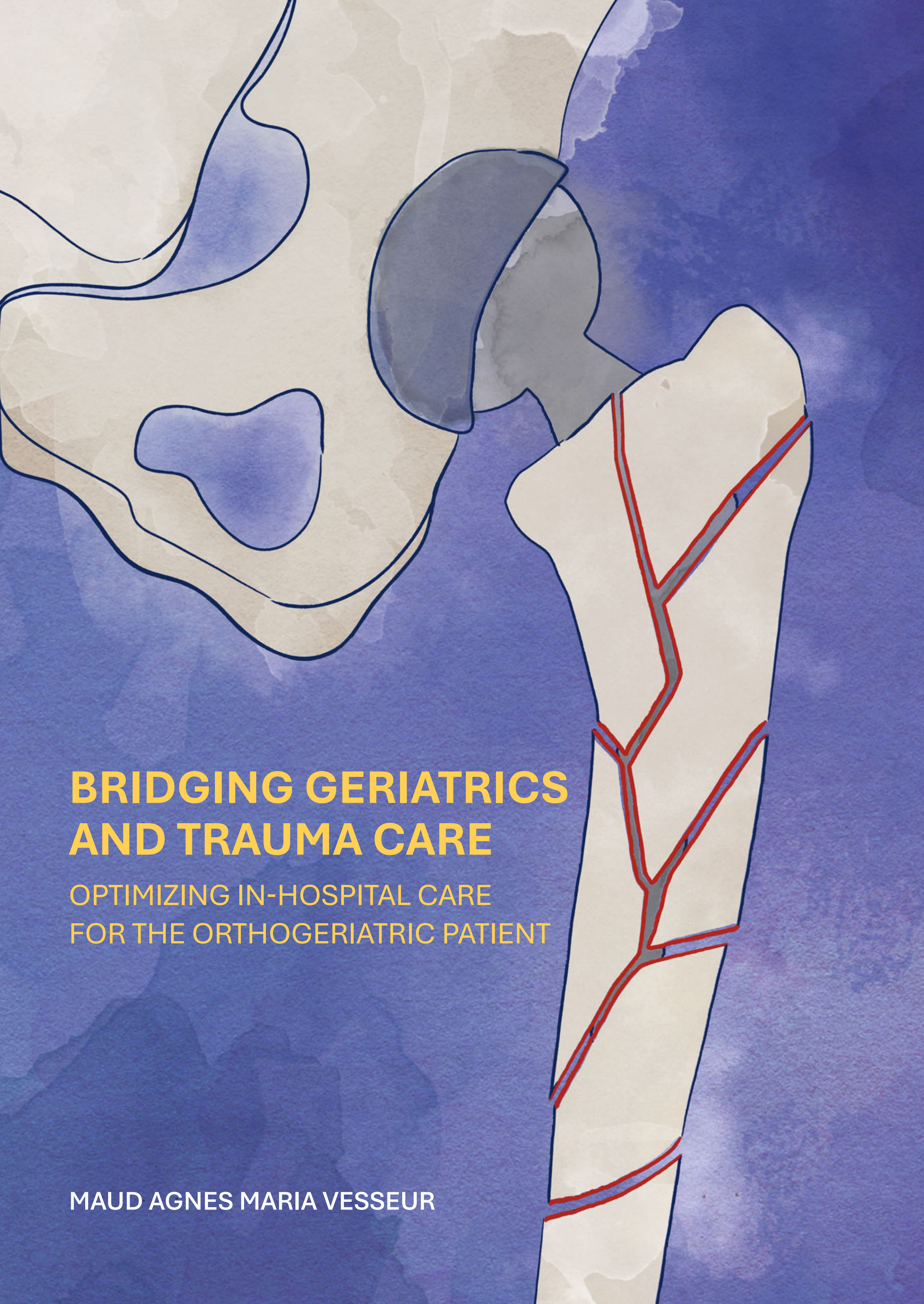

BRIDGING GERIATRICS AND TRAUMA CARE

OPTIMIZING IN-HOSPITAL CARE FOR THE ORTHOGERIATRIC PATIENT

MAUD AGNES MARIA VESSEUR

Bridging geriatrics and trauma care

Optimizing in-hospital care for the orthogeriatric patient

Maud Agnes Maria Vesseur

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General introduction and thesis outline

INTRODUCTION

Over the past decades, the incidence of periprosthetic femoral fractures (PPFF) and proximal femoral fractures (PFF) has risen significantly, both nationally and globally[1-2]. This trend reflects an ageing population, and the growing number of primary joint arthroplasties performed[3-6]. In the Netherlands national registry data show a steady increase in the number of patients sustaining these fractures, a pattern mirrored in international epidemiological studies[7]. These injuries predominantly affect a vulnerable patient population, often characterized by advanced age, frailty and multiple comorbidities, resulting in a high risk of complications and a one-year mortality rate that can exceed 20–30%[4,8-12]. Given the rising incidence and clinical vulnerability of this patient group, healthcare professionals are increasingly challenged to optimize the in-hospital care trajectory and improve decision-making in patient selection. Specifically, there is a critical need to identify which patients are likely to benefit from surgical intervention and which may not, to personalize treatment strategies and thereby improve outcomes. This aligns with the broader movement in medicine toward individualized, patient-centered care, a paradigm that underpins the central aim of this thesis.

