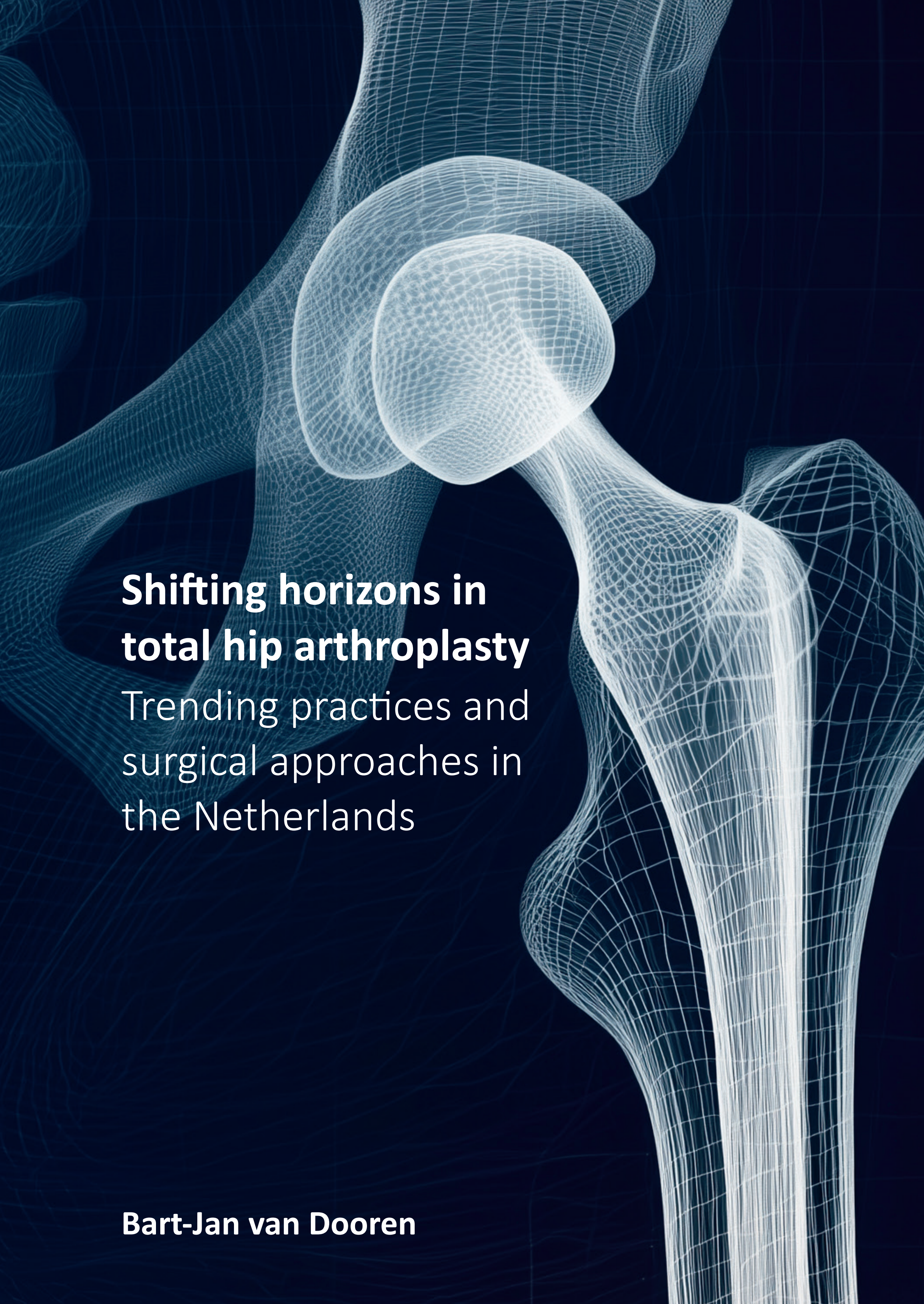

Shifting horizons in total hip arthroplasty

Trending practices and surgical approaches in the Netherlands

Bart-Jan van Dooren

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Work performed at University Medical Center Groningen and Medical Center Leeuwarden (Frisius MC). The research in this thesis was supported by an unrestricted grant from a non-profit foundation (Stichting MCL fonds). This study was conducted within the Health in Context Research Institute of the University Medical Center Groningen (UMCG) and under auspices of the research program Public Health Research (PHR). The printing of this thesis was financially supported by the Graduate School of Medical sciences (GSMS), the University of Groningen and the Dutch Orthopaedic Association (NOV).

Shifting horizons in total hip arthroplasty: Trending practices and surgical approaches in the Netherlands

Colofon

Author: B. van Dooren
Cover: Ninke van Wiggen
Layout and design: Ninke van Wiggen, persoonlijkproefschrift.nl
Provided by thesis specialist Ridderprint, ridderprint.nl
Printing: Ridderprint

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Proefschrift

ter verkrijging van de graad van doctor aan de
Rijksuniversiteit Groningen
op gezag van de
rector magnificus prof. dr. ir. J.M.A. Scherpen
en volgens besluit van het College voor Promoties.

De openbare verdediging zal plaatsvinden op

Woensdag 21 mei 2025 om 11:00 uur

door

Bart-Jan van Dooren

geboren op 26 december 1994

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Copromotores
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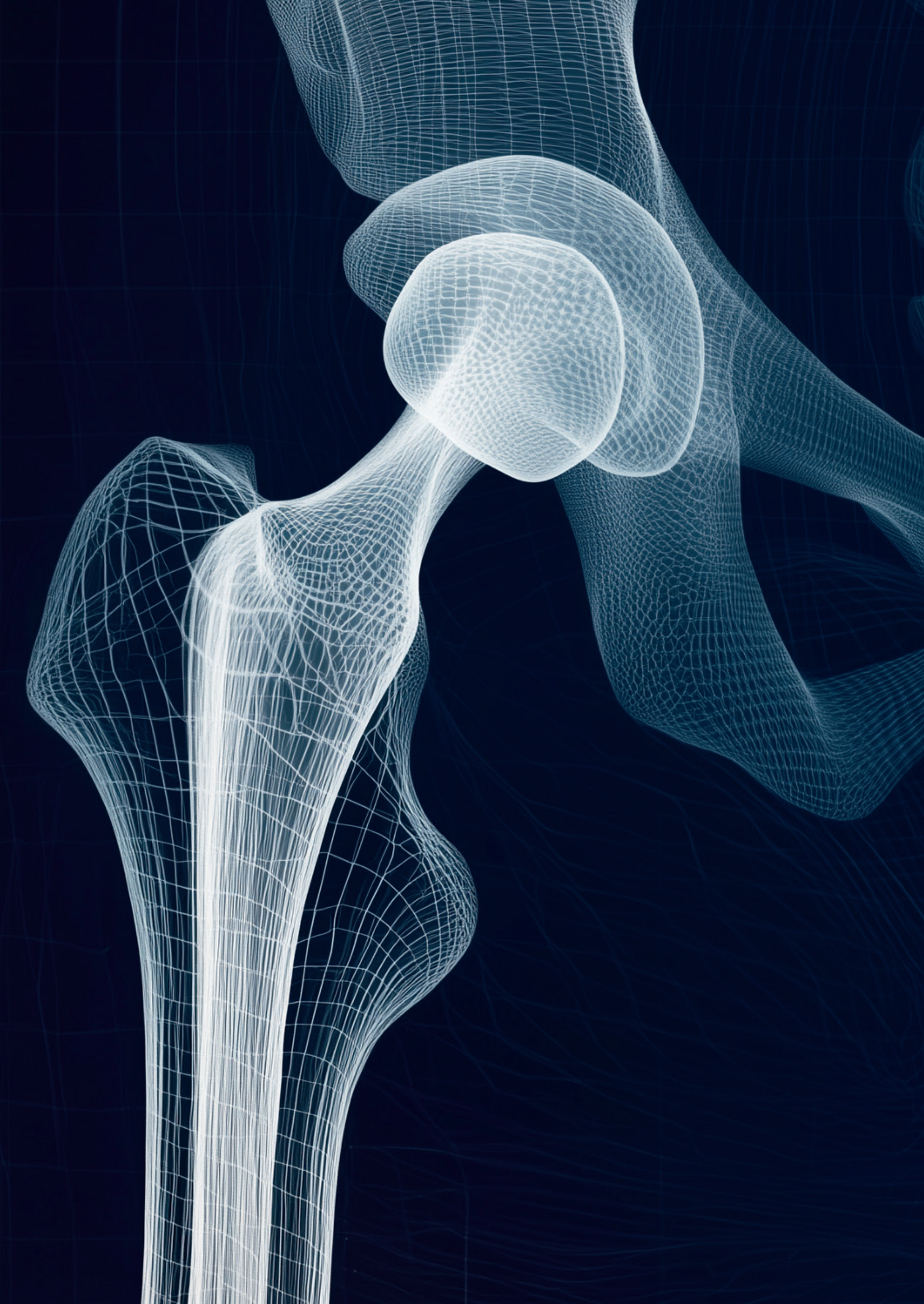

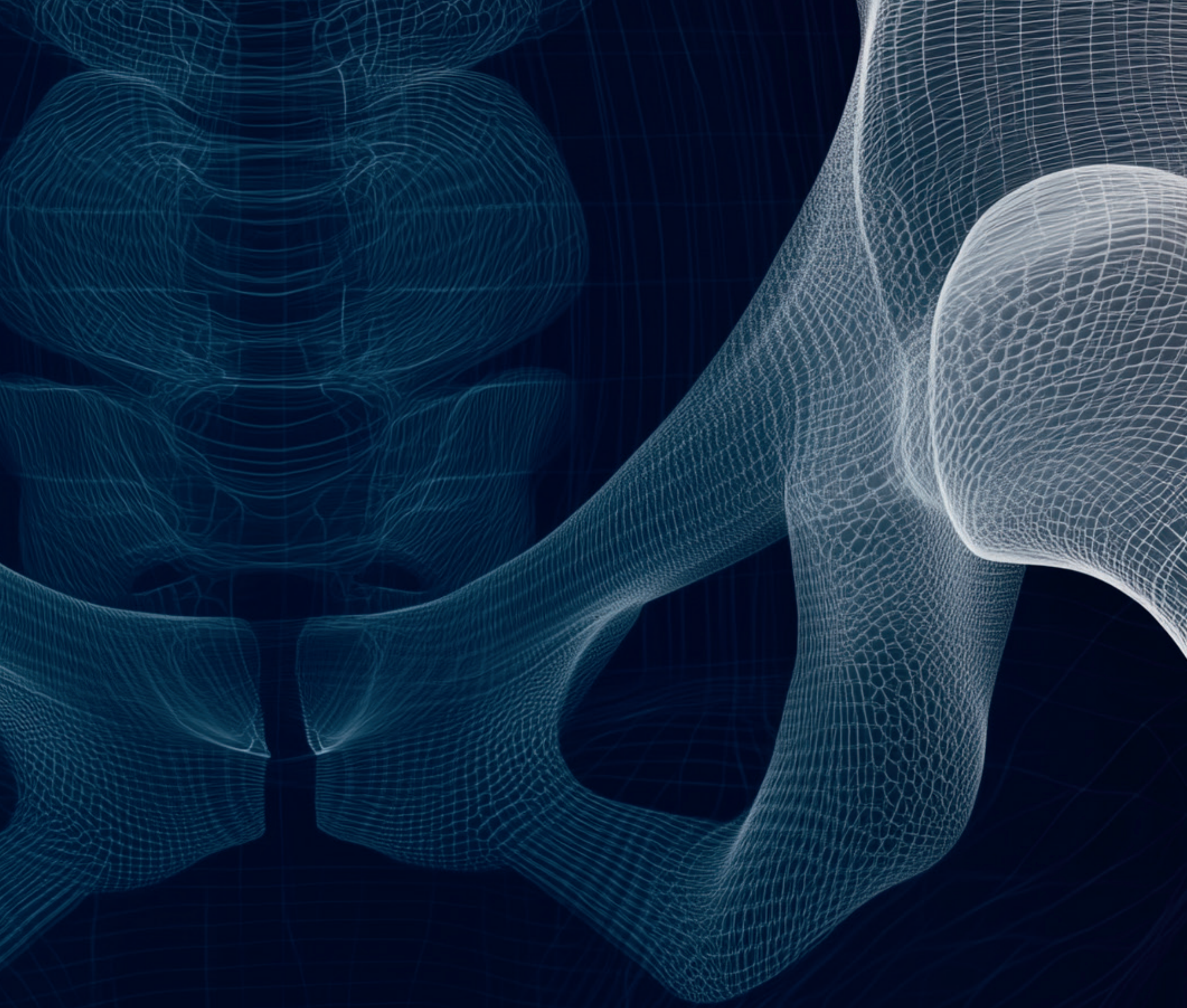

1

General introduction and outline

General introduction

Osteoarthritis (OA) is a chronic degenerative and progressive age-related disorder characterized by loss of joint cartilage and underlying bone [1]. OA is among the most common musculoskeletal disorders globally [2-3]. Knee OA is the most common form of OA, while hip OA follows as the second most common type, with a prevalence ranging from 4% to 7% [3-4]. It is anticipated that the prevalence of OA will continue to rise, potentially making it the most prevalent chronic health condition in the Netherlands by the year 2040 [5-6]. Typically, OA manifests with joint pain, stiffness and reduced functionality over time [1]. Nevertheless, the clinical presentation of the disease is highly variable and symptoms can range from being entirely asymptomatic to a permanently disabling disorder. Risk factors for developing OA include age, female gender, lifestyle and habits, physical inactivity, obesity, anatomical factors, and joint injury [7-9]. Treatment options for OA vary depending on the stage of the condition. In the early stages of OA, non-surgical approaches can be used to effectively manage the symptoms [7]. These include non-steroidal anti-inflammatory drugs (NSAIDS), physical therapy, and lifestyle adjustments like weight management and low-impact exercise. However, in case of end-stage OA, when conservative measures are no longer sufficient, surgical intervention may be necessary [10-11].

Over the past decade, the Netherlands has witnessed a notable increase in the prevalence of hip and knee OA, which has risen by 68% from 2011 to 2021 [12]. For men, this number rose from 307,800 in 2011 to 575,700 in 2021 [14]. Similarly, for women, the number increased from 634,900 in 2011 to 1,013,900 in 2021 [12]. That corresponds to approximately 6.6% of men and 11.5% of women being diagnosed with OA based on the population figures [12]. These absolute numbers highlight a substantial growth in OA prevalence in the Netherlands, underscoring the escalating burden of this condition on healthcare systems and individuals alike. This upward trend is expected to persist, driven by several contributing factors [12-18]. An aging population, coupled with rising retirement ages, has extended the active lifespan of individuals, exposing them to longer periods of joint wear [17-19]. Additionally, societal shifts towards sedentary lifestyles and increased rates of obesity have exacerbated the prevalence of OA among younger age groups [17-18]. These lifestyle factors, characterized by physical inactivity and unhealthy dietary habits, contribute significantly to the development and progression of OA, making it the leading chronic disease in terms of prevalence in the Netherlands [13-15].

Total hip arthroplasty

Total hip arthroplasty (THA), commonly known as total hip replacement, is a surgical procedure that involves hip replacement surgery of the damaged or diseased hip joint. In general, THA has proven to be highly effective in relieving pain, restoring mobility, and improving the overall quality of life for patients suffering from disabling hip conditions such as symptomatic end-stage OA [12-13]. While THA is generally safe and effective, it does carry risks and complications, such as infection, dislocations, periprosthetic fractures, loosening of the prosthesis, thromboembolic events, and nerve injuries [19-22]. Nevertheless, with advancements in technology and surgical techniques, THA has become a routine procedure with a high success rate and low complication rate [20]. THA is one of the most successful and commonly performed orthopedic procedures, with over 30,000 procedures performed each year in the Netherlands alone [23]. With an aging population and consequently an increase in the prevalence of hip OA due to factors such as increasing physical inactivity and increasing obesity and younger individuals requiring surgery, the number of THA procedures performed worldwide has been steadily increasing over the past several decades [6, 12-18]. In fact, THA is now considered one of the most frequently performed surgeries globally and the demand for THA will increase in the future.

It is expected that the societal impact of the increasing prevalence of hip OA and the consequent rise in THA procedures is significant [15-17]. This growing demand places a considerable financial burden on healthcare systems, necessitating increased allocations for surgical procedures, postoperative care, and long-term rehabilitation. As a result, healthcare budgets may become stretched, necessitating difficult decisions regarding resource allocation [6, 24-26].

Addressing this problem requires a multifaceted approach, including preventive measures to reduce the incidence of OA, efficient healthcare spending, resource allocation and potentially innovative funding mechanisms to ensure that the growing need for THA can be met without compromising other areas of healthcare [24-25]. Innovation plays a crucial role in this regard, as advancements in surgical techniques and technologies can significantly decrease the risk of complications, reduce hospital length of stay, and improve overall outcomes.

Advancements in total hip arthroplasty: A multifaceted approach

The origin of total hip replacement surgery can be tracked back to 1938 when Wiles developed the initial concept (Fig. 1a), in which both femur and acetabulum were replaced by metal components [10]. Further advancements were made in the 1950s by McKee and Watson Farrar, who transitioned from stainless steel to a cobalt-chrome-molybdenum alloy (Fig. 1b) in the development of metal-on-metal THAs. However, thanks to John Charnley's introduction of the low-friction arthroplasty, it was until the 1960s that THA gained widespread recognition and popularity [26]. Charley advocated for bone cement use and promoted the use of polyethylene instead of a metal-on-metal bearing (Fig. 1c).

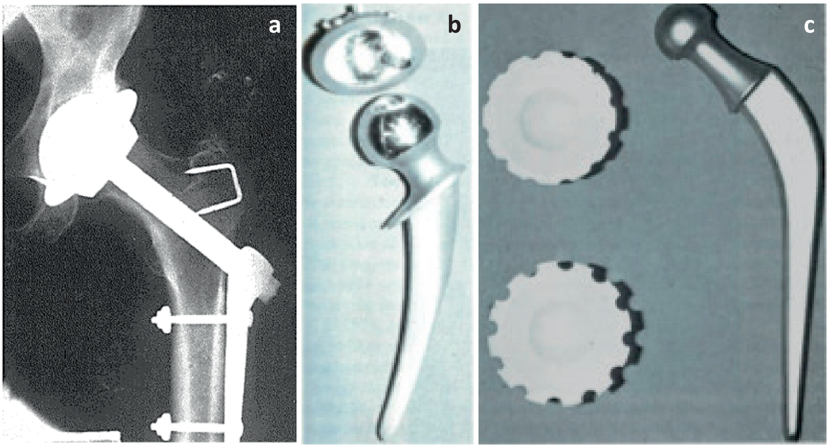

Figure 1 a-c. (a) Total hip replacement by Phillip Wiles. The original hip replacement at the Middlesex Hospital in London. (b) McKee-Farrar prosthesis, a metal-on-metal implant introduced by Ken McKee and John Watson-Farrar from Norwich in 1961; (c) Charnley prosthesis. The hip prosthesis with a cup of high-density polyethylene introduced by Sir John Charnley in 1962. [Wiles 1958, Coombs 1990].

The early outcomes of THA were disappointing [27]. This can be attributed to several factors such as suboptimal implant design, undersized femoral components, inadequate cementing techniques, insufficient antiseptic measures and excessive wear of the polyethylene liner [27]. The road to success for THA has been far from smooth and not without obstacles. Nonetheless, since this first-generation arthroplasty, significant progress has been made in the field of THA. This progress has occurred at various levels, including improvements at the patient level (patient selection), surgeon level (advancements in surgical techniques), prosthesis level (innovations in implant design), and improvements in hospital and management practices. This general introduction, will highlight some of the developments made in THA, with special focus on the different levels discussed.

The patient

The careful consideration and assessment of patients before surgery has become increasingly important for the overall success and long-term outcomes of THA. Patient selection and preoperative planning have become increasingly precise [28-29]. Moreover, previous studies have significantly contributed to surgeons' understanding of patient-related risk factors [30]. Hence, multiple patient related factors, such as comorbidities, an increased body mass index (BMI), young age, previous hip surgery and the diagnosis leading to THA surgery, have been identified as risk factors for complications and failure of THA [30]. These factors may consequently lead to the need for revision THA [30]. Although most patient factors cannot be modified, patient characteristics can be used to help surgeons counsel patients and give patients an individualized advice. Moreover, improved patient education and shared decision-making processes have empowered patients to actively participate in their care. Parallel with advancements in understanding patient-related factors influencing outcomes, a transformation in patient demographics has emerged. On one hand, the global population of THA recipients is progressively aging, largely due to the increase in life expectancy and innovations in healthcare [12-18]. This phenomenon has resulted in a surge in 'aged' patients with OA receiving THA. Simultaneously, there is a growing prevalence of younger patients opting for THA, driven by increasing obesity rates and physical inactivity, contributing to the development of OA at a younger age [31]. This dichotomy in the age distribution of THA recipients demonstrates an evolving patient landscape, demanding flexible and personalized approaches to meet the diverse needs of this heterogeneous population. Hence, despite the growing knowledge of patient factors influencing outcomes in THA, ongoing research is needed as our population is evolving.

The surgeon

Meanwhile, surgeon related factors such as surgical experience, surgical volume and the choice of surgical approach have been identified as factors affecting outcomes after THA [32-34, 36]. Therefore, orthopedic surgeons are constantly refining their skills, and staying updated with the latest medical advancements. In recent years, the evolution of surgical technology has led to continuous improvement and refinement in surgical techniques.

To gain access to the hip joint, multiple surgical approaches emerged, each offering distinct advantages and disadvantages [33-37]. The most commonly used approaches worldwide for THA include the posterior approach (PA), direct lateral approach (DLA), and the direct anterior approach (DAA). Currently, the posterior approach is reportedly the most common surgical approach worldwide. This approach provides adequate exposure to the hip joint but has limitations in terms of potential complications, such as postoperative dislocation [34]. The direct lateral approach (DLA), which was introduced by Hardinge et al in the 1980s, offered a more direct access to the hip joint, sufficient exposure of the femur and acetabulum, and reducing the risk of dislocation. However, a higher risk of abductor muscle weakness and limping is reported due to the surgically induced trauma on hip abductor muscles performed during the DLA [36]. In addition, previous findings indicate that patient-reported outcomes are generally inferior after THA with a direct lateral approach than after THA with other approaches [36-37].

In recent years, surgeons have refined their approaches to THA, resulting in improved surgical precision and reduced complications. Through the use of natural intramuscular and internervous intervals, the direct anterior approach (DAA) has been suggested to have several advantages over other surgical approaches, such as reduced soft tissue trauma, quicker recovery and a lower dislocation rate [34-36]. Like any surgical approach the DAA also has its share of disadvantages. The DAA is considered technically demanding and requires specialized training. Therefore a steep learning curve is seen [35]. Moreover, converting the DAA intra-operatively can be challenging, particularly in cases involving extensive revisions. Finally, an increased risk of nerve injury is seen in the DAA (e.g. femoral nerve and lateral femoral cutaneous nerve [36]. The DAA has gained popularity and is now the third most common surgical approach worldwide [38]. In the Netherlands the DAA is rapidly growing, counting for 44% of all primary THAs in 2022 [23].

To address limitations in traditional surgical methods, minimally invasive (MI) approaches for THA have gained popularity as an alternative to conventional surgical approaches. A new category of micro-posterior approaches has emerged, including the percutaneously-assisted total hip (PATH) approach, SuperCapsular (SuperCap) approach, Supercapsular Percutaneously-Assisted Total Hip (SuperPATH) approach and the Direct Superior Approach (DSA) [39-42]. The micro-posterior category of approaches distinguishes itself from the posterior approach by sparing most or all of the external rotators of the hip. The DSA is a relatively new minimally invasive technique that has been increasingly used in recent years [42]. The primary aim of the DSA is to minimize tissue trauma, offering potential benefits such as reduced dislocation risk, less pain and faster return to function [42]. However, the overall benefits of the DSA have been subject of debate. As the field continues to evolve, further advancements and refinements are expected. However, future research is needed to evaluate long-term outcomes and durability of these techniques.

The prosthesis

At the level of prosthesis, implants have witnessed significant improvements, including improved materials, designs, and fixation techniques, which contributed to improved implant longevity, reduced complication rates, and decreased revision rates [27,43]. For example, THA has seen a growing trend towards using larger femoral heads in the last decade, as they increase the range of hip movement before impingement and consequently reduce dislocation rates [34]. For example, 32 mm and 36 mm now are the most frequently used femoral head sizes, as reported by several arthroplasty registries [23, 44-47]. Moreover, alternative bearing surfaces have been introduced, such as ceramic-on-ceramic (CoC) and ceramized metal on crossed-linked polyethylene (XLPE), which has provided a reduced risk of implant failure due to wear [48]. Thirdly, the introduction of highly cross-linked polyethylene has significantly decreased the incidence of wear-related complications, such as implant loosening and osteolysis [49]. Modular implant systems and patient-specific implants have allowed for better customization and more precise fit. In addition, dual mobility cups have emerged as a significant advancement in THA in improving revision rates and specifically dislocation rates [50-51].

Hospital and management practices

Advancements in perioperative care has improved patient outcomes and accelerated recovery [52].

Multimodal analgesia and regional anesthesia techniques, have reduced postoperative pain, nausea and drowsiness, enabling early mobilization and rehabilitation [53]. Knowledge regarding the appropriate administration and duration of perioperative antibiotic prophylaxis plays a crucial role in preventing and reducing the risk of surgical site infections [54-55]. Finally, the implementation of optimized perioperative local protocols, e.g. the integration of rapid recovery pathways, significant reductions in hospitalization duration have been achieved and enabled a smoother recovery process [56]. Healthcare institutions have implemented strategies to streamline processes, reduce inefficiencies, and enhance overall healthcare delivery. Hospital administrators have been examining how services are organized and delivered, seeking ways to centralize care to specialized centers. Amid the evolving landscape of orthopedic care, recent years have witnessed significant challenges and transformations, particularly in the wake of the COVID-19 pandemic. For example, private hospitals have become more frequent health care service providers in the Netherlands lately, particularly in the field of arthroplasties and it is likely that private hospitals will continue to fill a substantial part of the capacity gap in the upcoming years. Hence, it is important to study the current situation of how and where the care for total hip- arthroplasty patients is performed.

Quality assurance and national arthroplasty registries

Finally, the establishment of comprehensive quality assurance programs and national joint registries has facilitated continuous monitoring and evaluation of THA outcomes [57-58]. National joint registries are centralized databases that collect information on arthroplasties, including data on patient characteristics, surgical techniques, implant types, and outcomes (e.g. complications, risk of revision, patient reported outcomes) [58]. Arthroplasty registers have become widely recognized on a global scale. Many countries have implemented these registers as important tools for tracking the performance and safety of arthroplasty procedures [57-59]. These registers can help to identify poorly performing implants, help to recognize patients who may be at increased risk for complications or implant failure, and identify areas for improvement (e.g. surgical techniques, implant design, patient selection criteria) as well as best practices [57-59]. In recent years, arthroplasty registries have provided surgeons and hospitals with audit and feedback on their performance, aiming to improve the quality of care delivered [60]. Moreover, arthroplasty registers have become an important source of data for research studies. In 2004, the international society of arthroplasty registers (ISAR) was formed. Currently, 40 national, regional or institutional registries are member of ISAR [61]. The focus of the society is to utilize the strength of cooperation and sharing of information and further enhance the capacity of individual registries to meet their own aims and objectives. This collaborative approach underscores the significance of these registries as invaluable repositories of real-world, nationwide data, contributing to evidence-based medicine and continuous advancements in orthopedic care.

The Dutch Arthroplasty Register

The Dutch Arthroplasty Register (LROI) is a nationwide population-based register in which information on joint arthroplasties in the Netherlands is collected. The LROI was initiated by the Netherlands Orthopaedic Association (NOV) in 2007 with the purpose of evaluating outcome of arthroplasty procedures [62]. LROI's primary objective is to improve quality of orthopaedic care and identify underperforming orthopaedic implants at an early stage. Additionally, it aims to ensure patient safety by collecting patient- and implant-related data, enabling national-level traceability of orthopaedic implants. The LROI initially started with the registration of hip and knee arthroplasties. In 2014, the registrations of shoulder, elbow and ankle arthroplasties were added to the database, followed by wrist and finger arthroplasties in 2016 [63].

Currently, the LROI covers all hospitals in the Netherlands. The degree of coverage and completeness of the LROI is documented to be higher than 97% [62]. Patient and surgical characteristics as well as the product and batch number of the implant component and cement are registered and entered into a centralized online database. The LROI collects data on patient characteristics, including age, sex, and general health (ASA score). In 2013, additional information such as BMI, smoking behavior, orthopedic vitality (i.e. Charnley score), and postal code was incorporated into the database. Prosthesis characteristics are obtained from an implant library within the LROI, which contains several core characteristics of all prostheses used in the Netherlands since 2007. Characteristics were provided by all implant manufacturers. For hip prostheses, these characteristics include prosthesis manufacturer, name, component type, alloy used, coating of the prosthesis, method of sterilization of the polyethylene, and the diameter of the femoral head. Moreover, registration includes the type of acetabular cup, femoral stem, femoral head, inlay component and fixation method [63]

The LROI is continuously evolving to meet the changing needs of orthopedic care. As healthcare practices advance and new techniques and technologies emerge, the LROI adapts to include them in its comprehensive database. Since the start of the registry, the registration of hip and knee prostheses has grown from 40,000 implants per year to recently 75,000 implants per year [9]. In December 2022, the one-millionth prosthesis was recorded in the LROI, with over half of these procedures being hip arthroplasties. LROI's wealth of data, collected over the years, has facilitated a wide range of research studies, improving patient outcomes, implant performance, and surgical techniques. The register continues to be a vital and indispensable resource for research studies. As of October 2023, a significant milestone has been achieved with the publication of the 100th research study utilizing data from the LROI [64].

Aim of this thesis

As mentioned earlier, the number of THA procedures is increasing. This trend is accompanied by a higher economic burden on healthcare systems. Consequently, exploring trends, improving quality of care and optimizing outcomes is essential to ensure the financial sustainability of these procedures. By incorporating innovations, new surgical techniques, quality registries, selecting suitable candidates and improving best practices, orthopedic surgeons strive to further improve the success of THA. In our continuous search to meet high standards, we develop new technologies with presumed improvements. Despite all technical advances in THA over the last decades, there is still a certain number of dissatisfied patients regarding the postoperative outcome after THA, and complications leading to subsequent revision surgery. Moreover, healthcare costs are escalating, presenting a critical economic challenge. With this in mind, the aim of this thesis is to explore recent trends in THA care in the Netherlands, specifically focusing on surgical approaches to optimize patient outcomes and enhance overall THA quality, using data from the Dutch Arthroplasty Register.

The introductory part of this thesis investigates current practice trends in arthroplasty surgery in the Netherlands. It focuses on the transition from public to private hospitals, analyzing patient demographics, reasons for revision surgeries, locations of revisions, and the associated risk for revision for total THA, TKA and UKA in public and private hospitals (Chapter 2). The second part of this thesis focuses on innovations in surgical approach for THA. First, Chapter 3 describes the implementation of the direct anterior approach in the Netherlands and explores its learning curve. Chapters 4 to 7 focus on the direct superior approach, which is a recent refinement of the traditional PL approach in THA. A comprehensive systematic review of the DSA is conducted (Chapter 4). Moreover, the impact of the DSA on the risk of revision is assessed (Chapter 5), as well as patient-reported outcome measures (PROMs) (Chapter 6). Finally, this part of the thesis aims to assess the learning curve associated with the DSA (Chapter 7). In Chapter 8, the results from the previous chapters are discussed collectively, highlighting the broader implications of these findings for clinical practice.

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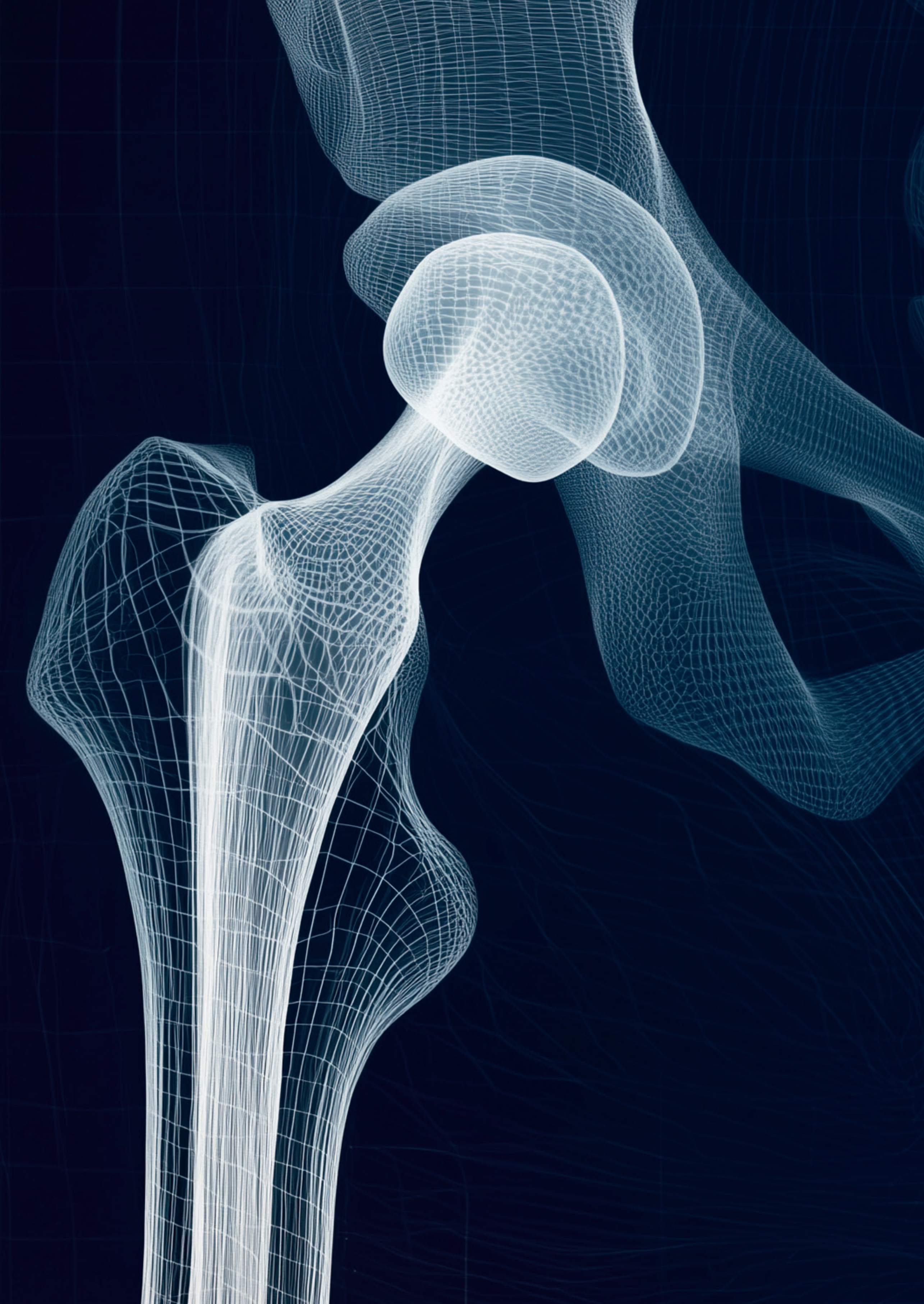
Part 1

Current practice trends in total joint arthroplasty



2

Time trends in case-mix and risk of revision following hip and knee arthroplasty in public and private hospitals: a cross-sectional analysis based on 476,312 procedures from the Dutch Arthroplasty Register.

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Acta Orthop. 2024 Jun 17;95:307-318
Auletius award Medical Center Leeuwarden (2024)

Abstract

Background and purpose

This study aims to assess time trends in case-mix and to evaluate the risk of revision and causes following primary THA, TKA, and UKA in private and public hospitals in the Netherlands.

Methods

We retrospectively analyzed 476,312 primary arthroplasties (public: n = 413,560 and private n = 62,752) implanted between 2014 and 2023 using Dutch Arthroplasty Register data. We explored patient demographics, procedure details, trends over time, and revisions per hospital type. Adjusted revision risk was calculated for comparable subgroups (ASA I/II, age ≤ 75, BMI ≤ 30, osteoarthritis diagnosis, and moderate–high socioeconomic status (SES).

Results

The volume of THAs and TKAs in private hospitals increased from 4% and 9% in 2014, to 18% and 21% in 2022. Patients in private hospitals were younger, had lower ASA classification, lower BMI, and higher SES compared with public hospital patients. In private hospitals, age and ASA II proportion increased over time. Multivariable Cox regression demonstrated a lower revision risk for primary THA (HR 0.7, CI 0.7–0.8), TKA (HR 0.8, CI 0.7–0.9), and UKA (HR 0.8, CI 0.7–0.9) in private hospitals. After initial arthroplasty in private hospitals, 49% of THA and 37% of TKA revisions were performed in public hospitals.

Conclusion

Patients in private hospitals were younger, had lower ASA classification, lower BMI, and higher SES compared with public hospital patients. The number of arthroplasties increased in private hospitals, with a lower revision risk compared with public hospitals.

Introduction

While public hospitals have traditionally been the primary providers of surgical procedures in the Netherlands, the significance of private hospitals in healthcare services has grown [1]. This is also notable in orthopedic procedures like total hip arthroplasty (THA), total knee arthroplasty (TKA), and unicompartmental knee arthroplasty (UKA), with an increasing number of these surgeries being conducted in private facilities in recent years [1]. This shift is driven by factors such as availability of services, extended waiting lists in public hospitals, and personal preferences of patients [2]. In addition to the growing need for arthroplasty, the COVID-19 pandemic had a strong impact on care, extending the waiting lists in public hospitals [2]. Efforts are being made to address the backlog of postponed surgeries in public hospitals; however, it may take some time towards full recovery. It is important to study the current situation of how and where the care for THA, TKA, and UKA patients is performed in the Netherlands. This study aims to assess time trends in case-mix and to evaluate the risk of revision and causes following primary THA, TKA, and UKA in private and public hospitals.

Methods

Study design and data source

This study is a population-based cross-sectional study from the LROI. Since 2007, information on patient, procedure, and implant characteristics has been collected [1]. Currently, the LROI achieves a completion rate exceeding 97% for primary THA, TKA, and UKA [3]. The LROI bureau determines hospital types using public information. Though not formally validated, LROI's annual report includes lists of university medical centers (UMCs), public hospitals, and private hospitals. Hospital types are confirmed annually by reviewing their classification and subsequently disclosed in the annual LROI report. This study is reported according to the STROBE guidelines [4].

Data selection

We included all primary THA, TKA, and/or UKA performed in private (n = 62,752) or public hospitals (n = 413,560) between January 1, 2014 and January 1, 2023. Prosthetic implants without a valid Orthopaedic Data Evaluation Panel (ODEP) rating, including those with a missing, expired, preor unknown ODEP category were excluded. Reliability of these ODEP implants cannot be assured, potentially impacting the validity of our results. Implants with an ODEP category < 5A were also excluded (Figure 1), as implants with a category < 5A are not permitted for general use in the Netherlands, except within the context of experimental studies. Primary procedures performed at university medical centers were not part of this dataset, as these patients form a non-representative group when compared with the general population.

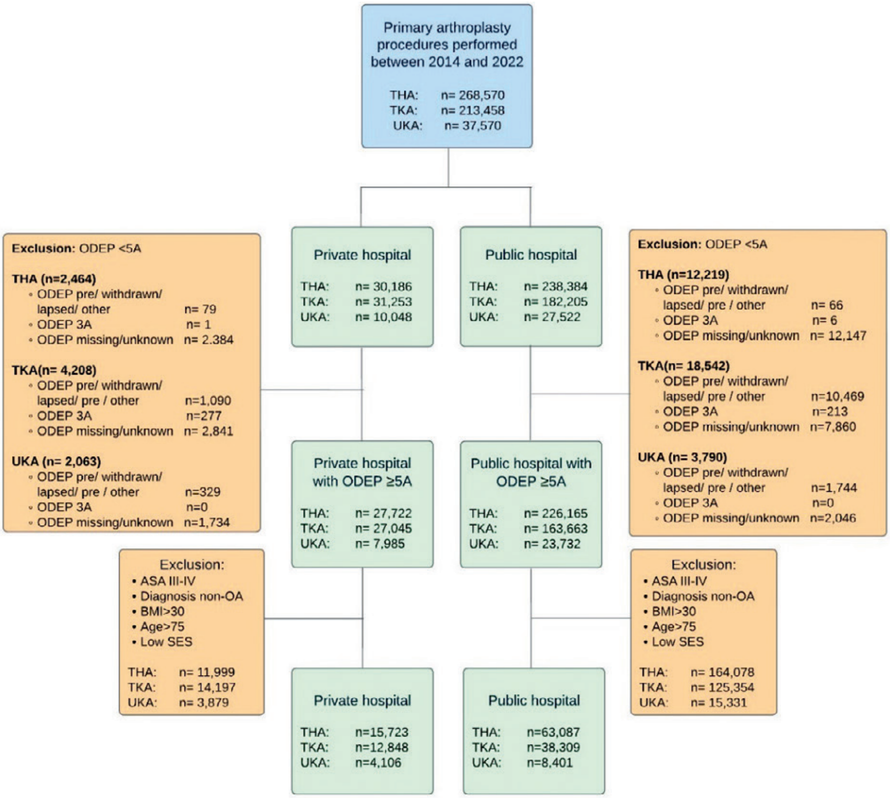

Figure 1. Flowchart included primary THA procedures.

Variables

Patient (case-mix), procedure, and implant characteristics were obtained from the LROI. Case-mix is defined as factors describing population variation including age, gender, health condition (ASA, BMI), and socio-economic status (SES). Data on SES was obtained from the Dutch Institute of Social Research, which calculated SES scores based on 4-number postal codes using average income, percentage of inhabitants with low income, percentage of unemployed residents, and education levels [5]. These scores were divided into quintiles at the 20th, 40th, 60th, and 80th percentiles. Subsequently, they were categorized into 3 groups: low SES (quintile 1), moderate SES (quintiles 2-4), and high SES (quintile 5). Information on vital status is received by linkage of data from the LROI and a national insurance database on health care (Vektis) [6]. Hospital type was defined as “private” or “public,” following the definition used by the LROI. Public hospitals are defined as healthcare facilities that are owned, operated, and funded by the government or a public entity. Private hospitals are defined as specialized healthcare facilities and are usually smaller independent providers that generally focus on 1 patient group, specialism, or treatment. The type of hospital performing revision was similarly categorized with the addition of “university medical center.”

Outcomes

Primary outcomes included risk of revision for any reason, for infection, and the risk of minor or major revision in private and public hospitals. Revision arthroplasty is considered as a modification (exchange, addition, or removal) of 1 or more components of the original prosthesis [1]. Major revisions were characterized as revision of the acetabular and/or femoral component for THAs and revision of the femoral or tibial component of the TKA or UKA. Minor revisions were defined as inlay and/or femoral head exchange, inlay, and/or patella exchange or addition in TKA, and debridement antibiotics and implant retention (DAIR) procedures. Secondary outcomes included descriptive statistics covering patient and procedure characteristics, annual trends, and changes over time. In addition, type of hospital of revision, for patients who primarily received arthroplasty in a public or private hospital, was examined.

Statistics

Patient and procedure characteristics and annual trends in private and public hospitals were expressed in numbers and percentages. Survival time was defined as time from primary arthroplasty to first revision arthroplasty for any reason, death or January 1, 2023 (end of follow-up). A crude cumulative incidence of revision was calculated for each hospital type using competing risk analyses, where death was considered to be a competing risk [7]. Multivariable Cox regression analyses were performed to calculate the risk of revision. To account for the significant differences in case-mix among hospital types, we specified a sub-selection of procedures. Procedures in patients with ASA I/II, age ≤ 75, BMI ≤ 30, OA diagnosis, and moderate to high SES were selected for survival analyses, as these patients are commonly treated in both types of hospitals. For all arthroplasties we adjusted for age, BMI, ASA class, and SES. Specifically for THA, we additionally adjusted for surgical approach. For TKA and UKA we added previous surgery as confounder into the model. Results were reported as hazard ratios (HR) with 95% confidence intervals (CI). The proportional hazard assumption for Cox models was assessed using scaled Schoenfeld residuals, which was not violated. For group comparisons, we used a chi-square test. For all tests, a 2-tailed significance level of $P < 0.05$ was used. SPSS statistics for Windows version 28.0 (IBM Corp ,Armonk, NY, USA) and R (R Foundation for Statistical Computing, Vienna, Austria) were used for statistical analyses.

Ethics, data sharing, funding, and disclosures

The study was approved by the scientific advisory committee of the LROI. Ethical approval was not required according to the Dutch Medical Research involving Human Subjects Act (WMO) as all data is completely anonymous. Data was registered confidentially with patient consent. Sharing of data is not permitted by the LROI due to privacy regulations. No funding was received. The authors declared no conflicts of interest. Complete disclosure of interest forms according to ICMJE are available on the article page. doi: 10.2340/17453674.2024.40906

Results

We included 253,887 primary THAs, 190,708 TKAs, and 31,717 UKAs (Figure 1). Prostheses with unknown, lapsed, pre-, missing, or ODEP category < 5A (THA 14,683; TKA 22,750; UKA 5,853) were excluded. In private hospitals, ODEP ratings were more frequently missing compared with public hospitals (THA 8% vs 5%; TKA, 9% vs 4 %; UKA 17% vs 7%). The median follow-up for THA, TKA, and UKA was 3.9, 4.1, and 3.1 years, respectively.

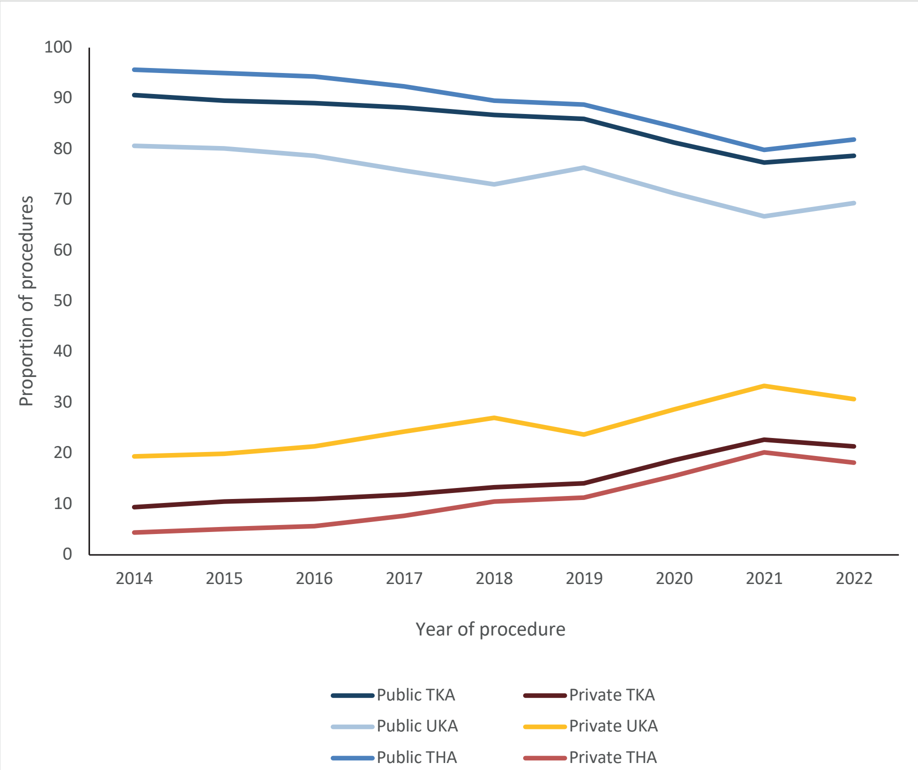

Figure 2. Distribution (%) of primary THA, TKA and UKA in the Netherlands between 2014 and 2022 according to hospital type (university medical centers not included).

