

Institution: University College London		
Unit of Assessment: 12- Engineering		
Title of case study: Orthopaedic implant analysis changed which joint implants were used and how they are monitored		
Period when the underpinning research was undertaken: 2014 -2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Alister Hart	Role(s) (e.g. job title): Professor and Orthopaedic Surgeon in the Division Of Surgery	Period(s) employed by submitting HEI: 2012- date
Period when the claimed impact occurred: 2014 - 2020		
Is this case study continued from a case study submitted in 2014? N		
1. Summary of the impact		
<p>Professor Hart's research at the Royal National Orthopaedic Hospital (RNOH) NHS Trust has helped identify the mechanisms that underly failure of some spine, hip and knee implants. The team's analysis of approximately 10,000 failed implants and associated patient records has (1) changed the way implants are monitored and recorded in the UK's national joint registry, improving data quality; (2) led to changes in regulation to remove unsafe implants from the market and (3) identified the cause of implant failure, informing surgeons and patients in revision surgery decision-making, reducing anxiety for approximately 56,000 affected patients and saving the NHS more than GBP9,000,000 in unnecessary surgery.</p>		
2. Underpinning research		
<p>In England and Wales, approximately 160,000 hip and knee replacement procedures are performed yearly, with two-thirds funded by the NHS. The majority of replacement joints last for more than 15 years, but at least 1% fail much more quickly. The annual cost of lower-limb surgery (mainly hip and knee replacement) in the UK is GBP2,500,000,000. The annual, direct cost of managing early failures is GBP250,000,000 and the medical-legal bill for implant issues, where failure is unexplained and liability challenged, is GBP150,000,000.</p> <p>To understand the reasons for replacement joint failures, Professor Hart's research group collected over 10,000 failed spine, hip and knee implants removed from patients in 29 countries worldwide, together with comprehensive medical imaging (X-rays, CT and MRI scans) and patient-specific clinical data. The implants' components were analysed using metrology equipment to characterise their surface topography and determine how they had worn and corroded. Data were statistically compared with clinical information about the patient and their surgery to identify the mechanisms and risk factors for failure and the clinical impact.</p> <p>Whilst investigating cases of unexplained failures in 2014, Hart's group found metal-on-metal (MOM) hips that had incompatible sizing of the "ball and socket" components. Such incompatibility is considered an NHS "never event" (a serious incident that is wholly preventable). The UCL team went on to investigate a larger series of 2,400 MOM components and discovered that 1% of these had a size mismatch (R1). The implants were highly worn and associated with elevated levels of metal in blood samples taken from the patients. The study was the first to demonstrate size mismatch as a direct cause of implant failure and showed that out of the 116,000 patients in the UK known to have had implant complications since 2003, 1,160 incidents may have been due to size mismatch, at a direct cost of at least GBP11,000,000 to the NHS.</p> <p>Hart's 1% size mismatch rate was almost double the rate reported by the UK National Joint Registry (NJR), which records every hip and knee replacement procedure performed in the</p>		

UK (2,835,101 records). This prompted the group to perform a large-scale data study in 2015 linking 2,000 of the MOM hip implants physically in their possession, with the data recorded by the NJR (**R2**). This high-quality data audit demonstrated that NJR had improperly recorded 60% of MOM hip failures and the authors made recommendations for improving future data quality.

During analysis of NJR data, Hart's group identified when generic hip implants were introduced in the UK. Although generics have the potential to save costs, their chemical make-up is not closely regulated. The team performed a detailed metrology investigation comparing a generic hip with its branded counterpart. Hart's analysis revealed that the generic hips were less dense and significantly rougher than branded hips. Both factors are known to adversely impact implant performance by increasing the risk of wear and corrosion (**R3**).

As part of this analysis, Hart identified that hip stem implants made of two separate components (dual-taper) rather than a one piece design, were showing signs of corrosion at the junction between these two components. This had devastating clinical effects with some patients enduring great suffering from a "corroded battery-like implant" that resulted in the death of surrounding tissue. Hart was then funded by the world's largest orthopaedic manufacturer to investigate this issue in their design of dual-taper hip. The team showed that almost all these implants were severely corroded at this junction. Statistical comparison with other stem designs and data on surgeon and patient factors confirmed that corrosion (and ultimately failure) was almost entirely due to this modular design (**R4**). This corrosion had significant detrimental effects in many of the 30,000 patients that were implanted with this brand alone; Hart showed it to be strongly correlated with high blood metal levels and with clinical evidence of soft tissue and bone destruction around the implants in these patients.

Following his series of publications on MOM hip wear and clinical failures, Professor Hart was asked by the Head of NHS England and the Government's Medicines & Healthcare products Regulatory Agency (MHRA) to help understand the risk of cardiac failure in patients with MOM implants: an Australian study had shown a 7-fold increase in cardiac failure in those with MOM hips. Hart's group extended their analysis of 8,000 retrieved components to incorporate data from the NJR, enabling the statistical comparison of cardiac failure in 53,529 MOM patients compared with 482,247 non-MOM patients; he found no link between MOM hips and cardiac failure (**R5**).

