formats. Other manufacturers' cementless hip stems are available, which may produce different results depending upon their specific performance. To assess a potential change in carbon emissions from a reduction in revision rates, the findings for the collared CORAIL™ stem with PINNACLE™ Cup have been applied across all cementless hip replacements numbered in the NJR reports.
- An implant product carbon footprint figure of 56 $kgCO_2e$ has been used for both primary and revision surgeries in Table 2. THA implant products can vary significantly depending on the clinical circumstances and a revision implant is likely to be larger than that used in primary THA and therefore carry a higher carbon cost. However, data for different implant sizes and materials are not available, and so this study used the same figure for both surgery types. This would be expected to result in a more conservative estimate of the reduction potential presented by lower revision rates associated with collared implants.
- The care pathway estimates (Table 2) use secondary data and are based on multiple assumptions. The study used default profiles and emission factors in the SHC Care Pathway Carbon Calculator. A default anaesthesia mix excluding Desflurane was used to estimate the carbon footprint of medical gas use in surgery.
- The care pathway map was developed in consultation with Mr John Evans. The figures used included 2 hours for primary THA surgery and 5 hours for revision THA surgery.
- The carbon modelling focussed on high-impact modules (i.e. surgery and inpatient stay) where the greatest variance between primary and revision THA procedures occurs. Lower-impact modules (i.e. GP/outpatient appointments) were included for a complete pathway visualisation.
- Blood transfusions are required during some THA surgeries (primary and revision), but the impact of transfusions is excluded from the scope of the case study.
- The initial point of entry to the revision pathway (Figure 1) is assumed to be via a GP appointment (2 $kgCO_2e$). In practice, a patient may also present via an emergency department or an outpatient appointment with the hip team. Use of the GP emission factor would be expected to result in a more conservative estimate of the reduction potential presented by lower revision rates associated with collared implants.
- The Getting it Right First Time (GiRFT) THA pathway recommends that at least 80% of patients over the age of 70 should receive a cemented stem,[13] so the recommendation to use the cementless CORAIL™ collared stem with PINNACLE™ Cup would not be suitable for this patient group. This study has not excluded primary or revision THA numbers based on patient age.

Acknowledgements

This document has been developed by the Sustainable Healthcare Coalition. Mr Jonathan Evans, Clinical Senior Lecturer in Trauma & Orthopaedics, University of Exeter, Exeter, United Kingdom assisted with mapping the THA care pathway; he did not receive any funding or benefits in kind for his contribution. The study was initiated by Johnson & Johnson as part of their membership of the Sustainable Healthcare Coalition. The Sustainable Healthcare Coalition comprises a range of organisations within the healthcare sector including pharmaceutical and medical device companies, trade bodies, procurement, government organisations and other stakeholders.

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