Case-mix, procedure and implant characteristics

Patients receiving THA, TKA, or UKA in private hospitals were generally younger, with lower BMI compared with patients from private hospitals (Tables 1–2, see Appendix). Also, patients from private hospitals generally had a lower ASA class and higher SES. The percentage of OA patients was 8% (CI 8.0– 8.5) higher in private hospitals. In THA, the proportion of patients with larger femoral head sizes (36 mm) was 19% (CI 18.5–19.7) higher in private hospitals compared with public hospitals. The direct anterior approach

(DAA) was preferred in private hospitals (59%), while the posterolateral approach (PLA) was favored in public hospitals (56%). In TKA, patellar components were 7% (CI 6.5–7.4) more commonly utilized in public hospitals than in private hospitals (Table 2, see Appendix).

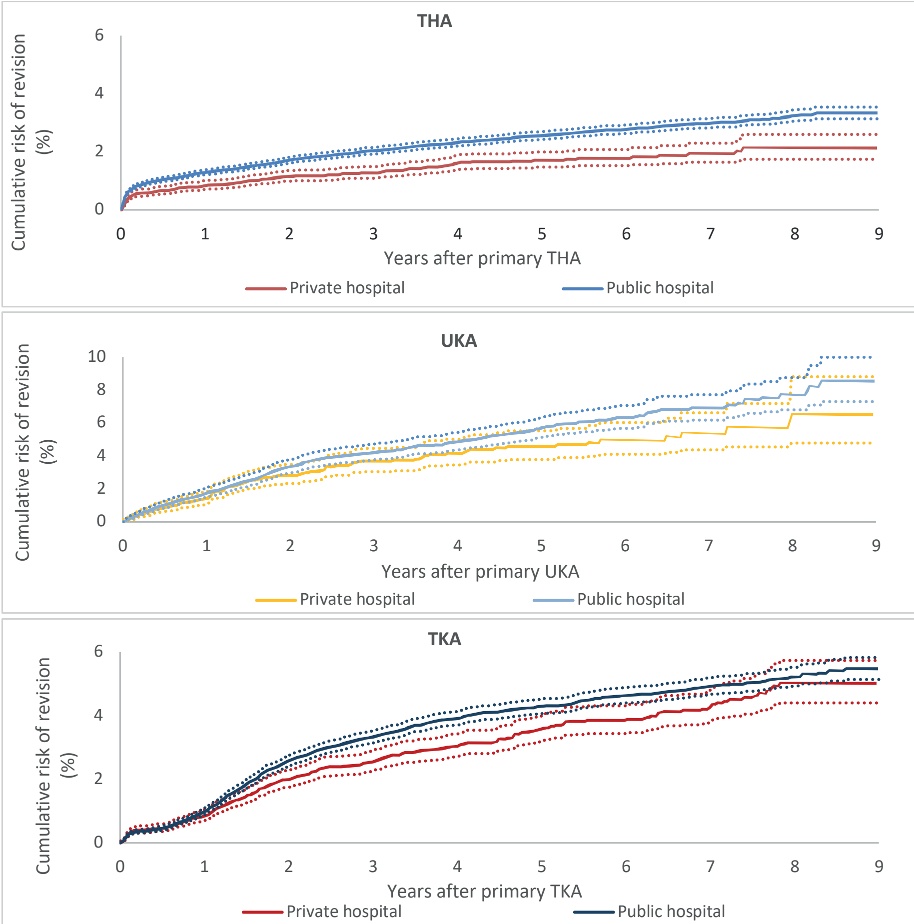

Figure 3 a-c. Crude cumulative incidence of revision for any reason in primary TKA, TKA and UKA per type of hospital for patients with ASA I-II, BMI ≤30, age ≤75, moderate or high SES and OA

Trends over time

Between 2014 and 2022, the proportion of primary procedures performed in private hospitals gradually increased from 4% to 18% for THAs, 9% to 21% for TKAs, and 19% to 31% for UKAs (Figure 2). In recent years (2020–2022), private hospitals showed an increase in the proportion of patients aged > 75 years for THA (+5%, CI 3.9–5.6), TKA (+4%, CI 3.3–5.1), and UKA (+4%, CI 2.3–4.9). In contrast, public hospitals observed minimal change. Private hospitals demonstrated a shift towards a higher proportion of ASA-II patients (THA: +8%, CI 7.0–9.2; TKA: +9%, CI 6.7–7.8; UKA: +13%, CI 10.5–14.8), while public hospitals observed an increase in patients with ASA III/ IV (THA: +9%, CI 8.9–9.7; TKA: +10%, CI 9.7–10.7; UKA: +7%, CI 6.2–8.2) (Tables 3 and 4, see Appendix).

Risk of revision for all causes

After subgroup selection, we observed lower 1-, 3-, 5-, and 7-year crude cumulative revision rates of THA in private hospitals compared with public hospitals (Figure 3a; Table 5, see Appendix). For TKA, 3- and 5-year revision rates were also lower in private hospitals (Figure 3b; Table 5, see Appendix). Crude cumulative revision rates for UKA were comparable between the 2 hospital types (Figure 3c; Table 5, see Appendix).

Multivariable Cox regression analysis demonstrated a lower risk of revision for primary THA (HR 0.8, CI 0.7–0.9), TKA (HR 0.8, CI 0.7–0.9), and UKA (HR 0.8, CI 0.6–1.0) in private hospitals compared with public hospitals (Table 6).

An overview of reasons for revision showed that, for THA, infection rates were lower in private hospitals compared to public hospitals (0.4% vs. 0.6%, respectively; $p = 0.02$). Similarly, dislocations, loosening of femur, and loosening of acetabulum were less frequent in private hospitals compared with public hospitals (Table 7). For TKA, there were no differences in infections, periprosthetic fractures, loosening of tibia, and loosening of femur between the 2 types of hospitals (Table 8). For UKA, private hospitals had comparable rates of infection, periprosthetic fracture, instability, loosening of tibia, loosening of femur, and inlay wear (Table 8).

Table 6. Multivariable survival analysis of revision for any reason in primary THA, TKA and UKA per type of hospital for patients with ASA I-II, BMI <30, age <75, moderate or high SES and diagnosis osteoarthritis.

Hospital	n	Revisions	Crude hazard ratio (CI)	Adjusted hazard ratio
			THA [a]	
Private	15,723	205	0.7 (0.6–0.8) [d]	0.8 (0.7–0.9) [d]
Public	63,087	1,513	1.0	1.0
			TKA [b]	
Private	12,848	348	0.8 (0.8–0.9) [d]	0.8 (0.7–0.9) [d]
Public	38,309	1,453	1.0	1.0
			UKA [c]	
Private	4,106	129	0.8 (0.7–1.0)	0.8 (0.6–0.98) [d]
Public	8,401	379	1.0	1.0

a. THA: Adjusted for age, BMI, ASA-class, SES, surgical approach.
b. TKA: Adjusted for age, BMI, ASA class, SES, previous surgery.
c. UKA: Adjusted for age, BMI, ASA class, SES, previous surgery.
d. $P < 0.05$.

Rik of revision for infection, minor and major revisions

Multivariable Cox regression analysis demonstrated no difference in the risk of revision for infection for primary THA (HR 0.9, CI 0.7–1.2), TKA (HR 0.9, CI 0.7–1.2), and UKA (HR 0.9, CI 0.5–1.7) in private hospitals compared with public hospitals. The adjusted risk of minor revision was lower in private hospitals for all arthroplasties compared with public hospitals (Table 9). The adjusted risk of major revision was lower in private hospitals for THA (HR 0.8, CI 0.7–0.9), but not for TKA (HR 0.9, CI 0.7–1.0) and UKA (HR 0.9, CI 0.7–1.2).

Table 7. Reasons for revision for THA, subdivided between private- and public hospitals between 2014 and 2022 for patients with ASA I-II, BMI ≤30, age ≤75, moderate or high SES and OA

	THA				
	Private hospital n = 15,723		Public hospital n = 63,087		
	n [a]	(%)	n [a]	(%)	P value
Infection	67	(0.4)	365	(0.6)	0.02
Periprosthetic fracture	42	(0.3)	191	(0.3)	0.5
Dislocation	38	(0.2)	383	(0.6)	<0.001
Loosening of femur	28	(0.2)	294	(0.5)	<0.001
Loosening of acetabulum	19	(0.1)	137	(0.2)	0.02
Cup/ liner wear	3	(0.0)	30	(0..0)	0.1
Other	39	(0.2)	305	(0.5)	<0.001

a. A patient may have more than 1 reason for revision;

Table 8. Reasons for revision for TKA and UKA, subdivided between private- and public hospitals between 2014 and 2022 for patients with ASA I-II, BMI ≤30, age ≤75, moderate or high SES and OA.

	TKA					UKA				
	Private hospital n = 12,772		Public hospital n = 38,309			Private hospital n = 7,985		Public hospital n = 23,732		
	n [a]	(%)	n [a]	(%)	P value	n [a]	(%)	n [a]	(%)	P value
Infection	76	(0.6)	262	(0.7)	0.3	16	(0.4)	34	(0.4)	0.9
Periprosthetic fracture	0	(0.0)	20	(0.1)	0.01	7	(0.2)	13	(0.2)	0.8
Instability	121	(0.9)	444	(1.2)	0.04	29	(0.7)	87	(1.0)	0.1
Loosening of tibia	68	(0.5)	238	(0.6)	0.2	25	(0.6)	52	(0.6)	0.8
Loosening of femur	24	(0.2)	87	(0.2)	0.4	6	(0.1)	14	(0.2)	0.9
Inlay wear	12	(0.1)	26	(0.1)	0.4	9	(0.2)	15	(0.2)	0.6
Malignement	42	(0.3)	193	(0.5)	0.01	17	(0.4)	44	(0.5)	0.4
Arthrofibrosis	27	(0.2)	142	(0.4)	0.01	1	(0)	7	(0.1)	0.2
Patellar pain	88	(0.7)	456	(1.2)	<0.001	12	(0.3)	30	(0.4)	0.6

a. A patient may have more than 1 reason for revision.

Table 9. Multivariable survival analysis of revision for infection, minor or major revisions in primary THA, TKA and UKA per type of hospital for patients with ASA I-II, BMI <30, age <75, moderate or high SES and diagnosis osteoarthritis.

Revision	n	Revisions (n)	Crude hazard ratio (CI)	Adjusted hazard ratio [a]
		THA [a]		
For infection				
Private	15,723	67	0.8 (0.6–1.1)	0.9 (0.7–1.2)
Public	63,087	365	1.0	1.0
Minor				
Private	15,723	54	0.6 (0.4–0.8) [d]	0.7 (0.5–0.95) [d]
Public	63,087	393	1.0	1.0
Major				
Private	15,723	147	0.7 (0.6–0.8) [d]	0.8 (0.7–0.9) [d]
Public	63,087	1106	1.0	1.0
		TKA [b]		
For infection				
Private	12,848	76	1.0 (0.7–1.2)	0.9 (0.7–1.2)
Public	38,309	262	1.0	1.0
Minor				
Private	12,843	185	0.8 (0.7–0.9) [d]	0.8 (0.7–0.9) [d]
Public	38,283	807	1.0	1.0
Major				
Private	12,843	159	0.9 (0.8–1.1)	0.9 (0.7–1.0)
Public	38,283	629	1.0	1.0
		UKA [c]		
For infection				
Private	4,106	16	1.1 (0.4–1.9)	0.9 (0.5–1.7)
Public	8,401	34	1.0	1.0
Minor				
Private	4,106	48	0.7 (0.5–1.0)	0.7 (0.5–0.9) [d]
Public	8,401	155	1.0	1.0
Major				
Private	4,106	80	0.9 (0.7–1.2)	0.9 (0.7–1.2)
Public	8,401	221	1.0	1.0

a. Adjusted for age, BMI, ASA-class, SES, surgical approach.
b. Adjusted for age, BMI, ASA class, SES, previous surgery.
c. Adjusted for age, BMI, ASA class, SES, previous surgery.
d. $p < 0.05$.

Type of hospital for revision

The majority (95–96%) of patients initially treated in public hospitals received their revision arthroplasty in a public hospital. In contrast, when primary arthroplasty was performed in a private hospital, 48% of THA revisions, 37% of TKA revisions, and 22% of UKA revisions were performed in another type of hospital (Table 10). This shift was mainly seen for major revisions (Table 11, see Appendix).

Table 10. Type of hospital of revision according to type of hospital of primary THA, TKA and UKA procedure. Values are count (%).

	Type of hospital of primary procedure	
Type of hospital of revision procedure	**Private hospital**	**Public hospital**
	THA	
Private hospital	220 (52)	25 (0.4)
Public hospital	171 (40)	6,384 (96)
University medical center	35 (8.2)	246 (3.7)
	TKA	
Private hospital	466 (63)	152 (2.5)
Public hospital	237 (32)	5,655 (95)
University medical center	37 (5.0)	174 (2.9)
	UKA	
Private hospital	207 (78)	40 (3.5)
Public hospital	56 (21)	1,094 (95)
University medical center	4 (1.5)	16 (1.4)

Discussion

The aim of our study was to assess time trends in case-mix and to evaluate the risk of revision and causes following primary THA, TKA, and UKA in private and public hospitals in the Netherlands. We hypothesized that patients treated in private hospitals are relatively healthier with fewer comorbidities and lower BMI compared with patients treated in public hospitals. Consequently, we expect that, when similar subgroups treated in both hospitals are compared, the revision rates would be comparable between both types of hospitals We found a significant rise in the proportion of patients treated in private hospitals in the Netherlands in recent years. Furthermore, significant differences in case-mix were observed between patients from private hospitals compared with patients from public hospitals. For patients who had the primary arthroplasty in a private hospital, a significant number of revisions were per formed in public hospitals or university medical centers. After subgroup selection, we found a lower risk of revision for all examined arthroplasties in patients from private hospitals compared with patients from public hospitals. These results must be interpreted cautiously, as unregistered confounding factors in registry data may affect outcomes.

Historically, concerns have been raised regarding outsourcing healthcare services to private providers potentially compromising the standard of care [8]. For instance, a study discovered that the heightened outsourcing of NHS services to private providers from 2013 to 2020 was associated with lower quality of patient care and elevated rates of deaths from treatable causes [8]. Also, previous research regarding orthopedic procedures from earlier periods revealed elevated revision rates for hip and knee replacements performed in private hospitals, casting doubt on their capacity to deliver high-quality healthcare [9-11]. As the private sector has become more professionalized, there has been a concerted effort to address earlier concerns through stringent regulatory frameworks. This is shown in more recent studies from various countries, which reported on the performance of private and public hospitals. A study from the Australian national arthroplasty registry reported higher revision rates for THA and TKA in patients treated in private hospitals [12]. However, the authors found no difference after controlling for implant choice, suggesting that the difference in revision rates was explained by the choice of implant, rather than the type of hospital. A study from England found that private providers, who tended to provide hip or knee replacements to healthier patients, had better outcomes when compared with public providers, even after adjustment for preoperative differences [13]. In addition, a retrospective study using the Norwegian Patient Register reported that private non-profit hospitals had significantly lower readmission rates compared with public hospitals among patients receiving THA [14]. While these studies are in principle comparable to our study, the healthcare systems may vary substantially between countries, which poses challenges in the comparison of results.

We found a clear difference in case mix for patients treated in private compared with public hospitals. Private hospitals predominantly treated younger patients with lower BMI and ASA class, primarily for OA. Previous international studies evaluated “cherry-picking” behavior among private hospitals [15-16]. It is suggested that private hospitals tend to treat less complex patients than public hospitals [15-16]. A contributing factor to this patient selection in private hospitals in the Netherlands is the guidance provided by the Dutch health care inspectorate [17]. According to these guidelines, private hospitals are advised to refrain from treating patients classified as ASA III/IV. This restriction leads to a certain selection of patients directed to private hospitals. This was confirmed in our data, as 97–98% of THA, TKA, or UKA patients in private hospitals had ASA I/II, and 96–99% of patients had a BMI < 35. Therefore, our data indicates that private hospitals adhere well to health inspection regulations, demonstrating a selective approach in treating patients.

The influence of case-mix on the rate of revision for hip and knee arthroplasties is well established in the literature. Hence, patient selection should be considered when interpreting revision rates of private and public hospitals. For instance, the a priori revision risk is significantly increased in patients with higher BMI and ASA class [18-22]. Notwithstanding our efforts to narrow the selection criteria to patients with ASA I/II, age ≤ 75, BMI ≤ 30, a diagnosis of OA, and moderate to high SES, in order to create equal groups, we observed a lower risk of revision among patients from private hospitals. We believe that, despite this subgroup selection, the disparities in patients between private and public hospitals may not be entirely addressed, and unobserved residual confounding may impact the results. For example, patients in public hospitals often present with comorbidities associated with a higher risk of revision (e.g., uncontrolled diabetes), which is not fully captured in registry data. Moreover, while ASA class is useful for preoperative assessment, it may not fully describe a patient profile. LROI registry data contain the diagnosis but lack information concerning the complexity of a surgical procedure. Patients with complex hip and knee conditions may face a higher risk of revision due to the inherent anatomical challenges. It is possible that private hospitals handle fewer surgeries of a complex nature, based on surgeon selection. For example, more complex conditions like hip dysplasia, abnormal anatomical morphology, post-traumatic injuries, bone deformities, and joint instability might be more frequently addressed in public hospital settings. However, we were unable to verify this with our data. Moreover, it could be possible that surgeons in private hospitals, where revision surgeries are less frequent compared with their counterparts in public hospitals, may possess a higher threshold for performing revision procedures. This could be attributed to factors such as lower caseloads, disparities in resource availability, and variances in access to multidisciplinary support teams. However, this is an assumption that we are unable to validate with our data and it is important to note that while this observation may apply to some smaller private clinics, it may not represent the situation in larger private hospitals, where revisions are part of the normal workflow. In addition, it is worth noting that in the Netherlands many surgeons work in both private and public settings, mitigating the perception of a threshold.

The lower revision rates observed in private hospitals can partially be explained by the difference in procedure-related factors. The most prominent difference in the risk of revision between private and public hospitals was observed in primary THAs. We observed a higher percentage of large femoral heads and utilization of the DAA in private hospitals. Previous studies reported lower dislocation rates when larger femoral heads are used [23]. Moreover, lower dislocation rates have been reported for the DAA compared with the PLA [23-26]. In addition, the LROI 2022 annual report demonstrated a lower 13-year risk of revision for any reason for the DAA (3.9%, CI 3.4–4.5) compared with the PLA (5.6%, CI 5.4–5.7) [1].

Increased surgical volume and surgeon experience have been associated with lower revision rates and may play a role in the difference in revision rates between private and public hospitals [27-29]. Private hospitals, often specializing in certain treatments, tend to have higher surgical volume in their area of expertise. As a result, surgeries are typically performed by experienced surgeons, potentially resulting in lower revision rates. Moreover, the absence of orthopedic residents in private hospitals may contribute, as some studies report higher revision rates for residents [30]. However, other research suggests that residents performing total joint arthroplasties under the guidance of experienced consultant colleagues achieve outcomes comparable to those of senior surgeons [31-33].

Limitations

First, due to the observational study design, this study lacks the ability to control for all confounding variables. Second, our data does not contain information regarding early postoperative complications that did not necessitate revision arthroplasty. Third, we stated that increased surgical volume and surgeon experience are associated with lower revision rates. However, we were unable to examine this with our data. Lastly, revision rates do not fully reflect the overall quality of care. Other quality indicators like patient satisfaction, readmission rates, mortality rates, rehabilitation progress, quality of postoperative care, and costs were not considered.

Conclusion

In the Netherlands, a significant rise is seen in arthroplasty procedures performed in private hospitals. Different case-mix is seen in private and public hospitals, with private hospitals predominantly treating younger, lower BMI, and relatively healthier patients. A lower risk of revision for all examined arthroplasties was seen in private hospitals.

Perspective

In perspective, it is likely that private hospitals will continue to fill a substantial part of the capacity gap in the upcoming years. The shift towards private hospital care is safe in terms of revision rates, on the premise of proper patient selection and backup facilities. Hence, the observed trend is well justified. It is suspected that the more comorbid and hence higher risk patients may be left to wait for their surgery in public hospitals. In addition, possible failed primary arthroplasty from a private hospital may need to be revised elsewhere, again increasing the waiting lists. Therefore, higher revision rates in public hospitals, in combination with the increased case mix complexity, emphasize the necessity for increased resource allocation and funding. Hence, directing more healthcare resources and funding to public hospitals may be necessary, particularly for complex patient needs.

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APPENDIX

Table 1. Patient and procedure characteristics of all primary total hip arthroplasties (THA) per type of hospital between 2014 and 2022.

THA					
	Private hospital (n= 27,722)		Public hospital (n= 226,165)		Difference between private and public
	n	(%)	n	(%)	% (CI)
Age					
< 60	6,769	(24)	34,208	(15)	9.3 (8.7 to 9.8)
60–74	16,588	(60)	115,213	(51)	8.9 (8.3 to 9.5)
≥ 75	4,364	(16)	76,677	(34)	–18.2 (–18.6 to –17.7)
Sex					
Male	10,260	(37)	78,302	(35)	2.4 (1.8 to 3.0)
Female	17,460	(63)	147,730	(65)	–2.4 (–3.0 to –1.8)
ASA class					
I	9,354	(34)	32,294	(14)	19.5 (18.9 to 20.0)
II	17,884	(64)	143,050	(63)	1.3 (0.7 to 1.9)
III–IV	436	(1.6)	50,545	(23)	–20.8 (–21.0 to –20.6)
BMI a					
< 18.5	140	(0.5)	2,067	(0.9)	–0.4 (–0.5 to –0.3)
18.5–25	11,201	(40)	73,830	(33)	7.8 (7.0 to 8.1)
25–30	11,757	(43)	92,344	(42)	1.2 (0.6 to 1.9)
30–35	4,105	(15)	40,175	(18)	–3.1 (–3.6 to –2.7)
35–40	275	(1.0)	11,188	(4.9)	–4.0 (–4.2 to –3.9)
>40	23	(0.1)	2,803	(1.2)	–1.2 (–1.2 to –1.1)
Diagnosis					
Osteoarthritis (OA)	26,341	(95)	195,858	(87)	8.3 (8.0 to 8.5)
Non-OA	1,356	(4.9)	29,648	(13)	–8.3 (–8.5 to –8.0)
Previous operation					
Yes	689	(2.5)	9,349	(4.1)	– 1.6 (–1.9 to –1.4)
No	26,651	(97)	214,904	(96)	1.6 (1.4 to 1.9)
Smoking					
Yes	2,353	(8.5)	23,370	(11)	–2.0 (–2.4 to –1.7)
No	24,817	(91)	195,206	(89)	2.0 (1.7 to 2.4)
Charnley					
A	12,300	(45)	93,733	(44)	0.7 (0.1 to 1.3)
B1	8,556	(31)	63,292	(30)	1.4 (0.1 to 0.2)
B2	5,401	(20)	49,208	(23)	–3.5 (–4.0 to –3.0)
C	1,129	(4.1)	5,752	(2.7)	1.4 (1.2 to 1.7)
Socioeconomic status					
Low	3,156	(12)	47,140	(21)	–9.4 (–9.8 to –8.9)
Moderate	15,335	(57)	135,102	(60)	– 3.5 (–4.1 to –2.8)
High	8,430	(31)	41,330	(19)	12.8 (12.3 to 13.4)

Table 1. Patient and procedure characteristics of all primary total hip arthroplasties (THA) per type of hospital between 2014 and 2022. (continued)

THA					
	Private hospital (n= 27,722)		Public hospital (n= 226,165)		Difference between private and public
	n	(%)	n	(%)	% (CI)
Fixation					
Cemented	1,074	(3.9)	56,429	(25)	–21.2 (–21.5 to –20.9)
Cementless	25,662	(93)	144,178	(64)	28.6 (28.2 to 29.0)
Reversed hybrid	392	(1.4)	8,761	(3.9)	–2.5 (–2.6 to –2.3)
Hybrid	544	(2.0)	15,584	(6.9)	–5.0 (–5.2 to –4.8)
Surgical approach					
Posterolateral	9,660	(35)	125,939	(56)	–20.8 (–21.4 to –20.2)
Anterior	16,310	(59)	65,373	(29)	29.9 (29.3 to 30.5)
Straight lateral	1,522	(5.5)	21,342	(9.4)	–3.9 (–4.2 to –3.7)
Direct superior	35	(0,1)	3,035	(1.3)	–1.2 (–1.3 to –1.2)
Other	195	(0.7)	10,476	(4.6)	–3.9 (–4.1 to –3.8)
Femoral head size					
22–28 mm	590	(2.2)	36,635	(16)	–14.2 (–14.4 to –14.0)
32 mm	15,824	(58)	139,586	(62)	–4.5 (–5.1 to –3.9)
36 mm	10,939	(40)	46,865	(21)	19.1 (18.5 to 19.7)
≥38 mm	0	(0.0)	818	(0.4)	–0.4 (–0.4 to –0.3)
Articulation [c]					
CoC	3,141	(12)	11,070	(5)	6.6 (6.2 to 7.0)
CoM	2	(0.0)	155	(0,1)	–0.1 (–0.1 to –0.1)
CoP	17,669	(65)	142,748	(65)	0.6 (–0.1 to 1.2) [a]
MoC	0	(0.0)	3	(0.0)	–0.001 (–0.002 to 0.002) [a]
MoP	1,979	(7.3)	48,945	(22)	– 14.9 (–15.2 to –14.6)
ZoP	4,197	(16)	17,040	(7.7)	7.8 (7.4 to 8.3)
Acetabulum ODEP b					
5A/5A*	1	(0.0)	1,951	(0.9)	–0.9 (–0.9 to –0.8)
7A/7A*	2,762	(10)	38,125	(17)	–6.9 (–7.2 to –6.5)
10A/10A*	2,258	(8.1)	33,803	(15)	–6.8 (–7.2 to –6.4)
13A/13A*	6,028	(22)	31,283	(14)	7.9 (7.4 to 8.4)
15A/15A*	16,673	(60)	121,003	(53)	6.6 (6.0 to 7.2)
Femur ODEP b					
5A/5A*	176	(0.6)	727	(0.3)	0.3 (0.2 to 0.4)
7A/7A*	1,690	(6.1)	9,191	(3.6)	2.0 (1.7 to 2.3)
10A/10A*/10B	6,571	(24)	20,796	(8.7)	14.5 (14.0 to 15.0)
13A/13A*	1,531	(5.5)	22,361	(9.9)	–4.3 (–4.7 to –4.1)
15A/15A*	17,754	(64)	174,090	(77)	–12.9 (–13.5 to –12.3)

a) Not significant.
b) Orthopaedic Data Evaluation Panel (ODEP). CoC = Ceramic on Ceramic; CoM = Ceramic on Metal; CoP= Ceramic on Polyethylene; MoC= Methal on Cobalt; MoP= Methal on Polyethylene; ZoP= Zirconium on Polyethylene

Table 2. Patient and procedure characteristics of all primary total knee (TKA) and unicompartmental knee arthroplasties (UKA) per type of hospital between 2014 and 2022.

	TKA					UKA				
	Private hospital (n=27,045)		Public hospital (n=163,663)		Difference between private and public	Private hospital (n=7,985)		Public hospital (n= 23,732)		Difference between private and public
	n	(%)	n	(%)	% (CI)	n	(%)	n	(%)	% (CI)
Age										
< 60	5,910	(22)	23,131	(14)	7.7 (7.2 to 8.2)	2,597	(33)	6,710	(28)	4.2 (3.1 to 5.4)
60–74	17,169	(63)	90,050	(55)	8.5 (7.8 to 9.1)	4,632	(58)	13,547	(57)	0.9 (–0.1 to 2.1) [a]
≥ 75	3,963	(15)	50,431	(31)	–16.2 (–16.7 to –15.7)	756	(9.5)	3,472	(15)	–5.2 (–5.9 to –4.4)
Sex										
Male	11,523	(43)	58,240	(36)	7.0 (6.4 to 7.6)	3,798	(47)	10,610	(45)	2.8 (1.6 to 4.1)
Female	15,519	(57)	105,323	(64)	–7.0 (–7.6 to –6.4)	4,187	(53)	13,114	(55)	–2.8 (–4.1 to –1.6)
ASA class										
I	7,278	(27)	15,866	(9.7)	17.3 (16.7 to 17.8)	2,607	(33)	3,559	(16)	17.7 (16.6 to 18.8)
II	18,963	(70)	108,217	(66)	4.0 (4.3 to 4.6)	5,078	(64)	16,053	(68)	–3.9 (–5.1 to –2.7)
III–IV	760	(2.8)	39,390	(24)	–21.3 (–21.6 to –21.0)	283	(3.6)	4,111	(17)	–13.8 (–14.4 to –13.2)
Diagnosis										
Osteoarthritis (OA)	26,260	(97)	158,167	(97)	0.4 (0.2 to 0.6)	7,872	(99)	23,355	(99)	0.2 (–0.1 to 0.4) [a]
Non-OA	703	(2.6)	4,958	(3.0)	–0.4 (–0.6 to –0.2)	87	(1.1)	309	(1.3)	–0.2 (CI –0.4 to 0.1) [a]
Previous operation										
Yes	9,723	(37)	41,944	(26)	11.0 (10.4 to 11.6)	2171	(28)	5,346	(23)	4.6 (3.5 to 5.7)
No	16,419	(63)	118,211	(74)	–11.0 (–11.6 to –10.4)	5669	(72)	17,820	(77)	–4.6 (–5.7 to –3.5)
Smoking										
Yes	2,054	(7.7)	12,857	(8.2)	–0.4 (–0.8 to –0.1)	653	(8.3)	2,189	(9.5)	–1.2 (–1.9 to –0.4)
No	24,601	(92)	144,545	(92)	0.4 (0.1 to 0.8)	7,217	(92)	20,875	(91)	1.2 (0.4 to 1.9)

Table 2. Patient and procedure characteristics of all primary total knee (TKA) and unicompartmental knee arthroplasties (UKA) per type of hospital between 2014 and 2022. (continued)

	TKA					UKA				
	Private hospital (n=27,045)		Public hospital (n=163,663)		Difference between private and public	Private hospital (n=7,985)		Public hospital (n= 23,732)		Difference between private and public
	n	(%)	n	(%)	% (CI)	n	(%)	n	(%)	% (CI)
BMI										
< 18,5	39	(0,1)	262	(0,2)	−0.1 (−0.1 to 0.1) [a]	5	(0.1)	14	(0.1)	−0.01 (−0.001 to 0.001) [a]
18.5–25	6,047	(22)	26,681	(17)	6.0 (5.4 to 6.5)	1,764	(22)	4,072	(18)	4.9 (3.9 to 6.0)
25–30	12,795	(48)	64,679	(40)	7.5 (6.9 to 8.2)	3,746	(47)	10,092	(43)	4.3 (3.1 to 5.6)
30–35	7,034	(26)	44,841	(28)	−1.6 (−2.2 to −1.1)	2,048	(26)	6,544	(28)	−2.0 (−3.1 to −0.8)
35–40	761	(2.8)	18,325	(11)	−8.5 (−8.8 to −8.3)	278	(3.5)	2,166	(9.3)	−5.7 (−6.4 to −5.2)
>40	152	(0.6)	6,245	(3.9)	−3.3 (−3.4 to −3.2)	49	(0.6)	502	(2.1)	− 1.5 (−1.8 to −1.3)
Charnley										
A	11,367	(43)	63,591	(39)	3.2 (2.6 to 3.9)	3,757	(48)	12,134	(52)	−3.7 (−5.0 to −2.4)
B1	9,167	(34)	55,658	(35)	−0.1 (−0.7 to 0.5) [a]	2,616	(34)	6,977	(30)	3.7 (2.5 to 4.9)
B2	5,106	(19)	36,290	(23)	−3.3 (−3.9 to −2.8)	1,279	(16)	4,031	(17)	−0.8 (−1.7 to −0.1)
C	937	(3.5)	5,335	(3.3)	0.2 (−0.0 to 0,2) [a]	162	(2.1)	294	(1.3)	0.8 (0.4 to 1.2)
Socioeconomic status										
Low SES	3,582	(14)	34,678	(22)	−7.7 (−8.3 to −7.4)	1,027	(13)	4,353	(19)	−5.3 (−6.2 to −4.4)
Moderate SES	15,331	(58)	97,108	(60)	−1.6 (−2.2 to −0.9)	4,475	(58)	14,600	(62)	−4.4 (−5.6 to −3.1)
High SES	7,285	(28)	29,760	(18)	9.4 (8.8 to 10.0)	2,224	(29)	4,488	(19)	9.6 (8.5 to 10.8)
Fixation										
Cemented	24,276	(90)	153,908	(94)	−4.3 (−4.7 to −3.9)	2,355	(30)	10,876	(46)	−16.3 (−17.5 to −15.2)
Cementless	1,635	(6.0)	5,344	(3.3)	2.8 (2.5 to 3.1)	5,628	(70)	12,843	(54)	16.4 (15.2 to 17.6)
Hybrid	1,134	(4.2)	4,411	(2.7)	1.5 (1.2 to 1.7)	2	(0.0)	13	(0.1)	−0.01 (−0.01 to 0.01) [a]

Table 2. Patient and procedure characteristics of all primary total knee (TKA) and unicompartmental knee arthroplasties (UKA) per type of hospital between 2014 and 2022. (continued)

	TKA					UKA				
	Private hospital (n=27,045)		Public hospital (n=163,663)		Difference between private and public	Private hospital (n=7,985)		Public hospital (n= 23,732)		Difference between private and public
	n	(%)	n	(%)	% (CI)	n	(%)	n	(%)	% (CI)
Surgical approach										
Medial parapatellar	26,265	(97)	156,447	(96)	1.6 (1.4 to 1.8)	7,692	(97)	21,953	(93)	4.0 (3.5 to 4.5)
Lateral parapatellar	89	(0.3)	1,244	(0.8)	–0.4 (–0.5 to –0.4)	104	(1.3)	145	(0.6)	0.7 (0.4 to 1.0)
Vastus	584	(2.2)	4,822	(3.0)	–0.8 (–1.0 to –0.6)	150	(1.9)	1,464	(6.2)	–4.3 (–4.7 to –3.9)
Other	30	(0.1)	849	(0.5)	–0.4 (–0.5 to –0.4)	5	(0.1)	108	(0.4)	–0.4 (–0.5 to –0.3)
Patella component										
Yes	3,840	(14)	34,604	(21)	–6.9 (–7.4 to –6.5)	n.a.	(n.a.)	n.a.	(n.a.)	n.a.
No	23,205	(86)	129,059	(79)	6.9 (6.5 to 7.4)	7,985	(100)	23,732	(100)	n.a.
Type of femur										
Posterior stabilized	16,225	(60)	97,739	(60)	0.3 (–0.4 to 0.9) [a]					
Minimally stabilized	10,774	(40)	62,808	(38)	1.5 (0.8 to 2.1)					
Other	46	(0.2)	3,116	(1.9)	–1.7 (–1.8 to –1.7)	n.a.	(n.a.)	n.a.	(n.a.)	n.a.
Tibia mobility										
Fixed	25223	(93)	143,781	(88)	5.3 (5.0 to 5.6)	2349	(29)	10,821	(46)	–16.2 (–17.4 to –15.0)
Mobile	n.a.	(n.a.)	n.a.	(n.a.)	n.a.	5627	(71)	12,834	(54)	16.4 (15.2 to 17.6)
Rotating	1822	(7)	19,657	(12)	–5.3 (–5.6 to –5.0)	9	(0.1)	77	(0.3)	–0.2 (–0.3 to –0.1)
ODEP										
5A/5A*/5B	902	(3.3)	2,319	(1.4)	1.9 (1.7 to 2.1)	11	(0.1)	515	(2.2)	–2.0 (–2.2 to –1.8)
7A/7A*	5,803	(22)	14,970	(9.1)	12.3 (11.8 to 12.8)	0	(0.0)	0	(0.0)	0
10A/10A*/10B	6,566	(24)	45,570	(28)	–3.6 (–4.1 to –3.0)	0	(0.0)	204	(0.8)	–0.9 (–1.0 to –0.7)
13A/13A*	3,636	(13)	45,390	(28)	–14.3 (–14.8 to –13.8)	7,592	(95)	15,177	(64)	31.1 (30.4 to 31.9)
15A/15A*	10,138	(38)	55,414	(34)	3.6 (3.0 to 4.2)	382	(4.8)	7,836	(33)	–28.2 (–29.0 to –27.5)

a. Not significant.

Table 3. Patient and procedure characteristics of all primary THAs per type of hospital according to period. Values are count (%).

	THA							
	Private hospital				Public hospital			
	2014–2019		2020–2022		2014–2019		2020–2022	
	n	(%)	n	(%)	n	(%)	n	(%)
Age								
< 60	3,119	(26)	3,650	(23)	23,532	(15)	10,676	(15)
60–74	7,487	(61)	9,101	(59)	78,833	(52)	36,380	(51)
≥ 75	1,599	(13)	2,765	(18)	50,253	(33)	26,424	(34)
Sex								
Male	4,591	(38)	5,669	(37)	52,443	(34)	25,859	(35)
Female	7,613	(62)	9,847	(63)	100,123	(66)	73466	(65)
ASA class								
I	4,682	(38)	4,672	(30)	24,111	(16)	8,183	(11)
II	7,333	(60)	10,551	(68)	98,810	(65)	44,240	(60)
III–IV	187	(1.5)	249	(1.6)	29,497	(19)	21,048	(29)
Diagnosis								
Osteoarthritis (OA)	11,454	(94)	14,887	(96)	133,197	(87)	62,661	(86)
Non-OA	745	(6.1)	611	(3.9)	19,0595	(13)	10,589	(14)
BMI								
< 18.5	67	(0.6)	73	(0.5)	1,351	(0.9)	716	(1.0)
18.5–25	4,886	(40)	6,315	(41)	49,144	(33)	24,686	(34)
25–30	5,279	(44)	6,478	(42)	62,865	(42)	29,479	(41)
30–40	1,825	(17)	2,555	(16)	34,679	(23)	16,684	(23)
>40	17	(0.1)	6	(0.0)	1,855	(1.2)	948	(1.3)
Fixation								
Cemented	661	(5.4)	413	(2.7)	39,095	(26)	17,334	(24)
Cementless	10,935	(90)	14,727	(95)	97,391	(64)	46,787	(64)
Reversed hybrid	249	(2.0)	143	(0.9)	6,510	(4.3)	2,251	(3.1)
Hybrid	343	(2.8)	201	(1.3)	8,820	(5.8)	6,764	(9.2)
Surgical approach								
Posterolateral	5,044	(41)	4,616	(30)	88,627	(58)	37,312	(51)
Anterior	5,885	(48)	10,425	(67)	36,708	(24)	28,655	(39)
Straight lateral	1,135	(9.3)	387	(2.5)	18,680	(12)	2,662	(3.6)
Direct superior	2	(0.0)	33	(0.2)	785	(0.5)	2,250	(3.1)
Other	140	(1.1)	55	(0.4)	7,884	(5.2)	2,592	(3.5)
Femoral head size								
22–28 mm	245	(2.0)	345	(2.2)	28,806	(19)	8,029	(11)
32 mm	6,983	(58)	8,841	(58)	91,961	(61)	47,625	(65)
36 mm	4,789	(40)	6,150	(40)	30,052	(20)	16,813	(23)
≥ 38 mm	0	(0.0)	0	(0.0)	490	(0.3)	328	(0.5)

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Table 3. Patient and procedure characteristics of all primary THAs per type of hospital according to period. Values are count (%). (continued)

	THA							
	Private hospital				Public hospital			
	2014–2019		2020–2022		2014–2019		2020–2022	
	n	(%)	n	(%)	n	(%)	n	(%)
Articulation								
CoC	1,208	(10)	1,933	(13)	8,877	(6.0)	2,193	(3.1)
CoM	0	(0.0)	2	(0.0)	17	(0.0)	138	(0.2)
CoP	7,649	(65)	10,020	(66)	93,104	(62)	49,644	(70)
MoC	0	(0.0)	0	(0.0)	3	(0.0)	0	(0.0)
MoP	593	(5.0)	1,386	(9.2)	36,827	(25)	12,118	(17)
ZoP	2,409	(20)	1,788	(12)	10,205	(6.8)	6,835	(9.6)

Table 4. Patient and procedure characteristics of all primary TKA and UKA per type of hospital according to period.

	TKA								UKA							
	Private hospital				Public hospital				Private hospital				Public hospital			
	2014–2019		2020–2022		2014–2019		2020–2022		2014–2019		2020–2022		2014–2019		2020–2022	
	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
Age																
< 60	3,520	(24)	2,390	(19)	16,878	(15)	6,253	(13)	1,343	(38)	1,254	(28)	4,066	(30)	2,644	(26)
60–74	9,271	(63)	7,898	(64)	63,623	(55)	26,427	(54)	1,900	(54)	2,732	(61)	7,759	(57)	5,788	(57)
≥ 75	1,866	(13)	2,097	(17)	34,228	(30)	16,203	(33)	261	(7.4)	495	(11)	1,758	(13)	1,714	(17)
Sex																
Male	6,320	(43)	5,203	(42)	40,347	(35)	17,893	(37)	1,631	(47)	2,167	(48)	5,963	(44)	4,647	(46)
Female	8,338	(57)	7,181	(58)	74,338	(65)	30,985	(63)	1,873	(53)	2,314	(52)	7,616	(56)	5,498	(54)
ASA class																
I	4,411	(30)	2,867	(23)	12,416	(11)	3,450	(7.1)	1,353	(39)	1,254	(28)	2,372	(18)	1,187	(12)
II	9,769	(67)	9,194	(75)	78,056	(68)	30,161	(62)	1,983	(56)	3,095	(69)	9,270	(68)	6,783	(77)
III–IV	472	(3.2)	288	(2.3)	24,141	(21)	15,269	(31)	165	(4.7)	118	(2.6)	1,937	(14)	2,174	(11)
Diagnosis																
Osteoarthritis (OA)	14,236	(97)	12,024	(98)	110,952	(97)	47,215	(97)	3,451	(99)	4,421	(99)	13,373	(99)	9,982	(99)
Non-OA	413	(2.8)	290	(2.4)	3,472	(3.0)	1,486	(3.1)	47	(1.3)	40	(0.9)	184	(1.4)	125	(1.2)
BMI																
< 18.5	24	(0.2)	15	(0.1)	187	(0.2)	75	(0.2)	2	(0.1)	3	(0.1)	10	(0.1)	4	(0.0)
18.5–25	3,236	(22)	2,811	(23)	18,289	(16)	8,392	(17)	717	(21)	1,047	(24)	2,283	(17)	1,789	(18)
25–30	6,933	(48)	5,862	(48)	45,312	(40)	19,367	(40)	1,638	(48)	2,108	(47)	5,733	(43)	4,359	(43)
30–40	4,194	(29)	3,601	(29)	44,315	(40)	18,851	(39)	1,031	(30)	1,295	(29)	5,017	(38)	3,693	(37)
> 40	131	(0.9)	21	(0.2)	4,447	(4.0)	1,798	(3.7)	43	(1.3)	6	(0.1)	281	(2.2)	211	(2.1)

Table 4. Patient and procedure characteristics of all primary TKA and UKA per type of hospital according to period. (continued)

	TKA								UKA							
	Private hospital				Public hospital				Private hospital				Public hospital			
	2014–2019		2020–2022		2014–2019		2020–2022		2014–2019		2020–2022		2014–2019		2020–2022	
	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
Fixation																
Cemented	13,943	(95)	10,333	(84)	106,984	(93)	46,924	(96)	1,119	(34)	1,156	(26)	7,150	(53)	3,726	(37)
Cementless	113	(0.8)	1,522	(12)	4,563	(4.0)	781	(1.6)	2,304	(66)	3,324	(74)	4,625	(47)	6,418	(63)
Hybrid	604	(4.1)	530	(4.3)	3,231	(2.8)	1,180	(2.4)	1	(0.0)	1	(0.0)	11	(0.1)	2	(0.1)
Surgical approach																
Medial parapatellar	14,041	(96)	12,224	(99)	109,859	(96)	46,588	(95)	3,317	(95)	4,375	(98)	12,618	(93)	9,335	(92)
Lateral parapatellar	64	(0.4)	25	(0.2)	985	(0.9)	259	(0.5)	59	(1.7)	45	(1.0)	105	(0.8)	40	(0.4)
Vastus	526	(3.6)	58	(0.5)	3,639	(3.2)	1,183	(2.4)	114	(3.3)	46	(0.8)	812	(6.0)	652	(6.4)
Other	4	(0)	26	(0.2)	92	(0.1)	757	(1.6)	1	(0.0)	4	(0.1)	19	(0.1)	89	(0.9)
Tibia mobility																
Fixed	13,746	(94)	11,477	(93)	99,557	(87)	44,224	(90)	1,191	(34)	1,158	(26)	7,091	(52)	3,730	(37)
Mobile	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2,304	(66)	3,323	(74)	6,495	(48)	6,410	(63)
Rotating	914	(6.2)	908	(7.3)	15,025	(13)	4,632	(10)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Unicondylar side																
Medial	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3,256	(92)	4,351	(99)	12,594	(99)	9,505	(99)
Lateral	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	54	(1.6)	51	(1.2)	89	(0.7)	47	(0.5)
Patella component																
Yes	2,088	(14)	1,752	(14)	25,048	(22)	9,556	(20)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
No	12,572	(86)	10,644	(86)	89,730	(78)	39,329	(80)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Type of femur																
Posterior stabilized	8,000	(55)	8,225	(66)	66,279	(58)	31,460	(64)	n.a.	n.a.	n.a.	n.a	n.a.	n.a.	n.a.	n.a.
Minimally stabilized	6,616	(45)	4,158	(34)	46,589	(40)	16,219	(33)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Other	44	(0.3)	2	(0.0)	1910	(1.7)	1,206	(2.5)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Table 5. Crude cumulative incidence of revision in primary TKA, TKA and UKA per type of hospital for patients with ASA I-II, BMI <30, age <75, moderate or high SES and osteoarthritis.

Crude cumulative incidence of revision						
	Private hospital			Public hospital		
	Number at risk	%	(CI)	Number at risk	%	(CI)
			THA			
1-year	13,989	0.7	0.6–0.8	58,896	1.0	1.0–1.1 [a]
3 year	7,834	1.2	1.0–1.4	45,874	1.9	1.8–2.0 [a]
5-year	4,215	1.7	1.4–1.9	31,861	2.4	2.3–2.6 [a]
7-year	1,683	1.9	1.6–2.2	16,851	2.9	2.7–3.0 [a]
			TKA			
1-year	11,667	0.5	0.4–0.6	35,994	0.5	0.4–0.5
3-year	7,445	2.4	2.1–2.7	27,958	3.0	2.8–3.2 [a]
5-year	4,686	3.3	2.9–3.7	19,648	4.1	3.9–4.4 [a]
7-year	2,519	4.1	3.7–4.6	10,385	4.8	4.5–5.1
			UKA			
1-year	3,585	0.8	0.6–1.2	7,590	1.0	0.8–1.3
3-year	1,905	3.4	2.8–4.1	5,173	3.9	3.5–4.4
5-year	1,041	4.5	3.7–5.4	3,130	5.3	4.7–5.9
7-year	472	5.2	4.2–6.3	1,460	6.8	6.1–7.6

a. Statistically significant.