Professor Hart then used his global surgeon network to collect failed hips with metal-on-polyethylene (MOP) bearings. His group performed a statistically controlled comparison of the extent of wear, corrosion, clinical outcomes and findings on medical imaging between these MOP hips and MOM hips of the same design. He found significantly less metal release in the MOP hips and far fewer incidences of clinical complications due to adverse metal reactions in patient tissue (**R6**).

This research has full approval from the UK Health Research Authority (HRA) and the patients in this research have consented for their implants and associated data to be stored and analysed at the implant centre. This research forms part of the NIHR portfolio and Hart's group continue to work closely with the MHRA to advise the regulator of adverse events relating to spine, hip and knee implants.

3 References to the research

- R1. Whittaker RK, Hexter A, Hothi HS, Panagiotidou A, Bills PJ, Skinner JA, **Hart AJ**. (2014). Component size mismatch of metal on metal hip arthroplasty: an avoidable never event. *J Arthroplasty*, 29(8): 1629-1634. DOI: 10.1016/j.arth.2014.03.008
- R2. Sabah SA, Henckel J, Cook E, Whittaker R, Hothi H, Pappas Y, Blunn G, Skinner GA, **Hart AJ** (2015). Validation of primary metal-on-metal hip arthroplasties on the National Joint Registry for England, Wales and Northern Ireland using data from the

London Implant Retrieval Centre: a study using the NJR dataset. *Bone Joint J*, 97-B(1): 10-18. DOI: 10.1302/0301-620X.97B1.35279

R3. Hothi H, Henckel J, Shearing P, Holme T, Cerquiglini A, Di Laura A, Atrey A, Skinner J, **Hart AJ**. (2017). Assessment of the equivalence of a generic to a branded femoral stem. *Bone Joint J*, 99-B(3): 310-316. DOI: 10.1302/0301-620X.99B3.BJJ-2016-1208.R1

R4. Di Laura A, Hothi HS, Henckel J, Kwon YM, Skinner JA, **Hart AJ**. (2018). Retrieval Findings of Recalled Dual-Taper Hips. *J Bone Joint Surg Am*. 100(19): 1661-1672. doi: 10.2106/JBJS.17.00790

R5. Sabah SA, Moon JC, Jenkins-Jones S, Morgan CL, Currie CJ, Wilkinson JM, Porter M, Captur G, Henckel J, Chaturvedi N, Kay P, Skinner JA, **Hart AJ**, Manisty C. (2018). The risk of cardiac failure following metal-on-metal hip arthroplasty. *Bone Joint J*, 100-B(1): 20-27 doi: 10.1302/0301-620X.100B1.BJJ-2017-1065.R1.

R6. Hothi H, Eskelinen A, Henckel J, Kwon YM, Blunn G, Skinner J, **Hart AJ**. (2017). Effect of Bearing Type on Taper Material Loss in Hips From 1 Manufacturer. *J Arthroplasty*, 33(5): 1588-1593. DOI: 10.1016/j.arth.2017.12.022

4 Details of the impact

Hart's research on orthopaedic implants has identified causes of joint implant failure; led to improvements in joint registry data acquisition and monitoring; and improved patient care by the introduction of an alert system to avoid "NHS never events" in orthopaedic surgery and preventing the use of unsafe generic implants. The improvements in patient care and monitoring are reducing patient anxiety and saving the NHS millions of pounds each year in unnecessary surgical procedures. The evidence provided by Hart's research was used by the directors of the NHS and the Medicines and Healthcare products Regulatory Agency (MHRA) to provide guidance to over 56,000 patients in the UK.

Orthopaedic implant monitoring

Hart's implant registry study (**R2**) identified significant gaps in registry data and demonstrated the need for data quality improvements in the NJR (largest implant registry in the world with over 60,000 website visits per year). This evidence was used by the medical director of the NJR to implement a programme of registry data quality improvement, resulting in a 12% increase in linkability, where the first implantation is linked to the removal of the implant (212,823 patients), between 2016 and 2019. The UCL-led work has been critical to data users from industry, surgeons, healthcare providers and patients worldwide (including countries such as France, German, Italy, Japan, the USA, Canada, Brazil, Russia, China and many more). The medical director of NJR stated: "*(this work) has given confidence to hospitals and surgeons that the data used to report the outcomes of their joint replacement procedures is accurate. Similarly, implant manufacturers and regulators have been reassured that the data used to evaluate the performance of different implant designs has been independently validated.*" (**S1**)

The group's size mismatch research (**R1**) was "*the first to quantify the prevalence of a mismatch in the sizes of the components used in hip replacement surgery*" (**S2**), and revealed that such implants with incompatible sizing will release metal into a patient's blood stream and tissue, leading to failure. The research (**R1**) showed this to be a direct cause of failure in every case investigated. This key output from Hart's work led to a real-time early-warning alert system created by the NJR and Northgate Public Services (NPS) to inform surgeons when a wrongly sized implant had been inserted and enable them to correct the problem before damage is done to the patient. As stated by the Head of Health Registries at NPS, '*This system (has) identified 21 genuine implant mismatches in the first year of implementation.*' (**S2**).