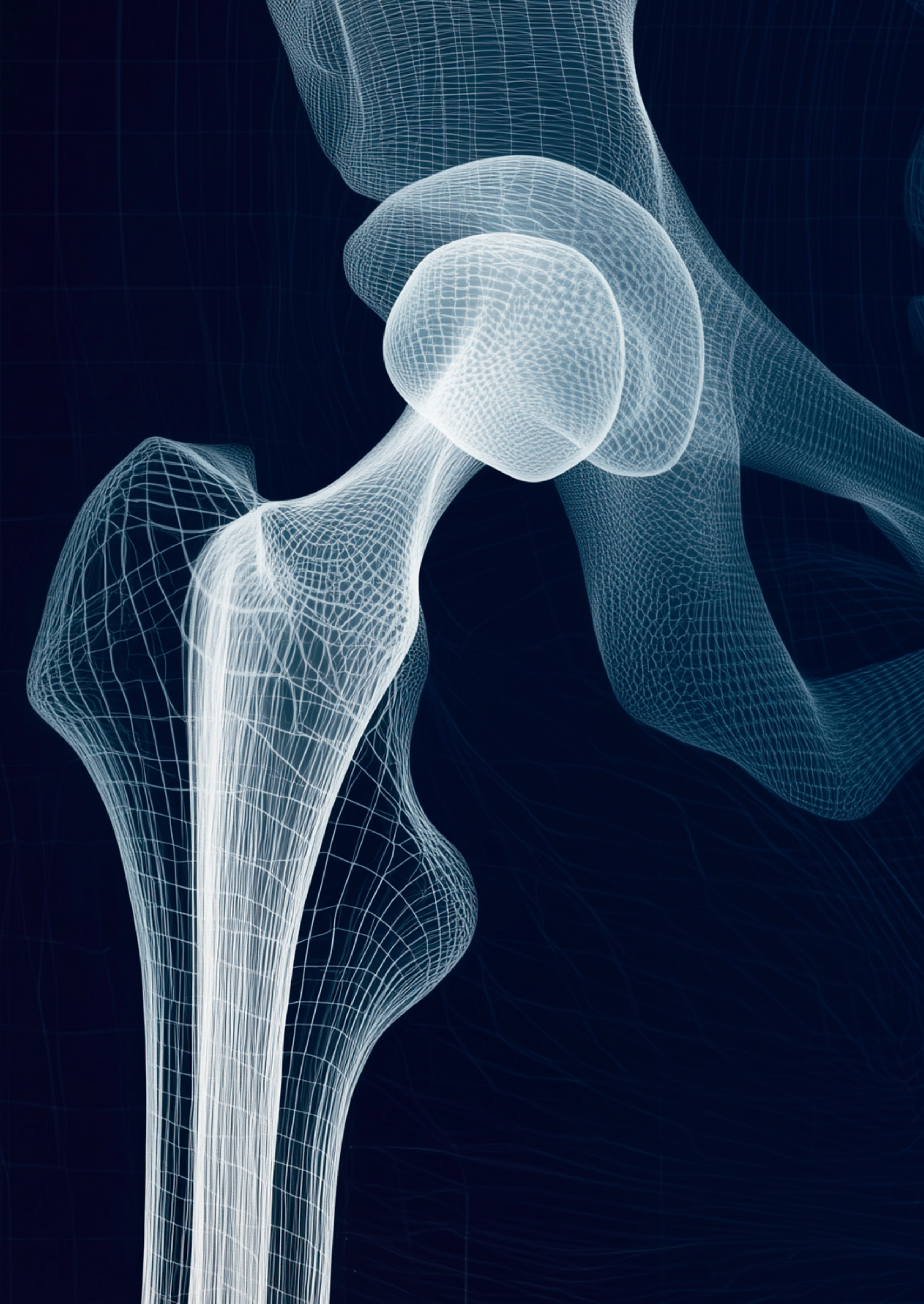
Table 11. Multivariable survival analysis of revision for infection, minor or major revisions in primary THA, TKA and UKA per type of hospital for patients with ASA I-II, BMI <30, age <75, moderate or high SES and diagnosis osteoarthritis.

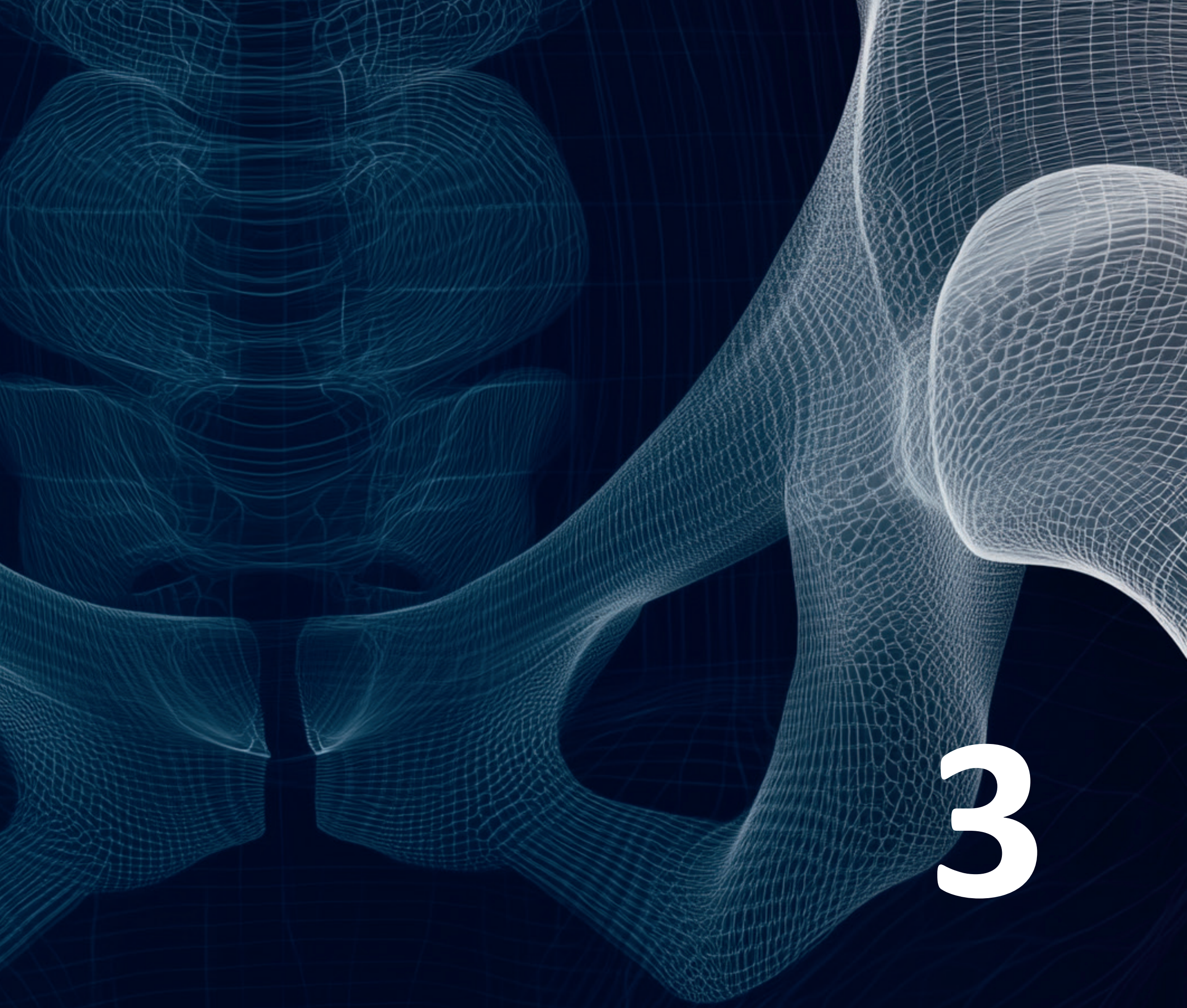
Revision	n	Revisions	Crude hazard ratio (CI)	Adjusted hazard ratio [a]
		THA [a]		
For infection				
Private	15,723	67	0.8 (0.6–1.1)	0.9 (0.7–1.2)
Public	63,087	365	1.0	1.0
Minor				
Private	15,723	54	0.6 (0.4–0.8) [d]	0.7 (0.5–0.95) [d]
Public	63,087	393	1.0	1.0
Major				
Private	15,723	147	0.7 (0.6–0.8) [d]	0.8 (0.7–0.9) [d]
Public	63,087	1106	1.0	1.0
		TKA [b]		
For infection				
Private	12,848	76	1.0 (0.7–1.2)	0.9 (0.7–1.2)
Public	38,309	262	1.0	1.0
Minor				
Private	12,843	185	0.8 (0.7–0.9) [d]	0.8 (0.7–0.9) [d]
Public	38,283	807	1.0	1.0
Major				
Private	12,843	159	0.9 (0.8–1.1)	0.9 (0.7–1.0)
Public	38,283	629	1.0	1.0
		UKA [c]		
For infection				
Private	4,106	16	1.1 (0.4–1.9)	0.9 (0.5–1.7)
Public	8,401	34	1.0	1.0
Minor				
Private	4,106	48	0.7 (0.5–1.0)	0.7 (0.5–0.9) [d]
Public	8,401	155	1.0	1.0
Major				
Private	4,106	80	0.9 (0.7–1.2)	0.9 (0.7–1.2)
Public	8,401	221	1.0	1.0

a) Adjusted for age, BMI, ASA-class, SES, surgical approach.
b) Adjusted for age, BMI, ASA class, SES, previous surgery.
c) Adjusted for age, BMI, ASA class, SES, previous surgery.
d) $p < 0.05$.

Part 2

Optimizing patient care: The shift towards new surgical approaches





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The Rise of the Direct Anterior Approach. Trends Learning Curve, and Patient charateristics of 63,182 primary total hip arthroplasties in the Dutch Arthroplasty Register.

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J. Arthroplasty 2024 Jul;39(7):1758-1764.e1.

Abstract

Background
The use of the anterior approach (DAA) in total hip arthroplasty (THA) has steadily increased in the Netherlands since 2007. The aim of this study was to outline how the DAA has been implemented in the Netherlands. Moreover, we investigated the learning curve of the DAA at a hospital level, and explored patient characteristics of the DAA compared with other approaches and during the learning phase after implementing the DAA.

Methods
In this population-based cohort study we included all primary THAs between 2007 and 2020 (n= 342,473) from the Dutch Arthroplasty Register. For hospitals implementing the DAA (n>20), patients were categorized in four experience groups using the date of surgery: 1 to 50, 51 to 100, 101 to 150 or >150. Subsequently, data from different hospitals was pooled and survival rates were calculated using Kaplan-Meier survival analyses. Adjusted revision rates were calculated using mixed Cox proportional hazard models (frailty).

Results
The use of the DAA gradually rose from 0.2% in 2007 to 41% of all primary THAs in 2020. A total of 64 (56%) hospitals implemented the DAA. However, not all hospitals continued using this approach. After implementation, the 5-year survival rate for the first 50 procedures was significantly lower (96% (Confidence Interval (CI) 95.8 to 97.2)) compared to >150 procedures (98% (CI 97.7 to 98.1)). Multivariable Cox hazard analyses demonstrated a higher risk of revision during the first 50 procedures compared with >150 procedures (Hazard Ratio 1.6, CI 1.3 to 2.0).

Conclusion
The use of DAA for primary THA significantly increased. For hospitals implementing DAA, a significant learning curve with increased revision risk was seen.

Introduction

In the last two decades there is an increase in the use of the Direct anterior approach(DAA) in primary Total hip arthroplasty(THA) in several countries [1–3]. In the Netherlands the preference for the DAA is steadily increasing from 2008 onwards [1,4]. In search of better outcomes and to meet the patients' request, many orthopaedic surgeons and clinics have shifted their surgical technique towards the DAA[5].

However, patients' perspective on the DAA may differ from scientific evidence [6,7]. The benefits and disadvantages of the DAA are under constant debate. The primary benefit of the DAA for THA is the potential for faster initial postoperative recovery when compared to alternative surgical approaches. Other benefits include improved early pain (VAS) scores and a shorter incisions [8]. In contrast, an extensive learning curve has been described [9,10]. One study reported that a completion of 50 cases is required in order to achieve operative times within normal limits [10]. Other studies describe that at least 100 primary THA procedures are needed to achieve revision rates within acceptable limits [9,11]. Another potential drawback of the DAA is a higher risk of early stem revision [12,13]

Due to the learning curve and thus far no clear demonstrable better functional outcome after 3 months, it is of great interest to examine how orthopaedic communities responded to the rise in interest of the DAA. The aim of this study was: 1) to outline how the DAA has been implemented in the Netherlands; 2) to examine the learning curve of the DAA at a hospital level; 3) to explore whether there are any disparities between patients who received THA using the DAA compared to other approaches; and 4) to explore patient characteristics during the learning phase after implementing the DAA.

Materials and methods

Study design and setting

This study was a retrospective observational registry study of all primary THAs performed in the Netherlands between January 1st 2007 and January 1st 2021, using data from the Dutch Arthroplasty Register (LROI). The study is reported according to the 'Strengthening the Reporting of Observational Studies in Epidemiology' (STROBE) guidelines.

Data source

The LROI is a nationwide database that prospectively collects data on all arthroplasties performed in hospitals throughout the Netherlands. It has been systematically collecting data since 2007. The LROI collects data on patient, procedure, and prosthesis characteristics through standardized registration forms or by uploads from the electronic patient file of the healthcare provider after surgery. Completeness of records is validated every year by comparing the number of procedures in the LROI with the number of procedures in the hospital information system (HIS). The LROI has 98% completeness for primary hip arthroplasty, with high validity of data [1,14].

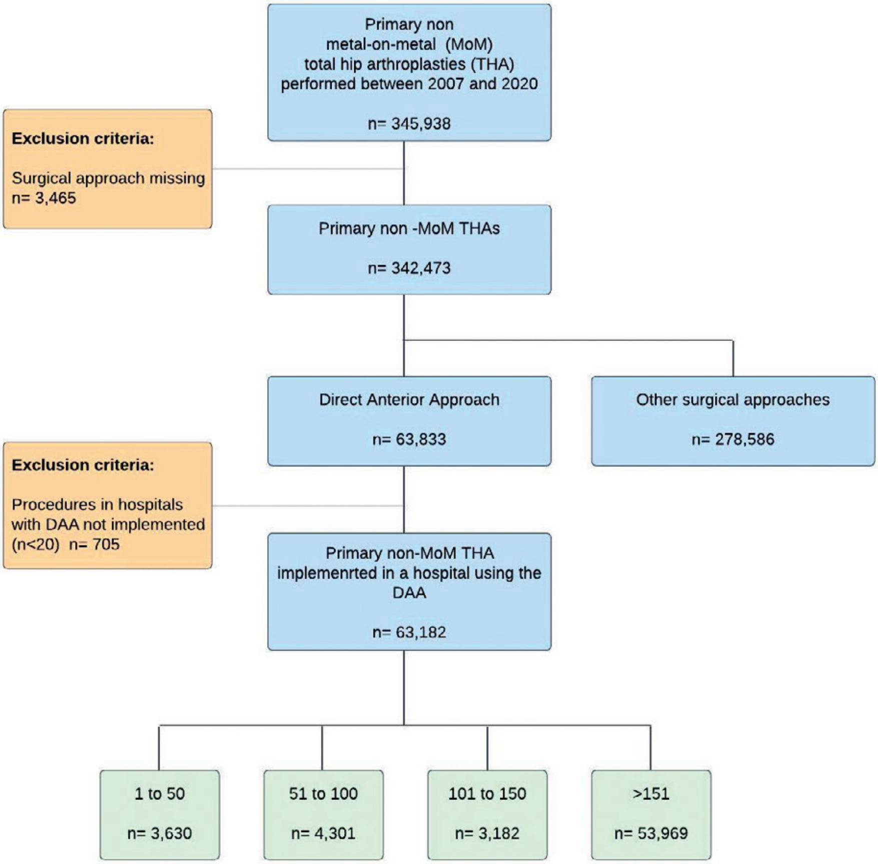

Figure 1. Flowchart describing included procedures.

Data selection

We included all primary THAs between 2007 and 2020. Metal-on-metal hip arthroplasties (including hip resurfacing) were excluded, as well as procedures in which the surgical approach was missing (n= 3,465) (Figure 1). To assess the trend of the DAA, the proportion of primary THA procedures performed using the DAA relative to the overall amount of annual THA procedures was calculated. Subsequently, the number of hospitals that implemented the DAA was determined. Hospitals were considered adopters when 20 or more primary THAs were reported per hospital using the DAA within a given year. Conversely, hospitals were considered to have discontinued their implementation when the number of DAA procedures performed in a consecutive year was <20 per hospital. Hospital-level data was determined, as surgeon-specific data was unavailable due to the anonymized nature of the data in the LROI. For hospitals implementing the DAA, patients were categorized in four phases based on date of surgery per hospital after the implementation: 1 to 50, 51 to 100, 101 to 150, and >151 procedures. Thereafter, data from different hospitals was pooled. The 5-year survival rates were calculated for different phases of the learning curve. Survival time was calculated as the time from primary THA to first revision arthroplasty for any cause, death of the patient, or the end of follow-up (January 1st 2021). A revision procedure was defined as any change (insertion, replacement, or removal) of 1 or more components. Also, patient and procedure characteristics (sex, age, American Society of Anesthesiologists(ASA) classification, diagnosis, previous surgery, Body Mass Index (BMI), and type of fixation) were explored for the DAA, and compared with other approaches and for various stages of the learning curve in hospitals implementing the DAA. Type of surgical approach was defined as: anterior, antero-lateral, direct lateral, posterolateral (PLA), and other.

Cohort

Overall, 342,473 primary THAs were included in the analyses. A total of 63,887 THA procedures were performed using the DAA, while 278,586 procedures were performed using alternative surgical approaches (Figure 1). For learning the curve analysis, we used all DAA procedures (n=63.887) Procedures performed in hospitals with less than 20 DAA procedures were excluded (n=705). There were 63,182 primary DAA THAs performed in an implementation hospital. The median follow up was 2.7 years (range 0 to 12.6).

Statistics

Continuous variables are presented as means and standard deviation (SD), and categorical data as counts and percentages. The course of implementation during follow up is presented in numbers per year with accompanying proportions. The crude survival probability was estimated by using Kaplan-Meier survival analysis with revision for any reason as the primary endpoint. Differences between experience sub-groups were assessed using log-rank tests. To account for the correlated structure of procedures within hospitals, mixed Cox proportional hazard models (frailty) with hospital as random effect was used to assess the difference in risk of revision between the experience subgroups [15]. Adjustments were performed for age, sex, ASA class, type of fixation and femoral head size. Results were reported as Hazard Ratios (HR) with 95% confidence intervals (CI). For all tests, a 2-tailed significance level of $P < 0.05$ was used. As BMI was only registered after 2014, sensitivity analyses were performed with additional adjustments for BMI. Analyses were performed using Statistical Package for the Social Sciences (version 26.0; IBM Corp, Armonk, New York) and R statistics (Coxme package) (R Foundation for Statistical Computing, Vienna, Austria) [16]

Results

Trend

The use of the DAA showed a significant increase over time. In 2007, 0.2% of all primary THAs were performed using the DAA, gradually rising to 41% in 2020 (Figure 2). Initially, 3 hospitals (3%) reported the use of the DAA in 2008 in over 20 cases, whereas this number increased to 64 hospitals (56%) by 2020 (Figure 3). In contrast, the use of direct lateral and antero-lateral approach diminished. For the posterolateral approach, only a slight decrease was observed (Figure 2). During the study period, 78 hospitals implemented the DAA. Overall, fourteen hospitals (21%) that initially adopted the DAA discontinued its use. All hospitals that discontinued the DAA performed less than 150 cases annually.

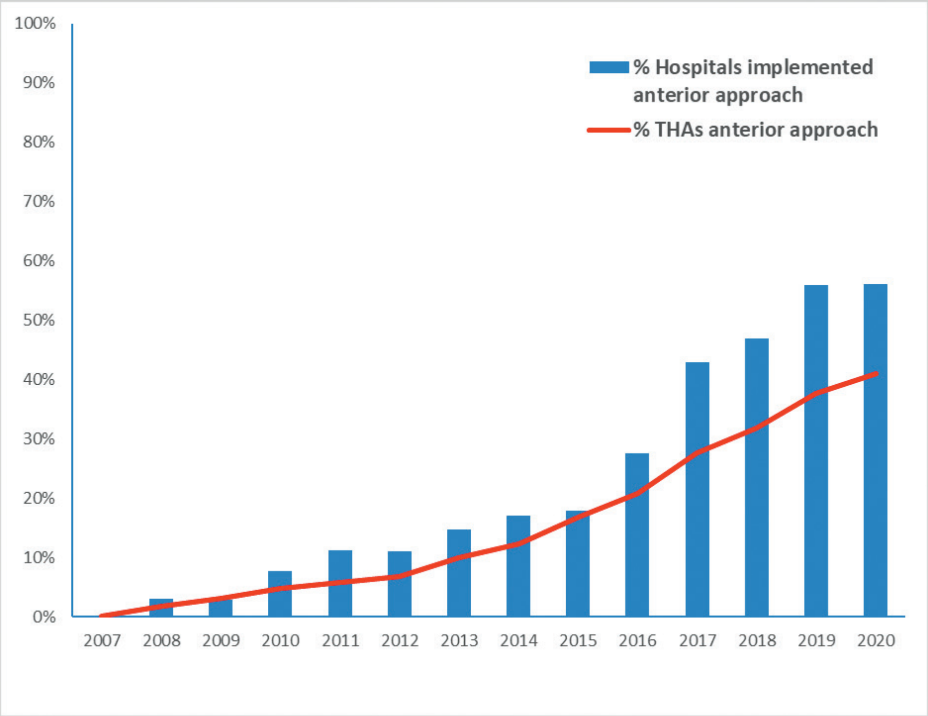

Figure 2. Proportion of primary total hip arthroplasty (THA)s performed annually with 1) proportion of THAs using the direct anterior approach (DAA) in relation to the overall amount of THAs annually (red line) and 2) the proportion of hospitals that implemented the DAA in relation to the overall number of hospitals in the Netherlands (blue bar).

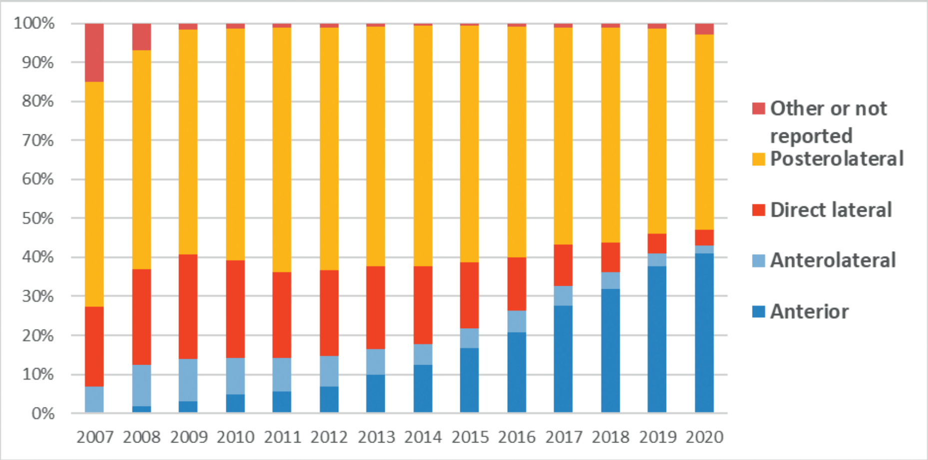

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Figure. 3. Proportion of primary total hip arthroplasties according to surgical approach in the Netherlands between 2007 and 2020.

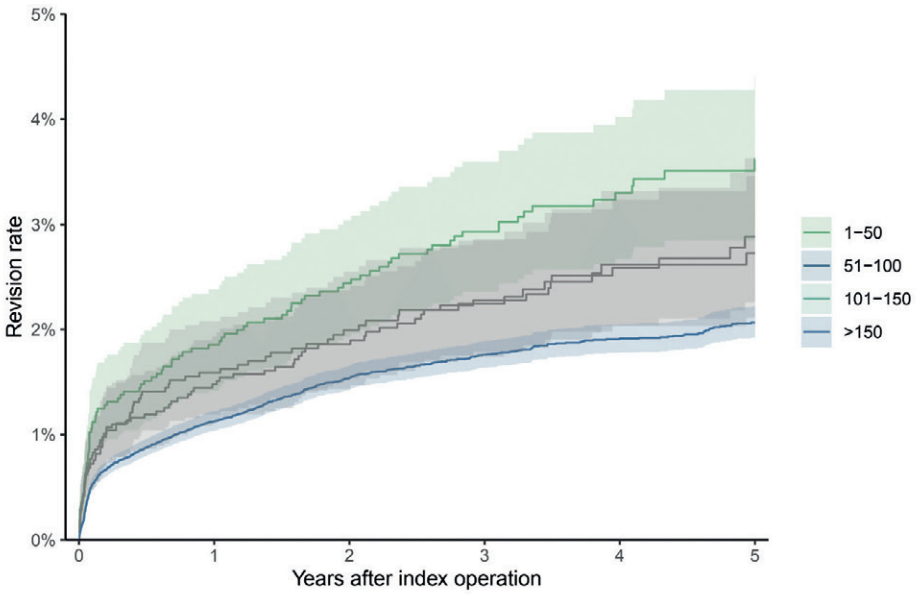

Figure 4. Revision rate for any type of reason in primary total hip arthroplasties according to direct anterior approach experience (number of cases performed after implementation per hospital) between 2007 and 2020 in the Netherlands.

Table 1. Cox hazard analyses between pooled direct anterior approach(DAA)experience groups (n=62,664).

DAA Experience groups	Hazard ratio crude (95%CI)	Hazard Ratio adjusted [a]
1-50 procedures	1.61 (1.29; 2.02)	*1.67 (1.32; 2.10)*
51-100 procedures	1.26 (0.99; 1.61)	1.24 (0.96; 1.58)
101-150 procedures	1.26 (0.98; 1.62)	1.25 (0.97; 1.62)
>150 procedures	*1.0 (ref)*	*1.0 (ref)*

a. adjusted for age, sex, American Society of Anesthesiologists class, fixation and femoral head size.

Hospital based learning curve

At 5 years, 1,095 (1.7%) THAs had been revised (Figure 4). The most common reasons for revision surgery after a DAA were femoral loosening (22%), periprosthetic fracture (19%), and infection (17%) (Table A.1, Appendix).

The overall 5-year survival rate for the DAA experience group >150 procedures was 98% (CI 97 to 98), which was significantly higher compared to the 1 to 50 procedures experience group (96% (CI 95 to 97)) (Figure 4). Multivariable survival analyses demonstrated that patients in the 1 to 50 group had a higher risk of revision (Hazards Ratio (HR) 1.7, Confidence Interval (CI) 1.3 to 2.1) compared with patients in the >150 group (Table 1). There was a trend towards a higher risk for revision for patients in groups 51 to 100 and 101 to 150, respectively, 1.2 (CI 1.0 to 1.6) and 1.3 (CI 1.0 to 1.6). However, results were not statistically significant. Sensitivity analyses, including BMI as a covariate into the analysis did not alter the results.

Patient characteristics during the learning curve

Comparable results were seen when the entire DAA group was compared to the non-DAA group, except for osteoarthritis and fixation (Table 2). A comparable distribution of age, sex, BMI, and fixation type was found in the DAA experience groups. Slightly higher values: BMI, ASA III to IV, and non-osteoarthritis patients were seen as the surgical experience increased (Table 3).

Table 2. Patient and procedure characteristics of all primary total hip arthroplasty with direct anterior approach or other approaches in the period 2007 to 2020 (n=342,473).

	Anterior approach, n= 63,887		**Other Approaches n= 278,586**	
	Mean	**(SD)**	**Mean**	**(SD**
Age	68.4	(10)	69.2	(11.5)
	n	**(%)**	**n**	**(%)**
Sex				
Female	42,385	(66)	183,761	(66)
Male	21,472 (34)	(34)	94,354	(34)
BMI				
<18.5	424	(0.7)	1,583	(1.0)
18.5-25	21,072	(37)	51,215	(32.3)
25-30	24,124	(42.4)	65,941	(41.6)
30-40	10,909	(19.2)	37,545	(23.7)
>40	368	(0.7)	2,151	(1.4)
ASA-score				
I	13,452	(21)	54,720	(20)
II	40,527	(64)	170,584	(63)
III-IV	9,532	(15)	46,719	(17)
Diagnosis				
Osteoarthritis(OA)	58,857	(92)	237,352	(85)
Non-OA	5,030	(8)	41,234	(15)
Previous surgery				
Yes	1,264	(2)	15,437	(6)
No	61,282	(98)	252,340	(94)
Fixation				
Cemented	7,804	(12)	85,502	(31)
Uncemented	50,367	(79)	164,394	(59)
Hybrid	5,636	(9)	27,392	(10)
Femoral head size				
22-28 mm	8,931	(14.9)	80,730	(29.7)
32 mm	35,895	(59.9)	138,123	(50.8)
36 mm	14,921	(24.9)	50,323	(18.5)
>= 38 mm	150	(0.3)	2,712	(1.0)

a. Numbers do not add up due to missing values.

3

Table 3. Patient and procedure characteristics of all primary total hip arthroplasty with direct anterior approach in an implementation hospital between 2007 to 2020 (n =63,182).

	1-50 (n= 3,630)		51-100 (n= 3,401)		101-150 (n= 3,182)		>150 (n= 52,969)	
	n	(%)	n	(%)	n	(%)	n	(%)
Sex [a]								
Female	2,554	(71)	2,347	(69)	2,191	(69)	34,817	(66)
Male	1,071	(29)	1,050	(30)	986	(31)	18,137	(34)
BMI								
<18.5	21	(0.8)	16	(0.6)	15	(0.6)	369	(0.8)
18.5-25	1153	(41.3)	1088	(39.3)	1016	(38.5)	17631	(36.5)
25-30	1185	(42.4)	1183	(42.7)	1122	(42.6)	20454	(42.4)
30-40	434	(15.5)	469	(16.9)	475	(18.0)	9454	(19.6)
>40	2	(0.1)	12	(0.4)	9	(0.3)	339	(0.7)
ASA class								
I	826	(23)	701	(21)	640	(20)	11,124	(21)
II	2,391	(66)	2,231	(66)	2,102	(67)	33,383	(63)
III-IV	383	(11)	441	(13)	417	(13)	8,176	(16)
Diagnosis								
Osteoarthrithis(OA)	3,437	(95)	3,197	(94)	2,990	(94)	48,611	(92)
Non_OA	193	(5)	204	(6)	192	(6)	4358	(8)
Previous surgery [a]								
Yes	70	(2)	67	(2)	54	(2)	1052	(2)
No	3,363	(98)	3,093	(98)	2,914	(98)	51,257	(98)
Fixation [a]								
Cemented	341	(9)	352	(10)	347	(11)	7,705	(12)
Uncemented	3,039	(84)	2,718	(80)	2,530	(80)	41,518	(79)
Hybrid	243	(7)	325	(10)	301	(9)	4,726	(9)
Femoral head size [a]								
22-28 mm	448	(12.8)	369	(11.6)	353	(12.2)	7,533	(15.2)
32 mm	2,126	(60.6)	2,047	(64.4)	1,856	(63.9)	29,535	(59.5)
36 mm	904	(25.8)	742	(23.3)	681	(23.5)	12,464	(25.1)
>= 38 mm	30	(0.9)	22	(0.7)	13	(0.5)	82	(0.2)

a. Numbers do not add up due to missing values.
b. BMI data was only available starting from 2014 onwards.

Discussion

This study shows that there is an increasing trend towards performing more anterior total hip replacements in the Netherlands. Over the past 13 years, an impressive increase of the DAA from 0.7% to 41% in primary THA was seen. A total of 78 hospitals adopted the DAA. However, 14 hospitals (18%) that initially adopted the DAA later discontinued its use. After implementation, a higher risk of revision was seen for the first 50 procedures, suggesting the presence of discernible learning curve. Finally, our results did not reveal substantial differences in patient characteristics between the surgical experience groups, with exception of minor variations in ASA class, BMI, and diagnosis.

Our results are in line with current literature. A survey by Abdel et al in 2019 among 628 members of the American Association of Hip and Knee Surgeons revealed a significant increase of DAA usage among respondents – increasing from 12 to 40% between 2009 and 2019 [2]. A smaller increase was seen in Norway, with only 9% of patients treated with the DAA in 2021 [17]. Registry data from Sweden, Denmark, and Finland in 2022 indicated little to no increase in DAA utilization [3,18,19]. In Canada, Pincus et al reported a rise in DAA usage from 8% in 2015 to 12% in 2017 among 30,098 patients [12]. The Australian registry, recording surgical approach data since 2015, shows that the DAA is more common in younger patients with lower BMI and ASA class. In 2022, around 29% (n=60,905) of THAs in Australia were performed using the DAA [20].

Perhaps the most important outcome when implementing a new surgical approach is the complication risk associated with it. Our study revealed an increased risk of infection, periprosthetic fracture (PFF) and loosening of the femoral component (Table A.1, Appendix). Based on current literature, THAs via the DAA seem to be associated with a higher risk of revision due to aseptic loosening of the stem compared with other approaches [12,13,21]. This is likely attributed to the challenge of accurately sizing the femoral component owing to limited visualization of the proximal femur in DAA procedures leading to early subsidence and aseptic loosening [13,21,22]. Patients who have a higher BMI pose additional difficulties as the exposure of the femur and proper placement of the stem become more challenging, due to the presence of abundant fat tissue and reduced ability to adduct the leg. This contributes to an increased risk of muscle damage, limited visualization of the proximal femur, and wound complications[23–25]. Moreover, PFFs were a common cause of revision, which is consistent with literature from the Australian and Swedish joint replacement registries, as well as several other studies [22,26–28]. However, recent literature has sparked some debate by suggesting that the choice of surgical approach may not be the primary determining factor in these findings. Factors like fixation type and implant design have emerged as potential factors influencing PFF rates in DAA patients. For instance, one study found a significantly lower risk of PFF with collared stems compared to non-collared stems and fit-and-fill stem compared to single-wedge designs [29]. Unfortunately, we were unable to confirm this hypothesis as our dataset did not include information on prosthesis type. With regard to fixation, we found considerably less use of cemented fixation in our DAA cohort. There is sufficient evidence that cemented fixation can reduce the risk of femoral complications [30]. Cemented femoral fixation may hypothetically decrease femur sided complications during the initial phases of surgeon's learning curve. Also, we found a higher risk of infection, which may be attributed to the technical complexity of the DAA and the surgeon's experience. This was confirmed by our results. In the first 50 cases after implementation, the infection rate was 16 of 3,630 (0.44%), decreasing to 11 of 3,182 cases (0.35%) in the 101 to 150 group, and 145 of 52,969 (0.27%) in the >150 procedures group. Hence, as surgeons become more proficient with the DAA, this risk can be reduced over time.

We found a marked improvement in survival after reaching a certain threshold of surgical cases (>150). This is in accordance with previous papers that have described a learning curve for the DAA [9,10]. Peters et al conducted a study using Dutch registry data. The authors reported a learning curve for the DAA of 100 cases. However, their sample was restricted to six high-volume centers that initiated the use of the DAA in the Netherlands. This methodology may introduce a selection bias towards "early adopters" and limit generalizability to less specialized orthopaedic facilities incorporating the DAA [10]. Berndt et al retrospective case series on 140 hips showed a 5-year survival rate of 96.9%, but 14 patients with perioperative complications were excluded, most of which occurred in the first twenty cases [26]. Gofton et al's case series found that excluding the initial twenty THAs resulted in a significant improvement in survivorship rate, from 78.9% to approximately 96.3% at five years [27]. Similarly, Muller et al's single surgeon retrospective series showed a 96.3% five-year survival rate after excluding the first 20 cases, which had only achieved 80% survival [28]. Our experience group of 1 to 50 patients achieved a 96.5% five-year survivorship, which is comparable with previous studies that report results on a surgeon level [11]. While we observed a higher revision risk in the first 50 cases, it is essential to note that the DAA still exhibit excellent survival rates when compared to the PLA, even during the early phases of the learning curve. Van Steenbergen et al reported a lower 5-year revision rate for the DAA (2.3%) compared to PLA (3.1%) [31]. Notably, the 5-year revision rates for DAA improved over time (from 3.5% in 2017 to 2.3% recently), reflecting a learning curve effect. In our study, we found crude 5 year survival rates for the 1 to 50 group of 96.5%, which is only slightly lower compared to the survival rates for the PLA.

It is hypothesized that during the initial phases of the learning curve, surgeons tend to be selective in their patient choices. This targeted approach allows surgeons to refine their skills in a controlled setting before tackling more complex cases [23,32]. In contrast to our expectations, the results in our large cohort did not reveal substantial differences in patient characteristics between the surgical experience groups, with a minimal increase in BMI, ASA class, and number of non-OA patients over the course of surgical experience.

Although there was some patient selection during the implementation, this was less then generally expected.

Our study's primary strength is its utilization of the LROI database, a population-based nationwide registry. This database has been noted for its high level of completeness [14]. Our study encompasses the entire Netherlands, which enhances the generalizability of the findings. Moreover, our study had the advantage of a 5-year follow-up period. However, registry data is also observational in nature and lacks the ability to control for all confounding variables. In addition, the registry does not provide information regarding complications that did not necessitate revision surgery. These include complications like dislocations, proximal femoral fractures treated with open reduction and internal fixation alone, and DAIR procedures without a component exchange. Furthermore, our analyses relied on the number of DAA cases performed by each hospital as an indicator of hospital-level adoption. Due to the anonymized nature of the LROI data, we were not able to use surgeon-specific data, including cases where experienced DAA surgeons may have switched hospitals. Consequently, we were unable to assess variations in surgeon volume. Nevertheless, we believe that our hospital-level approach remains valuable in evaluating the implementation of the DAA, as hospitals play an important role in establishing protocols and guiding their surgical teams in adopting new approaches. Despite these potential limitations, our results were in corroboration with other studies describing the learning curve on an individual surgeon level. Also, we acknowledge the potential influence of surgeon generations and career stages as factors impacting the DAA implementation and outcomes. Second-generation surgeons may benefit from a shorter learning curve due to the insights and experiences shared by their first-generation counterparts. Moreover, orthopaedic fellows who acquire DAA skills during training may have an advantage, resulting in a smoother learning curve and improved outcomes [33]. Conversely, experienced surgeons accustomed to the PLA may encounter unique challenges when transitioning to the DAA due to established habits. This represents a limitation in our analysis, as these nuances may not have been captured in our hospital-level approach.

It is likely that the percentage of THAs using DAA will further increase. We advise hospitals and surgeons to mitigate the learning curve for the DAA as much as possible. The DAA has not yet been proven superior to other surgical approaches [34]. A careful learning program and patient selection must be employed to reduce complications during the initial stages of implementing this approach. This can include anatomical dissections courses, virtual reality simulated surgery, commencing the implementation with colleagues, and mentoring programs to ensure that the surgical team is appropriately skilled [35,36]. We recommend caution in adopting the DAA and subsequent utilization in a limited capacity, similar to what was observed among the 14 hospitals that discontinued the DAA in our study population. In the Netherlands, surgeons are advised to collaboratively decide on the surgical approach with their patients[37]. However, there is no explicit protocol or guideline outlining the specific topics to be covered (e.g. the learning curve). The authors believe that, just as with all surgical procedures, all possible adverse outcomes during the implementation of surgical technique should be mentioned to the patient. Consequently, for the sake of our patients, it is important to openly discuss when a surgeon is in their learning curve.

Conclusion

The use of DAA for primary THA in the Netherlands has significantly increased with 56% of Dutch hospitals who implemented the DAA. For hospitals implementing the DAA, there is a significant learning curve, especially in the first 50 procedures. Furthermore, there is a slight patient selection for the DAA experience groups with <150 procedures. If there is a strong wish to adopt a new approach one must do so with proper guidance to decrease the patient burden of this transition.

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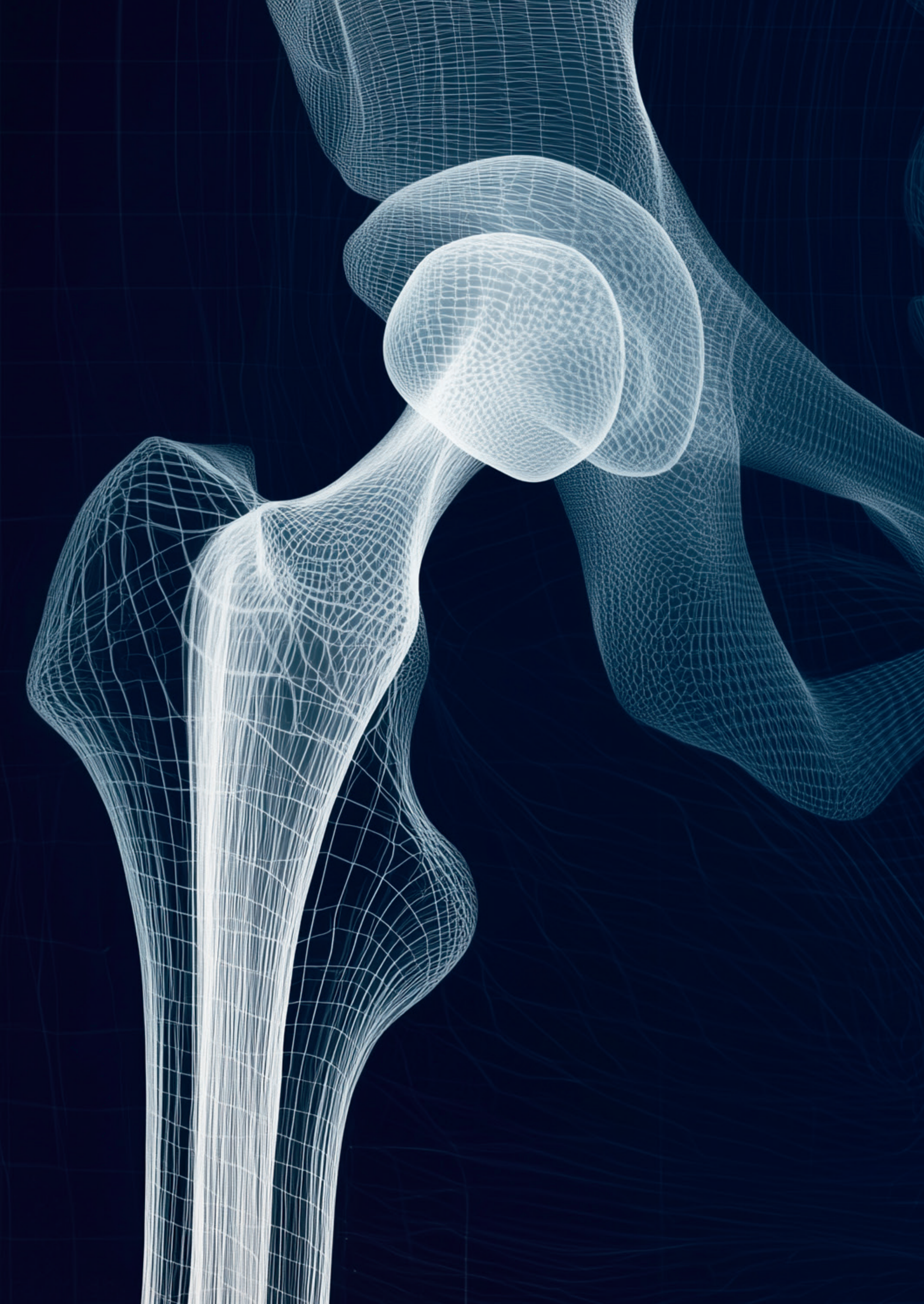
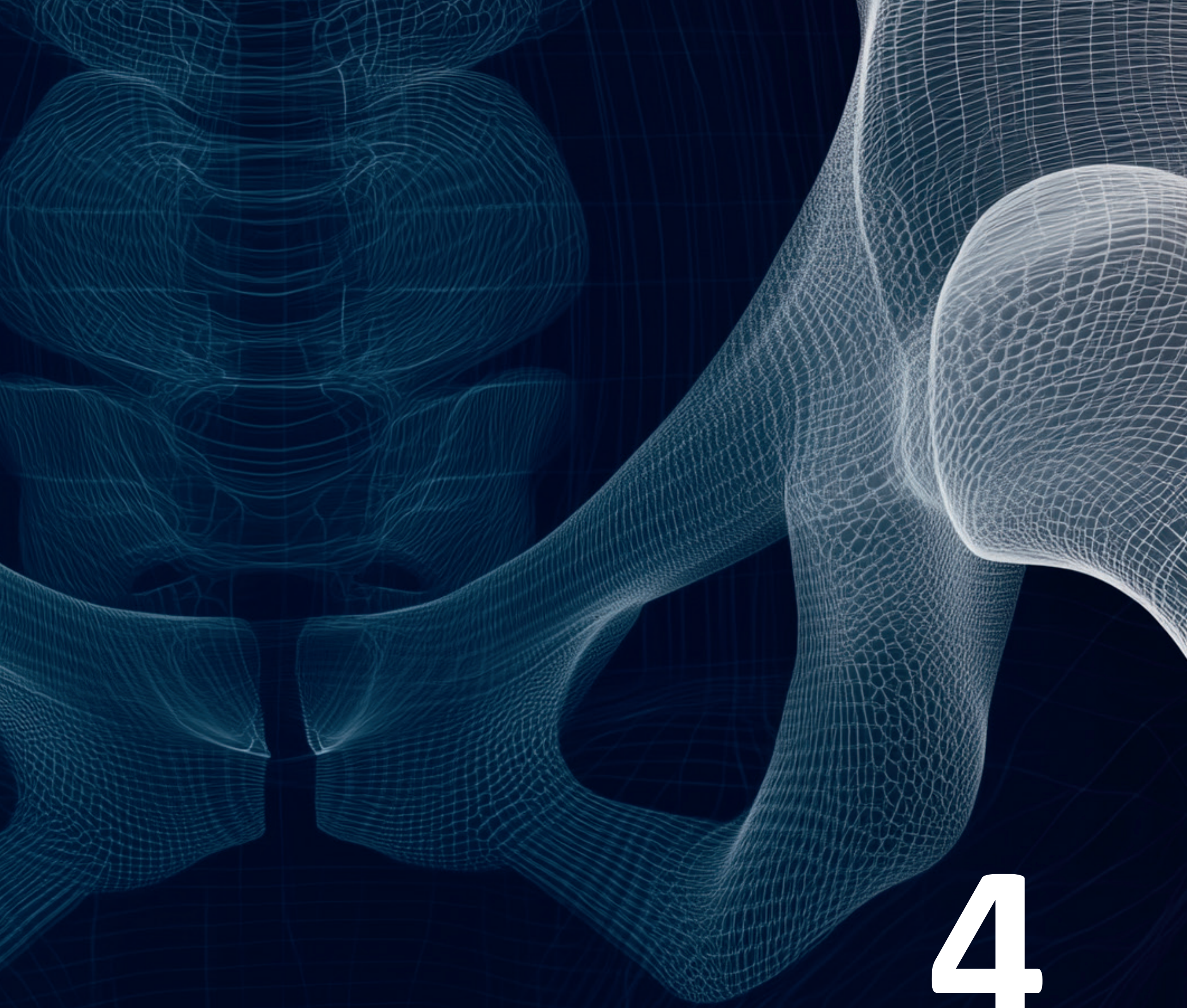
Appendices

Table A.1 Reasons for revision within 5 years in primary total hip arthroplasty using the direct anterior approach(DAA) according to DAA experience group learning curve phase in the Netherlands (n= 63,182).

	1-50 [b] (n= 106)		1-100 [b] (n= 79)		101-150 [b] (n= 70)		>150 [b] (n= 840)	
Reason for revision	n	(%)	n	(%)	n	(%)	n	(%)
Infection	16	(15)	17	(22)	11	(16)	145	(17)
Dislocation	12	(11)	12	(15)	16	(23)	132	(16)
Periprosthetic fracture	20	(19)	14	(18)	19	(27)	156	(19)
Loosening femoral component	27	(26)	20	(25)	16	(23)	178	(21)
Loosening acetabular component	12	(11)	9	(11)	8	(11)	76	(9)
Liner wear	4	(4)	1	(1)	2	(3)	10	(1)
Other[a]	20	(19)	20	(25)	16	(23)	189	(23)

a. Other was defined as periarticular ossification, symptomatic metal on metal articulation, Girdlestone or undefined reasons.
b. A procedure may have more than one reason for revision. As such, the total is over 100%.





4

The Direct Superior Approach in Total Hip Arthroplasty: A Systematic Review

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The Journal of Bone & Joint Surgery Reviews. 2024 Mar 15;12(3)e23.00182.

Abstract

Background
Evolution of the surgical approach for total hip arthroplasty (THA) has led to the development of the minimally invasive direct superior approach (DSA). It is hypothesized that the DSA reduces postoperative pain and hospital length of stay (LOS). We aimed to provide an overview of current evidence on clinical, functional, and radiological outcomes with respect to risk of revision, complications, pain scores, physical function, operative time, LOS, blood loss, radiological outcomes, and learning curve.

Methods
A comprehensive search of Medline, Embase, Web of Science, Cochrane Central Register of Controlled Trials, and Google Scholar, reported according to the PRISMA-S guidelines, was conducted to identify studies evaluating clinical, functional, and radiological outcomes of the DSA. Quality assessment was performed using the Cochrane Risk of Bias tool and Newcastle-Ottawa Scale. The review protocol was prospectively registered in the International Prospective Registry of Systematic Reviews (PROSPERO).

Results
17 studies were included, generally of moderate quality. Qualitative synthesis evidenced accurate implant positioning, short LOS, and a short learning curve. Conflicting findings were reported for postoperative complications compared to conventional approaches. Better functional outcomes were seen in the early postoperative period than the posterolateral approach. Outcomes such as blood loss and operative time exhibited conflicting results and considerable heterogeneity.

Conclusions
Based on moderate-certainty evidence, it is uncertain if the DSA provides short-term advantages over conventional approaches such as PLA. There is limited evidence on long-term outcomes post-THA using the DSA. Further studies and ongoing registry monitoring is crucial for continuous evaluation of its long-term outcomes.

Introduction

The selection of the surgical approach for total hip arthroplasty (THA) in daily practice is determined by surgeon experience, training, and personal preferences [1]. The posterolateral approach (PLA) is the most frequently used technique for THA, although a shift to the anterior approach (DAA) is observed more recently [2]. The DAA is known to have a reduced revision risk for dislocation, early mobilization and reduced hospital length of stay (LOS) compared to the PLA, but a higher risk of femoral-sided revision and a steep learning curve is reported [3-7].

In order to decrease dislocation rates and improve the early recovery of patients undergoing the traditional PLA, the direct superior approach (DSA) was introduced. The DSA, a modification of the PLA, preserving the iliotibial band and short external rotators, excluding the piriformis and conjoint tendon [8-9]. It is hypothesized that the DSA may help reduce postoperative pain, intraoperative blood loss, and hospital LOS [10-13]. By contrast, it is hypothesized that minimally invasive THA may lead to increased risk of complications such as component malposition and femoral stem undersizing [14]. Last, implementation of new surgical approaches is associated with a learning curve in which higher operative times and complication rates can be encountered [5-7]. Although numerous studies suggest a benefit for patients undergoing minimally invasive THA, some surgeons remain skeptical that these changes in surgical technique are responsible for the observed improvements [15].

In this systematic review, we aim to provide an overview of current evidence on clinical, functional, and radiological outcomes in primary THA performed using the DSA. Complication rates, reasons for revision, pain scores, physical function, operative time, hospital LOS, blood loss, radiological outcomes, and learning curve were explored.

Methods

Protocol and registration

A systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [16]. The protocol of this systematic review was prospectively registered in the International Prospective Registry of Systematic Reviews (PROSPERO) (ID: CRD42022371913).

Surgical technique

The objective of the DSA is to preserve the iliotibial tract, obturator externus tendon, and quadratis femoris muscle [17]. The procedure involves a small incision along the posterior edge of the greater trochanter, extending in proximal direction. An incision is made through the gluteus maximus fibers, skin, subcutis, and gluteus maximus fascia, ensuring preservation of the iliotibial band. The gluteus maximus is incised. The conjoined tendon and piriformis tendon are detached, marked, and positioned posteriorly. Lifting the gluteus minimus, a capsulotomy is performed in line with the femoral neck. Subsequently, the hip is dislocated, and this is succeeded by the resection of the femoral neck, reaming of the acetabulum, and the insertion of the femoral and acetabular components. Long DSA Hohmann retractors and specialized reamers are used for this procedure. The capsule is closed side-to-side, the piriformis reattached, and the fascia, subcutaneous tissue, and skin closed in layers. Detailed illustrations of the DSA, are displayed in a comprehensive article by Barret et al. [9].

Eligibility criteria

Studies were eligible if: (1) authors reported on the outcome of primary THA through the DSA; (2) at least 10 adult patients were included; (3) full text was available; (4) operative technique was defined; (5) written in English, French, Dutch, or German. Exclusion criteria were: (1) cadaveric studies; (2) no original research (3) no full text available; (4) former systematic reviews; (5) animal studies; (6) hip hemi-arthroplasties; and (7) revision procedures. Furthermore, we excluded alternative posterior-oriented minimally invasive methods, including the Supercapsular Percutaneously Assisted Total Hip (SuperPATH), due to its specific emphasis on preserving the piriformis muscles and avoiding intra-operative hip dislocation.

Search strategies, information sources, and study selection

Studies investigating the outcome of the DSA to THA were identified using Cochrane Central Register of Controlled Trials (CENTRAL), Medline, Embase, Web of Science, and Google Scholar on December 18, 2023. The Medline search strategy was developed and transferred into similar search strategies for the other databases in collaboration with a clinical librarian (A.M.v.d.W.-O.). The search in all databases was performed with a combination of the following keywords: “arthroplasty,” “hip replacement,” “hip prosthesis,” “direct superior,” “direct superior approach,” “iliotibial,” and “transpiriformis” (Table S1 supplementary data). References of the included articles were screened to identify additional studies. Eligibility assessment was performed by 2 independent reviewers (B.v.D. and R.M.P.) using Rayyan [18]. Disagreements were solved by consulting the senior author (W.P.Z.).

Data extraction

Data extraction was performed independently by 2 authors (B.v.D. and R.M.P.). Any disagreement was resolved by discussion between the reviewers. In case of no consensus, the conflict was resolved by the senior author (W.P.Z.). The following data were extracted: study design, study population, author, publication year, country, patient characteristics (age, gender, body mass index [BMI]), operative treatment strategy, length of follow-up, and outcome. Primary outcome measures were (1) revision rates, (2) type of complication, (3) pain and physical function measured with patient-reported outcome measures, and (4) radiological outcomes as assessed using plain pelvic and hip radiographs. Secondary outcome measures were (1) operative time, (2) LOS, (3) blood loss, and (4) learning curve.

Quality appraisal and risk of bias assessment

Two authors (B.v.D. and R.M.P.) independently assessed the risk of bias and methodological quality of the included studies. Randomized controlled trials (RCTs) were assessed using the Cochrane Risk of Bias tool. A study is judged to have high risk of bias if at least 1 domain scores as such. Observational studies were assessed with the Newcastle-Ottawa Scale, which consists of 8 items with 3 subscales and a maximum score of 9 for these 3 subscales. The quality of the studies was determined based on the obtained scores: low quality 0 to 3, moderate quality 4 to 7, and high quality 8 to 9.

Data synthesis and analysis

Owing to the small number of studies, the retrospective design, large heterogeneity of the control groups, and differences in outcomes reported, we were not able to perform a quantitative synthesis of the data as it would be methodologically unsound. Therefore, data are described narratively in the Results section. A summary of findings for each outcome in which 3 or more studies are selected for this review is provided.

Results

Study selection

We identified 388 studies from electronic databases searches. One hundred eighty-one studies were excluded after reviewing duplications using EndNote, and 207 articles were screened by title and abstract, of which 52 articles were eligible for full-text screening. Ultimately, 17 qualifying articles were selected [10-13, 17, 19-30] (Figure 1).

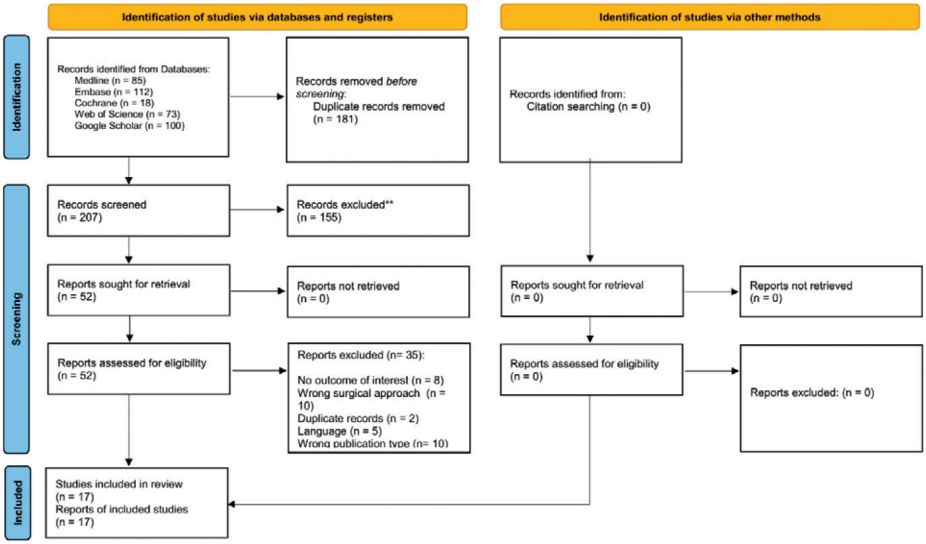

Figure 1. PRISMA flow diagram of included studies. PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Quality assessment and methodology

The characteristics of included studies are presented in Table I. Seventeen studies including 3,551 patients met the inclusion criteria [10-13, 17, 19-30]. The number of patients per study ranged from 20 to 1,341, with a mean age range of 51 to 74 years (Table I). Follow-up ranged from 3 months to 2.7 years. Fifteen studies had an observational design, including 2 register studies (n = 1,341 and n = 343) [29-30]. Two studies were RCTs [26, 28]. We found that most studies had a moderate level of evidence (Tables II and III; Fig. 2). The major methodological limitations were retrospective design, small sample sizes, and no independent blind assessment of end points.

Table 1. Characteristics of the included studies.

Author, Year Country	Study design	Follow-up (SD)	No. patients DSA (n)	Control group (n)	Age, mean in years (range)	Sex (male/ female in %)	BMI (kg/m2)	Outcome variables
Roger 2011 [17] USA	Retrospective cohort study (case series)	22 months (14-33)	135	n.a.	72 (45-92)	51/49	27.3(19,5-40)	2-3, 8-11,14
Duijnisveld [19] Netherlands	Prospective cohort study	12 months	52	MPA* 52	DSA: 69 (±8.4), MPA: 69 (±8.4)	46/54	25 (±3.4)	2-11, 13
Ezzibdeh 2021 [10] USA	Retrospective case-controlled study	2.7 years (±0.7)	20	MPA* 20	DSA: 51 (±12), MPA: 64 (±9)	50/50	26(±5)	2-3, 8-12
Ezzibdeh 2020 [20] USA	Retrospective cohort study (case series)	108 days (±36)	301	n.a.	63 (±10)	43/57	28.4 (±5.3)	2, 8-10, 12
Ezzibdeh 2020 [21] USA	Retrospective cohort study (case series)	108 days (±28)	40 (20 vs 20)	MPA* 20	1st 20 DSA: 58(±10) 2nd 20 DSA: 51(±12) MPA: 64(±9)	65/35 vs 50/50	28(±5)	3, 8-13
Kenanidis 2022 [12] Greece	Retrospective case-controlled study	12 months	100	PL 100	DSA: 65.4 (±8.4), PL: 65.5 (±7.9)	42/58	28.38 (±3.09)	1-3, 4,6, 8-11, 14
Korth, 2021 [22] USA	Retrospective case series	2.2 (±0.4 years)	40	n.a.	55 (±12)	57.5/42.5	27 (±5)	2-3, 8-12, 14
Leonard 2021 [13] UK	Retrospective case-controlled study	1 year	100	PL 100	DSA: 68.0 (26 to 88), PL: 68.05 (29-89)	61/39	28 (16.9-50.4)	2, 4, 5, 8-11, 13
LeRoy 2020 [11] USA	Retrospective cohort study	1 year	403	PL 273	DSA: 63.4 (±10.4), PL: 63.4 (±9.2)	50.5/49.5 vs 47.1/52.9	29.5 (±6) vs 28.1 (±5.1)	2, 8-10
Nam 2016 [23] USA	Prospective cohort study	Minimum 1 year 2.8 (±1.0) years	42	MPA* 196	DSA: 63.9 (±6.1), MPA: 52.4 (±6.1)	-	-	4

Table 1. Characteristics of the included studies. (continued)

Author, Year Country	Study design	Follow-up (SD)	No. patients DSA (n)	Control group (n)	Age, mean in years (range)	Sex (male/ female in %)	BMI (kg/m2)	Outcome variables
Siljander 2020 [24] USA	Retrospective case-controlled study	3 months	333	DAA 1.846 PL 3.162	DSA: 62(±11), DAA: 65 (±10), PL: 64 (±11)	46/54	27.4 (±4.4)	1,2, 8, 10
Tsiridis 2020 [25] Greece	Prospective cohort study	1 year	200	n.a.	66.53 (±8.87) (49-87)	35.5/64.5	27.59 (±2.98)	2, 3, 6, 8-11, 14
Ulvivi 2021 [26] Italy	Prospective RCT	6 months	22	PL 23	DSA: 74 (±8.9), PL: 72 (±7.7)	32/68	23 (±2.8)	2-4, 6, 8-10, 12
Watanabe 2021 [27] Japan	Retrospective case-controlled study	2 years (±0.4)	30	PL 30	DSA: 68.7 (±8.8), PL: 66.2 (±9.4)	17/83	24 (±3.7)	2, 11
Xiao 2021 [28] China	Prospective RCT	3 months	49	PL 57	DSA: 71.06 (±10.87), PL: 73.93 (±10.02)	33/67	27.73 (±4.18)	3, 4, 8, 14
Van Dooren 2023 [29] Netherlands	Retrospective cohort study	1.6 years	1,341	DAA 56.626 PL 117.576	DSA: 68,21 (±10.1), PLA: 69,1 (±10.6)	37/63	26.4 (±4.1)	1,2
Van Dooren 2023 [30] Netherlands	Retrospective cohort study	1 year	343	DAA 15.017 PL 22.616	DSA: 68.0(±8.5), DAA: 68.6 (±9.1), PLA: 69.1(±9.1),	35/65	26.1 (±4.0)	4,5,6,7

1, risk of revision; 2, complications; 3, Harris Hip Score; 4, pain scores (NRS VAS); 5, OHS; 6, HOOS-PS; 7, EQ5D; 8, operative time; 9, blood loss; 10, time to hospital discharge LOS; 11, accuracy of implant position; 12, gait analysis; 13, learning curve; 14, incision length. * not available, due to categorized nature of data.

Table 2. Risk of bias assessment using the Newcastle-Ottawa Quality Assessment Scale for cohort studies.

Cohort				
Studies	**Selection**			
	Representativeness of the exposed cohort	**Selection of the non-exposed cohort**	**Ascertainment of exposure to implants**	**Demonstration of absence of outcome of interest at start of study**
Roger 2011 [17]	★	☆	★	★
Duijnisveld 2020 [19]	★	★	★	★
Ezzibdeh 2020 [21]	★	★	★	★
Ezzibdeh 2020 [20]	★	★	★	★
Korth, 2021 [22]	★	☆	★	★
LeRoy 2020 [11]	★	★	★	★
Nam 2016 [23]	★	★	★	★
Siljander 2020 [24]	★	★	★	★
Tsiridis 2020 [25]	★	☆	★	★
Van Dooren 2023 [29]	★	★	★	★
Van Dooren 2023 [30]	★	★	★	★

* A study can be given a maximum of one star for each numbered item within the Selection and Outcome categories. A maximum of two stars can be given for Comparability. A star was left white when it was not allocated. The quality of the studies was determined on the basis of the obtained scores: low quality 0–3, moderate quality 4–7, high quality 8–9.

Table 3. Risk of bias assessment using the Newcastle-Ottawa Quality Assessment Scale for case control studies.

Case control				
Studies	**Selection**			
Author, year	**Is the case definition adequate?**	**Representative-ness of the cases**	**Selection of controls**	**Definition of Controls**
Ezzibdeh 2021 [10]	☆	★	★	★
Kenanidis 2022 [12]	★	★	★	★
Leonard 2021 [13]	☆	★	★	★
Watanabe 2021 [27]	★	★	★	★

* A study can be given a maximum of one star for each numbered item within the Selection and Exposure categories. A maximum of two stars can be given for Comparability. A star was left white when it was not allocated. The quality of the studies was determined on the basis of the obtained scores: low quality 0–3, moderate quality 4–7, high quality.

Comparability	Outcome			Total quality
Comparability of cohorts based on design or analysis	Assessment of outcome	Was follow-up long enough to have outcomes	Adequacy of follow-up of cohorts	
☆☆	☆	★	☆	4/9 moderate
★☆	☆	★	★	7/9 moderate
☆☆	☆	★	☆	5/9 moderate
☆☆	☆	★	☆	5/9 moderate
☆☆	☆	★	★	5/9 moderate
★☆	★	★	☆	7/9 moderate
☆☆	☆	★	☆	5/9 moderate
★★	★	★	☆	8/9 high
★☆	★	★	★	7/9 moderate
★★	★	★	★	9/9 high
★★	★	★	☆	8/9 high

Comparability	Exposure			Total quality score
Comparability of cases + controls	Ascertain-ment of exposure	Same ascertainment method for cases + controls	Non-response rate	
☆☆	☆	★	☆	4/9 moderate
★☆	★	★	★	8/9 high
☆☆	☆	★	☆	4/9 moderate
★☆	☆	★	☆	6/9 moderate

Outcomes

Complications

Fourteen studies reported on complication rates (Table 4). Complication rates were reported at different timepoints (3 months to 2.7 years). Overall, 51 (1.6%) complications were reported and in 39 (1.3%) cases revision surgery was needed. The most common reason for revision was periprosthetic fracture. Eight (0.3%) cases of postoperative dislocation were observed, for which five revisions were performed. No revisions for cup malpositioning were reported. One revision due to excessive leg lengthening and one revision for inadequate offset was reported [17].

Seven studies compared DSA with PLA complication rates [11-13, 24, 26-27, 29]. Ulvivi et al. performed an RCT comparing the postoperative results of 25 DSA patients with 25 PLA patients. They reported a higher rate of adverse events (two dislocations and one periprosthetic fracture) for the DSA (3/25; 12%) compared to one (thromboembolic event) for the PLA (1/25; 4%). Both dislocations were treated with closed reduction [26]. One high quality large register study reported a lower overall risk of revision (1.6% vs 3.1%) and for dislocation (0.3% vs 1,0%) for the DSA (n=1,341) compared to the PLA (n=117,576) [29]. In addition, no difference in risk of revision for periprosthetic fracture was found (0.3% vs 0.4%). In contrast, another high-quality retrospective observational statewide registry study found a significantly higher early revision rate (p=0.015) for the DSA (n=333 with 1.5% revisions) compared to the PLA (n=3,162 with 0.4% revisions) [24]. The difference in revision rates in the latter study was due to the number of periprosthetic fractures. In contrast, no difference in dislocations or infection was reported. Four other observational studies did not find any difference in complication rates between the DSA and the PLA or mini posterior approach (MPA) [11-13, 27]. Overall, while a RCT with small sample sizes suggest a disadvantage for the DSA, larger real-world evidence studies present different outcomes.

Pain

Seven studies reported on postoperative pain scores [12-13, 19, 23, 26, 28]. Four studies [12-13, 19, 28] reported on immediate postoperative VAS scores. Xiao found lower pain scores for the DSA than for the standard PLA in the first three postoperative days (p<0.001) [28]. By contrast, one high-quality study found no significant difference in pain scores between the DSA and the PLA on the first postoperative day and last day of hospitalization [12]. We found through moderate to high-quality studies that postoperative pain levels did not differ clinically between DSA and PLA patients in the first 5 days or after 1, 2, 3, and 4 weeks, 3 months, and 6 months [13, 26, 30]. Duijnisveld et al. reported comparable pain scores between the DSA and MPA on the first postoperative day and last day of hospitalization, and no difference in pain scores during rest and activity at 3 months and 1 year follow-up [19]. Last, one study with moderate evidence reported no difference in the incidence of moderate-to-severe pain between the DSA and MPA over the trochanter, anterior thigh, or lateral thigh at a minimum of 1-year follow-up [23].

Physical function

The most commonly used instrument to measure postoperative recovery was the Harris Hip Score (HHS), where higher scores represent better physical functioning. In total, 9 studies reported on functional scores after using the HHS [10, 12, 17, 19, 21-22, 25-26, 28]. Mean HHS scores in the early postoperative phase were better for the DSA than for the PLA in one high quality study and one RCT [12, 28] (Table 5): both studies reported significantly higher HHS for the DSA than for the PLA after 1 month follow-up. One RCT found significantly higher HHS for the DSA than for the PLA at 1 week follow-up [26]. By contrast, another RCT reported no difference in functional improvement (HHS) after 1 week and 1 month follow-up [26]. None of the included studies found a significant difference in HHS between the DSA compared with their PLA or MPA counterparts at 3 months, 6 months, 1 year, or 2 years follow-up. [10, 12, 22, 25-26].

Four moderate-to-high-evidence studies reported patient-reported outcomes using the Hip Disability and Osteoarthritis Outcome Score (HOOS) questionnaire [12, 25-26], a hip-specific questionnaire intended to evaluate symptoms and functional limitations of patients suffering from hip dysfunction. One RCT reported no difference in HOOS between the DSA and the PLA after 1 week, 2 weeks, 3 weeks, 1 month, 3 months, and 6 months [26]. Second, a high quality study reported significantly higher functional scores for the DSA at 1 month follow-up than for the PLA. After 1 month DSA and PLA functional scores were comparable [12,26, 30].

Table 4. Number of complications for the DSA per study.

	Roger 2011[11] N= 135	Duijnisveld 2020[19] N= 52	Ezzibdeh 2021[10] N=20	Ezzibdeh 2020[20] n=301	Ezzibdeh 2020[21] n=40	Kenanidis 2022[12] n=100	Korth, 2021[22] n=40
Follow-up mean	22 months	12 months	2.7 years	108 days	90 days	12 months	2.2 years
Surgical complication rate	3 (2.2%)	2 (3.8%)	0 (0%)	7 (2.3%)	0 (0%)	1 (1%)	0 (0%)
Revision rate	2 (1.5%)	2 (3.8%)	0 (0%)	4 (1.3%)	0 (0%)	1 (1%)	0 (0%)
Complication type							
Dislocations	0	0	0	0	0	0	0
Superficial wound infection	0	0	0	N/R	0	1	0
Deep wound infection	0	0	0	N/R	0	0	0
Intraoperative fracture	1 †	0	0	3	0	0	0
Postoperative fracture	N/R	2	0	4	0	N/R	0
Loosening	0	N/R	0	N/R	0	N/R	0
Sciatic nerve palsies	0	0	N/R	N/R	0	0	N/R
Thromboembolic event	0	0	N/R	2	N/R	0	N/R
Other ‡	2 (2 r)	0	0	0	0	0	0

* Treated with closed reduction; †, OSM during primary surgery; N/R, not reported; ‡, defined as excessive leg lengthening and/or inadequate offset; r, revision(s); rev, revised.

Leonard 2021[13] n=100	LeRoy 2020[11] n=403	Siljander 2020[24] n=333	Tsiridis 2020[25] n=200	Ulvivi 2021[26] n=25	Watanabe 2021[27] n=30	Van Dooren 2023[28] n=1,341	Total N=3,117
1 year	2 years	3 months	1 year	6 months	2 years	1.6 years	
1 (1%)	0 (0%)	10 (3%)	2 (1%)	3 (12%)	1 (3.3%)	21 (1.6%)	51 (1.6%)
1 (1%)	0%	5 (1.5%)	2 (1%)	1 (4%)	0 (0%)	21 (1.6%)	39 rev; 1.3% and 8 (0.5%) treated intraoperatively
N/R	0	2* (1 r)	0	2*	0	4	8 (5; 0.2% rev)
N/R	0	N/R	1	0	0	N/R	2 (2; 0.1% rev)
N/R	0	1 (1 r)	1	0	0	4	6 (6; 0.2% rev)
0	0	3 †	0	0	1	N/R	8 (8; 0.3% rev)
1	0	4 (3 r)	N/R	1	0	4	16 (15; 0.5% rev)
N/R	0	N/R	N/R	0	N/R	7	7
N/R	N/R	N/R	0	0	0	N/R	0
N/R	N/R	2	0	0	N/R	N/R	4
0	0	0	0	0	0	2	6 (4; 0.1% rev)

Table 5. Preoperative and postoperative Harris Hip Scores.

Study	Groups	HHS baseline	HHS 1 month	HHS 3 months	HHS 6 months	HHS 1 year	HHS 2 years	Outcome
Korth 2021[22]	DSA	57 (17)		88 (12)		96 (6)	97 (5)	Significant HHS improvement (p<0.001) compared to baseline. Plateau by 2 years (p=0.359)
Tsiridis 2020[25]	DSA	44.8 (5)	80 (4.6)	87.9 (5)		91.4 (5.4)		Significant HHS improvement (p<0.001) at 1,3, and 12 months compared to baseline.
DSA vs MPA								
Duinisveld 2020[19]	DSA	56 (16)		87 (16.9)		87 (16.2)		Significant HHS improvement (p<0.001) compared to baseline. No difference between DSA and MPA (p=0.75).
	MPA	54 (15)		85 (16.4)		89 (14.8)		
Ezzibdeh 2021[10]	DSA	56 (11)		89 (12)		N/R	98 (6)	Significant HHS improvement (p<0.001) compared to baseline. No difference between DSA and MPA at 3 months (p=0.72) and 2 years (p=0.389).
	MPA	61 (20)		89 (10)		N/R	96 (11)	
Ezzibdeh 2020[21]	DSA	56 (11)		89 (11)				No difference in mean HHS between DSA and MPA at 3 months (p>0.05)
	MPA	61 (20)		89 (10)				
DSA VS PL approach								
Kenanidis 2022[12] †	DSA	44.5 (3.6)	81.6 (3.3)	88.9 (3.3)	92.6 (3.6)			Significant HHS improvement at all follow-up times (p<0.001) compared to baseline. Greater functional improvement for the DSA at 1 month (P<0.001) compared to the PLA.
	PL	44.4 (3.8)	77.8 (4.0)	88 (3.7)	92.7 (2.3)			
Ulvivi 2021[26] ‡	DSA	N/R	N/R	N/R	N/R			Significant HHS improvement (p<0.001) at 6 months compared to baseline. No statistically significant differences between groups. Plateau after 3 months.
	PL	N/R	N/R	N/R	N/R			
Xiao 2021[28] † ‡	DSA	N/R	N/R	N/R				Significant HHS improvement from baseline to 1 week, 1 month, and 3 months. DSA had higher HHS at 1 week and 1 month (P=0.00).
	PL	N/R	N/R	N/R				

* Roger (2011) not reported due to unknown timepoint of HHS measurement; N/R, numbers not reported.
† Significant difference between groups.
‡ Numbers missing, since results were reported in figures.

Radiological outcomes

Nine studies reported on acetabular cup inclination angle [10, 13, 17, 19-22, 25, 27] and seven studies reported on acetabular cup anteversion [10, 13, 17, 21-22, 25, 27] (Table 6). Most studies use the Lewinnek safe zone (5–25° anteversion, 30–50° inclination) to measure optimal implant positioning [31]. Five studies reported a mean cup inclination and mean cup anteversion within the Lewinnek safe zone [10, 20-22, 27]. The DSA showed cup inclination and anteversion comparable to the MPA and PLA [10, 27]. Ezzibdeh et al. found that the mean cup anteversion was slightly higher for the MPA (16±4°) than for the DSA (12±3°) [21]. Leonard et al. reported a significantly higher cup inclination and lower cup anteversion for the DSA than for the PLA [13]. Still, both studies reported that all THAs were within the Lewinnek safe zone.

Hospital length of stay (days)

LOS was recorded in 11 studies as a measure of recovery. In the majority of studies the LOS of patients undergoing a DSA to THA was significantly reduced compared with that of PLA or MPA patients [10-13, 21, 24]. Four studies compared DSA with PLA lengths of stay, all reporting a significantly lower LOS for the DSA than for the PLA [11-13, 24]. Two studies with moderate evidence reported a significantly lower LOS for the DSA than for the MPA [10,21]. Duijnisveld et al. reported no difference in LOS between the DSA and MPA [19].

Operative time

Twelve studies have investigated operative time. Considerable heterogeneity in mean operative time was seen (range 57-130 minutes). Six studies compared DSA with PLA mean operative times [11-13, 24, 26, 28]: three moderate-to-high-evidence studies found a shorter operative time for the DSA than for the PLA [11,24,28], one study reported longer operative time for the DSA (90±14 minutes) than for the PLA (77±20 minutes) [26], and two studies reported no difference in operative time [12-13]. Duijnisveld et al. reported significantly longer operative time for the DSA than for the MPA [19]. Ezzibdeh et al. reported comparable operative time for the first 20 DSA THAs than for the first 20 MPA THAs, yet a significant decrease in operative time was seen for the second 20 DSA THAs, suggesting a learning curve effect [21].

Blood loss

Blood loss in ml was recorded in 10 studies [10,12-13, 17, 19-22, 25-26]. Three studies compared DSA with PLA blood loss [12-13, 26]. Ulvivi et al. showed significantly lower BL for the DSA than for the PLA (149ml vs 225ml, respectively, p=0.04) [26]. Other studies reported no statistically significant differences in DSA and PLA blood loss (data not shown). Three studies compared DSA with MPA blood loss [10,19,21]. Duijnisveld reported comparable BL between the DSA and MPA [23], while Ezzibdeh et al. reported lower blood loss for the DSA than for the MPA [10,21].

Table 6. Radiological parameters.

	Method	Groups	Cup inclination	Cup anteversion	Implant positioning
Roger 2011[17]	AP radiograph	DSA	41 (21-49)	21 (15-27)	No revisions for component malpositioning
Korth 2021[22]	AP radiograph	DSA	38.8 (5.4)	12.9 (3.7)	All DSA within Lewinnek safe zone
Tsiridis 2020[25]	AP radiograph	DSA	44.15 (33.5)	20.76 (3.59)	No revisions for component malpositioning
Ezzibdeh 2020[20]	AP radiograph	DSA	42±5	N/R	All DSA within Lewinnek safe zone
DSA vs MPA					
Duijnisveld 2020[19]	AP radiograph	DSA	51 (6)	N/R	Acetabular inclination higher for the DSA compared to the MPA (p=0.028)
		MPA	54 (7)	N/R	
Ezzibdeh 2021[10]	AP radiograph	DSA	39.1 (5.4)	13.5 (4.4)	All DSA within Lewinnek safe zone
		MPA	38.3 (5.8)	16 (4.4)	
Ezzibdeh 2020[21]	AP radiograph	DSA	1st 20 cases: 39 (6) 2nd 20 cases: 39 (5)	1st 20 cases: 12 (3)2nd 20 cases: 13 (4)	MPA slightly more anteversion compared to first 20 DSA cases (p=0.006). All cases within Lewinnek safe zone.
		MPA	38 (6)	16 (4)	
DSA vs PLA					
Leonard 2021[13]	AP radiograph	DSA	46.3 (6.1)	13.9 (6.8)	Statistically different inclination and anteversion between DSA and PLA
		PL	42.7 (5.8)	18.5 (6.9)	
Watanabe 2021[27]	CT image	DSA	42.1 (5.3)	21.9 (6.9)	All DSA within Lewinnek safe zone
		PL	41.8 (6.5)	22.3 (11.7)	

Incision length

A total of five studies with 524 procedures reported on incision length in centimeters (cm). Mean incision length varied from 8.9 (SD 2.3) to 9.16 (SD 1.25) cm. Two studies reported statistically significantly lower incision lengths for the DSA than for the PLA [12,26].

Learning curve

Three studies reported on the learning curve [13, 19, 21]. First, Ezzibdeh et al. reported that the learning curve for the DSA is lower than 20 patients [21]. The authors reported similar intraoperative blood loss and LOS when comparing the first 20 DSA cases with the second set of DSA THAs. Duijnisveld et al. reported that the DSA was found to have no learning curve in terms of implant positioning [19]. No significant differences were found in the DSA group for operative time, blood loss, or change in perioperative hemoglobin level, suggesting the absence of a learning curve. Last, Leonard et al. reported no difference in operative time and estimated mean blood loss between the first 100 DSA THAs and a matched PLA cohort [13]. All DSA cases, including the one with a learning curve, were included in their study.

Discussion

The DSA is suggested as a minimally invasive surgical approach for THA, aiming to optimize outcome for THA patients. The DSA may provide an earlier functional recovery with slightly better functional scores in the first postoperative month. However, after 3 months no differences in functional scores were seen compared with the PLA and MPA. The DSA enables adequate implant positioning and resulted in a shorter LOS compared to the PLA. Last, the learning curve for the DSA seems to be short. However, no differences were reported in pain scores. Finally, most studies show no significant differences in complication rates, but one RCT reported higher complications with DSA, in contrast to another large registry study. Hence, we found through moderate-certainty evidence that the DSA may not offer advantages over alternative approaches in terms of complication rates and pain scores.

Currently there is one narrative review from Kayani et al. and one review and meta-analysis from Zang et al. [8,32], with findings similar to ours. Higher-quality studies with bigger numbers have been published since. Our study, building on previous work by Kayani et al. and Zang et al., extends the literature on DSA outcomes. In comparison to Zang et al's systematic review, our study takes a more comprehensive approach, incorporating a broader range of outcomes such as complications, pain scores, radiological results, operative time, and the learning curve. Additionally, our study includes a larger number of studies, particularly incorporating those from 2023, as well as integrating data from two large registry studies [24, 29-30].

Perhaps the most important outcome with a new surgical approach is the complication risk associated with it, particularly in the initial stages of the learning curve. The DSA seems to be associated with low risk of postoperative dislocations, sciatic nerve palsies, loosening, and wound complications. Although the short-term complication risk seems to be low for the DSA, the evidence presented in the manuscript does not strongly support the conclusion that the DSA offers significant benefits over conventional approaches in terms of complication rates. The most common reason for short-term revision for the DSA was intraoperative and postoperative fractures. Most notably, intraoperative fractures have been related with difficulty in exposing and manipulating the femur during femoral preparation. Based on current literature, the rate of intraoperative femoral fractures ranges from 0% to 5.3%, regardless of surgical approach [33-36]. Recently, Bruggeman et al. conducted a large registry study using the Norwegian Arthroplasty Register including 218,423 primary THAs, reporting an intraoperative periprosthetic fracture rate of 1.0% [36]. In our review we found an intraoperative periprosthetic fracture rate of 0.3% and an overall periprosthetic fracture rate of 0.8% for the DSA, which is consistent with current literature.

Second, we found that the DSA may provide an earlier functional recovery with slightly better functional scores in the first postoperative month. This early functional recovery could be explained by the muscle-sparing and iliotibial band-preserving nature of the DSA. However, it has been difficult to objectively determine precisely which factors are responsible for improved patient outcomes. We cannot rule out that some surgeons may have selectively applied the DSA to non-obese and younger patients who are predisposed to recover quickly. However, most studies reporting differences in functional outcomes between the DSA and controls matched patients based on sex, age and BMI or reported no difference in sex, age or age between groups. However, it is important to note that some studies with comparable functional scores between the DSA and controls were based on low-level evidence, and the patient demographics may not have been adequately matched in all included studies. Therefore, the exact benefits of the DSA in terms of early recovery remain unclear.

Third, the importance of implant positioning and its impact on short-term and long-term outcomes is well established in THA. Poor implant positioning can result in increased dislocation rates, component impingement, increased surface wear, and reduction of implant survivorship [37]. In DSA THAs, acetabular bone resection is performed using specialized reamers. Achieving adequate implant position can be more challenging. In the present study we found that DSA THAs can be performed safely in terms of implant positioning. Direct access to the acetabulum and femur seems easily obtained. The majority of studies reported a mean cup inclination and mean cup anteversion within the Lewinnek safe zone. None of the included studies reported revisions for cup malpositioning or femoral stem undersizing. One revision due to excessive leg lengthening and one revision for inadequate offset was reported [17]. Hence the DSA seems to be safe in terms of implant positioning.

Last, we found considerable heterogeneity in surgical outcomes such as operative time and blood loss. In our opinion, the heterogeneity in outcomes might be explained by the nature of the included studies in terms of their local protocols, surgeon experience, enhanced recovery pathways, use of modern anesthetic techniques, and the routine use of tranexamic acid. Most studies did not consider confounding factors when comparing blood loss, therefore it was difficult to draw conclusions about blood loss in the DSA compared to other approaches. We think that operative time is an outcome parameter that is difficult to generalize, since it can be influenced by multiple confounding factors (e.g. surgeon experience, adequate exposure, assistance or operation room team). Moreover, during the surgeon's learning curve there usually is a prolonged operative time. The wide variation in operative times for the DSA supports the idea that the surgeon's proficiency plays an important role and shows that there is potential for a shorter operative time.

This review has some limitations. First, most included studies were retrospective cohort studies and case series, so the level of evidence is less robust and more prone to selection, reporting, and interpretation bias. Second, we were not able to pool data owing to the small number of studies, the retrospective design, the large heterogeneity of the control groups, and differences in outcomes reported. Hence, we did not proceed to a quantitative synthesis. Third, most studies were conducted by a single surgeon specifically trained in the posterior approach and DSA to THA. Thus, surgeon experience and annual case volume may vary between the included studies. Moreover, the evidence in this systematic review does not strongly support significant benefits of the DSA over alternative methods. A limitation includes the need for careful patient education, clarifying that "superior" refers to an anatomical direction, not superiority in outcomes. Discussions with patients should focus on individual factors, preferences, and potential benefits or risks associated with different approaches. Finally, due to insufficient data, important outcome parameters such as postoperative gait analysis could not be considered. Our findings should be interpreted with caution given these limitations.

Conclusion

Based on presently available moderate-certainty evidence, it is uncertain if the DSA provides short-term advantages over conventional approaches such as PLA. However, registry data indicate lower revision rates for dislocation with the DSA, offering valuable real-world insights. There is currently a lack of evidence on its long-term efficacy and safety. Further prospective studies are needed, and ongoing registry monitoring is crucial for continuous evaluation of its long-term outcomes.

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Appendices

Table A1. search strategy for each database performed on 28/12/2023.

Database	Search strategy	Number of articles
Medline (Ovid)	(Arthroplasty, Replacement, Hip/ or Hip Prosthesis/ or total hip.ab,kf,ti. or THA.ab,kf,ti. or ((hip or hips or femoral or femur) adj4 (arthroplast* or prosthe* or replac*)).ab,kf,ti.) and (direct superior*.ab,kf,ti. or superior approach*.ab,kf,ti. or iliotibial*.ab,kf,ti. or transpiriformis.ab,kf,ti. or trans piriformis.ab,kf,ti.) limit 1 to (yr="2000-Current")	n= 85
Embase.com	('hip arthroplasty'/exp OR 'hip replacement'/exp OR 'hip prosthesis'/exp OR 'total hip':ti,ab,kw OR THA:ti,ab,kw OR ((hip OR hips OR femoral OR femur) NEAR/4 (arthroplast* OR prosthe* OR replac*)):ti,ab,kw) AND ('direct superior*' OR 'superior approach*' OR iliotibial* OR transpiriformis OR 'trans piriformis'):ti,ab,kw AND [2000-2024]/py	n=112
Web of Science core collection	TS=(("total hip" OR THA OR ((hip OR hips OR femoral OR femur) NEAR/4 (arthroplast* OR prosthe* OR replac*))) AND ("direct superior*" OR "superior approach*" OR iliotibial* OR transpiriformis OR "trans piriformis")) AND PY=2000-2024	n=73
Cochrane Central	(("total hip" OR THA OR ((hip OR hips OR femoral OR femur) NEAR/4 (arthroplast* OR prosthe* OR replac*))) AND (direct NEXT superior* OR superior NEXT approach* OR iliotibial* OR transpiriformis OR "trans piriformis"):ti,ab,kw)	n=18
Google scholar	"direct superior"|"superior approach"|transpiriformis|"trans piriformis" "total hip"|"hip arthro plasty"|"hip prosthesis"|"hip prostheses"|"femoral prosthesis"|"femoral prostheses"|"femoral head prosthesis"|"femoral head prostheses"|"femur prosthesis"|"femur prostheses"|"hip replacement"|"femoral replacement"|"femoral head replacement"|"femur replacement"	n=(first) 100 articles screened
Total = 388		

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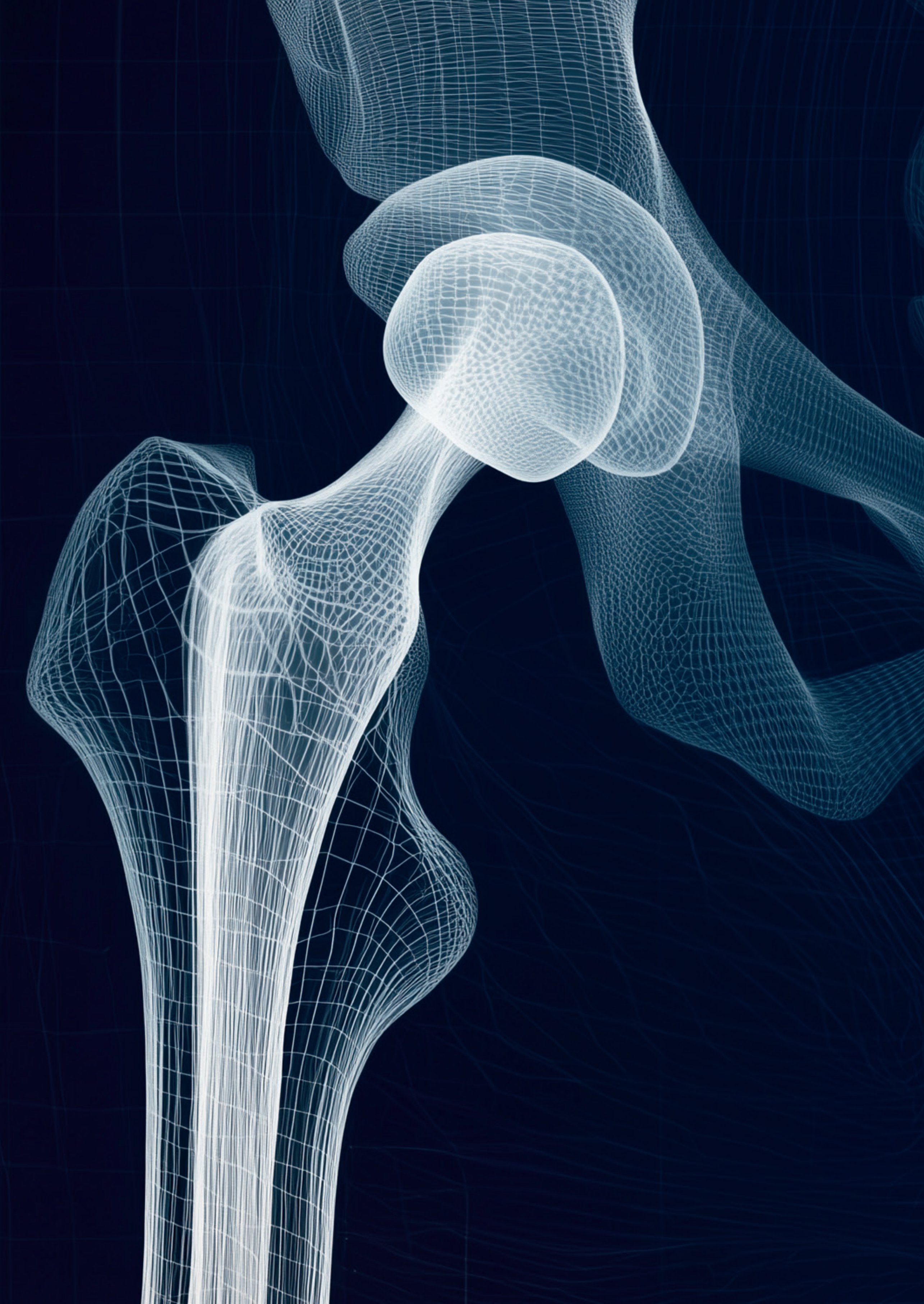

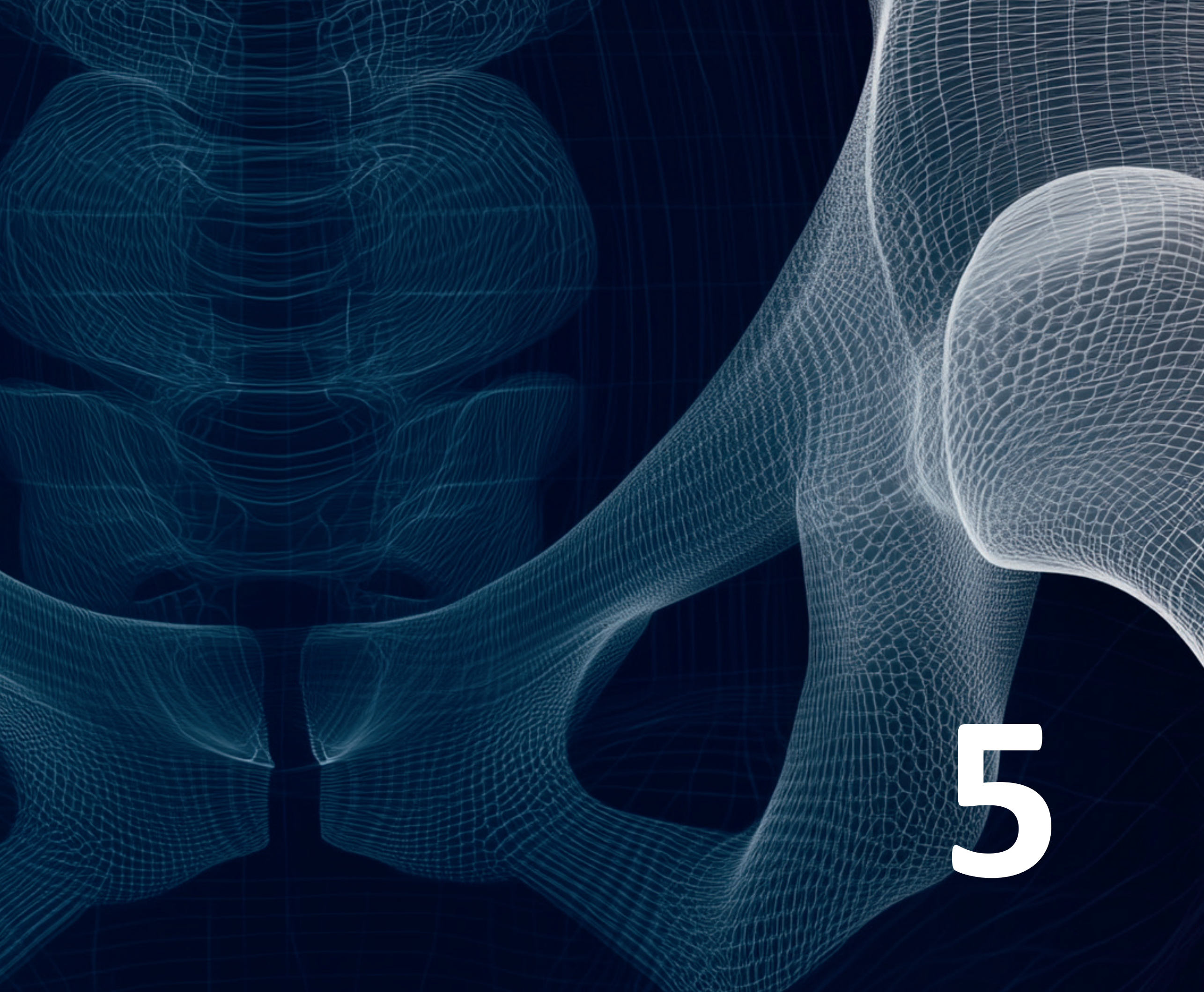

5

Revision risk by using the direct superior approach (DSA) for total hip arthroplasty compared with postero-lateral approach: early nationwide results from the Dutch Arthroplasty Register (LROI)

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Acta Orthopaedica 2023, 94: 158-164
Van Rens award (2022) Dutch Arthroplasty Association (NOV)

Abstract

Background and purpose

The direct superior approach (DSA) is a modification of the classic posterolateral approach (PLA) for total hip arthroplasty (THA), in which the iliotibial band and short external rotators are spared. The revision rate of the DSA has not been investigated previously using arthroplasty registry data. We examined the reasons and risk of revision of the DSA, compared with the direct anterior approach (DAA) and PLA.