Additionally, as a direct result of the UCL study, NPS retrospectively reviewed the NJR database to identify patients in the UK with potential size incompatibility that were at risk of early implant failure. To date, 172 at-risk patients have been identified (**S3**). They are all receiving enhanced clinical follow up through regular blood metal level testing and medical imaging for early signs of high implant wear, at which point revision will be considered. The

early detection of these issues prevented unexplained implant failures from occurring, **saving the NHS at least GBP1,500,000** in preventable revision surgery.

Hart's research and expertise has also directly influenced surgeons' decision in treating patients with mismatched MOM hip replacements. One consultant orthopaedic surgeon said: *"This paper by Alister Hart's research group at UCL and the RNOH...prompted me to consider mismatch as the cause of unusually high blood metal levels in one of my metal hip patients... (the analysis performed by Alister's team) confirmed a size mismatch had occurred and, on this basis, I performed revision surgery to remove the components"* (S4).

Removal of unsafe orthopaedic implants from the market

Analysis of generic orthopaedic implants (R3) showed that truly equivalent generic solutions are not yet possible. This data was used by the UK Government regulator of new implants, Beyond Compliance, to adjust the safety rating that was awarded to this generic design (S5). This study (R3) influenced the large-scale debate about the use of generic implants in the UK (S6), which ultimately saw the manufacturer, Orthimo Limited, being dissolved.

Hart's program of dual-taper implant work (R4) showed that these modular stem designs were the single largest risk factor for severe corrosion and implant failure (as opposed to other surgeon, implant and patient factors). These findings were used by the Scientific Committee on Health and Environmental Risks of the European Commission to update their implant safety recommendations, which now advise against this use of dual-taper hips (S7). These recommendations were welcomed by the UK Medical and Healthcare products Regulatory Agency (MHRA) and since Hart's publication, modular neck implants are no longer used in the UK due to the knowledge that severe corrosion in these designs has detrimental effects on patients (S3).

Change in medical practice to avoid unnecessary NHS tests for patients

The findings from the cardiac study (R5) were used by the head of the NHS to reassure 56,000 patients in the UK who have MOM hips that they were not at an increased risk of heart failure due to their implant (S8, S9). This study helped address the *"well recognised patient anxiety and increased pressure on the NHS"* due to panics over *"higher rate of heart failure"*, which is thought to be *"a significant risk to patients, the orthopaedic community and the NHS as a whole"* (S8). Left unaddressed, *"the worry was an acute service breakdown due to a crisis that overwhelmed care pathways based on incomplete evidence and fear. This would have meant 56,000 metal hip patients needing to be seen by 2 specialities with a large number of operations having to be redone within as little as 6 months"* in the NHS (S10).

Hart's MOP hip research (R6) reassured surgeons and patients with MOP implant designs their implants were safe. This research evidence informed advice given by the British Hip Society (BHS) about the management of MOP patients thereby avoiding unnecessary blood testing and medical imaging on a significant number of patients. *"These guidelines, based on Hart's research, continue to be the advice from the BHS to surgeons about the management of their MOP patients. This is particularly significant (...) as 27% of the 67,500 primary hip procedures performed in 2018 were of this MOP design"* (S11). **This led to a saving to the NHS of approximately GBP9,000,000** in 2018 alone by avoiding unnecessary clinical tests.

5. Sources to corroborate the impact

- S1. Testimonial, Former Medical Director of the National Joint Registry
- S2. Testimonial, Head of Health Registries at Northgate Public Services
- S3. 17th Annual Report of the National Joint Registry
- S4. Testimonial, Consultant Orthopaedic Surgeon, Circle Bath Hospital
- S5. Testimonial, Chairman ODEP & Beyond Compliance
- S6. Haddad FS. (2017). Heritage must be earned. *Editorial. Bone Joint J*, 99-B (3): 289-290. DOI: [org/10.1302/0301-620X.99B3.BJJ-2017-0150](https://doi.org/10.1302/0301-620X.99B3.BJJ-2017-0150)
- S7. Testimonial, Director, Hamburg Research Centre of Medical Technology
- S8. Testimonial, Clinical Director of Medical Devices, MHRA

S9. Testimonial, Former Medical Director of the National Health Service
S10. Testimonial, Former National Clinical for MSK & Consultant Orthopaedic Surgeon
S11. Testimonial, President (2019-2020), British Hip Society