Patients and methods

In this population-based cohort study we included 175,543 primary THAs performed between 2014 and 2020 (PLA: n = 117,576; DAA: n = 56,626; DSA: n = 1,341). Competing risk survival analysis and multivariable Cox proportional hazard analyses, adjusted for potential confounders, were performed.

Results

After 3 years, crude revision rates due to any reason were 2.1% (95% confidence interval [CI] 1.3–3.3) for DSA, and 2.9% (CI 2.8–3.0) for PLA. Crude dislocation revision rates were 0.3% (CI 0.1–0.8) for DSA, versus 1.0% (CI 0.9–1.0) for PLA. Dislocation revision rate for DSA did not differ from DAA (0.3% [CI 0.2–0.3]). Multivariable Cox regression analysis demonstrated no overall difference in revision rates for the DSA (HR 0.6 [CI 0.4–1.0) compared with the PLA. Lower risk of revision due to dislocation was found in patients operated through the DSA (HR 0.3 [0.1–0.9]) compared with the PLA.

Conclusion

Early nationwide results suggest that the DSA for THA seems to show a tendency towards a lower risk of revision for dislocation but no overall reduced revision risk compared with the PLA.

Introduction

Recurrent dislocation is the most common cause of early revision in primary total hip arthroplasty (THA)[1,2]. Risk factors associated with recurrent dislocation are surgical approach and femoral head size [1,3-5]. In the Netherlands, the posterolateral approach (PLA) is the most frequently used approach (50%) in hip replacement, although the direct anterior approach (DAA) has gained considerable popularity over the past years [2]. The DAA has been associated with a reduced risk of revision for dislocation, compared with the PLA, but a higher risk of femoral stem revisions has previously been reported [1,6-7].

To reduce dislocation rates and enhance recovery of patients operated on through the classic PLA, the direct superior approach (DSA) was developed. The DSA is an adaptation of the PLA, in which the iliotibial band and short external rotators (except for the piriformis or conjoint tendon) are preserved [8-10]. The main goals of a muscle-sparing approach are to enhance early recovery and decrease complications. In comparison with the PLA, the DSA should therefore improve implant stability. Outcomes of THA with the DSA have shown that reliable implant positioning can be obtained with a low early complication rate [11-13]. Shorter length of hospital stay and enhanced recovery with higher functional scores were recorded in comparison with the PLA [14-19]. Contrary to the DAA, the learning curve seems to be limited [10-11,20]. Whether a limited learning curve will be found outside specialist centers remains to be proven. In addition, there is need for stronger evidence to support the claim for a reduced dislocation risk with the DSA.

We examined the early outcomes of the DSA, using Dutch nationwide arthroplasty data. Specifically, we examined the risk of revision for dislocation, as well as the risk of revision for any other reason than dislocation.

Patients and methods

Study design

This is a population-based cohort study of all primary THA using the DAA, PLA or DSA in a Dutch hospital. Data from January 1 2014, to December 31, 2020, was retrieved from the Dutch Arthroplasty Register (LROI). The study is reported according to the STROBE/RECORD guideline.

Setting and data source

The Dutch Arthroplasty Register (LROI) is a nationwide population-based register which prospectively collects data on joint arthroplasties in the Netherlands since 2007. The LROI was initiated by the Dutch Orthopaedic Association (NOV). Data from arthroplasties performed in the Netherlands can be entered directly into the LROI databases using the

LROI webforms or by uploads from the electronic patient file of the healthcare provider. In this manner patient, procedure (e.g. surgical approach) and prosthesis characteristics are uniformly and completely collected. Internal checks and defaults are included in the system to stimulate valid and optimal registration. Completeness of records is validated every year by comparing the number of procedures in the LROI with the number of procedures in the hospital information system (HIS). Therefore, a high validity and data quality is retained for both primary and revision THAs [21, 22]. The register covers 100% of Dutch hospitals with a completeness of 99% for primary THAs and over 97% for hip revision arthroplasty in the last 5 years [2, 21].

Participants

Eligible patients who received a primary non metal-on-metal (MoM) THAs using the DAA, PLA or DSA in a Dutch hospital between 2014–2020 and registered in the LROI were included. Demographic data, procedure, prosthesis characteristics and outcome measures were provided by the LROI.

Outcome

The primary outcome is the short-term risk of revision for any reason, for dislocation and for any other reason except dislocation. Revision was defined as a change, addition or removal of 1 or more components of the prosthesis [2]. All revision procedures and reasons for revision are registered during revision surgery. Multiple reasons for revision can be registered (e.g. infection, dislocation, periprosthetic fracture, liner wear and/or loosening). An overview of revision procedures was provided by the LROI. Afterwards, reasons for revision were categorized by the authors as dislocation and non-dislocation including all reasons for revision except dislocation.

Surgical technique

DSA is being collected in the LROI since 2014. The orthopedic surgeon fills out which surgical approach is used during surgery using mandatory LROI webforms. DSA is performed by selected dedicated hospitals in the Netherlands with a strong interest in this technique. Registration for DSA is therefore optimal. The validity for the registration of surgical approaches for primary THA is checked annually and was 99.3% in the past year [22]. The DSA has been described in detail by Roger et al. [18]. In short, the patient is in lateral decubitus position. From the posterosuperior corner of the greater trochanter extending proximally in line with the gluteus maximus fibers, the skin, subcutis and gluteus maximus fascia are minimally incised, sparing the iliotibial band. The gluteus maximus is split and the piriformis and, if conjoined, the obturator internus tendon are detached, tagged and reflected posteriorly. The gluteus minimus is elevated and after a capsulotomy in line with the collum femoris, the hip is dislocated, followed by femoral neck resection, acetabulum reaming and implantation of acetabular and femoral components using long DSA Hohmann retractors and specialized reamers. The capsule is closed side-to-side, the piriformis reattached; and the fascia, subcutaneous tissue and skin closed in layers.

Statistics

Group comparisons were made using a chi-square test. Survival time was calculated as the time from primary THA to first revision arthroplasty for any reason, death of the patient, or the end of the follow-up period (January 1st 2021) using competing risk analysis. We calculated the 1-, 3- and 5-year crude cumulative incidence of revision for any reason, dislocation and other reason except dislocation.

Multivariable Cox proportional hazard analyses were performed to test for differences in risk of revision for any reason, revision for dislocation and revision for all other causes than dislocation, adjusted for possible confounding variables (i.e., age, gender, ASA-score, Body Mass Index [BMI], diagnosis, previous surgery, femoral head size, fixation- and articulation type). For all categorical covariates added to the model, the proportional hazards assumption was checked and met by inspecting log-minus-log curves. P-values below 0.05 were considered statistically significant. Results were reported as hazard ratios (HR) with 95% confidence intervals (CI). All analyses were performed using SPSS version 24.0.

Sensitivity analyses

Separate post-hoc sensitivity analyses were conducted in order to assess whether altering any of our assumptions or inclusions within the model may lead to different final interpretations of our data [23]. First, the multivariable Cox proportional hazard analysis was repeated for the period of 2007–2020 without BMI since this confounder was only available in the LROI from 2014 onwards. Secondly, we repeated the multivariable Cox proportional hazard analysis for the period of 2016–2020 to obtain more equal follow-up time between approaches, since the DSA was introduced more recently compared with the DAA and PLA. Furthermore, we performed a sensitivity analysis where all dual mobility cups were excluded from the analysis. Finally, we performed a sensitivity analysis for THAs procedures for osteoarthritis (OA), since a higher risk of revision is seen in THAs for acute fracture [24].

Ethics, funding, data sharing and disclosures

The study was approved by the LROI board and scientific advisory board of the LROI and the Medical Ethical Committee of the University Medical Center Groningen (No. METc 2021/280). The dataset was processed in compliance with the regulations of the LROI governing research on registry data. Restrictions apply to the availability of these data, which were used under license for the current study. This project was supported by an unrestricted grant from a non-profit founding Stichting MCL fonds. No benefits in any form have been received or will be received related directly or indirectly to the subject of this article. No conflicting interests were declared.

Results

175,543 primary non-MoM THA´s were analyzed (Figure 1).

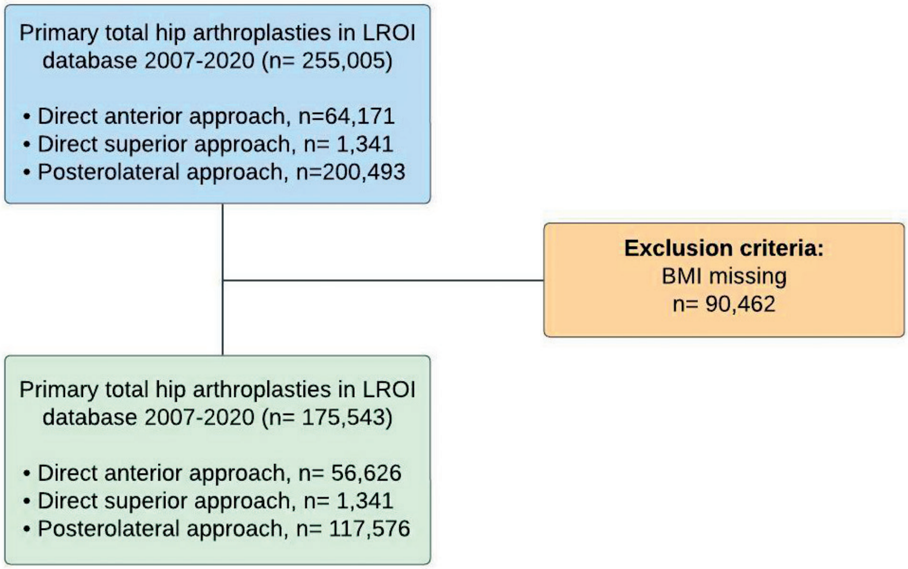

Figure 1. Flow chart included patients.

Patient characteristics

175,543 primary THAs performed between 2014 and 2020 were included (PLA 117,576; DAA 56,626; DSA 1,341). The median length of follow-up was 2.9 years (range 0–7), with a shorter follow-up for the DSA (1.6 years; range 0–6) compared with the PLA (3.3 years; range 0–7). An overview of patient characteristics is set out in Table 1.

Table 1. Patient and procedure characteristics of all primary THA with posterolateral DSA or anterior approach from 2014-2020 (n =175,543).

	PLA (n=117,576; 67%)		DSA (n= 1,341;0.8%)		DAA (n=56,626;32.3%)		Total (n=175,543; 100%)	
	n	(%)	n	(%)	n	(%)	n	(%)
Age						c		a
<60	19,605	17	253	19	9,789	17	29,647	17
60–74	60,049	51	703	52	31,062	55	91,814	52
≥75	37,741	32	385	29	15,759	29	53,885	31
Sex								a
Male	41,758	36	496	37	19,202	34	61,456	35
Female	75,702	64	845	63	37,413	66	113,960	65
ASA score								a
I	18,773	16	241	18	11,372	20	30,386	17
II	74,300	63	858	64	36,204	64	111,362	64
III–IV	24,368	21	242	18	9,002	16	33,612	19
Diagnosis								a
OA	99,379	85	1,220	91	52,167	92	152,766	87
Non-OA	17,964	15	120	9	4,398	7.8	22,482	13
Previous operation								a
Yes	6,728	5.8	32	2.4	1,117	2.0	7,877	4.6
No	108,933	94	1,304	98	54,692	98	164,929	95
Operation year								a
2014–2016	52,244	44	88	6.6	14,434	26	66.766	38
2017–2020	65,332	56	1253	93	42,192	74	108,777	62
Smoking								a
Yes	12,748	11	153	11	5,490	9.8	18,391	11
No	99,580	89	1,186	87	50,559	90	151,325	89
BMI		b						a,b
< 18.5	1,124	1.0	19	1.4	420	0.8	1,563	0.9
18.5–25	37,128	32	535	40	20,739	37	58,402	34
25–30	48,103	42	554	41	23,686	42	72,343	42
30–40	27,436	24	229	17	10,698	19	38,363	22
>40	1,596	1.4	4	0.3	359	0.6	1,959	1.1
Charnley		b						a
A	49,756	45	602	46	24,779	45	75,137	45
B1	31,714	29	374	29	17,227	32	49,315	30
B2	25,187	23	318	24	11,520	21	37,025	22
C	3,510	3.2	19	1.4	1,067	2.0	4596	2.8

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Table 1. Patient and procedure characteristics of all primary THA with posterolateral DSA or anterior approach from 2014-2020 (n =175,543). (continued)

	PLA (n=117,576; 67%)		DSA (n= 1,341;0.8%)		DAA (n=56,626;32.3%)		Total (n=175,543; 100%)	
	n	(%)	n	(%)	n	(%)	n	(%)
Fixation				[b]		[b]		[b]
Cemented	35,946	31	695	52	6,136	11	42,777	24
Cementless	68,724	59	470	35	45,411	80	114,605	65
Reversed	4,299	3.7	138	10	2,205	3.9	6,642	3.8
hybrid	7,883	6.7	27	2.0	2,474	4.4	10,384	5.9
Hybrid	522	0.4	11	0.8	316	0.6	849	0.5
Head size				[b]				[a,,b]
22–28 mm	23,211	20	380	29	6,121	12	29,712	18
32 mm	66,672	58	794	61	34,499	65	101,965	60
36mm	24,367	21	131	10	12,072	23	36,570	22
>38 mm	681	0.6	0	0	41	0.1	722	0.4
Articulation								[a]
CoC	5,494	4.9	0	0	4,748	9.2	10,242	6.2
CoM	39	0	1	0.1	1	0	41	0
CoP	66,108	59	1,014	83	32,296	63	99,418	60
MoC	1	0	0	0	1	0	2	0
MoP	29,664	27	92	7.5	11,077	21	40,833	25
ZoP	10,598	9.5	118	9.6	3,585	6.9	14,301	8.7

ASA score: American Society of Anesthesiology score, BMI: Body Mass Index, OA: Osteoarthritis, CoC: Ceramic-on-ceramic, CoM: Ceramic-on-metal, CoP: Ceramic-on-polyethylene, MoC: metal-on-ceramic, MoP: Metal-on-polyethylene, ZoP: oxidized-zirconium-on -polyethylene.
a. $p < 0.001$.
b. Numbers do not add up to total due to unknown or missing values.

Reasons for revision

4,608 (2.6%) THAs were revised during the follow-up period. 21 revisions were performed in the DSA group. Reasons for revision differed between the surgical approach groups. PLA THAs were more often revised for dislocation, while DAA and DSA THAs were revised more often because of loosening of the femoral component and periprosthetic fractures (Table 2).

Table 2. Reasons for revision in primary THA with according to approach in the period 2014–2020 in the Netherlands (n =175,543 of which 4,608; 2.6% THAs were revised).

	PLA N = 117,576 with 3,688 (3.1%) revisions		DSA N = 1,341 with 21 (1.6%) revisions		DAA N = 56,626 with 899 (1.6%) revisions		Total N = 175,543 With 4,608; 2.6% revisions	
	n	%	n	%	n	%	n	%
Infection	1,121	30	4	19	267	30	1,392	30
Periprosthetic fracture	501	14	4	19	190	21	695	15 [b]
Dislocation	1,209	33	4	19	147	16	1,360	30 [b]
Loosening of femoral component	447	12	4	19	174	19	625	14 [b]
Loosening of acetabular component	303	8.2	3	14	87	9.7	393	8.5
Cup/ liner wear	58	1.6	0	0	18	2.0	76	1.6
Periarticular ossification	31	0.8	0	0	14	1.6	45	1.0
Girdlestone	55	1.5	0	0	24	2.7	79	1.7 [a]
Other	490	13	2	9.5	139	16	631	14

a. $p < 0.05$ between different groups.
b. $p < 0.001$.
c. A procedure may have more than 1 reason for revision. As such, the total is over 100%.

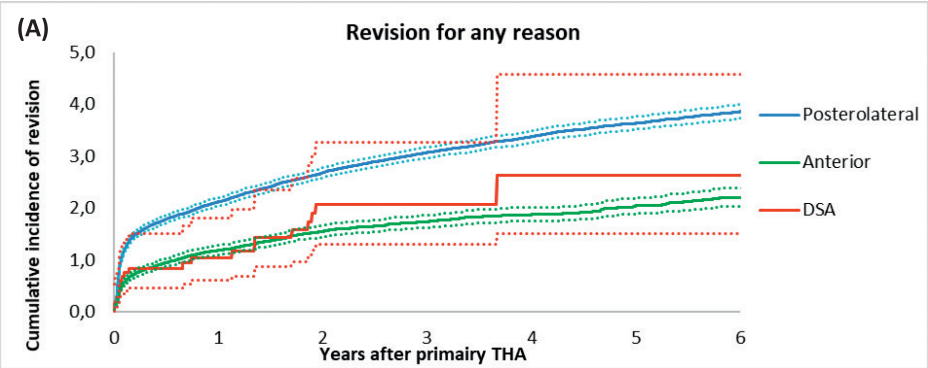
Overall revision

The overall crude cumulative incidence of revision for all causes after 1, 3 and 5 years for THAs using DSA were respectively 0.8% (CI 0.5–1.5), 2.1% (CI 1.3–3.3) and 2.6% (CI 1.5–4.6). The crude revision rate was lower for the DSA compared with the PLA (1.8% [CI 1.7–1.9]) after 1 year. At 3 and 5 years, the overall crude revision rate was comparable for the DSA compared with the PLA (respectively 2.9% (CI 2.9–3.0); 3.5% (CI 3.4–3.6). The crude revision rates for DSA were comparable with the DAA (Table 3, Figure 2a).

Table 3. Crude cumulative incidence of revision in primary THAs according to surgical approach performed in 2014-2020 in the Netherlands (n =175,543).

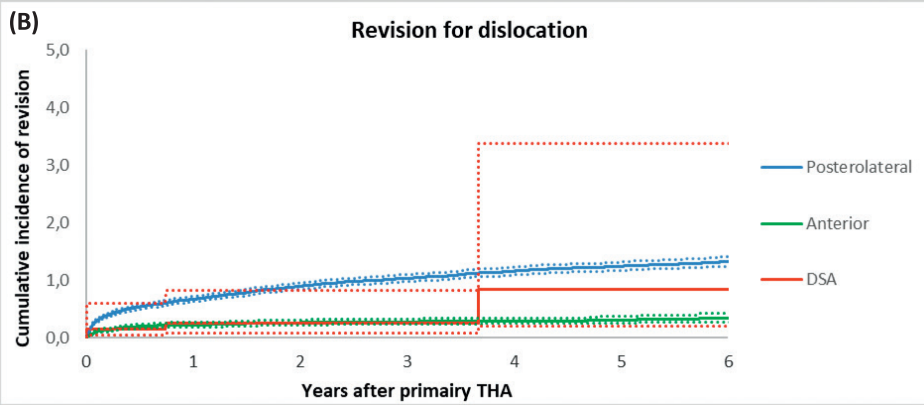
	PLA		DSA		DAA	
	%	CI	%	CI	%	CI
Revision for any reason (n=4,608 revisions)						
1 year	1.8	1.7–1.9	0.8[a]	0.5-1.5	0.9[b]	0.9–1.0
3 years	2.9	2.8–3.0	2.1	1.3-3.3	1.7[b]	1.5–1.8
5 years	3.5	3.4–3.6	2.6	1.5-4.6	1.9[b]	1.8–2.1
Revision for dislocation (n=1,360 revisions)						
	%	CI	%	CI	%	CI
1 year	0.5	0.5–0.6	0.15	0.04–0.60	0.19[b]	0.16–0.23
3 years	1.0	0.9–1.0	0.26[a]	0.1–0.8	0.27[b]	0.23–0.32
5 years	1.2	1.1–1.3	0.84	0.2–3.4	0.29[b]	0.24–0.34
Revision for any other reason than dislocation (n=3,248 revisions)						
	%	CI	%	CI	%	CI
1 year	1.3	1.2–1.3	0.7	0.4–1.3	0.8[b]	0.7–0.8
3 years	2.0	1.9–2.1	1.8	1.1–3.0	1.4[b]	1.3–1.5
5 years	2.4	2.3–2.5	1.8	1.1–3.0	1.6[b]	1.5–1.8

a. p < 0.05 (DSA vs PL).
b. p < 0.05 (DAA vs PL).

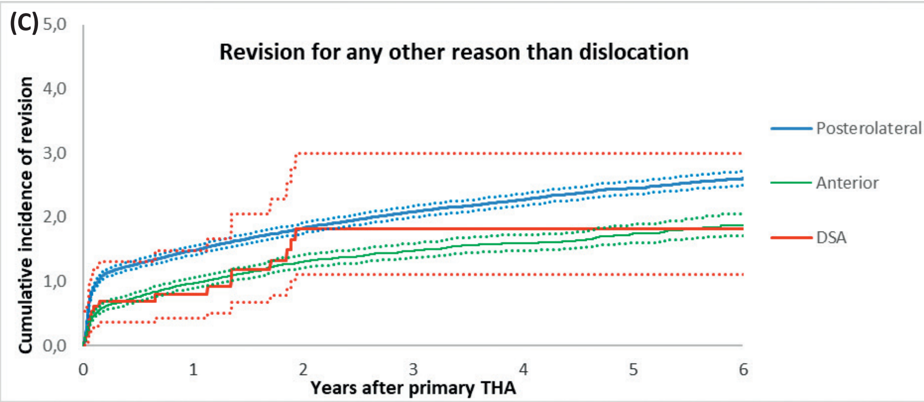


	1 year	3 years	5 years
Posterolateral	107.396	73.018	39.037
Anterior	49.616	26.611	10.325
DSA	1.016	427	7

Figure 2. Crude cumulative incidence of revision for any reason (a), for dislocation (b), and for any other reason than dislocation (c) in primary THAs according to surgical approach performed in 2014-2020 in the Netherlands including number at risk by time in years (n=175,543).



	1 year	3 years	5 years
Posterolateral	106.401	72.685	38.952
Anterior	49.287	26.542	10.306
DSA	1.008	427	7



	1 year	3 years	5 years
Posterolateral	106.800	72.841	38.997
Anterior	49576	26,603	10,321
DSA	1014	426	7

Figure 2. Crude cumulative incidence of revision for any reason (a), for dislocation (b), and for any other reason than dislocation (c) in primary THAs according to surgical approach performed in 2014-2020 in the Netherlands including number at risk by time in years (n=175,543).

Revision due to dislocation

4 revisions due to dislocation were performed in the DSA group. The crude cumulative incidence of revision due to dislocation after 1, 3 and 5 years for the DSA subgroup were 0.2% (CI 0.04–0.6), 0.3% (CI 0.1–0.8) and 0.8% (CI 0.2–3.4), and were comparable with the DAA (respectively 0.2% (CI 0.16–0.23), 0.3% (CI 0.2–0.3) and 0.3% (CI 0.2–0.3)). PLA THAs showed a higher 3-year crude cumulative incidence of revision due to dislocation compared with the DSA (1.0% (CI 0.9–1.0) vs 0.3% (CI 0.1–0.8)). At 1 and 5 years, the crude revision rates for dislocation were comparable for the DSA compared with the PLA (Table 3, Figure 2b). Multivariable Cox regression analysis demonstrated, after adjusting for potential confounders, a lower risk of revision due to dislocation for the DSA and the DAA compared with PLA (respectively HR 0.3 [CI 0.1–0.9] and HR 0.3 [CI 0.2-0.4] vs HR 1.0) (Table 4).

Table 4. Multivariable survival analysis for revision according to surgical approach in primary THAs in the period 2014–2020.

	N	Revisions	Crude hazard ratio (CI)	Adjusted hazard ratio [a]
Revisions for any reason				
DSA	1,341	21	0.6 (0.4–1.0) [b]	0.6 (0.4–1.0) [b]
DAA	56,626	899	0.5 (0.5–0.6) [b]	0.6 (0.56–0.64) [b]
PLA	117,576	3,688	1.0	1.0
Revision for dislocation				
DSA	1,341	4	0.4 (0.1–1.0) [b]	0.3 (0.1–0.9) [b]
DAA	56,626	147	0.3 (0.2–0.3) [b]	0.3 (0.2–0.4) [b]
PLA	117,576	1,209	1	1
Revision for any other reason than dislocation				
DSA	1,341	17	0.8 (0.5–1.2)	0.8 (0.5–1.3)
DAA	56,479	752	0.7 (0.6–0.7) [b]	0.8 (0.7–0.8) [b]
PLA	117,576	2,479	1	1

a. Adjusted for gender, age, ASA-score, diagnosis, previous operations, femur head diameter, fixation articulation and BMI.
b. $p < 0.05$.

Revision due to any other reason except dislocation

3,248 THAs were revised due to any other reason than dislocation. The crude 1-year revision rate was lower for the DAA (0.8% [CI 0.7–0.8]) and comparable for the DSA (0.7% [CI 0.4–1.3]), compared with the PLA (1.3% [CI 1.2–1.3]) (Table 2, Figure 2c). Multivariable Cox regression analyses showed no statistically significant difference in risk of revision due to any other reason than dislocation between the different approaches (Table 3).

Sensitivity analyses

First, we repeated the multivariable Cox proportional hazard analysis for the period 2016–2020 to obtain more equal follow-up time between the 3 approaches, with a median follow-up of respectively 2, 1.6 and 2.4 years for the PLA, DSA and DAA. Hereafter, the DSA showed similar HRs for risk of revision due to any reason (HR 0.6 [0.4–1.0]) and dislocation (HR 0.4 [0.1–1.0]) compared with the previous analysis (respectively HR 0.6 [0.4–1.0] and 0.3 [0.1–0.9]). Although HRs were similar for dislocation between the approaches, the difference was not statistically significant, which can be possibly explained by the reduced sample size. Secondly, the multivariable Cox proportional hazard analysis was repeated for the period of 2007–2020 (n = 266,005). BMI was excluded from the analysis since BMI was registered from 2014. Hereafter, the analyses showed that the hazard ratios for the DSA were comparable for the overall risk of revision (HR 0.6 [0.4–1.0] and for revision due to dislocation (HR 0.3 [0.1–0.9]), compared with the previous analysis. Furthermore, we performed a sensitivity analysis without dual mobility bearings. This analysis showed similar HRs for the DSA for risk of revision due to any reason (HR 0.7 [0.4–1.0]) and dislocation (HR 0.4 [0.1–0.9]) compared with the previous analysis. Finally, after excluding THAs for non-OA, the DSA showed slightly higher HRs for risk of revision due to any reason (HR 0.8 [0.5–1.2]) and dislocation (HR 0.4 [0.2–1.1]) compared with the previous analysis. Revision for any reason and for dislocation did not remain significant compared with the initial analysis.

Discussion

We found similar crude revision rates for the DSA compared with the PLA at 3 years postoperatively (2.1%, resp. 2.9%). Crude dislocation revision rates after 3 years were lower after DSA than after PLA (0.3%, resp. 1%). After correction for confounders, there was no longer a lower risk of revision for any reason but lower risk of revision due to dislocation for the DSA compared with the PLA. The outcomes of the DSA were similar with the outcomes of the DAA. To our knowledge, this is the first nationwide registry study to report on the outcomes of the DSA.

To date, most DSA studies have been case series or case-control studies from specialized centers with limited follow-up. Based on these retrospective series it may be concluded that the DSA can reduce the risk for dislocation and enhance early recovery [14]. One prospective single surgeon study of 200 cases did not find any dislocations in the DSA group within the first year [13]. Overall, they reported 2 complications: 1 acute deep and 1 superficial wound infection. Roger (2012) reported 3 complications in 135 patients operated through the DSA with a mean follow-up of 22 months (range 14–33). No dislocations were observed [18]. In contrast, 1 recent randomized controlled trial compared self-reported and clinical measurements between subjects after DSA (n = 22) compared with the PLA (n =23). The authors reported 1 periprosthetic fracture and

2 dislocations due to falls in the DSA group compared to 1 complication in the PLA group in the first 3 months after surgery [19]. Both dislocations were treated with closed reduction, without further consequences.

Multiple large registry studies have been performed to compare revision rate of primary THAs related to surgical approach [1,6]. Hoskins et al. in 2020 examined the revision rates between surgical approaches with data from the Australian Orthopaedic Association National Joint Replacement Registry between 2015 and 2018 [6]. They reported a higher revision rate for femoral sided revisions for the DAA compared with the PLA. Furthermore, a higher rate of dislocation was found for the PLA, which is in line with our results. Likewise, Zijlstra et al. in 2017 reported that the DAA has been associated with a reduced risk of revision for dislocation, compared with the PLA, but a higher risk of femoral sided revisions was seen [1]. To our knowledge, no registry studies have previously reported on the mid-term survival of the DSA.

Our results may be affected by case-mix factors. Several studies demonstrated based on registry data that high ASA scores and severe obesity are the strongest predictors for short-term revision after a primary THA in patients with OA [25-26]. In our study, patients in the PLA and DSA cohort were more likely to be ASA III–IV compared with the DAA group and therefore have a potentially higher risk of early revision. In addition, our data showed a lower BMI in the DSA cohort compared with the PLA and DSA cohorts, which might partly explain the low number of dislocations. This may represent an inherent selection bias of the study, as DSA is generally performed only in patients with a BMI below 35. Therefore, we corrected for BMI (and other potential confounders) using multivariable Cox proportional hazard analyses, and found similar outcomes as in the unadjusted results. In addition, sensitivity analyses showed similar HRs for revision due to dislocation for the DSA after excluding BMI from the analysis.

Revision for dislocation

At 3 years, crude revision rates for dislocation were lower for the DSA compared with the PLA. However, at 1 and 5 years we found comparable crude risk of revision for dislocation with the DSA approach, compared with the PLA. After correction for confounders, we found a lower risk of revision due to dislocation for the DSA compared with the PLA. A previous study using Dutch arthroplasty data demonstrated an increased risk of revision due to dislocation for THAs using 22–28-mm femoral head components [1]. Our study demonstrated a higher number of small femoral heads (22–28 mm) for the DSA compared with the PLA (respectively 29% and 20% of registered THAs). Compared with the PLA, the DSA however demonstrated a lower adjusted risk of dislocation revision, even with a relatively higher number of small femoral heads. This suggests the DSA shows promising results with regard to dislocation risk, even in the presence of small femoral heads. This is further stressed by the relatively low number of 36-mm heads with DSA, compared with DAA THA (10% versus 23%), while demonstrating a similar risk for revision due to dislocation.

Limitations

The generalizability of these results is subject to certain limitations. For instance, this is a non-randomized, observational study and is therefore impacted by selection bias. Second, this study has a limited number of patients in the DSA subgroup (n = 1,341) and a limited median follow-up of 19 months. This is reflected in the relatively broad confidence intervals seen in our data, some of which border on their significance with respect to the PLA. Furthermore, based on data from the LROI annual reports from the last years, we can conclude that the DSA is used in 5 large volume centers, which is rather limited [2]. Surgeon experience and annual case volume is not registered in the LROI (for privacy reasons), and hence these factors may act as possible confounders, for which we cannot adjust. Moreover, data on non-surgically treated dislocations after THA are not available in the LROI, since only revision procedures are registered. Likewise, there is no data on THAs that were treated for postoperative complications by reoperation using open reduction and internal fixation in case of a periprosthetic fracture. Furthermore, some surgical factors that can potentially affect the risk of revision (e.g. choice of prosthetic system and implant positioning) were not available. Lastly, some DSA may erroneously have been registered as PLA, depending on the ICT systems in the hospital, since not every digital system had the option to separately register the DSA in addition to the usual approach options. Moreover, the exact distinctions between DSA, minimally invasive PLA and classical PLA are not clearly defined and these approaches may be used by surgeons as a sliding scale. We cannot fully rule out that some surgeons may have registered a DSA approach for what other surgeons would consider a minimally invasive PLA. A key strength of the present study was that no exclusion for learning curve was performed. Since the DSA is a relatively new approach the early phases of the learning curve can potentially affect our results. In our study all THAs operated through the DSA were included, strengthening the generalizability of the DSA results.

The DSA can be promising for the future as this approach shows similarities with the PLA. The same anatomical landmarks and lateral decubitus position are used and therefore the DSA seems to be easy to adopt for surgeons trained with the PLA. If required, intra-operative conversion to the PLA is possible.

Conclusion

We found that DSA had lower risk of revision for dislocation but not for overall revision. For orthopedic surgeons experienced in the PLA, the DSA offers an attractive opportunity to modify the PLA in order to improve future outcomes after THA.

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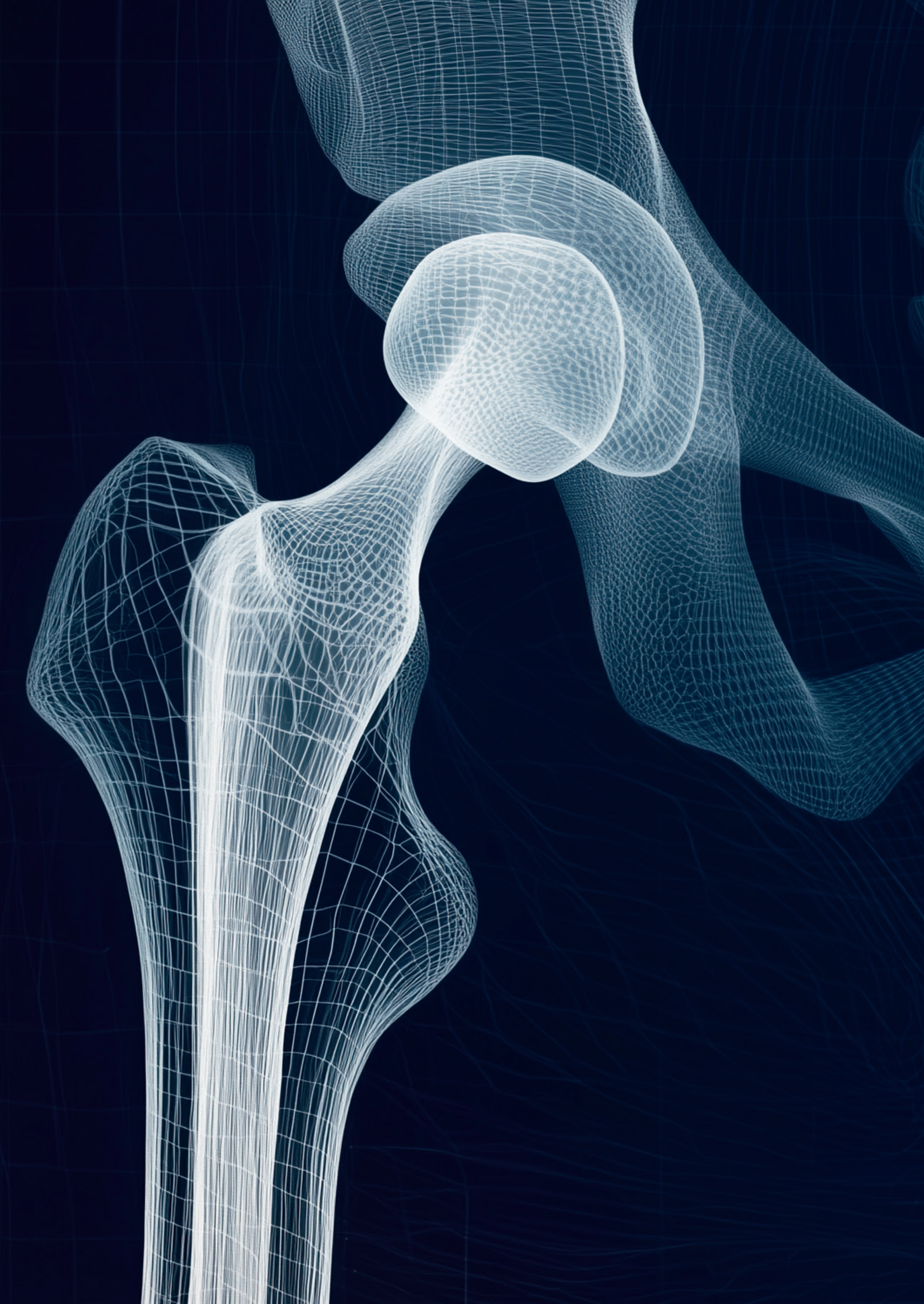

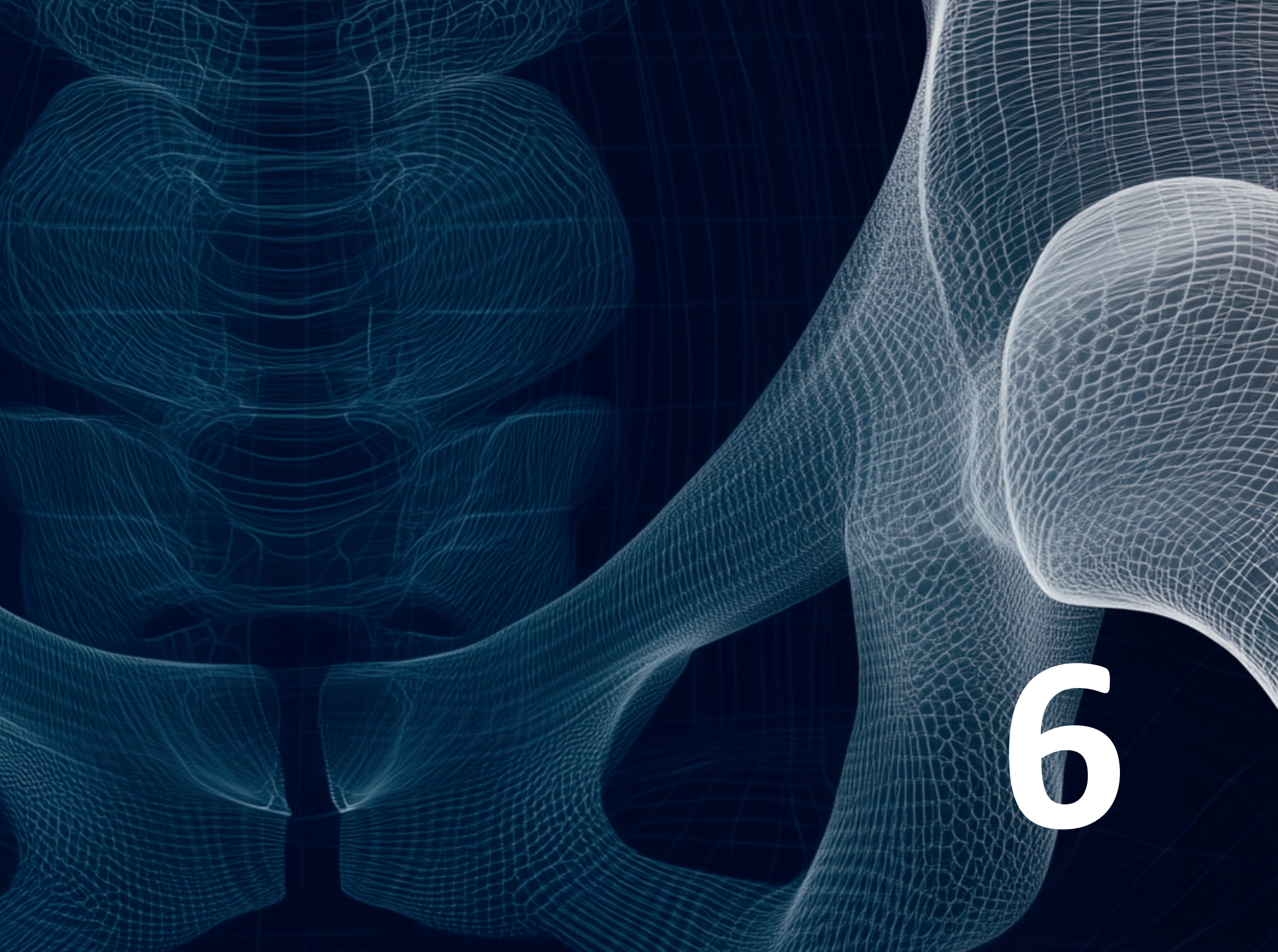

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No clinically relevant difference in patient-reported outcomes between the direct superior and the posterolateral approach or anterior approach for primary total hip arthroplasty: Analysis of 37,976 primary hip arthroplasties in the Dutch Arthroplasty Registry

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Acta Orthopaedica 2023, Oct 31;94:543-549

Abstract

Background and purpose

The direct superior approach (DSA) is a modification of the posterolateral approach (PLA) for total hip arthroplasty (THA). Patient Reported Outcome Measures (PROMs) of the DSA have not been investigated previously using nationwide data. Our aim was to assess PROMs after THA using the DSA compared with the PLA, and secondarily, to the anterior approach (DAA).

Patients and methods

In this population-based cohort study we included 37,976 primary THAs performed between 2014 and 2020 (PLA: n = 22,616; DAA: n = 15,017; DSA: n = 343) using Dutch Arthroplasty Registry data. PROMs (NRS pain, EQ-5D, HOOS-PS and OHS) were measured preoperatively, 3 and 12 months postoperatively. Repeated measurements were analyzed using mixed effects models, adjusted for confounders, to investigate the association between surgical approach and PROMs over time.

Results

From baseline to 3 and 12 months, improvements for NRS pain scores, EQ-5D and OHS were comparable for the DSA compared with the PLA or DAA. No difference was found in HOOS-PS improvement 3 months postoperatively between DSA and PLA (–0.2, 95% confidence interval [CI] –2.4 to 1.9) and between DSA and DAA (–1.7, CI –3.9 to 0.5). 12 months postoperatively, patients in the DSA group improved –2.8 points (CI –4.9 to –0.6) more in HOOS-PS compared with the DAA, but not with the PLA group (–1.0, CI –3.2 to 1.1).

Conclusion

Our study showed no clinically meaningful differences between the DSA and either PLA or DAA.

Introduction

Patient reported outcome measures (PROMs) and patient-satisfaction measures are increasingly being used to monitor surgical success after total hip arthroplasty (THA) from a patient's perspective [1]. Various surgical approaches, have been investigated for their potential impact on PROMs after THA [2-5]. Recently, THAs performed through a minimally invasive muscle sparing approach have become increasingly popular. This trend has resulted in the development of the direct anterior approach (DAA) as well as the direct superior approach (DSA). The DSA is a minimally invasive adaptation of the classic posterolateral approach (PLA) for THA, in which the fascia lata and short external rotators (except the piriformis or conjoint tendon) are preserved [6-7]. The DSA was developed with the aim to provide earlier pain relief, to restore function as quickly as possible and to decrease dislocation rates [6-8]. Despite the growing interest, there are limited data on the proposed benefits of the DSA compared with conventional approaches and whether it really affects the outcome from a patient's perspective [9-16]. In addition, nationwide data on PROMs after the DSA is lacking. The aim of our study is to examine whether the DSA improves PROMs after 3 and 12 months following THA compared with 1) the PLA and 2) the DAA. We hypothesized that the DSA would result in greater improvement after 3 months on functional scores compared with the conventional PLA, but not to the DAA.

Patients and methods

Study design

This is a population-based cohort study including all primary THAs using the DSA, PLA or DAA in Dutch hospitals performed from January 1, 2014, to January 1, 2021. Data was retrieved from the Dutch Arthroplasty Registry (LROI). The study is reported according to the STROBE guidelines [17].

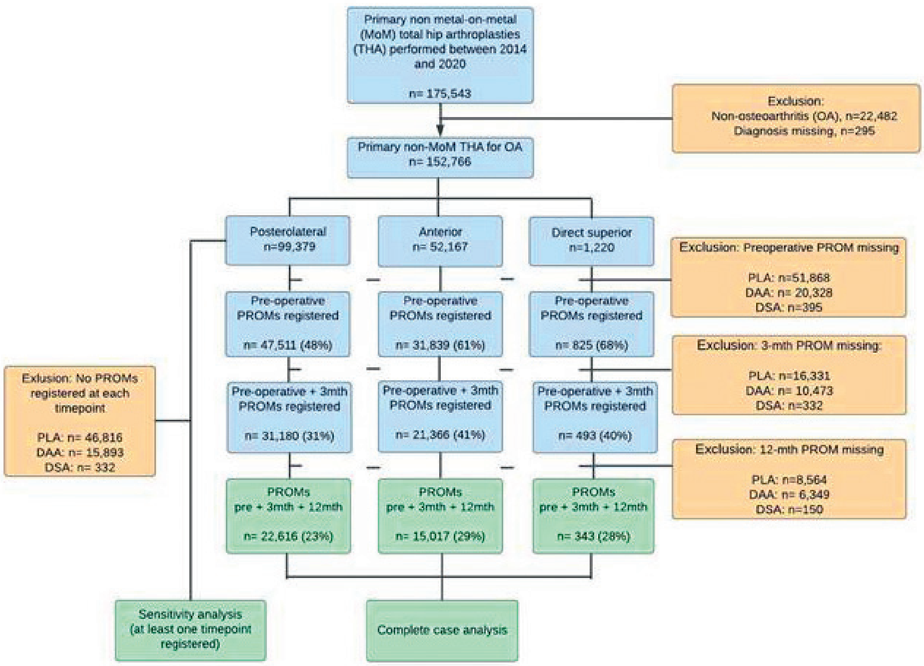

Figure 1. Flowchart of included procedures.

Setting and data source

LROI is a nationwide population-based register that prospectively collects data on joint arthroplasties since 2007. Completeness is validated annually by comparing the number of procedures in the LROI with hospital records. Therefore, a high validity and data quality is obtained with 99% coverage in the last 5 years [18-19]. PROMs are being routinely recorded from patients who underwent THA for osteoarthritis (OA) since 2014. Patients are asked to complete the PROMs questionnaire preoperatively, at 3 and at 12 months postoperatively. Preoperative PROMS are typically filled out at the outpatient clinic, whereas after surgery, PROMs can be completed electronically via email invitation or using pen and paper.

Outcome

5 PROMs were retrieved from the LROI: 1) numeric rating scale (NRS) pain at rest (range 0–10); 2) NRS pain during activity (range 0–10); 3) EQ-5D-5L with EQ-5D index score (range 0–1), which is an overall measure of the patients' health status 4) Hip disability and Osteoarthritis Outcome Score – Physical function Short form (HOOS-PS, range 0–100), which measures limitations in physical activities due to hip-related problems; and 5) Oxford Hip Scores (OHS, range 0–48) as a measure of function and pain after THA. Improvement was measured preoperatively to 3 and 12 months postoperatively. An improvement in NRS pain score of 1.86, Q5D-index score of 0.31, HOOS-PS of 23 and OHS of 2 or more from preoperatively to 1-year follow-up were defined as clinically meaningful. These thresholds were based on a previous publication [20-23].

Statistics

Descriptive statistics on patient and procedure characteristics are presented according to surgical approach. Mixed effect models were used to analyze pain at rest, pain during activity, EQ-5D index, HOOS-PS and OHS preoperatively, at 3 months and 1 year after surgery, for the 3 surgical approach groups. No adjustments for multiple comparisons were applied. All models were adjusted for age, sex, BMI and ASA-score. The patient effect was considered as a random effect in the model. The interaction of time by approach was considered to adjust for the within subject variation over time. Model assumptions were checked with residual plots for each dependent variable and were found to be acceptable. P values below 0.05 were considered statistically significant. Results were reported with 95% confidence intervals (CI). Statistical analyses were performed using IBM SPSS Statistics version 14.0. The analysis methodology was guided by established principles by Christensen et al. [24].

Sensitivity analysis

A robustness test was performed to determine the sensitivity to missing data [24-25]. In this analysis, we included initially excluded patients with missing data under the assumption of Missing at Random (MAR). Multiple imputation (MI) was used, wherein the missing values in the dataset were replaced with imputed values drawn from a linear regression model with the observed PROMs as explanatory variables. The results were then compared with the original results.

Ethics, funding, data sharing and potential conflicts of interest

The study was approved by the scientific advisory committee and board of the LROI and is in compliance with the regulations of the LROI. Ethical approval was not required according to the Dutch Medical Research Involving Human Subject Act (WMO) as all data were received completely anonymous as part of routine clinical care. Restrictions apply to the availability of these data. No funding was received. No conflicting interests were declared. Completed disclosure forms for this article following the ICMJE template are available on the article page doi: 10.2340/17453674.2023.23729.

Results

Patients

All registered primary THA for OA through the DSA, PLA and DAA between 2014 and 2020 (n = 37,976), and with PROM questionnaires available at all timepoints were included. Procedures with metal-on-metal bearing were excluded (Figure 1). Patients in the DSA and DAA groups were generally younger and more likely to be female compared with the PLA group (Table 1).

Table 1. Descriptive statistics of preoperative patient and procedure characteristics of all primary THA with direct superior (DSA), posterolateral (PLA), or anterior approach (DAA) from 2014–2020 with pre-, 3-, and 12-months PROM data.

	DSA (n = 343)		PLA (n = 22,616)		DAA (n = 15,017)		Total (n = 37,976)	
	n	(%)	n	(%)	n	(%)	n	(%)
Age (years)								
<60	57	17	3,277	15	2,357	15	5,691	15
60-74	199	58	12,973	57	8,782	59	21,954	58
≥75	87	25	6,361	28	3,878	26	10,326	27
Sex								
Male	120	35	8,655	38	5,135	34	13,910	37
Female	223	65	13,947	62	9,882	66	24,052	63
ASA-score								
I	82	24	4,116	18	3,067	20	7,265	19
II	210	61	14,214	63	9,837	66	24,261	64
III–IV	51	15	4,280	19	2,112	14	6,443	17
Previous operation								
Yes	1	0.3	436	2	156	1	593	2
No	341	99.7	22,062	98	14,770	99	37,173	98
Smoking	[b]							
Yes	35	10	2,027	9	1,251	8	3,313	9
No	308	90	20,192	91	13,723	92	34,223	91
BMI								
< 18.5	3	1	122	1	83	0.6	208	1
18.5–25	155	45	6,859	30	5,401	36	12,415	33
25–30	131	38	9,811	44	6,542	44	16,484	43
30–40	53	16	5,486	24	2,842	19	8,381	22
> 40	1	0.3	277	1	83	0.6	361	1
Charnley								
A	143	42	9,652	43	6,648	44	16,443	43
B1	115	34	6,892	31	5,002	33	12,009	32
B2	77	22	5,073	22	3,013	21	8,163	22
C	7	2	868	4	327	2	1,202	3

ASA-score: American Society of Anesthesiology score; BMI: Body Mass Index; Numbers do not add up to total due to unknown or missing values.

PROMs

Baseline NRS pain scores during activity were higher in the DSA group compared with the DAA group (adjusted mean difference 0.4, CI 0.2–0.6). In addition, HOOS-PS scores at baseline were higher in the DSA group compared with the DAA group (4.2, CI 2.4–6.1) (Figure 2, Table 2, Table 3 shows unadjusted values], Appendix). All PROM scores improved at 3 months and 12 months postoperatively for all surgical approaches (Table 2). From baseline to 3 and 12 months, the mean improvement for NRS pain scores (Figure 3), EQ-5D, and OHS did not differ for the DSA compared with the PLA and the DAA. From baseline to 3 and 12 months postoperatively, improvement in HOOS-PS scores did not differ between DSA and PLA. For the DSA compared with the DAA, the mean difference in improvement in HOOS-PS was –1.7, CI –3.9 to 0.5 at 3 months. At 12 months postoperatively, the DSA group showed larger improvement in HOOS-PS com-pared with the DAA group (–2.8, CI –4.9 to –0.6) (Figure 3). Postoperative improvements in pain at rest, pain during activ-ity, OHS, and HOOS-PS exceeded the pre-established MCIDs from the literature (Table 2). For all PROMs examined, the difference between surgical approaches over time fell below their pre-established MCIDs, indicating no clinically relevant difference between surgical approach groups (Table 2).

Sensitivity analysis

The results obtained from the sensitivity analysis were largely consistent with the original analysis. While some differences were observed in terms of significance, confidence intervals, direction, or magnitude of the effects (Table 5, see Appendix), these differences did not have a significant impact on the overall conclusions drawn from the original analysis. This suggests that the findings are robust.

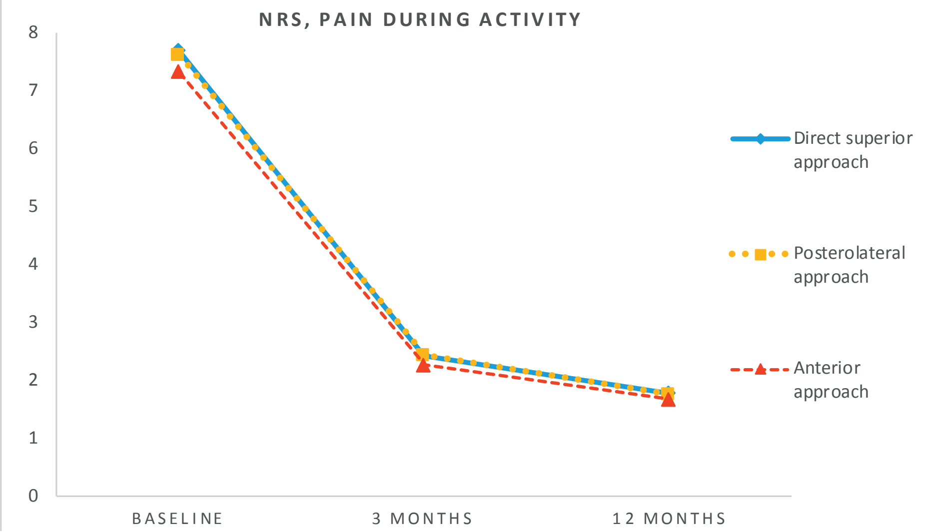

Figure 2. NRS pain during activity preoperatively, at 3 months postoperatively, and at 12 months postoperatively, adjusted for age, sex, ASA-score, and BMI.

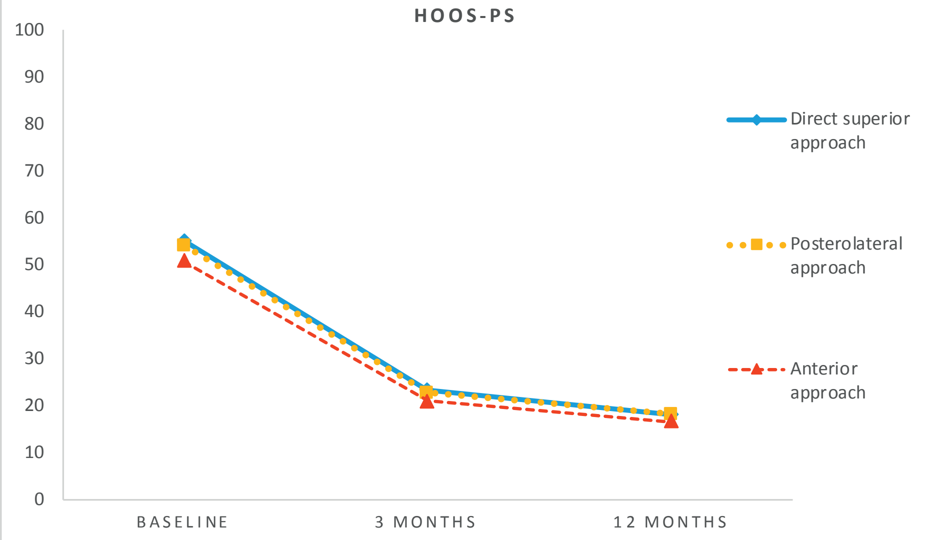

Figure 3. HOOS-PS preoperatively, at 3 months postoperatively, and at 12 months postoperatively, adjusted for age, sex, ASA-score, and BMI.

Table 2. Adjusted mean difference (CI) of NRS pain, EQ-5D index score, HOOS-PS, and OHS between preoperative and 3- and 12-month postoperative scores and between surgical approaches at 3 months and 12 months postoperatively.[a]

PROM	DSA N = 343	PLA N = 22,616	DAA N = 15,017	DSA vs PLA	DSA vs DAA
	Mean change (CI)[b]	Mean change (CI)[b]	Mean change (CI)[b]	Difference in mean change (CI)[c]	Difference in mean change (CI)[c]
Pain at rest					
Baseline to 3 months	– 3.9 (–4.2 to –3.6)	– 4.1 (–4.2 to –4.1)	– 3.8 (–3.9 to –3.8)	0.2 (–0.1 to 0.5)	–0.1 (–0.4 to 0.2)
Baseline to 12 months	– 4.2 (–4.5 to –3.9)	– 4.4 (–4.5 to –4.4)	– 4.1 (–4.2 to –4.1)	0.2 (–0.1 to 0.5)	–0.1 (–0.4 to 0.2)
Pain during activity					
Baseline to 3 months	– 5.3 (–5.6 to –5.0)	– 5.2 (–5.2 to –5.2)	– 5.0 (–5.1 to –5.0)	–0.1 (–0.4 to 0.2)	–0.2 (–0.5 to 0.1)
Baseline to 12 months	– 5.9 (–6.2 to –5.6)	– 5.9 (–5.9 to –5.8)	– 5.6 (–5.7 to –5.6)	–0.1 (–0.3 to 0.3)	–0.3 (–0.6 to 0.04)
EQ–5D index score					
Baseline to 3 months	0.2 (0.21 to 0.26)	0.2 (0.24–0.24)	0.2 (0.23–0.24)	–0.01 (–0.03 to 0.01)	–0.002 (–0.03 to 0.02)
Baseline to 12 months	0.3 (0.26 to 0.31)	0.3 (0.28–0.29)	0.3 (0.27–0.28)	0.01 (–0.02 to 0.03)	0.02 (–0.01 to 0.04)
HOOS–PS					
Baseline to 3 months	– 32 (–34 to –30)	– 31 (–32 to –31)	– 30 (–30 to –30)	–0.2 (–2.4 to 1.9)	–1.7 (–3.9 to 0.5)
Baseline to 12 months	– 37 (–39 to –35)	– 36 (–36 to –36)	– 34 (–35 to –34)	–1.0 (–3.2 to 1.1)	–2.8 (–4.9 to –0.6)[b]
OHS					
Baseline to 3 months	16 (15 to 17)	16 (16–16)	16 (16–17)	–0.4 (–1.4 to 0.7)	–0.4 (–1.5 to 0.6)
Baseline to 12 months	19 (18 to 20)	19 (19–19)	19 (19–19)	0.1 (–0.9 to 1.2)	0.3 (–0.8 to 1.3)

a Results from a multiple linear mixed effect models adjusted for age, sex, BMI and ASA score with PROM variable as the dependent variable and surgical approach, time, and interaction between time and surgical approach as independent variables.
b $P < 0.05$. All changes in score between baseline and follow-up within each group are significant.
c A negative number for pain at rest, pain during activity and HOOS-PS means larger decrease in scores and thus more improvement over time compared with the other approach. A negative number for EQ-5D and OHS means less increase in scores and thus less improvement compared with the other approach.

Discussion

We aimed to examine whether the DSA improves PROMs after 3- and 12-months following THA compared with 1) the PLA and 2) the DAA. We found no clinical relevant improvements on all PROMs at 3 and 12 months after primary THA between the approaches.

Previous registry-based studies from the Norwegian, Dutch and UK National Joint registry have not been able to show a clear benefit of 1 specific surgical technique in terms of PROMs [2, 3, 26]. This is the first large registry-based study comparing the PROMs of the DSA with the PLA or the DAA. Most studies reporting on PROMs after THA using the DSA have been case series or case-control studies from specialized centers [9-15]. Ulvivi et al. compared the DSA with the PLA through a randomized trial [16]. The authors reported comparable improvement in pain scores up to 6 months. With regard to functional scores, 1 study reported superior functional scores in the first month for the DSA compared with the PLA [14]. In contrast, other studies reported no difference in functional scores (HOOS and HHS) between the DSA and the PLA at 3 months, 6 months, 1 year or 2 years of follow-up [10-12, 14, 16]. Our study aligns, showing a comparable magnitude of improvement for the DSA, PLA and DAA at 3 and 12 months of follow-up.

It is essential to distinguish between statistical significance and clinical importance, since a statistically significant result does not automatically indicate a clinically important difference [24]. In our study, we found that the improvements in pain at rest, pain during activity, OHS and HOOS-PS after 3 months exceed the pre-established MCIDs from literature, indicating their clinical relevance for each surgical approach. For all PROMs examined, the (absolute value of the) boundaries of the confidence intervals for the difference between surgical approaches fell below their pre-established MCIDs [20-23]. Thus, the mean effect of DSA does not differ in terms of clinical relevance from the mean effect of DAA and PLA respectively. Only for the HOOS-PS scores the difference between the DSA and DAA groups at 12 months was statistically significant (–2.8, CI –4.9 to –0.6). However, we believe this difference is not clinically relevant since both the DSA and DAA patients had already exceeded the MCID threshold, and the lower bound difference of 4.9 is much less than the MCID of 23.

Limitations

Missing data frequently represent a potential source of bias in clinical research [24]. In the present study, we focused on patients with complete PROM data, but this approach could introduce bias by assuming that data is missing completely at random (MCAR). To address this, we performed a sensitivity analysis to investigate the possible bias that arose from this assumption. This analysis included patients with missing data, assuming it occurred at random (MAR), to provide a more comprehensive perspective on the effectiveness of the interventions in the entire study population. Although some results changed in significance, direction, or magnitude, the boundaries of the confidence intervals of the difference in mean change remained below the pre-defined MCID values for all PROMs, so the conclusion drawn from the original analysis remained, providing further support for the strength and reliability of our findings.

A number of limitations need to be considered. First, data on early postoperative PROMs were not collected, which limits our insight into the potential benefits of a tissue-sparing approach in the first days after surgery. Secondly, although this is a large cohort study, it has a limited number of DSA patients. The relatively broad confidence intervals for the DSA suggests that our study may have been insufficiently powered to detect smaller differences between the surgical approaches. Thirdly, a limitation of our study was the lack of differentiation between various posterolateral approaches (including tissue-sparing techniques), as all posterolateral THAs are registered under a single category. Another limitation was that baseline characteristics between groups were not balanced. However, the linear mixed effect models used account for variation across individuals in their baseline levels by including a random effect for each patient. This allows for modeling of individual-specific variability in PROMs outcomes, while also estimating the population-level effects. Furthermore, response rates on postoperative PROMS were low, which could introduce non-response bias. However, linear mixed effect models allow for missing data that depends on the explanatory variables in the model and are thus robust to determining estimates in presence of missing data [25]. Finally, we acknowledge that we are presenting a large number of p-values, which could be subject to multiple testing issue.

Conclusion

Our study showed no clinically meaningful differences between the DSA and either PLA or DAA.

Perspectives

Given the fact that we did not detect clinically important differences between the DSA and the PLA or DAA in this study, we should be cautious recommending a specific surgical approach to our patients. Ultimately, the choice of surgical approach should be based on multiple factors, such as the patient's medical history, body habitus, the complexity of the procedure, the surgeons experience, as well as a consideration of the risks and benefits of each approach. For example, based on the findings from our previous paper, it is noteworthy that the DSA may offer an advantage in terms of reduced risk of dislocation [8].

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Appendices

Table 3. Unadjusted mean (CI) of NRS pain, EQ-5D index score, HOOS-PS, and OHS preoperatively and 3 and 12 months postoper-atively for different surgical approachessurgical approaches (superior [DSA], posterolateral [PLA), or anterior approach [DAA]).

PROM	Baseline	3 months postoperative	12 months postoperative
NRS pain at rest			
Direct superior	5.0 (4.8–5.3)	1.2 (1.0–1.3)	0.8 (0.6–1.0)
Posterolateral	5.3 (5.3–5.4)	1.2 (1.1–1.2)	0.9 (0.9–1.0)
Anterior	5.0 (4.9–5.0)	1.1 (1.1–1.2)	0.8 (0.8–0.9)
NRS pain during activity			
Direct superior	7.3 (7.1–7.5)	2.1 (1.5–2.6)	1.4 (0.9–1.9)
Posterolateral	7.3 (6.9–7.7)	2.0 (1.5–2.8)	1.4 (0.7–2.1)
Anterior	7.0 (6.5–7.4)	1.7 (1.0–2.5)	1.1 (0.3–1.8)
EQ-5D index score			
Direct superior	0.5 (0.53–0.57)	0.8 (0.73–0.82)	0.8 (0.79–0.88)
Posterolateral	0.5 (0.49–0.57)	0.8 (0.70–0.83)	0.8 (0.76–0.89)
Anterior	0.6 (0.53–0.61)	0.8 (0.73–0.86)	0.8 (0.79–0.92)
HOOS-PS			
Direct superior	50 (48–52)	18 (14–22)	13 (8.7–17)
Posterolateral	49 (46–53)	18 (12–23)	12 (6.4–18)
Anterior	46 (42–49)	14 (8.2–20)	8.7 (2.9–15)
OHS			
Direct superior	24 (23–25)	40 (38–42)	43 (41–45)
Posterolateral	23 (21–24)	39 (36–42)	42 (39–45)
Anterior	24 (22–26)	40 (37–43)	44 (41–46)

Table 4. Adjusted mean (CI) of NRS pain, EQ-5D index score, HOOS-PS, and OHS preoperatively and 3 and 12 months postoperatively for different surgical approaches (superior [DSA], posterolateral [PLA), or anterior approach [DAA]).

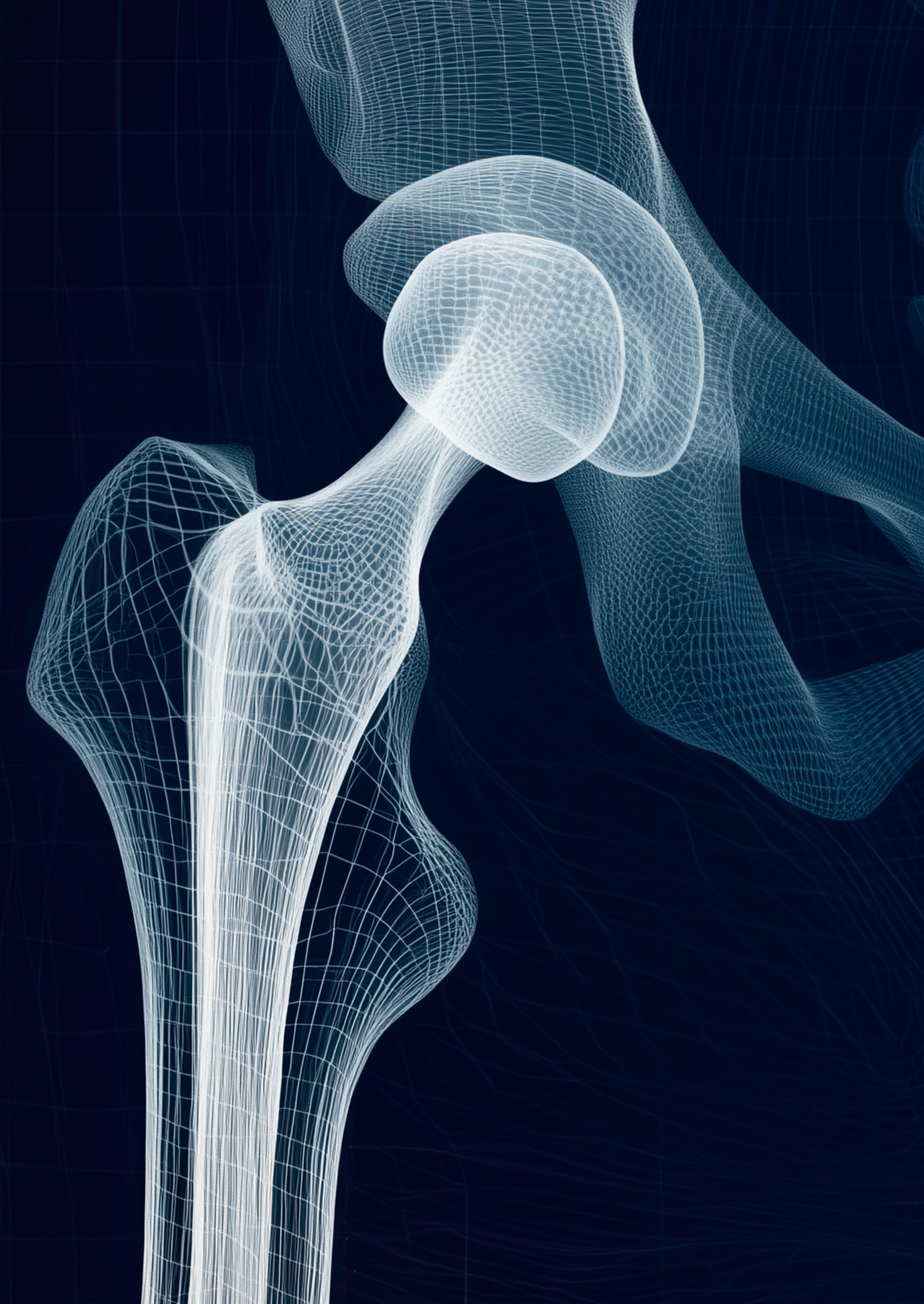
PROM	Baseline	3 months postoperative	12 months postoperative
NRS pain at rest			
Direct superior	5.3 (5.0–5.6)	1.4 (0.8–2.0)	1.1 (0.6–1.6)
Posterolateral	5.6 (5.5–5.6)	1.4 (1.3–1.5)	1.1 (1.1–1.2)
Anterior	5.2 (5.2–5.3)	1.4 (1.3–1.5)	1.1 (1.0–1.2)
NRS pain during activity			
Direct superior	7.7 (7.5–7.9)	2.4 (1.9–3.0)	1.8 (1.3–2.3)
Posterolateral	7.6 (7.6–7.7)	2.4 (2.3–2.5)	1.8 (1.7–1.8)
Anterior	7.3 (7.3–7.4)	2.3 (2.2–2.4)	1.7 (1.6–1.8)
EQ-5D index score			
Direct superior	0.5 (0.46–0.50)	0.7 (0.67–0.75)	0.8 (0.72–0.81)
Posterolateral	0.5 (0.47–0.47)	0.7 (0.70–0.72)	0.8 (0.74–0.76)
Anterior	0.5 (0.49–0.50)	0.7 (0.72–0.74)	0.8 (0.76–0.78)
HOOS-PS			
Direct superior	55 (53–57)	24 (20–28)	18 (14–22)
Posterolateral	54 (54–55)	23 (22–24)	18 (18–19)
Anterior	51 (51–51)	21 (20–22)	17 (16–18)
OHS			
Direct superior	20 (19–21)	36 (34–38)	40 (38–41)
Posterolateral	20 (20–20)	36 (36–37)	39 (39–39)
Anterior	21 (21–21)	37 (37–38)	40 (40–40)

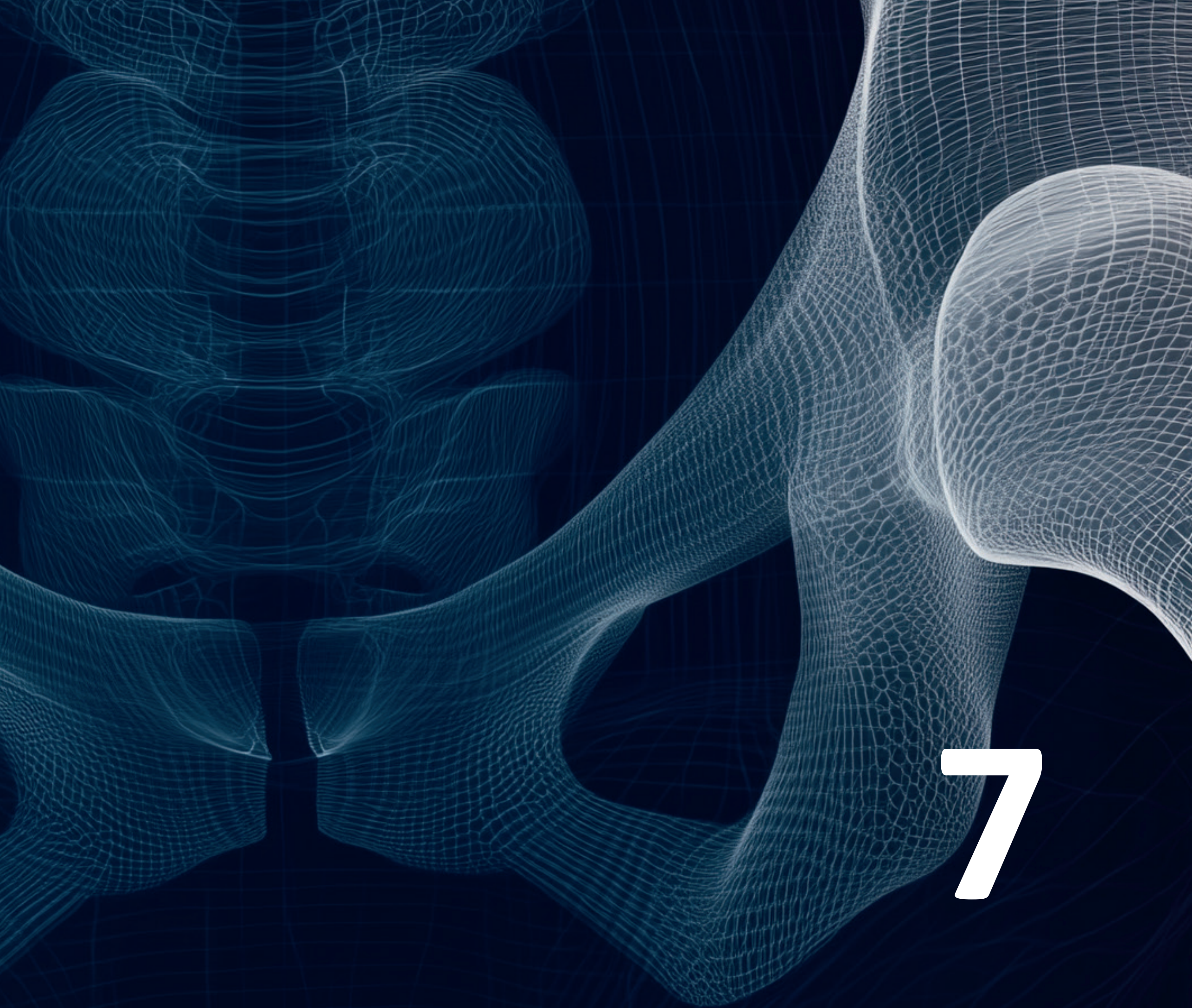
Adjusted mean and 95% CI were calculated from linear mixed model adjusted for age, sex, BMI and ASA-score.

Table 5 Sensitivity analysis[a]: Adjusted mean difference (CI) of NRS pain, EQ-5D index score, HOOS-PS, and OHS between preoperative and 3- and 12-month postoperative scores and between surgical approaches (superior [DSA], posterolateral [PLA], or anterior approach [DAA]) at 3 months and 12 months postoperatively.

PROM	DSA n= 888	PLA n= 52,563	DAA n = 36,274	DSA vs PLA	DSA vs DAA
	Mean change (CI) [b]	Mean change (CI) [b]	Mean change (CI) [b]	Difference in mean change (CI) [c]	Difference in mean change (CI) [c]
Pain at rest					
Baseline to 3 months	– 3.7 (–3.9 to –3.5)	– 3.8 (–3.8 to –3.8)	– 3.5 (–3.8 to –3.7)	0.1 (–0.1 to 0.3)	–0.1 (–0.3 to0.1)
Baseline to 12 months	– 3.8 (–4.0 to –3.6)	– 4.0 (–4.0 to –4.0)	– 3.8 (–3.6 to –3.5)	0.2 (0.1 to 0.4) [b]	–0.1 (–0.3 to 0.2)
Pain during activity					
Baseline to 3 months	– 4.9 (–5.1 to –4.7)	– 4.8 (–4.8 to –4.8)	– 4.6 (–4.7 to –4.6)	–0.1 (–0.3 to 0.1)	–0.2 (–0.4 to –0.01) [b]
Baseline to 12 months	– 5.3 (–5.5 to –5.1)	– 5.3 (–5.3 to –5.3)	– 5.1 (–5.1 to –5.1)	0.1 (–0.2 to 0.2)	–0.2 (–0.4 to 0.03)
EQ–5D index score					
Baseline to 3 months	0.2 (0.21 to 0.24)	0.2 (0.23 to 0.23)	0.2 (0.24 to 0.25)	–0.01 (–0.02 to 0.01)	0.004 (–0.01 to 0.02)
Baseline to 12 months	0.2 (0.23 to 0.26)	0.3 (0.26 to 0.26)	0.2 (0.22 to 0.22)	–0.01 (–0.02 to 0.01)	0.002 (–0.02 to 0.02)
HOOS–PS					
Baseline to 3 months	– 29 (–31 to –28)	– 30 (–30 to –29)	– 28 (–29 to –28)	0.2 (–1.2 to 1.7)	–1.0 (–2.5 to 0.4)
Baseline to 12 months	– 33(–34 to –31)	– 33 (–33 to –33)	– 32(–32to –31)	0.5 (–1.0 to 2.0)	–1.0 (–2.5 to 0.6)
OHS					
Baseline to 3 months	15 (14 to 16)	15 (15 to 16)	15 (15 to 15)	–0.3 (–1.0 to 0.4)	–0.1 (–0.8 to 0.6)
Baseline to 12 months	17 (17 to 18)	18 (18 to 18)	17 (17 to 17)	–0.5 (–1.1 to 0.2)	–0.1 (–0.7 to 0.7)

a. Sensitivity analysis using MI. Results from pooled data using a linear mixed effect models adjusted for age, sex, BMI and ASA score with PROM variable as the dependent variable and surgical approach, time, and interaction between time and surgical approach as independent variables.
b. $p < 0.05$. All changes in score between baseline and follow-up within each group are significant.
c. A negative number for pain at rest, pain during activity an HOOS-PS means larger decrease in scores and thus more improvement over time compared with the other approach. A negative number for EQ-5D and OHS means less increase in scores and thus less improvement compared with the other approach.





7

Low revision rate throughout the adoption of the direct superior approach in primary total hip arthroplasty: An analysis based on 1,551 total hip arthroplasties from the Dutch Arthroplasty Register

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Hip international 2024 Sep 34(5):614-621

Abstract

Background
Recently, surgeons introduced a minimally invasive modification on the classic posterolateral approach (PLA) in total hip arthroplasty (THA): the direct superior approach (DSA). We investigated the association between surgeon's experience and the risk of early revision of the DSA in primary THA, using data from the Dutch Arthroplasty Register (LROI).

Methods
We retrieved all primary THAs performed using the DSA in 4 hospitals between 2016 and 2022 (n=1,551). Procedures were sorted in 5 groups using the date of operation and number of previous procedures per surgeon: 1-25, 26-50, 51-75, 76-100 or >100. Subsequently, data from different surgeons was pooled together and the risk of revision was calculated via a multilevel time-to-event analysis.

Results
The overall revision rate was 1.5% after a mean follow-up of 2 years. Patients from the 1-25 group had comparable risks of revision compared to patients in the >100 group (hazard ratio [HR] 1.0, CI 0.3-3.2). The risk for patients in groups 26-50, 51-75 and 75-100 was also not statistically different from the >100 group (resp. HR 1.5 (CI 0.5-5.0), 1.8 (CI 0.5-6.4) and 0.5 (CI 0.1-4.0)). Main reasons of revision were dislocation (0.5%) and infection (0.4%).

Conclusion
We did not identify an association between the surgeon's experience and the early risk of revision for the DSA in primary THA in the Netherlands. The DSA seems safe in the early adoption phases with a low risk of revision due to dislocation and revision for all other causes.

Introduction

The surgical approach in total hip arthroplasty (THA) remains a subject to debate due to lack of superior evidence for one specific approach [1-4]. In the last decade, the posterolateral approach (PLA) was the most commonly used approach in primary THA in the Netherlands, followed by the direct anterior approach (DAA) [5]. Both approaches have certain advantages and disadvantages. For instance, component placing in the PLA is relatively easy due to a clear view of the acetabulum and proximal femur [1,6]. The DAA seems to reduce early patient reported pain and decreases post-operative hospital stay [2]. In terms of adverse events, the PLA is associated with a higher risk of revision due to dislocation, whereas the DAA is associated with a higher risk of femoral-sided revisions [7]. In addition, the DAA is a technically demanding approach with a significant learning curve [8,9]. In attempt to reduce the dislocation rate in the PLA, the use of larger femoral heads and repair of the posterior capsule has been proven effective [7,11]. To further diminish the dislocation risk and enhance early recovery, posterolateral trained surgeons introduced the direct superior approach (DSA). The DSA is a modification of the classic PLA in which the iliotibial band and short external rotators are spared. Also, an alternative capsule incision with direct repair is used [10,12]. Since the DSA is a minimally invasive surgical (MIS) approach, with all inherent risks of minimally invasive surgery, knowledge of outcome in relation to experience is essential. We investigated the association between the surgeon's experience and risk of early revision for the DSA in primary THA, using nationwide data from the Dutch Arthroplasty Register (LROI).

Materials and methods

Study design

The study design is a population-based cohort study of all primary THAs via DSA originating from 4 high-volume hospitals from the Netherlands between 2016 and January 1st 2022. The study is reported according to the STROBE guidelines [13].

Setting and data source

Data was obtained via the LROI in which arthroplasties from all hospitals in the Netherlands are registered since 2007 [14]. The data has a completeness of >98% for THAs since 2012, with a high validity [15,16]. Since data in the LROI is anonymized and information on individual surgeons is blinded, it was not possible to directly assess the surgeon's experience and investigate the association with early revision risk for the DSA on a full nationwide scale. Hence, we initiated a cooperation between 4 high-volume hospitals, contributing to 89% of all DSA procedures registered in the Netherlands [5], so individual surgeon data could be unblinded. Descriptive information, procedure details and implant characteristics were obtained via the LROI [8]. Information on vital status was obtained by matching data from the LROI and Vektis, a national insurance database on healthcare [17].

Outcome

Revision rates were determined for the separate phases of the learning curve. All procedures were ordered per surgeon by the date of operation. Subsequently, the procedures were divided into 5 groups based on the surgical experience (1-25, 26-50, 51-75, 76-100 and >100 procedures performed). Subsequently, data from different surgeons was pooled. Cutoff points were based on practical considerations and the distribution of the data available for analysis. To ensure consistency regarding the registration of DSA THAs, the collaborating surgeons defined a DSA if they were able to spare the iliotibial tract and short external rotators together with a superior capsule incision with a side-to-side capsule repair. If one of these conditions was not met, a PLA was registered.

Statistical analysis

Survival was defined as the time from primary THA to first revision arthroplasty for any reason, death or January 1st 2022 (end of follow-up). Revision arthroplasty is considered as a change of one or more components of the original prosthesis. Standard time to revision analysis regards death as censored information, resulting in overestimation of revision rates [18]. Therefore, we used competing risk analyses where death was considered a competing risk, to calculate a crude cumulative incidence of revision. We calculated 1-, 3- and 5 years crude revision percentages per operation group. Also, because all patients 'belong' to a certain hospital, differences in outcome could be resulting from dissimilarities in protocols amongst the different hospitals. To adjust for this random center effect, we used a gamma frailty model with frailty effects for hospitals [19]. According to the hierarchical structure of the data, patients were defined as level 1 and hospitals as level 2. Hereafter, a multilevel Cox regression analysis was performed with BMI as confounding factor [20]. Results were reported as hazard ratios (HR) with 95% confidence intervals (CI). Proportional hazard assumption was checked using the Schoenfeld residuals, which was not violated. For all tests, a two-tailed significance level of $p < 0.05$ was used. The use of SPSS statistics for Windows version 28.0 (Armonk, NY: IBM Corp) and SAS software (SAS institute Inc., Cary, NC, USA) were employed for statistical analyses.

Sensitivity analysis

To increase reliability of data, we excluded surgeons who performed less than 5 implantations in our primary analysis. A sensitivity analysis was conducted with the inclusion of the surgeons with less than 5 DSA procedures to assess whether the results lead to different outcomes. Also, we added an adjusted 1-year risk of revision in patients with 1 year follow-up to account for the difference in follow-up time between patients.

Ethical approval

The research protocol was approved by the board of the LROI and is in compliance with the regulations of the LROI. Ethical approval was not required according to the Dutch Medical Research Involving Human Subject Act (WMO) as all data were received completely anonymous as part of routine clinical care and in accordance with Dutch and EU data protection rules.

Results

All registered primary THAs via DSA between 2016 and 2022 were retrieved (*n* = 1679). A total of 1551 primary THAs were analysed (Figure 1). Descriptive and clinical data on all patients is presented in Table 1. The mean follow-up was 2 years. The total number of surgeons was 22, originating from 4 hospitals. The number of procedures per hospital varied from 146 to 925. The total number of DSA procedures in 2016 was 81, which gradually rose to 503 in 2021 (Supplemental Table 1). 22 surgeons performed at least 25 procedures, and 5 surgeons performed >100 procedures (Supplemental Table 2).

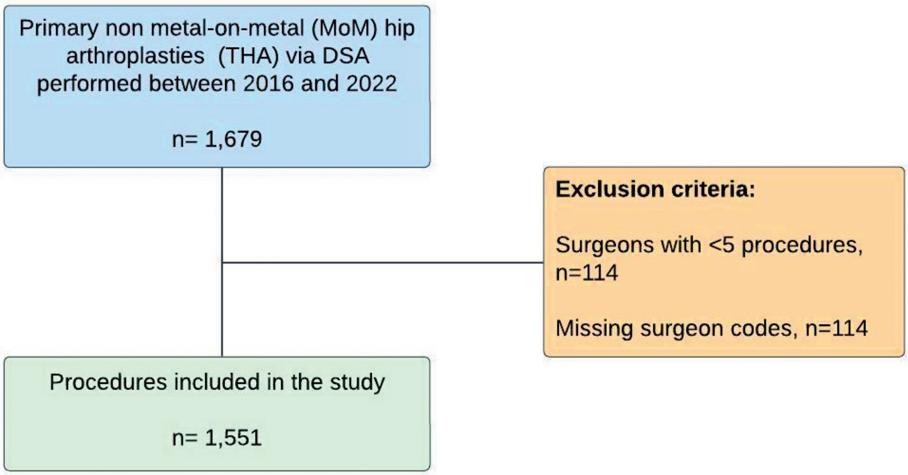

Figure 1. Flowchart for the study.

Table 1. Descriptive and clinical data on all patients who received a primary THA via DSA between 2016 and 2022 in the 4 participating hospitals (n =1,551).

	1-25		26-50		51-75		76-100		>100		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Age												
<60	66	14	47	15	31	15	34	23	86	21	265	17
60-74	266	57	174	56	109	53	85	56	222	53	856	55
>75	135	29	87	28	65	32	32	21	111	26	430	28
Gender												
Female	290	62	183	59	126	61	99	66	279	66	977	63
Male	177	38	125	41	79	39	52	34	141	34	574	37
ASA score[a]												
I	69	15	61	20	40	20	33	22	61	15	264	17
II	290	62	196	63	129	63	88	58	273	65	976	63
III-IV	108	23	51	17	36	18	30	20	86	20	311	20
Diagnosis[a]												
OA	428	92	289	94	192	94	139	92	367	87	1415	91
Non-OA	39	8.4	19	6.2	13	6.3	12	7.9	53	13	136	8.8
BMI[a]												
<18,5	9	1.9	1	0.3	2	1.0	1	0.7	7	1.7	20	1.3
18,5-25	197	42	124	40	77	38	53	35	157	37	608	39
25,1-30	190	41	133	43	85	41	53	35	176	42	637	41
30,1-40	71	15	49	16	40	20	44	29	76	18	280	18
>40,1	0	0	1	0.3	1	0.5	0	0.0	4	1.0	6	0.4
Charnley score												
A	209	45	140	45	91	44	66	44	186	44	692	45
B1	127	27	85	28	62	30	50	33	112	27	436	28
B2	103	22	74	24	45	22	31	21	97	23	350	23
C	13	2.8	3	1.0	2	1.0	3	2.0	8	1.9	29	1.9
N.a. (non-OA)	15	3.2	6	1.9	5	2.4	1	0.7	17	4.0	44	2.8
Fixation												
Cemented	261	56	158	51	115	56	72	48	235	56	841	54
Cementless	164	35	125	41	70	34	64	42	149	35	572	37
Reversed Hybrid	38	8.1	21	7	15	7.3	15	9.9	30	7.1	119	7.7
Hybrid	4	0.8	4	13	5	2.5	0	0.0	6	1.5	19	1.2
Femoral head size												
22-28	132	29	87	9	63	31	39	26	67	16	388	25
32	292	64	187	63	123	61	104	70	310	74	1016	67
36	35	7.6	26	8.7	16	7.9	5	3.4	38	9.2	120	7.9

Table 1. Descriptive and clinical data on all patients who received a primary THA via DSA between 2016 and 2022 in the 4 participating hospitals (n =1,551). (continued)

	1-25		26-50		51-75		76-100		>100		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Bearing type[a]*												
CoP	366	84	255	79	161	80	108	76	278	69	1138	78
MoP	42	9.6	34	11	28	14	19	13	76	19	199	14
ZoP	30	6.8	26	9.1	12	6.0	16	11	47	12	131	8.9

a. $p < 0.05$:
* Numbers do not add up to total due to unknown or missing values.
ASA score: American Society of Anesthesiology score, Non-OA: dysplasia, fracture, inflammatory arthritis, late posttraumatic, osteonecrosis, rheumatoid arthritis, tumor, and other, BMI: Body Mass Index, CoP: Ceramic-on-polyethylene, MoP: Metal-on-polyethylene, ZoP: oxidized-zirconium-on-polyethylene.

Crude cumulative incidence of revision

23 THAs (1.5%) were revised. The most frequent reasons for revision were dislocation (n= 7; 0.5%) and infection (n= 6; 0.4%) (Table 2). The crude 1-year revision rate for the 1-25 group was 0.9% (CI 0.3-2.3), whereas the 26-50 and 51-75 group demonstrated a 1.7% (CI 0.7-4.0) and 1.5% (CI 0.5-4.5) risk of revision. In the 76-100 and >100 group the revision rate was respectively 0.9% (CI 0.1-6.6) and 1.5% (CI 0.6-3.6). The crude cumulative incidence of revision after 3- and 5 years was comparable between groups (table 3, figure 2).

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Table 2. Reasons for revision in all primary THAs via DSA performed between 2016 and 2022 (n=23). Values are count (%).

	1-25 n= 467.	26-50 n=308.	51-75 n=205.	76-100 n=151.	>100 n=420.	Total n (%) n= 1,551
Revised	6 (1.3)	6 (1.9)	6 (2.9)	1 (0.7)	5 (1.2)	23 (1.5)
Reason for revision[a]						
Dislocation	1	2	1	1	2	7 (0.5)
Infection	2	2	1	0	1	6 (0.4)
Periprosthetic fracture	2	0	1	0	2	5 (0.3)
Loosening of femur	1	0	2	0	0	3 (0.2)
Loosening of acetabulum	0	2	1	0	0	3 (0.2)
Cup / liner wear	0	0	0	0	0	0 (0)
Other*	0	0	0	0	0	0 (0)

a. A patient may have more than 1 reason for revision.
* Other was defined as: Girdlestone, Periarticular ossification, Symptomatic metal-on-metal or Malalignment.

Table 3. Crude cumulative incidence of revision (%) for the different experience groups for primary THA via DSA (non case-mix corrected).

n (%), (95% CI)	1-25 n=467	26-50 n=308	51-75 n=205	76-100 n=151	>100 n=420
1-year	0.9 (0.3-2.3)	1.7 (0.7-4.0)	1.5 (0.5-4.5)	0.9 (0.1-6.6)	1.5 (0.6-3.6)
3-year	1.1 (0.5-2.8)	2.3 (1.0-5.3)	3.4 (1.3-8.4)	0.9* (0.1-6.6)	1.5 (0.6-3.6)
5-year	1.9* (0.8-4.8)	2.3* (1.0-5.3)	3.4* (1.3-8.4)	n.a.* (n.a.)	n.a.* (n.a.)

* Number at risk <50.

Overall adjusted multilevel survival analysis

Multilevel, multivariable survival analysis demonstrated a comparable risk of revision in patients operated within the 1-25 group (HR 1.0, CI 0.3-3.2) compared to patients within the >100 group. In the 26-50 and the 51-75 group, the HR was not statistically different from the >100 group, albeit higher (HR 1.5, CI 0.5-5.0 and HR 1.8, CI 0.5-6.4). Patients from the 75-100 group demonstrated a lower risk (HR 0.5, CI 0.1-4.0), although not statistically significant (Table 4). There was a statistically significant lower risk of revision for patients with a BMI <18.5 (HR 0.3, CI 0.1-0.8) and a BMI 18.5-30 (HR 0.4, CI 0.1-1.0) compared to patients with a BMI >30.1.

Table 4. Multivariable survival analysis of patients who underwent THA via DSA between 2016 and 2022 in the 4 participating hospitals according to a multilevel time-to-event analysis.

Experience groups	Hazard ratio (95% CI)[a]
1-25	1.0 (0.3-3.2)
26-50	1.5 (0.5-5.0)
51-75	1.8 (0.5-6.4)
76-100	0.5 (0.1-4.0)
>100	1.0 (reference)

a. Adjusted for BMI.

Sensitivity analysis

When surgeons with less than 5 DSA procedures were included, the results were comparable to the previous analyses (data not shown). The adjusted 1-year revision risk demonstrated a comparable risk of revision for the >100 group (1.0) compared to the 1-25 group: HR 0.6 (0.2-2.4).

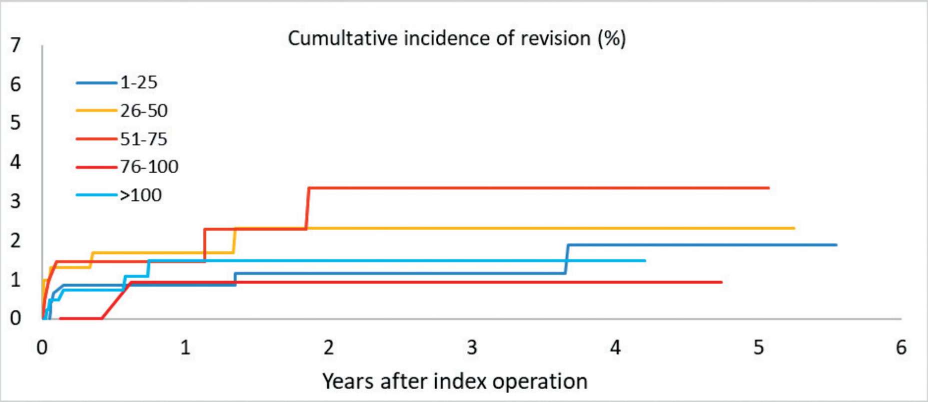

Figure 2. Crude cumulative incidence of revision (%) for the different experience groups for primary THA via DSA.

Discussion

We found a comparable risk of revision for patients with a primary THA operated via DSA within the five defined experience groups. Therefore, we did not identify an association between the surgeon's experience and the risk of revision of the DSA in primary THA. To the best of our knowledge, this study is the first nationwide, registry-based analysis of the individual surgeon's experience in relation to the risk of revision of the DSA in primary THA.

The risk of revision associated with the DSA during the early phases of the learning curve was comparable to that reported for the DAA and PLA in existing literature. Van Dooren et al. reported an overall 1-year revision risk for the DSA of 0.8%, which was comparable to the DAA (0.9% (CI 0.9-1.0)) and superior to the PLA (1.8% (CI 1.7-1.9)) [10]. In line with these results, the annual report of the LROI demonstrated that the 1-year revision risk of major revision among patients with OA ranged between 0.98-1.22% for the PLA and 0.67-1.03% for the DAA, for various time intervals between 2009 to 2020 [16]. In our study, the 1-year crude-cumulative risk of revision of the 1-25 and 26-50 experience groups was 0.9% and 1.7%. Since these results are comparable to the outcomes of PLA and DAA, we conclude that the adoption of the DSA does not result in an increased rate of revision.

Previous studies investigated the learning curve of the DSA using surgical parameters and cup positioning. Duijnisveld et al. found no significant learning effect in the first 52 patients who received a THA via DSA in terms of surgical time, perioperative blood loss and hemoglobin level change [21]. Ezzibdeh et al. found no statistically significant differences between the first 20 patients operated via DSA compared to the next 20 patients regarding intraoperative blood loss, length of hospital stay and post-operative

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analgesic use. The authors only reported a statistically significant decrease in surgical time after 20 procedures [22]. A decrease in surgical time was also reported by Leonard et al. comparing the first 10 patients operated via DSA to the 80th-100th patient [23]. When adopting a MIS approach, one should be aware of an increased risk of complications. In addition, the general criticism on MIS approaches in THA is that occasionally limited exposure of the acetabulum is obtained as a result of the small surgical field, with a higher risk of component malpositioning [24]. This may lead to instability and subsequent implant revision, impingement and increased polyethylene wear [24,25]. Also, this wear and inadequate weight distribution can cause loosening of components [26]. Learning curve studies of the DSA using plain radiographs reported adequate cup positioning, according to the Lewinnek safe zone in the different experience phases [22,27]. These studies therefore suggest that while the DSA is a MIS approach, component placing is not influenced by a potential lack of procedure-related experience.

Case mix

Majority of the patients in our analysis were female (63%) and aged over 60 years (83%), which both are comparable to the total population of patients who received a THA in the Netherlands in 2021 [28]. However, the patients in our study were rather healthy as demonstrated by low BMI and ASA scores compared to national numbers [28]. This might be the result of strict selection by orthopaedic surgeons in the introduction and use of the DSA. Peters et al. described that patient characteristics influence the rate of revision in THA as BMI and ASA score were the strongest predictors for an increased short-term revision rate [29]. The revision percentages demonstrated in this study are lower than revision percentages of other approaches [4,8,9]. Therefore, our results may have been affected by this selection. As surgical skills improve, surgeons might be able to expand their patient selection criteria. This may result in more patients being suitable for THA via DSA, who were previously considered high-risk. For example, patients with high BMI, ASA scores and other etiologies than OA. We only found a significant higher percentage of patients with non-OA as etiology for THA in the >100 group compared to the other groups. This suggests that increased experience with the DSA results in an expanded patient selection.

Revision rates

A possible reason for the low revision rate in all groups, could be that mainly experienced posterolateral-trained surgeons perform the DSA. The step from a PLA to a DSA is more natural than from any other approach, in which a learning curve can be avoided. The crude revision percentages we found are low and are at least comparable with revision rates of the DAA. However, due to wide confidence intervals no distinctive conclusions in relation to other approaches could be made. In a similar study regarding the learning curve of the DAA, crude 5-year revision percentages of the first 25 patients were 3.2%, in the second 25 it was 3.1%, and it was only after 100 cases the revision percentage was lower than 2% [8]. The crude 5-year revision percentage of the DSA in the first 25 patients was 1.9%. This comparison suggests that already in the early learning phase, the DSA is safe surgical approach to adopt. Although several studies state that the DSA demonstrates low dislocation rates [21,22,30], the most frequent reason for revision in our patients was dislocation. One of the assumed advantages of the DSA is that by sparing the iliotibial tract and short external rotators, stability to the joint is enhanced and postoperative mobilization is optimized. Despite the fact that dislocation was the most frequent reason for revision, the absolute percentage of revision for dislocation overall was 0.5%. This percentage demonstrates a superior value compared to the 5-year revision for dislocation percentage of the PLA (1.1%) stated by van Steenbergen et al. in a register analysis of 269,280 THAs in the Netherlands [31]. This suggests that based on our data, the DSA decreases the rate of revision for dislocation in comparison to the PLA.

Limitations

Some limitations of this study should be considered. As our data only contains the frequency and the reason for revision, it lacks information on postoperative complications which did not result into revision arthroplasty. Including dislocation for which closed reduction was performed, periprosthetic fractures managed with open reduction internal fixation and periprosthetic infections for which a DAIR (debridement, antibiotics and implant retention) procedure was performed without component exchange. Furthermore, our data did not contain information on surgical parameters or instruments used, length of hospital stay or radiological measurements of component placement. Moreover, the extent of surgical experience of the surgeons prior to starting the DSA was not evaluated. Furthermore, the risks of bias in observational studies apply for this study, especially the risk of patient selection bias is present. Also, the frequency of events was low, so conclusions must be drawn with caution. However, the low rate of revisions in all groups also suggest that procedure-related experience is not related to the risk of revision for the DSA. The overall generalizability of our study may be limited due to a relatively small number of surgeons and hospitals in our data. However, the cases contribute to 89% of all DSA procedures performed in the Netherlands till date. Our results therefore, demonstrate a near-complete representation of the current situation in the Netherlands.

Further research

Future studies should include and assess all relevant outcomes (e.g., complications, radiological outcomes, length of stay). Furthermore, since the DSA is a relatively new surgical approach, follow up registry research must be done to evaluate the overall performance of the DSA compared to other approaches.

Implications for clinical practice

This study adds to the current debate on choosing the best surgical approach for the individual patient receiving a primary THA. The DSA can be a promising as it shows similarities with the PLA in terms of patient positioning and anatomical landmarks.

Therefore, this approach seems easy to adopt for surgeons who are familiar with the PLA, which is considered an advantage compared to other MIS approaches which are radically different than the traditional approaches. Last, knowledge of the risk of revision in relation to experience for the DSA optimizes patient safety because it creates awareness of the necessary experience for an orthopaedic surgeon.

Conclusions

In conclusion, by using LROI data we did not find an association between experience of the individual surgeon and the risk of revision while adopting the DSA in primary THA. The DSA seems safe in the early phases of the learning curve with a low risk of revision due to dislocation and a low risk of revision for all other causes.

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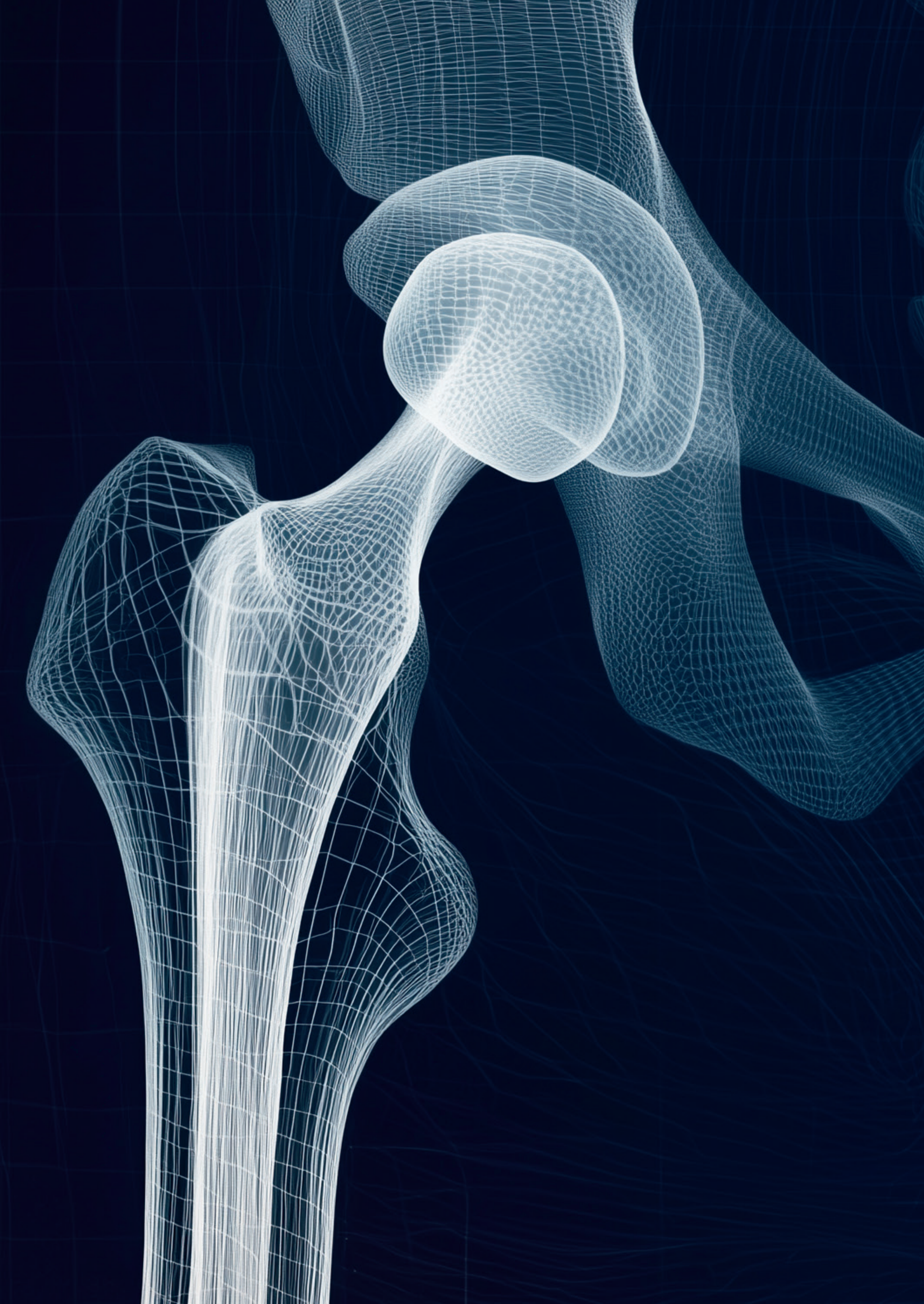
Appendix

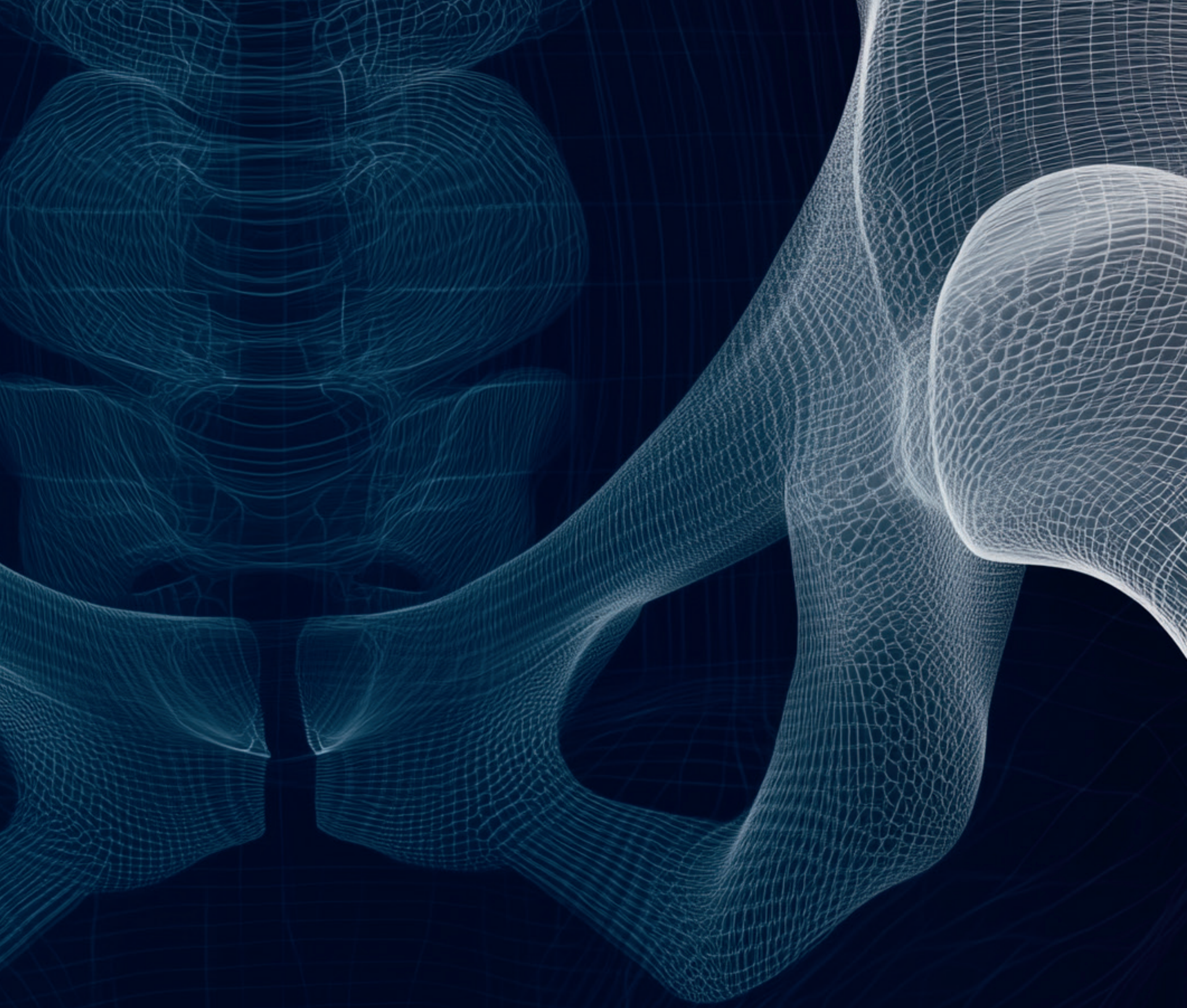
Table 1 Appendix. Number of surgeons and DSA procedures per hospital per year.

Hospital	No. of surgeons	No. of procedures	2016	2017	2018	2019	2020	2021
Hospital 1	14	925	57	85	136	130	189	328
Hospital 2	3	253	7	33	31	46	93	43
Hospital 3	2	227	0	0	0	2	93	132
Hospital 4	3	146	17	60	53	15	1	0
Total	22	1,551	81	178	220	193	376	503

Table 2 Appendix. Number of surgeons per operation group, divided per hospital.

	1-25	26-50	51-75	76-100	>100
Number of hospitals	4	4	4	4	3
Number of surgeons per hospital					
Hospital 1	14	9	6	4	3
Hospital 2	3	3	1	1	1
Hospital 3	2	2	1	1	1
Hospital 4	3	2	1	1	0
Total	22	16	9	7	5





8

General discussion

General discussion

The aim of this thesis was to study the evolving landscape of THA. In that context this thesis encompasses two key topics. First, it discusses current trends in location of THA surgery in the Netherlands, like the shift from general hospitals towards private hospitals. Secondly, it focuses on innovative surgical approaches such as the anterior and direct superior approach.

Specifically, the goals of this thesis were:

1. To explore current trends in hip and knee arthroplasties in the Netherlands. We focused on the transition from public to private hospitals, we explored patient demographics, reasons for revision surgeries, locations of revisions, and the associated risk for revision for total THA, TKA and UKA in public and private hospitals (Chapter 2).

2. To investigate and critically assess the implementation of innovations in surgical approaches for THA. We investigated the rise and implementation of the direct anterior approach in the Netherlands in the last decade and we explored its learning curve. Finally, we explored the recent introduction of the Direct Superior Approach, a refinement of the traditional posterior-lateral approach in THA. Through a systematic review and registry studies, we assessed revision rates, Patient-Reported Outcome Measures (PROMs), and the learning curve associated with this surgical approach.

These research aims have been addressed in the previous chapters. In this final chapter, we will discuss the main findings and limitations of these previous chapters. Finally, we will discuss the clinical implications of our findings, and suggest ideas for future research.

Part 1 current practice trends in total joint arthroplasty

As discussed in the introduction, the increasing prevalence of hip OA is expected to have a substantial societal impact, with a consequent rise in demand for THA procedures placing significant financial pressure on the healthcare system, resulting in a constantly evolving landscape in terms of healthcare delivery, surgical techniques, and patient expectations [1-9]. In the Netherlands, for instance, this transition reflects changing patterns in resource distribution as private facilities play a growing role in meeting the increasing demand for arthroplasty procedures in recent years [10]. In our next paragraph, we will discuss the first (introductory) part of this thesis, focusing on the shift toward private facilities and examining current trends in hip and knee arthroplasty care in the Netherlands.

The shift towards private facilities

In the Netherlands, we are observing a significant trend towards more patients opting for treatment in private hospitals [10]. This shift is driven by the escalating waiting lists in public hospitals during covid-19 and beyond, prompting patients to seek quicker access and personalized care [11-12]. Factors influencing these decisions include personal preferences, the length of waiting lists, and the availability of specialized services [11-18]. Patients are increasingly prioritizing their healthcare choices based on these factors, emphasizing the importance of accessibility and tailored treatment options in their decision-making process.

The introductory part of this thesis, utilizing real-world data from the Dutch Arthroplasty Register, convincingly demonstrates the ongoing transformation in the orthopaedic healthcare landscape in the Netherlands. **Chapter 2** describes the shift towards private hospitals over time and explores patient characteristics over time in both hospital types. Our study revealed a significant rise in the proportion of patients treated in private hospitals in the Netherlands in recent years, which is in line with studies from other countries [15-18]. Previous research indicates that in recent years, numerous healthcare systems that were once publicly owned or financed have shifted towards privatization, predominantly by outsourcing services to the private sector [15]. We think that this shift, at least in part, can be attributed to the growing demand for arthroplasty surgery. Previous studies have consistently highlighted a significant increase in the demand for THA surgeries [19-22]. As mentioned in our previous paragraph, changing demographics further influence the landscape of THA patients. This includes an increase in the number of younger patients seeking THA due to factors such as physical inactivity, obesity, sports injuries, and degenerative conditions [6-7]. In contrast, with global populations aging and obesity rates on the rise, there has been a notable increase in demand for THA procedures among older and overweight individuals [23-24]. Along with this trend, there has been a parallel evolution in the needs and expectations of patients [25-27]. Patients are assuming more active roles in their own care, seeking greater convenience, choice, and personalized services [25-27]. Furthermore, as patients become more informed and proactive in managing their health, they are seeking THA procedures that offer not only pain relief and improved mobility but also quicker recovery times and minimally invasive techniques. This surge in demand, coupled with capacity limitations within the healthcare system, may lead to a shift towards utilization of other types of hospitals such as private hospitals. With traditional hospital settings facing increasing pressure to accommodate the rising number of THA procedures, and alternative care settings may become more prominent options.

However, the question remains: is this shift toward private hospitals safe? In **Chapter 2** we found that a different case-mix is observed in private and public hospitals, with private hospitals predominantly treating younger, lower BMI, and relatively healthier patients. It is well known that case-mix factors such as age, ASA score, and BMI significantly influence revision rates, meaning that these differences in patient demographics make direct comparisons between hospital types challenging. However, when selecting comparable subgroups between both hospital types, a lower risk of revision for all examined arthroplasties was observed in private hospitals. Hence, in terms of revision rates, this trend seems to be well justified, suggesting that private hospitals can be a safe and effective option for certain patient groups. The current patient selection criteria used in private hospitals, focusing on patients, with ASA scores of 2 or less, and a BMI under 35, seem to be effective in maintaining low complication and revision rates.

Nevertheless, our findings also indicated that a significant number of revisions because of complications after primary arthroplasties performed in private hospitals were subsequently carried out in other types of hospitals, often in public or academic centers. This highlights the need for greater collaboration and clearer agreements between private and public hospitals regarding the management of revisions. Establishing guidelines on where surgeries and revisions should be performed could improve patient outcomes by ensuring that complex cases are referred to centers with the appropriate expertise, while more routine procedures continue to be safely managed in private and public hospitals.

Finally, in **chapter 2** we observed a notable demographic shift in the patient populations served by both private and public hospitals over the years. Private hospitals demonstrated an increasing proportion of patients classified as ASA-II, while public hospitals witnessed a rise in patients categorized as ASA-III/IV. Consequently, both hospital types experience an uptick in the number of more comorbid patients. This surge in demand, coupled with capacity limitations within the healthcare system, may result in patients with more complex medical conditions being prioritized for treatment [28]. Limited resources, coupled with the prioritization of urgent cases and the impact of an aging population, contribute to longer waiting times for elective surgeries [28]. Consequently, individuals with higher ASA scores, indicative of greater medical complexity, are more likely to receive timely surgical intervention, leading to their increased representation in surgical queues.

In conclusion, the healthcare landscape for patients with OA is undergoing rapid evolution, driven by factors such as demographic shifts, technological advancements, and changing patient expectations. To address the demand for THA surgeries, healthcare systems must proactively prepare to meet the growing need for THA surgeries by optimizing resources, enhancing surgical capacity, and implementing strategies to ensure equitable access to care for all individuals in need. The current approach to patient selection in private clinics seems to be working well, and coordinated efforts between public and private hospitals will be crucial in meeting the challenges of the growing OA burden.

Main findings	
Chapter 2	• A significant rise is seen in arthroplasty procedures performed in private hospitals in the Netherlands. • Different case-mix is seen in private and public hospitals, with private hospitals predominantly treating younger, lower BMI and relatively healthier patients. • A lower risk of revision for all examined arthroplasties was seen in private hospitals for specific sub-groups. • When primary arthroplasty was performed in a private hospital, a significant number of revisions were performed in another type of hospital

Part 2: Optimizing Patient Care: The shift towards new surgical approaches

As previously discussed, the indications for THA have broadened significantly, leading to an increase in procedures performed on younger, working-aged individuals who have different expectations from the surgery. Unlike the, for example, traditional demographic of 85-year-old patients with severe OA, today's patients are often eager to return to work and resume their normal activities as quickly as possible. Consequently, the focus on quick recovery, short hospital stays, lower postoperative pain scores and high quality of life post-surgery has become more crucial than ever (although this is important for any patient obviously). In order to meet these expectations, the current focus in THA is on minimally invasive techniques and fast track recovery. In recent years, healthcare systems have employed various strategies to address the increasing demand for THA surgeries. One key approach involves refining surgical techniques to enhance patient outcomes, reduce complications, reduce length of hospital stays, and consequently bolster capacity. Choice of surgical approach has been identified as a factor affecting complication rates, length of stay and postoperative recovery [29-33]. Which approach is used depends on the preferences of the surgeon, his or her training and the hospital standards. Among these advancements, the direct anterior approach and superior approach in hip replacement surgery has emerged as a promising option.

The rise of the direct anterior approach

Chapter 3 delves into one notable development that has emerged over the last decade in the Netherlands: the rise of the Direct Anterior Approach (DAA) in primary THA. **Chapter 3** provided evidence of the growing popularity of the DAA. We found that, over the past 13 years, an impressive increase of the DAA from 0.7% to 41% in primary THA was seen in the Netherlands, while the direct lateral approach diminished strongly. In total, 64 (56%) hospitals implemented the DAA. Albeit perhaps not at the same scale as observed in the Netherlands, other countries like the United States, Australia, Canada, Norway, Finland, Sweden and Denmark reported an increase in the use of the DAA as well [34-39]. As discussed in the previous chapters. This surgical technique claims several potential advantages, including decreased muscle damage, minimized soft tissue trauma, and preservation of important anatomical structures. Additionally, the DAA is associated with a reduced risk of dislocation and improved joint stability [29]. As a result, its adoption has become increasingly popular among straight lateral and other surgeons seeking for superior functional outcomes, reduced hospital stays, and accelerated postoperative recovery, in connection with fast-track recovery protocols.

However, although increasingly popular the DAA also has its shortcomings. In **chapter 3** we found that, after implementation, a higher risk of revision was seen for the first 50 DAA procedures, suggesting the presence of a discernible learning curve. This learning curve was also observed in previous studies [40-42]. For example, Peters et al. conducted a study utilizing Dutch registry data, wherein they reported a learning curve for the DAA of 100 cases [42]. In addition, previous studies have shown that the risk of femoral sided revisions is higher for the DAA when compared to the PLA [43-44]. Consequently, caution is warranted in adopting the DAA, emphasizing the importance of thorough training and proficiency attainment to mitigate potential risks.

Nevertheless, It is likely that the percentage of THAs using DAA will further increase [10, 35-38]. The growing interest in the DAA across different parts of the world reflects ongoing advancements in orthopedic care and patient-centered treatment approaches. Building on the advancements and challenges associated with other surgical approaches such as the DAA, new minimal invasive approaches have been and will be developed. Surgeons with specialized training in posterolateral techniques have refined their skills. In response to the challenges posed by the DAA, these surgeons have dedicated efforts to enhance the PLA further, ultimately resulting in the development of the Direct Superior Approach (DSA) [45-46]. The subsequent paragraph delves into this technique.

Main findings	
Chapter 3	• The use of DAA for primary THA significantly increased. • For hospitals implementing DAA, a significant learning curve with increased revision risk was seen.

The implementation of the direct superior approach

In **chapter 4** we presented a systematic review regarding the DSA. We found that the DSA may provide an earlier functional recovery with slightly better functional scores in the first postoperative month compared to the PLA. However, after 3 months no differences in functional scores were seen. We found that the DSA enables adequate implant positioning and resulted in a shorter LOS compared to the PLA. Lastly and luckily, the learning curve for the DSA seems to be short. However, no differences were reported in pain scores. Previous systematic reviews from Kayani et al. and one review and meta-analysis from Zang et al. reported comparable results [45-46]. Although short-term results of the DSA appear promising, with early outcomes showing no inferiority compared to other surgical approaches, it is important to exercise caution in interpreting these findings. First, it is crucial to acknowledge that the DSA is a relatively new surgical technique, and as such, limited studies have been conducted in recent years. Furthermore, it is notable that the majority of studies investigating the DSA originate from a handful of countries, including the Netherlands, Italy, Greece, the United States, and China. Hence, we encountered limitations during this review process, including the predominance of retrospective study designs, heterogeneity among control groups, and the absence of data pooling due to these methodological constraints. It became evident that existing literature was sparse, and studies evaluating revision rates and patient reported outcomes of the DSA were lacking. Recognizing this gap, an objective of this thesis was to address this pressing need by conducting larger-scale registry studies using data from the LROI, to provide more robust evidence regarding the DSA and identify areas for further investigation **(chapter 5-7).**

Main findings	
Chapter 4	• It is uncertain if the DSA provides short-term advantages over conventional approaches such as PLA. • Registry data indicate lower revision rates for dislocation with the DSA, offering valuable real-world insights.

Risk of revision after DSA

In chapter 5 we examined the reasons and risk of revision of the DSA compared with the DAA and PLA, using data from the LROI. Revision rates of the DSA had not been investigated previously using arthroplasty registry data. **In chapter 5** we found, after correction for confounders, that there was no overall difference in revision rates for the DSA compared with the PLA or the DAA. However, a lower risk of revision due to dislocation was seen in patients operated through the DSA compared with the PLA. Multiple large registry studies have provided valuable insights into the revision rates of primary THA associated with different surgical approaches [30,32,33]. However, to our knowledge there are no studies that report revision rates for dislocation comparing the DAA or PLA with the DSA. Our findings underscore a potential advantage of the DSA in mitigating the risk of revision for dislocation, a complication that can significantly impact patient outcomes. In addition, as patient demographics continue to evolve, with a growing number of comorbid patients and highly active younger individuals seeking THA, the need for techniques that minimize complications such as dislocation becomes paramount. By prioritizing techniques that demonstrate reduced revision rates and lower risks of dislocation, we can effectively address the evolving needs of diverse patient populations.

Main findings	
Chapter 5	• Early nationwide results suggest that the DSA for THA seems to show a tendency towards a lower risk of revision for dislocation but no overall reduced revision risk compared with the PLA.

Patient reported outcome measures after DSA

With regard to PROMs, it is important to note that there is currently no clear consensus regarding which surgical approach for THA yields the best results [47-48]. Various surgical approaches, each with their advantages and disadvantages, have been investigated for their potential impact on PROMs after THA [47-48]. In **chapter 6** we investigated whether the DSA improves PROMs after THA compared to 1) the PLA and 2) the DAA. Five PROMs were retrieved from the LROI: 1) NRS pain at rest, 2) NRS pain during activity, 3) EQ-5D-5L with EQ-5D index score, 4) Hip disability and Osteoarthritis Outcome Score - Physical function Short form (HOOS-PS), and 5) Oxford Hip Scores (OHS). **In chapter 6** we found statistically significant improvements on all PROMs at 3- and 12-months after primary THA. The 12 month improvement in physical functioning, as measured by HOOS-PS, was larger for the DSA compared to the DAA. No differences were found between the DSA and PLA. Although results were statistically significant, absolute differences in HOOS-PS scores between the DSA and DAA were relatively small and therefore not clinically relevant.

Although numerous studies have explored PROMs related to various surgical approaches, the results have been inconsistent [47-48]. Given the multifactorial nature of PROMs—affected by individual characteristics, satisfaction, psychological factors, coping strategies, surgical expertise, implant selection, and rehabilitation protocols. it becomes clear that PROMs alone are not sufficient to determine the “best” surgical approach for THA. Therefore, the optimal surgical approach for THA in terms of PROMs may vary depending on the individual patient’s unique needs and preferences. Given the fact that we did not detect clinically important differences between the DSA and the PLA or DAA, we should be cautious recommending a specific surgical approach to our patients. Ultimately, the choice of surgical approach should be based on multiple factors, such as the patient’s medical history, body habitus, the complexity of the procedure, the surgeons experience, as well as a consideration of the risks and benefits of each approach. Orthopedic surgeons must carefully weigh the available evidence and consider the unique circumstances of each patient when selecting the most appropriate surgical approach for their needs.

Main findings	
Chapter 6	• Regarding PROMs we found no clinically meaningful differences between the DSA and either PLA or DAA. • We should be cautious recommending a specific surgical approach to our patients based on PROMs alone.

Learning curve of the DSA

In **chapter 7** we investigated the learning curve of the DSA. We did not identify an association between the surgeon's experience (surgical volume) and the early risk of revision for the DSA in primary THA in the Netherlands. Specifically, patients treated by surgeons with varying levels of experience, ranging from 1 to 25 cases to over 100 cases, exhibited similar hazard ratios for revision, with no statistically significant differences noted between groups. This suggests that even for surgeons who are still relatively unfamiliar with this technique, adopting the DSA appears to be safe. Furthermore, the lower dislocation rates observed with the DSA, as presented in Chapter 5, signify a promising opportunity for surgeons to potentially reduce their revision rates, particularly for dislocation-related complications. Previous studies have predominantly focused on assessing the learning curve of the DSA using surgical parameters such as blood loss, operation time, length of stay and cup positioning [49-50]. To our knowledge, our study represents the first study examining revision rates and surgeon volume as parameters for the learning curve of the DSA. It is important to note that the learning curve encompasses more than just revision risk; it also includes factors such as operation time, blood loss, and overall surgical efficiency. By focusing on surgical case volume and revision rates, our study provides a broader perspective on the DSA's learning curve.

In summary, the results of this thesis highlight that although the DSA may not show substantial benefits in PROMs over other approaches, it does demonstrate low revision rates during its adoption and lower dislocation rates compared to the PLA. Moreover, the data shows the DSA learning curve to be safe and not potentially harmful to patients. These findings suggest that the DSA holds promise as a viable option in THA.

Main findings	
Chapter 7	• There is no association between the surgeon's experience and the early risk of revision for the DSA in primary THA in the Netherlands. • The DSA seems safe in the early adoption phases with a low risk of revision due to dislocation and revision for all other causes.

Impact of this thesis

A common consensus is that numbers of arthroplasties continue to rise in developed countries; and the peak for both primary and revision implantations has not yet been reached. The rise in demand for THA underscores its significance as a leading chronic disease management intervention, especially given the aging population and increasing prevalence of obesity-related joint issues. Looking ahead to 2040, the anticipated increase in OA cases will include both comorbid patients and younger individuals [4-8, 51-53]. As the incidence of OA increases, there will be a greater need for effective first-line interventions, including lifestyle modifications, weight management, and physical therapy. When conservative measures are insufficient, THA becomes the last line of defense. When surgery is needed, recent surgical techniques such as the direct anterior and direct superior approach hold promise in potentially alleviating the economic and health burdens associated with hip OA, as projected for the 2040s. Importantly, there is no single “best” surgical approach for THA. Both the DAA and DSA present viable options for safe prosthetic surgery with low dislocation rates. Surgeons should offer personalized recommendations, considering all relevant factors (such as BMI). With the insights garnered from these studies, surgeons are now better equipped to offer personalized advice to patients seeking THA treatment. Surgeons can discuss the revision rates and outcomes associated with each surgical approach, allowing patients to make informed decisions about their treatment options.

As the need for hip replacements at advanced stages of life is becoming more prevalent, the orthopedic community must collaborate to determine the most appropriate settings for different patient groups. For example, our data supports that patients classified as ASA 2, under 75 years old, with a BMI under 35, and of higher socioeconomic status can be safely and effectively treated in private care providers. In the future, the orthopedic profession should coordinate on how to best organize these services, including addressing complications, managing revisions, and handling financing. This includes enhancing capacity in both public and private hospital settings to accommodate the rising number of procedures. To achieve this, stringent collaboration among healthcare stakeholders is essential. Surgeons, in particular, must adopt a patient-centered approach, meticulously selecting the most appropriate surgical strategies tailored to individual patient needs and circumstances. Patients can be guided on the most appropriate healthcare facility for their procedure, considering factors such as ASA-score, age, BMI and diagnosis. However, we recommend caution when using revision rates alone. Factors like patient health conditions, behaviors, motivations, hospital waiting lists, difference in surgical practices and post-surgery care must also be taken into account.

Future perspectives

Moving forward, efforts should be continued towards refining surgical techniques, optimizing implant designs, and implementing strategies to minimize complications for specific patient groups. It is essential for research efforts to keep pace with these advancements to ensure that patients receive the most effective and innovative care available. With regard to the DSA, there remains a need for future studies to assess its nationwide and long-term outcomes. Thirdly, a randomized controlled comparison of DSA and PLA (or DAA) would add methodologically strong evidence to the current knowledge. Such a trial (SPLASH) is currently underway in Zwolle, Leeuwarden and Breda. Regarding THA arthroplasty location, efforts defining the optimal patient selection criteria for safe treatment in private clinics and reaching national consensus, would help the orthopedic society to timely serve as many patients given the current waiting lists and shortages of personnel. Therefore, further research in these areas is crucial to better understand the full spectrum of benefits and limitations of the DSA and to inform clinical decision-making effectively.

In addition to the above, the collaboration between general, private, and academic hospitals is paramount. Establishing clear agreements on where surgeries and revisions should be performed would streamline processes. For example, future studies should focus on whether complex cases are best handled in academic centers or if more routine procedures can be effectively managed in private clinics. Efforts to define optimal patient selection criteria for safe treatment in private, public and university medical centers and reach national consensus would help the orthopedic society serve as many patients as possible in a timely manner.

Finally, it is essential to consider prevention as a critical component of the overall strategy for managing OA. While advances in surgical approach, implant design and surgical interventions are vital in addressing the needs of patients with advanced OA, preventive measures must play an equally important role in reducing the incidence and progression of the disease. Preventive strategies could include promoting healthy lifestyles, encouraging weight management, increasing physical activity, and implementing early interventions to mitigate risk factors associated with OA development. Prominent examples of effective preventive strategies include promoting healthy lifestyles through initiatives like the GLAD (Good Life with osteoArthritis in Denmark) program, which emphasizes education and self-management techniques, and AKTIVA, a program focused on increasing physical activity and improving overall fitness levels in individuals at risk of OA [54,55]. Finally, beweegzorg Noord has been implemented in the Netherlands. Beweegzorg Noord, for instance, aims to flatten the demand for surgical OA care through a stepped-care program in primary care, combining education on OA and lifestyle with evidence-based exercise interventions.

In conclusion, while our study highlights important findings about the effectiveness of different healthcare settings for THA, there is still significant room for improvement. The growing complexity of patient demographics and the increasing economic burden of THA demand ongoing efforts to refine patient selection, enhance collaboration between public and private hospitals, and optimize care pathways and surgical approaches. As the demand for THA continues to rise, further research, innovation, and the adoption of advanced surgical techniques will be essential to ensuring that healthcare systems can deliver the highest standard of care efficiently and effectively.

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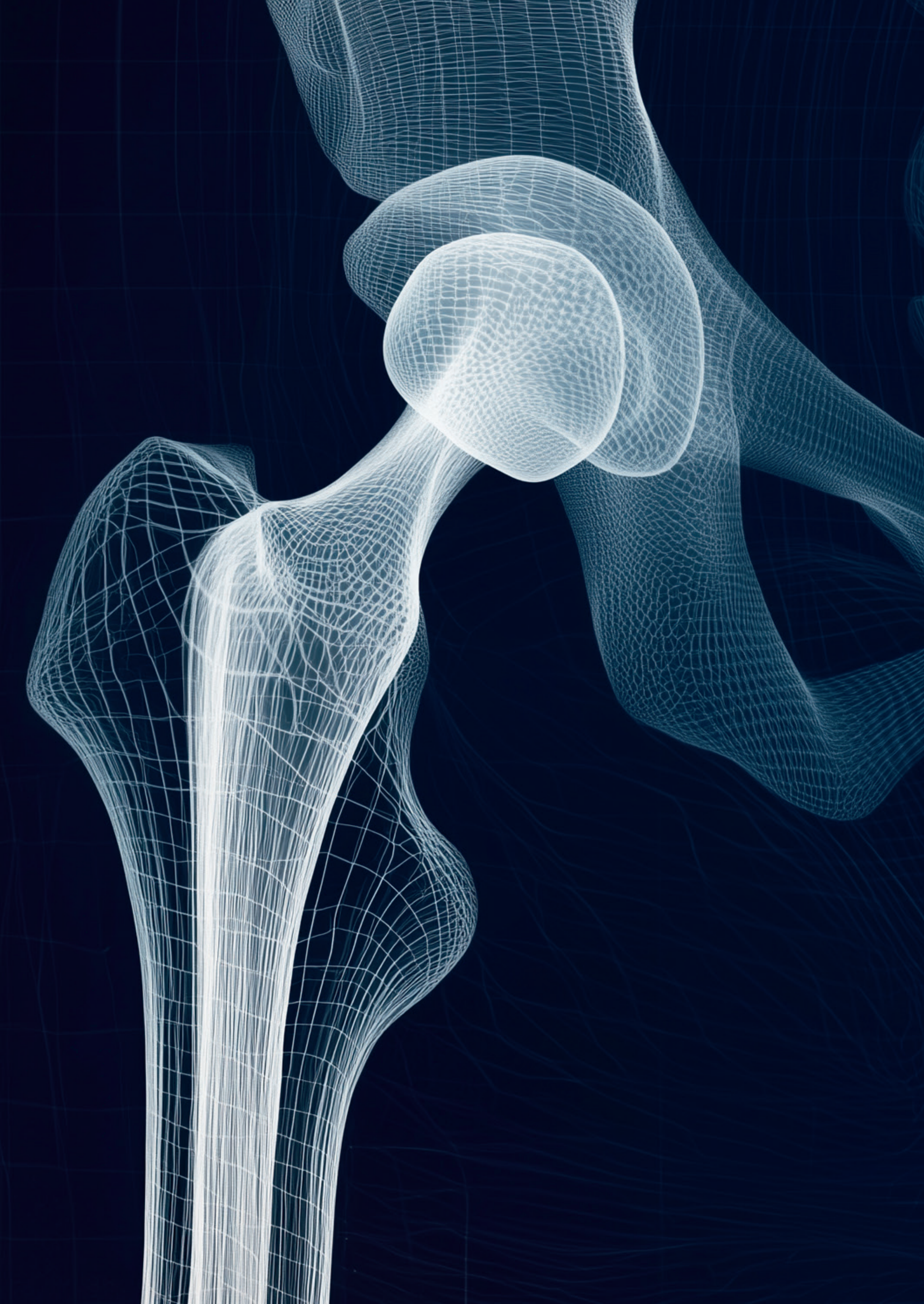
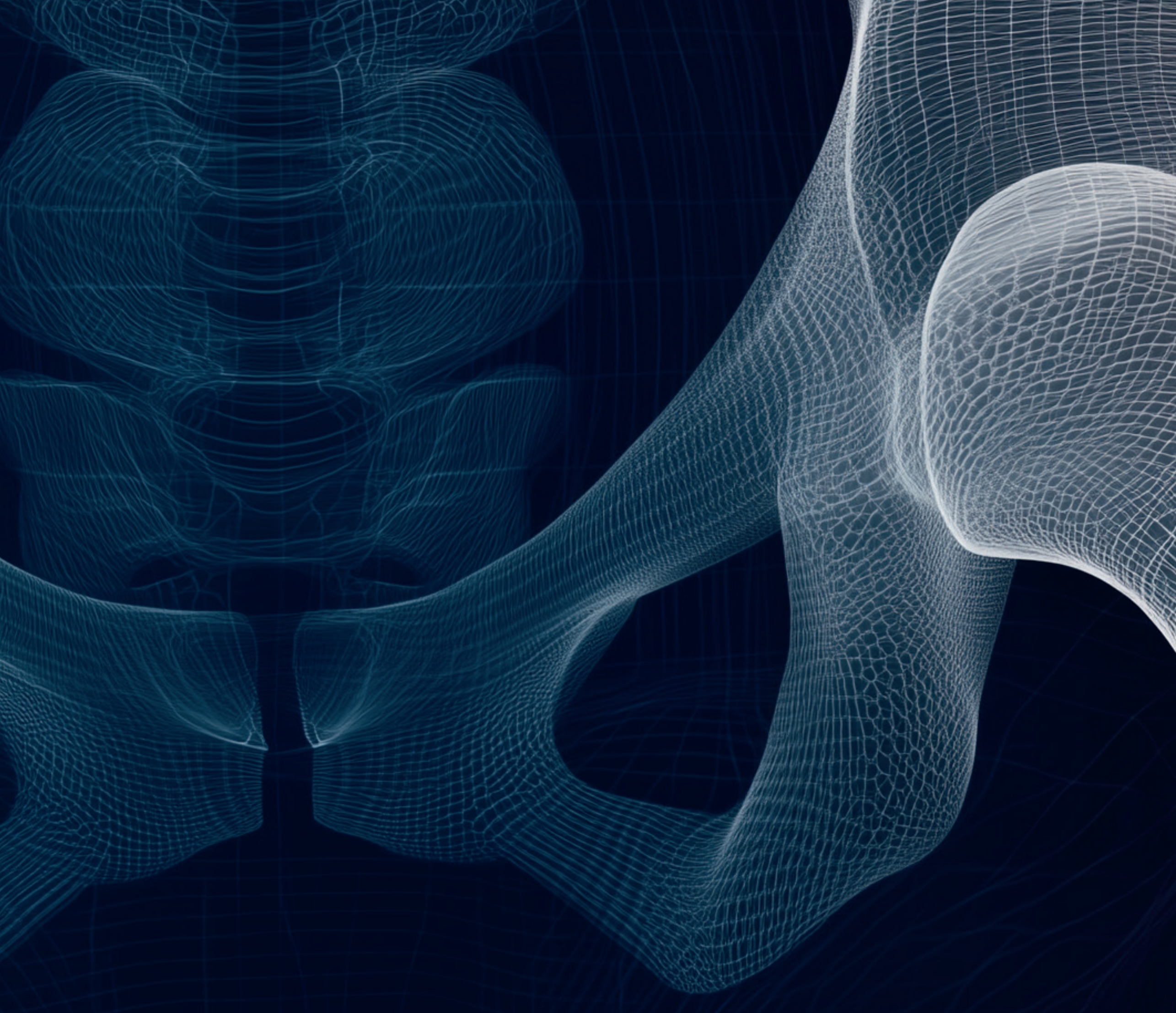




9

Summary / Samenvatting

Summary

Chapter 1 highlights the sharp rise in the prevalence of osteoarthritis (OA), particularly in the hip and knee joints, with projections indicating that the trend will continue in the coming years. Consequently, improving quality of care and optimizing outcomes is essential to ensure the financial sustainability of these procedures. The chapter discusses various treatment approaches, from early interventions like lifestyle modifications and physical therapy to more advanced surgical options for severe cases. Orthopedic surgeons address these needs by integrating innovations, adopting advanced surgical techniques, utilizing quality registries, selecting suitable candidates, and refining best practices to enhance the success of THA. Despite all technical advances in THA over the last decades, there is still a certain number of dissatisfied patients regarding the postoperative outcome after THA, and complications leading to subsequent revision surgery. With this in mind, the aim of this thesis was to explore recent trends in THA care in the Netherlands, specifically focusing on surgical approaches to optimize patient outcomes and enhance overall THA quality, using data from the Dutch Arthroplasty Register (LROI).

Part 1 current practice trends in total joint arthroplasty

The **first part** of this thesis investigates current practice trends in arthroplasty surgery in the Netherlands. It focuses on the transition from public to private hospitals (**Chapter 2**). **Chapter 2** examines the shift of hip and knee replacement surgeries from public to private hospitals in the Netherlands. Data from 476,312 surgeries (413,560 in public hospitals and 62,752 in private hospitals) were analyzed from the LROI. The study highlights differences in patient demographics between hospital types. Patients in private hospitals were younger, had lower ASA-classification, lower BMI and higher SES compared to public hospital patients. Revision risks for primary THA, TKA, and UKA were lower in private hospitals. However, nearly half of revisions for THA and TKA originally done in private hospitals were later performed in public hospitals. The findings suggest that private hospitals are safe options for these surgeries when patient selection is done carefully and there is access to appropriate follow-up care.

Part 2: Optimizing Patient Care - The Shift Towards New Surgical Approaches

In recent years, healthcare systems have employed various strategies to address the increasing demand for THA surgeries. One key approach involves refining surgical techniques to enhance patient outcomes, reduce complications, reduce length of hospital stays, and consequently bolster capacity. Which approach is used depends on the preferences of the surgeon, his or her training and the hospital standards. Among these advancements, the direct anterior approach and superior approach in hip replacement surgery have emerged as a promising option (Chapter 3-7)**.**

Chapter 3 examines the rapid increase in the use of the DAA for THA in the Netherlands. Using data from 63,182 primary THAs recorded in the LROI between 2007 and 2020, the study shows that DAA adoption grew from just 0.2% of procedures in 2007 to 41% by 2020, with 56% of hospitals implementing this approach. The analysis highlights the significant learning curve associated with DAA; survival rates were lower during the first 50 procedures (96%) compared to after 150 cases (98%). Cox regression models revealed that the revision risk during the first 50 DAA procedures was significantly higher (HR 1.6) compared to after more than 150 cases, indicating that hospitals require substantial experience before achieving optimal outcomes with this approach.

Chapter 4 to 7 examines the use of the Direct Superior Approach (DSA) in the Netherlands, a minimal invasive adaptation of the posterolateral approach. **Chapter 4** is a systematic review that evaluates the DSA for THA. This review included 17 studies that assessed clinical, functional, and radiological outcomes such as revision rates, complications, pain scores, and hospital length of stay (LOS). The findings suggest that DSA may reduce postoperative pain and shorten LOS, but the evidence on complications and long-term outcomes remains inconsistent. While early functional outcomes showed some advantages over conventional approaches like the posterolateral approach (PLA), there were no clear long-term benefits. We concluded that more high-quality studies are needed to fully understand the impact of DSA on outcomes.

In **chapter 5**, we analyzed 175,543 primary THAs performed between 2014 and 2020 using nationwide registry data from the LROI. This study compared the revision rates of the DSA (n=1,341) with the PLA (n=117,576) and DAA (n=56,626). The dislocation revision rate for DSA was significantly lower (0.3%) compared to PLA (1.0%), and comparable to DAA (0.3%). Multivariable Cox regression analysis showed no significant difference in overall revision rates between DSA and PLA (HR 0.6), though DSA had a lower risk of dislocation revision (HR 0.3), suggesting potential advantages in preventing dislocations.

In **chapter 6**, we explored patient-reported outcome measures (PROMs) for 37,976 primary THAs performed between 2014 and 2020 using the LROI. The study compared PROMs across three approaches: DSA (n=343), PLA (n=22,616), and DAA (n=15,017). The results showed that there were no clinically significant differences in pain reduction, quality of life and functional improvement between the three approaches. However, patients in the DSA group demonstrated a slight improvement in HOOS-PS scores 12 months postoperatively compared to the DAA group, though this difference was not clinically meaningful. Hence, our study showed no clinically meaningful differences between the DSA and either PLA or DAA.

In **chapter 7**, we investigated the learning curve for DSA in a cohort of 1,551 primary THAs performed between 2016 and 2022. The surgeries were performed by various surgeons at different stages of experience (grouped as 1-25, 26-50, 51-75, 76-100, or

>100 procedures). The overall revision rate was 1.5% after an average follow-up of two years. The analysis showed no significant difference in revision risk across experience levels, suggesting that the DSA is a safe approach even during early stages of adoption.

Finally, **chapter 8** provides a summary and reflection on the key findings of this research. It discusses the implications for practice and directions for future research. This thesis highlights the increasing demand for THA in response to rising cases of OA. It emphasizes the importance of refining surgical techniques, such as the Direct Anterior and Direct Superior Approaches, to reduce complications and improve outcomes. Personalized treatment strategies are crucial, with recommendations for patient selection based on various factors. Future research should focus on optimizing implant designs, refining patient criteria for surgical settings, and integrating preventive measures to manage OA effectively. Enhanced collaboration among healthcare providers is vital to address the growing complexity of patient demographics and the economic burden of THA.

Samenvatting

Hoofdstuk 1 beschrijft de stijging in het aantal heupvervangende operaties in Nederland. Deze groei brengt steeds hogere kosten met zich mee voor de gezondheidszorg, wat de druk vergroot om zowel de efficiëntie als de kwaliteit van de zorg te verbeteren. In het hoofdstuk worden de verschillende behandelbenaderingen besproken, variërend van vroege interventies zoals leefstijlveranderingen en fysiotherapie tot meer chirurgische opties. Door een combinatie van factoren werken ziekenhuizen en orthopedisch chirurgen voortdurend aan het verbeteren en stroomlijnen van de zorg rondom heupvervangende operaties. Zo worden nieuwe innovaties en geavanceerde operatietechnieken geïntroduceerd, kwaliteitsregistraties nauwgezet bijgehouden, en wordt er scherper geselecteerd op geschikte patiënten. Door deze geïntegreerde aanpak kunnen chirurgen complicaties en de noodzaak van heroperaties verminderen, waardoor patiënten sneller herstellen en de algehele tevredenheid over het resultaat toeneemt. Ondanks alle technische vooruitgang van de afgelopen jaren, zijn er nog steeds patiënten die niet tevreden zijn over hun herstel na een heupvervanging, en zijn er complicaties die een nieuwe operatie noodzakelijk maken. Het doel van dit proefschrift is om recente ontwikkelingen in THA-zorg in Nederland te onderzoeken, waarbij de nadruk ligt op chirurgische benaderingen voor het plaatsen van een THA om de resultaten voor patiënten te optimaliseren. Hiervoor is gebruikgemaakt van gegevens uit het Landelijk Register Orthopedische Implantaten (LROI), een uitgebreide Nederlandse databank die informatie bevat over onder andere de overlevingsduur van implantaten, complicaties, patiëntkenmerken en revisies.

Deel 1: Trends in Heup- en Knie-vervangende operaties in Nederland

In **deel 1** van dit proefschrift worden de huidige trends in heup- en kniechirurgie in Nederland onderzocht, waarbij de verschuiving van publieke naar private ziekenhuizen centraal staat **(Hoofdstuk 2)**. In **hoofdstuk 2** worden gegevens van 476.312 operaties geanalyseerd: 413.560 in publieke en 62.752 in private ziekenhuizen (zelfstandige behandelklinieken). De resultaten tonen aan dat patiënten in private ziekenhuizen over het algemeen jonger zijn, een lagere ASA-score en BMI hebben en vaker een hogere sociaal-economische status hebben. Het risico op een heroperatie voor primaire THA, TKA en UKA was lager in private ziekenhuizen. Echter, bijna de helft van de revisies na operaties die oorspronkelijk in private ziekenhuizen werden uitgevoerd, vond plaats in publieke ziekenhuizen. Deze bevindingen suggereren dat private ziekenhuizen een veilige optie zijn voor deze operaties, mits patiënten zorgvuldig worden geselecteerd en goede nazorg beschikbaar is.

Deel 2: Optimaliseren van Zorg – Nieuwe chirurgische benaderingen voor het plaatsen van een heupprothese

Om de toenemende vraag naar heupvervangende operaties te kunnen bijhouden, richten chirurgen zich op het verfijnen van chirurgische technieken om de resultaten voor patiënten te verbeteren, complicaties te verminderen, de opnameduur te verkorten en de capaciteit te vergroten. Onder de nieuwe technieken hebben de Directe Anterieure (DAA) en de Direct Superior benadering (DSA) zich ontwikkeld als veelbelovende methoden **(hoofdstukken 3-7)**.

In **hoofdstuk 3** wordt de snelle toename van het gebruik van de DAA in Nederland besproken. Uit gegevens van 63.182 primaire THA's tussen 2007 en 2020 blijkt dat het gebruik van deze techniek groeide van 0,2% van de operaties in 2007 tot 41% in 2020. Uit de analyse blijkt dat de DAA een steile leercurve heeft; de overlevingskans van de prothese was lager in de eerste 50 operaties (96%) vergeleken met na 150 operaties (98%). Dit laat zien dat chirurgen ervaring moeten opdoen voordat ze optimale resultaten met deze methode behalen.

Hoofdstukken 4 tot en met 7 behandelen de DSA, een minimaal invasieve variant van de posterolaterale benadering (PLA). **Hoofdstuk 4** bevat een systematische review waarin de DSA voor THA wordt geëvalueerd. Deze review omvatte 17 studies die klinische, functionele en radiologische uitkomsten zoals revisiepercentages, complicaties, pijnscores en de lengte van het ziekenhuisverblijf hebben beoordeeld. De resultaten suggereren dat de DSA mogelijk de postoperatieve pijn kan verminderen en de ziekenhuisopname kan verkorten. Echter, het bewijs over complicaties en langetermijnresultaten blijft inconsistent. Hoewel de vroege functionele uitkomsten enkele voordelen vertoonden ten opzichte van traditionele benaderingen zoals de posterolaterale benadering (PLA), waren er geen duidelijke langetermijnvoordelen. We concludeerden dat er meer onderzoek nodig is om de impact van de DSA op de uitkomsten volledig te begrijpen.

In **hoofdstuk 5** analyseerden we 175.543 primaire THA's die tussen 2014 en 2020 zijn uitgevoerd met behulp van landelijke registratiedata van het Landelijk Register Orthopedische Implantaten (LROI). Deze studie vergeleek de kans op heroperatie na het krijgen van een heupprothese via de DSA (n=1.341) met de PLA (n=117.576) en de directe anterieure benadering (DAA) (n=56.626). Het revisiepercentage vanwege heupluxatie voor de DSA was aanzienlijk lager (0,3%) in vergelijking met de PLA (1,0%) en vergelijkbaar met de DAA (0,3%). Dit suggereert mogelijke voordelen van de DSA bij het voorkomen van heup luxaties na een heupvervangende operatie.

In **hoofdstuk 6** onderzochten we de patiënt-gerapporteerde uitkomstmaten (PROM's) voor 37.976 primaire THA's die tussen 2014 en 2020 zijn uitgevoerd met behulp van gegevens van het LROI. De studie vergeleek PROMs tussen drie benaderingen: DSA (n=343), PLA (n=22.616) en DAA (n=15.017). De resultaten lieten zien dat er geen klinisch significante verschillen waren in pijnvermindering, kwaliteit van leven en functie tussen de drie benaderingen.

In **hoofdstuk 7** onderzochten we de leercurve voor de DSA in een groep van 1.551 primaire THA's die tussen 2016 en 2022 zijn uitgevoerd. De operaties werden uitgevoerd door verschillende chirurgen met verschillende ervaringsniveaus (gegroepeerd als 1-25, 26-50, 51-75, 76-100 of >100 procedures). De analyse toonde geen significant verschil in het revisierisico tussen de ervaringsniveaus, wat suggereert dat de DSA een veilige benadering is, zelfs in de vroege stadia van implementatie.

Tot slot geeft **hoofdstuk 8** een samenvatting van en reflectie op de belangrijkste bevindingen, gevolgd door implicaties voor de praktijk, beleid en vervolgonderzoek. Deze thesis laat zien dat de vraag naar heupvervangingen toeneemt door de stijging van het aantal gevallen van artrose. Het benadrukt hoe belangrijk het is om chirurgische technieken te verbeteren, zoals de Direct Anterieure benadering en de Direct Superior benadering, om complicaties te verminderen en de resultaten voor patiënten te verbeteren. Toekomstig onderzoek dient zich te richten op het verbeteren van implantaatontwerpen, het vaststellen van optimale patiëntcriteria, het uitvoeren van meer gerandomiseerde gecontroleerde onderzoeken naar de Direct Superior Approach (DSA) om de effectiviteit en veiligheid van deze techniek verder te onderbouwen. Integratie van preventieve maatregelen, zoals het bevorderen van gezonde levensstijlkeuzes, kan helpen het risico op artrose te verminderen. Tot slot is goede samenwerking tussen zorgverleners cruciaal om de toenemende complexiteit van patiënten en de financiële druk van totale heup prothesiologie effectief aan te pakken, met als doel een betere coördinatie en efficiëntie in de zorg.

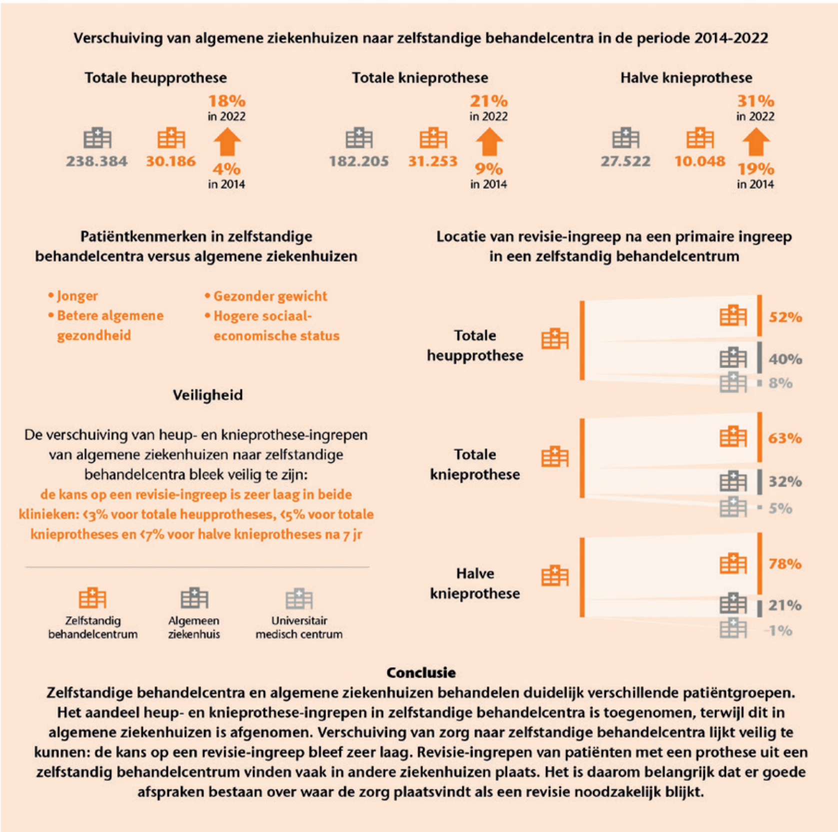
Infographics LROI

Verschuiving van heup- en knieprothese-ingrepen van algemene ziekenhuizen naar zelfstandige behandelcentra

In Nederland kunnen patiënten voor een totale heupprothese, totale knieprothese of halve knieprothese terecht in zelfstandige behandelcentra, algemene ziekenhuizen en universitair medische centra.

In dit onderzoek is de verschuiving van heup- en knieprothese-ingrepen van algemene ziekenhuizen naar zelfstandige behandelcentra in Nederland bekeken. Er is gekeken naar kenmerken van patiënten en procedures, en veranderingen over de tijd.

Daarnaast is er gekeken naar veiligheid: het risico op een revisie-ingreep na het krijgen van een heup- of knieprothese in algemene ziekenhuizen bekeken vergeleken met het risico op een revisie na het krijgen van een heup- of knieprothese in zelfstandige behandelcentra. Hierbij is alleen gekeken naar patiënten die een prothese kregen vanwege artrose, niet ouder dan 75 jaar, met een goede algemene gezondheid, zonder obesitas en een gemiddelde tot hoge sociaaleconomische status.

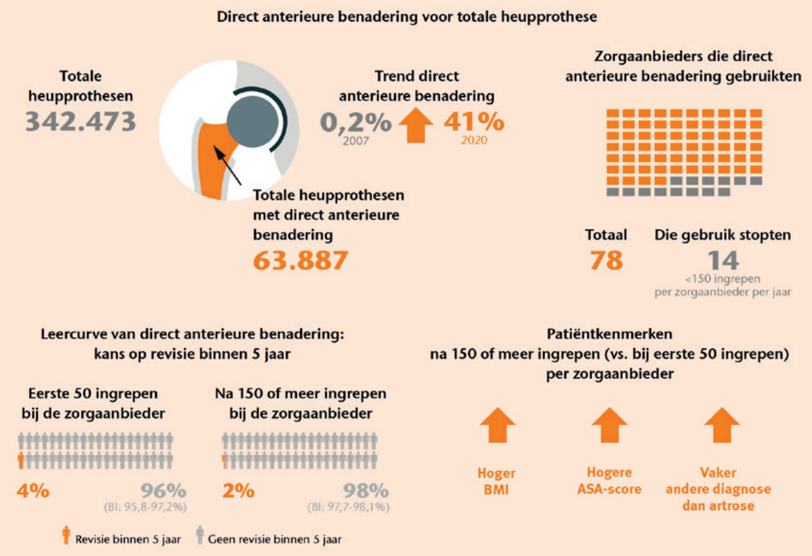


Time trends in case-mix and risk of revision following hip and knee arthroplasty in public and private hospitals: a cross-sectional analysis based on 476.312 procedures from the Dutch Arthroplasty Register. BJ van Dooren, P Bos, RM Peters, LN van Steenbergen, E de Visser, JM Brinkman, BW Schreurs, WP Zijlstra. Acta Orthopaedica June 2024.

WETENSCHAPPELIJK ONDERZOEK MET LROI-DATA

Gebruik en leercurve direct anterieure benadering voor totale heupprothese

In de laatste twintig jaar is er wereldwijd steeds meer gebruik gemaakt van de *direct anterieure benadering* voor het plaatsen van primaire totale heupprothesen. Hierbij maakt de orthopedisch chirurg een incisie aan de voorkant van de heup, in plaats van aan de zijkant of achterkant, zoals bij andere benaderingen. Ook in Nederland is deze aanpak sinds 2008 steeds populairder geworden. Hoewel er voordelen zijn, zoals sneller herstel en minder pijn, maken sommige mensen zich zorgen over de *leercurve* – de tijd die het kost om deze techniek goed onder de knie te krijgen. Deze studie onderzocht hoe de direct anterieure benadering in Nederland wordt gebruikt, wat de leercurve voor de direct anterieure benadering is op ziekenhuisniveau, welke verschillen er zijn tussen patiënten en welke kenmerken belangrijk zijn tijdens het leerproces. Hiervoor zijn data van alle primaire totale heupprothese-ingrepen bekeken die tussen 2007 en 2020 zijn uitgevoerd.



Conclusie

Het gebruik van de direct anterieure benadering voor het plaatsten van een totale heupprothese in Nederland is flink gestegen, maar chirurgen moesten wel wennen aan deze nieuwe techniek. Over het algemeen leverde de direct anterieure benadering goede resultaten op wat betreft overleving van de prothese, maar in het begin waren er meer revisie-ingrepen nodig. Dit geeft aan dat het belangrijk is om bij de invoering van nieuwe technieken, zoals de direct anterieure benadering, aandacht te besteden aan een zorgvuldig implementatieproces, waaronder het selecteren van geschikte patiënten en goede begeleiding bij het leren van een nieuwe techniek. Ook open communiceren met patiënten over de leercurve is van belang. Deze bevindingen sluiten aan bij de wereldwijde trend van toenemend gebruik van de direct anterieure benadering.

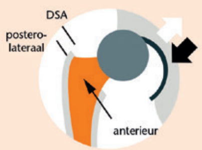
The Rise of the Direct Anterior Approach: Trends, Learning Curves, and Patient Characteristics of 63,182 Primary Total Hip Arthroplasties in the Dutch Arthroplasty Register (LROI). L Rietbergen, BJ van Dooren, WP Zijlstra, IN Sierevelt, BW Schreurs, LN van Steenbergen, SCJ Vos. Journal of Arthroplasty 2024.

Eerste resultaten van de direct superieure benadering bij het plaatsen van een totale heupprothese: lager risico op revisie vanwege luxatie

Verschillende chirurgische benaderingen worden gebruikt bij het plaatsen van een totale heup prothese (THP). De anterieure (voorste) en posterolaterale (achterste) benadering zijn de meest gebruikte operatietechnieken in Nederland. Van de anterieure benadering is bekend dat er een lange *learning curve* is. De direct superieure benadering (DSA) is een nieuwe, minimaal invasieve benadering, dat betekent dat een kleinere snede gemaakt wordt. Deze techniek is afgeleid van de klassieke posterolaterale benadering. DSA is ontwikkeld om de schade aan belangrijke spiergroepen te beperken. Recente studies laten zien dat het risico op een revisie vanwege het uit de kom schieten van het heupgewricht (luxatie) laag is voor de DSA.

Met LROI-data onderzochten we de samenhang tussen de chirurgische benadering en het revisiepercentage vanwege luxatie en revisie voor elke andere reden dan luxatie. Hiervoor werden de resultaten van DSA vergeleken met die van de anterieure en posterolaterale benadering. Revisiepercentages en het risico op revisie zijn berekend, rekening houdend met patiëntkenmerken.

Kans op revisie vanwege luxatie bij verschillende benaderingen voor totale heupprothese in de periode 2014-2020

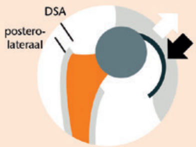


Revisie vanwege luxatie binnen 3 jaar

DSA	posterolateraal	anterieur
1.341	117.576	56.626
0,3% (BI: 0,1-0,8%)	1,0% (BI: 0,9-1,0%)	0,3% (BI: 0,1-0,8%)

Revisie binnen 3 jaar · Geen revisie binnen 3 jaar

Kans op revisie vanwege luxatie*

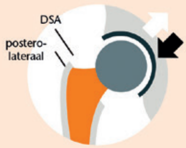


DSA versus posterolateraal

DSA lagere kans

0,3 × zo grote kans (BI: 0,1-0.9)

Kans op revisie vanwege een andere reden dan luxatie*



DSA versus posterolateraal

gelijke kans

0,8 × zo grote kans (BI: 0,5-1,3)

* rekening houdend met patiëntkenmerken

Conclusie

Deze eerste studie naar de resultaten van de direct superieure benadering (DSA) laat in de eerste drie jaar een lagere kans op revisie vanwege luxatie zien ten opzichte van de posterolaterale benadering. Het risico op revisie vanwege elke andere reden dan luxatie van een totale heupprothese is vergelijkbaar voor de DSA en posterolaterale benadering. Deze resultaten wijzen erop dat de DSA een goed alternatief kan zijn voor de posterolaterale benadering bij het plaatsen van een totale heupprothese.

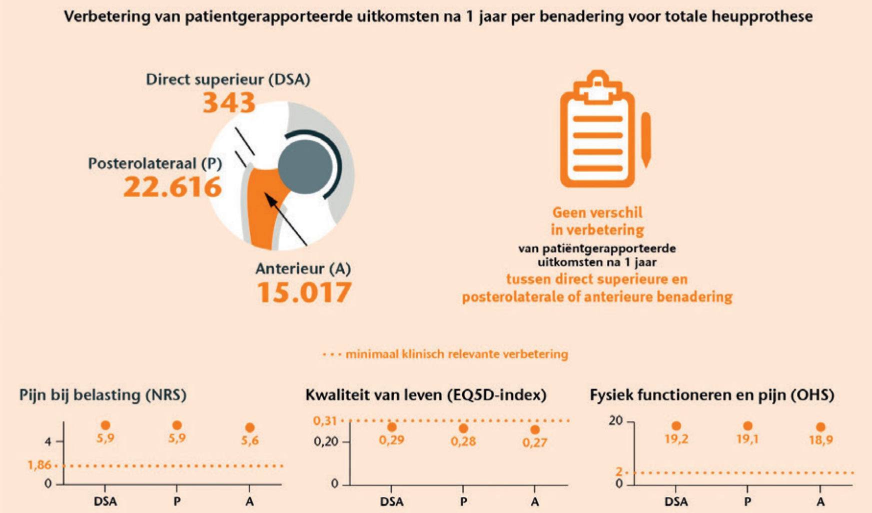
Revision risk by using the direct superior approach (DSA) for total hip arthroplasty compared with postero-lateral approach: early nationwide results from the Dutch Arthroplasty Register (LROI). B van Dooren, RM Peters, HB Ettema, BW Schreurs, LN van Steenbergen, SBT Bolder, WP Zijlstra. Acta Orthopaedica 2023.

WETENSCHAPPELIJK ONDERZOEK MET LROI-DATA

Geen verschil in patiëntgerapporteerde uitkomsten tussen direct superieure benadering en posterolaterale of anterieure benadering voor plaatsen totale heupprothese

Bij het plaatsen van een totale heupprothese zijn er voor de chirurg verschillende manieren om bij het heupgewricht te komen. De *anterieure*, of voorste, en *posterolaterale*, of achterste, benadering zijn de meest gebruikte operatietechnieken in Nederland. De *direct superieure* benadering is een nieuwe, minimaal invasieve benadering, afgeleid van de klassieke posterolaterale benadering. Deze techniek heeft zich de afgelopen jaren bewezen als een succesvolle techniek, met als voordeel dat het de spieren en omliggende weefsels spaart. De pijn na de operatie zou minder zijn en het herstel zou sneller moeten verlopen. Deze mogelijke voordelen zijn bij Nederlandse patiënten nog niet onderzocht.

Het doel van dit onderzoek was om te bekijken of patiënten 3 maanden en 1 jaar na het krijgen van een totale heupprothese via de direct superieur benadering beter scoren op zelf-gerapporteerde uitkomsten (PROMs) dan patiënten die een totale heupprothese krijgen via de anterieure of posterolaterale benadering. Alle patiënten met een totale heupprothese vanwege heupartrose en ingevulde PROMs voor, 3 maanden na en 1 jaar na de operatie in de periode 2014-2020 werden bekeken. Pijn, kwaliteit van leven en functie werden onderzocht. Hierbij is rekening gehouden met patiëntkenmerken die van invloed kunnen zijn op de uitkomsten, zoals leeftijd, geslacht, ASA-score voor algemene gezondheid en BMI. Daarnaast werd gekeken of verschillen in zelf-gerapporteerde uitkomsten tussen benaderingen klinisch relevant waren door deze te vergelijken met klinisch relevante verschillen zoals benoemd in de literatuur.



Conclusie

Patiënten rapporteren minder pijn en een verbeterd fysiek functioneren na een totale heupprothese-ingreep. Er lijken geen klinisch relevante verschillen te zijn in patiëntgerapporteerde uitkomsten tussen DSA en zowel posterolaterale als anterieure benadering. De orthopedisch chirurg moet dan ook voorzichtig zijn met het aanbevelen van een specifieke chirurgische benadering op basis van patiëntgerapporteerde uitkomsten. De keuze voor een chirurgische benadering moet gebaseerd zijn op meerdere factoren, zoals de medische geschiedenis van de patiënt, lichaamsbouw, de complexiteit van de ingreep, de ervaring van de chirurg en een afweging van de risico's en voordelen van elke benadering.

No clinically relevant difference in patient-reported outcomes between the direct superior approach and the posterolateral or anterior approach for primary total hip arthroplasty: analysis of 37,976 primary hip arthroplasties in the Dutch Arthroplasty Registry. B van Dooren, RM Peters, LN van Steenbergen, RAJ Post, HB Ettema, SBT Bolder, BW Schreurs, WP Zijlstra. Acta Orthopaedica 2023.

WETENSCHAPPELIJK ONDERZOEK MET LROI-DATA

Leercurve direct superieure benadering bij totale heupprothese

Verschillende operatietechnieken worden gebruikt om de heup te benaderen bij het plaatsen van een totale heupprothese. De *anterieure* – voorste – en *posterolaterale* – achterste – benadering zijn het meest gangbaar in Nederland, elk met eigen voor- en nadelen. Vooral de steile leercurve van de anterieure benadering is een onderwerp van discussie. Recent is er een nieuwe benadering geïntroduceerd: de *direct superieure benadering*, die minimaal invasief is en bepaalde spieren ontziet. Deze benadering is een variant op de posterolaterale benadering.

Studies laten zien dat de kans op een revisie vanwege een luxatie – uit de kom schieten – van de prothese laag is bij plaatsing met de direct superieure benadering. Er was tot nu toe nog geen informatie bekend over een eventuele chirurgische leercurve.

In deze studie is gekeken naar de samenhang tussen de leercurve voor het plaatsen van een totale heupprothese met de direct superieure benadering van orthopedisch chirurgen uit vier ziekenhuizen in Nederland en de kans op revisie.

Leercurve van de direct superieure benadering

Totaal direct superieur
1.551

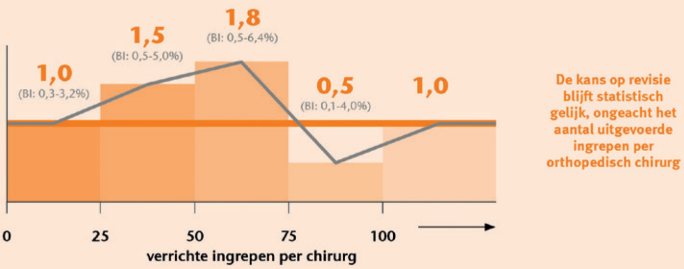
Kans op revisie na een gemiddelde follow-up van 2 jaar

1,5%

Kans op revisie voor dislocatie na een gemiddelde follow-up van 2 jaar

0,5%

Kans op revisie naar aantal verrichte ingrepen per orthopedisch chirurg



Conclusie

We vonden geen verband tussen de ervaring van de orthopedisch chirurg in het gebruik van de direct superieure benadering en de kans op revisie. Dit suggereert dat er geen significante leercurve is voor de direct superieure benadering bij het plaatsen van een totale heupprothese. De direct superieure benadering lijkt veilig in de beginfase van het leerproces, met een laag risico op revisie door luxatie of door andere oorzaken.

Low revision rate throughout the adoption of the direct superior approach in primary total hip arthroplasty: an analysis based on 1551 total hip arthroplasties from the Dutch Arthroplasty Register. P Bos, BJ van Dooren, RM Peters, HB Ettema, SBT Bolder, FP van den Berg, NJGM Veeger, BW Schreurs, WP Zijlstra. Hip International 2024.

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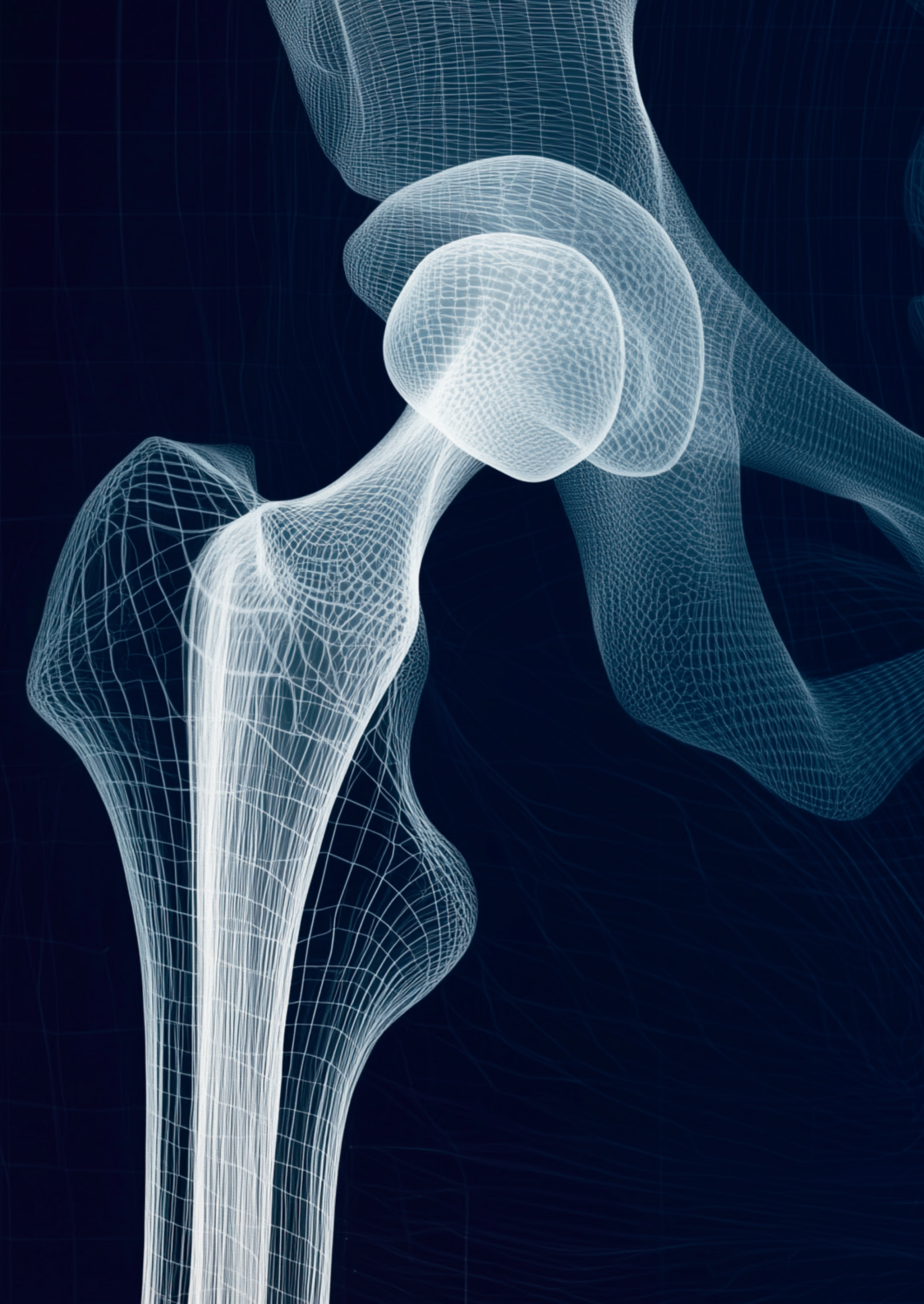

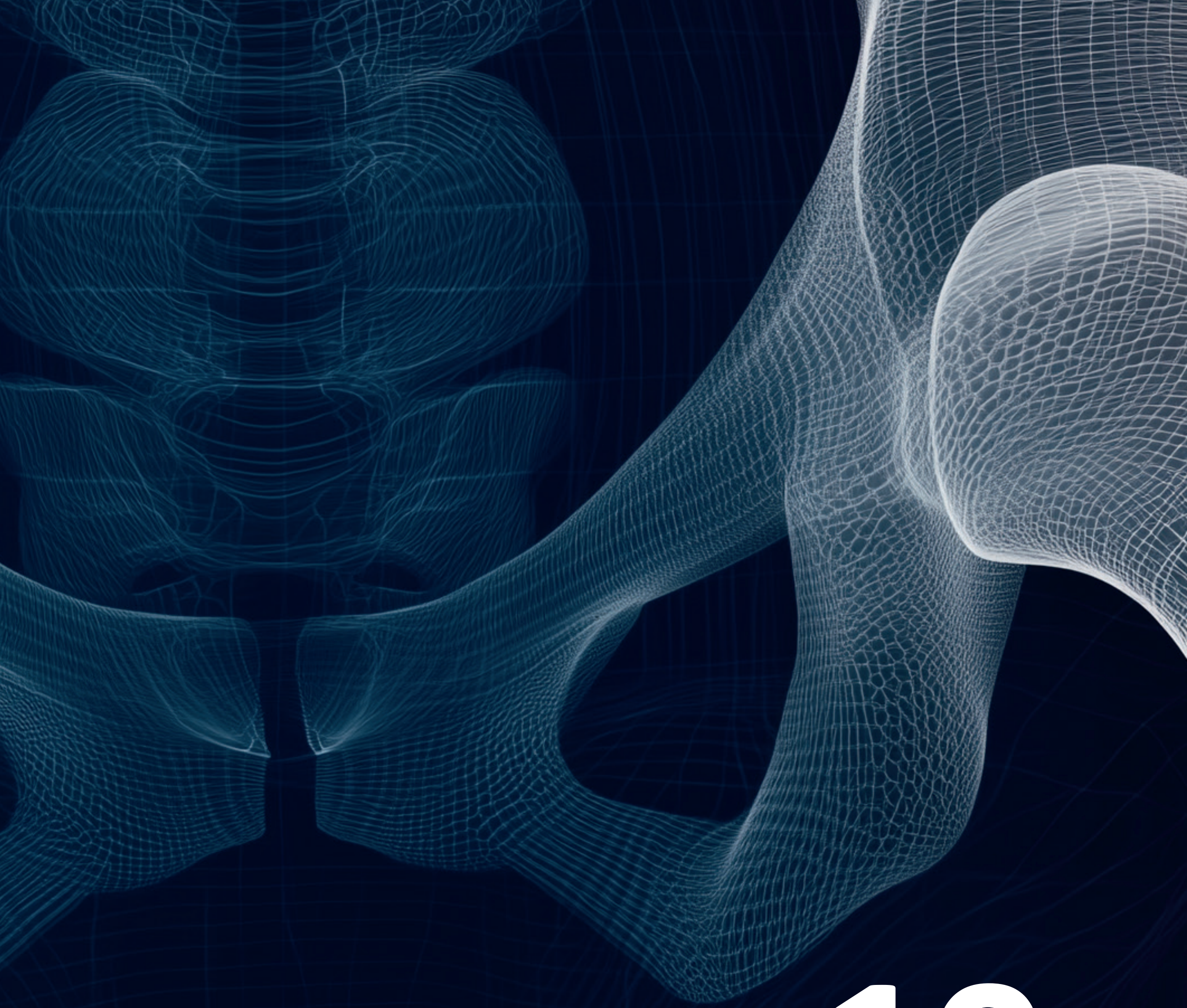

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Dankwoord

“Het is een rijdende trein, je hoeft er alleen maar op te springen. Laten wij de trein rijdende houden.” Ik herinner me de woorden nog als de dag van gisteren, en het waren deze woorden die uiteindelijk de doorslag gaven om het avontuur van een PhD-traject aan te gaan. Na een jaar werken als basisarts in de orthopedie kreeg ik de kans om verder te groeien en een nieuwe richting in te slaan. Het idee om deze sprong te wagen kwam met twijfels, maar de aanmoediging van mijn omgeving gaf me de moed om het toch te doen. Kijk waar ik nu sta: omringd door een fantastisch team dat mijn ontwikkeling en vooruitgang heeft vormgegeven. Deze reis zou niet mogelijk zijn geweest zonder jullie steun.

Ik wil beginnen met het bedanken van mijn co-promotores, Wierd en Rinne. Jullie waren altijd beschikbaar en boden onmisbare steun. **Wierd**, je geduld en betrokkenheid zijn ongeëvenaard. Dag in, dag uit was je beschikbaar voor vragen en discussies, hoe druk je agenda ook was. Je hebt altijd tijd, zelfs als dat betekende dat je je avonden moest opofferen om werk na te kijken. Bedankt voor de gezellige tripjes! De congressen, de etentjes, borrels en brainstormsessies met jou en de rest van de groep waren van onschatbare waarde. Je enthousiasme en steun hebben me enorm geholpen in mijn ontwikkeling als onderzoeker. Ik ben dankbaar voor alles wat ik van je heb geleerd.

Beste **Rinne**, bedankt voor je ongelooflijke vermogen om van alles iets moois te maken. Ondanks je drukke leven met twee jonge kinderen en je opleiding tot orthopeed, vind je altijd de energie om dag in dag uit anderen te helpen. Je enthousiasme is aanstekelijk, en je betrokkenheid is iets waar ik veel waardering voor heb. Het is een voorrecht om jou als collega te hebben, en ik kijk ernaar uit om samen verder te werken aan mooie projecten. Nadat je terug bent uit Australië natuurlijk!

Prof Dr. Jutte, beste **Paul,** ik herinner me nog goed dat eerste gesprek aan tafel in mijn eerste jaar als ANIOS, waar alles begon. Ik vertelde je over mijn wens om met onderzoek aan de slag te gaan en vroeg me af of er mogelijkheden waren binnen het UMCG. Al snel werden er meerdere lijntjes uitgezet naar verschillende personen waar ik terecht kon. Het liep uiteindelijk anders dan ik had verwacht, en zo vond ik mezelf in de gelegenheid om een PhD in Leeuwarden te doen. Ondanks dat het een externe PhD was, stelde jij je onmiddellijk beschikbaar als promotor voor mijn onderzoek. Je deskundigheid en kennis waren van onschatbare waarde in dit proces, en je was altijd bereid om je tijd en inzichten te delen. Dank je wel voor al je hulp en support.

Dr. Stevens, beste **Martin,** jij was de drijvende motor achter alle handige tips en tricks gedurende mijn PhD. Iedere keer als ik tegen een probleem aanliep, was jij daar met je oplossingsgerichte benadering. “Heb je die al benaderd?...”. Jouw praktische adviezen hielpen me niet alleen om mijn onderzoek in de goede richting te sturen, maar zorgden er ook voor dat ik het proces met plezier en zelfvertrouwen doorliep. Onze gesprekken waren kort maar krachtig en ontzettend waardevol. Ik kijk met veel plezier terug op onze samenwerking.

Waar was dit onderzoek zonder de **LROI**. Dankzij de LROI hebben we in slechts twee jaar tijd maar liefst acht onderzoeken kunnen uitvoeren met hun waardevolle data. Dit is alleen mogelijk geweest door de inzet en bijdragen van veel mensen.

In het bijzonder wil ik **Liza van Steenbergen** bedanken. **Liza**, de vraagbaak van de LROI. Je was altijd bereikbaar voor een gezellige Zoom-sessie waarin we konden praten over van alles en nog wat om daarna een vragenvuur af te vuren. Daarnaast wil ik je ook hartelijk danken voor al je hulp met presentaties, onderzoeken en data-analyse. Je tips en tricks rondom onderzoek waren ontzettend waardevol en hebben me enorm geholpen.

Ook een speciale dank aan **Geke, Bart, Anneke** en alle andere leden van de LROI voor hun waardevolle data en ondersteuning. Zonder jullie bijdrage zou dit onderzoek niet mogelijk zijn geweest!

Ik wil mijn oprechte dank uitspreken aan de **MCL Academie**, die dit onderzoek mogelijk heeft gemaakt. Dankzij hun financiële ondersteuning, de mogelijkheid om een PhD-traject te volgen, het bieden van werkgroepen, cursussen, statischtische ondersteuning en de vergoedingen voor internationale congressen, heb ik veel waardevolle ervaring opgedaan. Daarnaast waardeer ik de gezelligheid met collega-onderzoekers uit verschillende vakgebieden, wat mijn groei als onderzoeker heeft gestimuleerd. Daarnaast wil ik **prof. dr. Christiaan Boerma** en alle andere betrokkenen bedanken voor hun begeleiding en steun gedurende dit traject.

Graag wil ik alle coauteurs bedanken voor de prettige samenwerking en waardevolle feedback. In het bijzonder wil ik Wim Schreurs noemen, die bij vrijwel elk onderzoek betrokken is geweest. Zijn zeer waardevolle klinische blik op alle onderwerpen heeft ons werk enorm verrijkt.

Leden van de beoordelingscommissie, Prof. Dr. R.G.H.H. Nelissen, Prof. Dr. C.J.C. Lamoth en Prof. Dr. S.K. Bulstra, hartelijk dank voor jullie tijd en aandacht voor het lezen en beoordelen van mijn proefschrift.

Peter, Paul, Pax, Wierd en Bas van de orthopedische maatschap Leeuwarden. Heel erg bedankt voor jullie vertrouwen in mij. Jullie hebben ervoor gezorgd dat ik de orthopedie nog leuker ben gaan vinden. De mix van serieus werk en die ontspannen, grappige sfeer, hebben deze periode in Leeuwarden onvergetelijk gemaakt. Ik kijk met een glimlach terug op mijn eerste jaar als anios. Dank jullie wel voor alles!

Veel dank aan mijn collega's voor de gezellige samenwerking en de leuke pauzemomenten tijdens mijn PhD

Lieve **vrienden en (schoon) familie**, af en toe wat anders dan een PhD is ook gezond, en daar zijn jullie altijd de beste in! Jullie hebben me keer op keer geholpen om te ontspannen en te genieten van het leven buiten werk. Dank jullie wel voor de geweldige momenten, de feestjes, de uitjes, de vrienden weekenden en de dagen karten!

Lieve **pap, mam en Anniek**, Ik wil jullie allemaal enorm bedanken voor alles wat jullie voor me hebben gedaan. Mam, dankjewel voor je liefdevolle, luisterende oor. Jouw geduld en begrip betekenen de wereld voor me. Pap, ik ben je zo dankbaar voor het feit dat in jouw ogen alles mogelijk is, zolang je er maar tijd en inzet in stopt. Je hebt me geleerd dat met discipline en doorzettingsvermogen niets te groot is om te bereiken. Lieve zus, bedankt voor alle lekkere kopjes koffie en de gezellige borrelavonden. Jouw steun en de mooie momenten die we samen delen zijn onbetaalbaar.

Lieve **Liset**, zonder jou was dit proefschrift nooit afgekomen. Wat ben ik blij dat jij mijn vriendin bent! Tijdens mijn PhD-traject hebben we samen een hoop mijlpalen gevierd, waaronder de spannende stap van het kopen van ons huis. Ik geniet ontzettend van onze gezamenlijke klussessies. Maar wat ik nog meer waardeer, is dat je me soms een schop onder de kont geeft om het klussen even te laten voor wat het is en me te herinneren aan de belangrijke dingen, zoals het afronden van mijn PhD. Je weet precies wanneer ik me moet focussen en dat ik niet in de valkuil moet stappen van te veel afleiding. Daarnaast wil ik je ook bedanken voor de manier waarop je naar mijn verhalen luistert, zelfs als ik merk dat je er misschien niet altijd zin in hebt. Het is geweldig om iemand te hebben die me begrijpt en me aanmoedigt om mijn doelen te bereiken. Tot slot kan ik onze geweldige reis naar Canada niet vergeten! Het congres was niet alleen een kans om mijn onderzoek te presenteren, maar ook een mooie gelegenheid om samen te genieten van een kleine welverdiende vakantie. Ik kijk ernaar uit dat we in de toekomst nog veel meer reisjes mogen maken naar mooie landen!

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About the author

Bart van Dooren was born on the 26th of December, 1994 in Arnhem, where he grew up with his parents and sister. After completing his pre-university education (VWO) at the Stedelijk Gymnasium in Arnhem in 2014, he began his medical study at the University of Groningen. During his master's program, Bart developed a strong interest in orthopedic surgery, which he pursued further through clinical experiences. In the final year of internships, he decided to focus on orthopedic surgery at the Medical Center Leeuwarden.

After earning his Master of Science degree in 2020, Bart worked as a junior doctor at the Orthopedics Department at the Medical Center Leeuwarden for one year and three months. It was here that he gained his first experience in research, which ultimately led him to start a full-time PhD trajectory in December 2021, affiliated with both the Medical Center Leeuwarden and the University Medical Center Groningen.

On the 1st of December, 2023, Bart began his training as an orthopedic surgeon, starting with the preliminary surgical training at the Martini Hospital in Groningen. He continued to work one day a week in Leeuwarden to complete his PhD research.

In his personal life, Bart lives with his partner Liset in their recently bought and renovated home in Groningen. Outside of work, he enjoys tackling home improvement projects, which allow him to relax while developing his practical skills, much like those required in his work in orthopedics.

Professionally, Bart will continue his orthopedic surgery training at the Martini Hospital (MZH), Medical Center Leeuwarden (MCL) and University Medical Center Groningen (UMCG). He is eager to refine his surgical skills, appreciating the craftsmanship involved in both his home projects and his work with patients.