History

The development of total hip arthroplasty (THA), to relieve pain and improve function in individuals with severe hip problems, such as osteoarthritis or rheumatoid arthritis, represents one of the most significant advances in orthopaedic surgery during the 20th century[13]. Initially conceptualized in the early 20th century, modern THA was pioneered by Sir John Charnley in the 1960s, who introduced the low-friction arthroplasty using a metal femoral component, polyethylene acetabular cup, and acrylic bone cement[14-15]. Since then, continuous innovations in implant design, materials, and surgical technique have significantly improved patient outcomes and implant longevity[16]. However, as the number of hip arthroplasties (HA) continues to rise globally, particularly among aging populations, the incidence of complications will also increase. Among these, PPFF have emerged as a complex and increasingly common challenge in both primary and revision HA[17]. These fractures, occurring in the femur surrounding or involving a hip implant, can significantly affect implant stability, patient mobility, and overall prognosis, necessitating careful preoperative planning and specialized management strategies[18-19].

Definition

PPFF are defined as fractures that occur in the femur adjacent to or involving a hip implant, either during or after HA surgery[20]. Resulting in early or late PPFF[21-22]. These fractures can compromise the stability of the implant and present a significant surgical challenge, especially in elderly or osteoporotic patients[23]. To guide diagnosis and treatment, the Vancouver classification system, introduced by Duncan and Masri in 1995, remains the most widely accepted and clinically useful framework to categorize PPFF (Figure 1). The classification categorizes PPFF based on three key parameters: the location of the fracture, the stability of the femoral implant and the quality of the surrounding bone stock. Vancouver Type A fractures occur in the trochanteric region (either greater [AG] or lesser [AL] trochanter), Type B fractures occur around or just distal to the stem and are further divided into B1 (stable implant), B2 (loose implant with good bone stock), and B3 (loose implant with poor bone stock), while Type C fractures occur well distal to the stem tip[24]. This classification not only aids in standardized communication but also plays a crucial role in determining the appropriate surgical approach and fixation method[25-26].

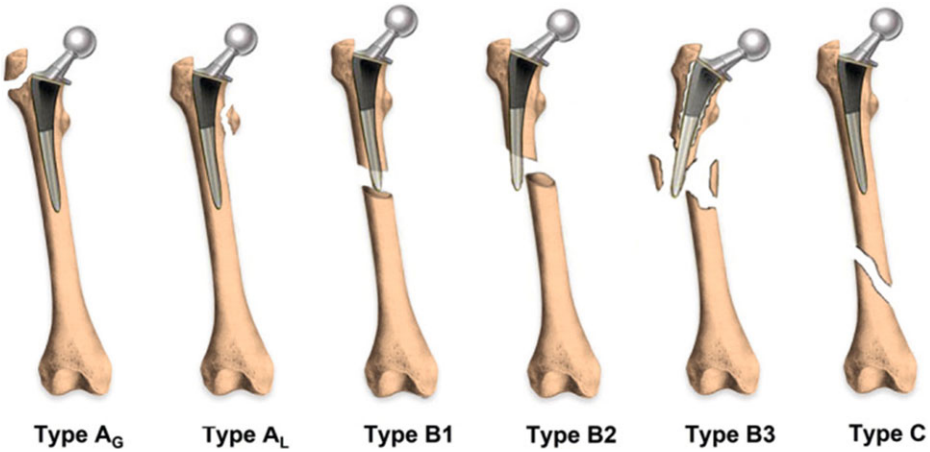

Figure 1: Visual representation of the Vancouver classification system for PPFF[27]

Orthogeriatric challenges; postoperative mobilization

Since the first recorded hip replacement in 1891, HA has evolved into one of the most successful and commonly performed orthopaedic procedures worldwide[13]. Driven by aging populations, an increasing prevalence of osteoarthritis and expanded surgical indications, including in younger, more active patients, the global number of THA continues to rise[3-6]. The annual incidence of HA per 100 000 Dutch inhabitants aged ≥ 40 years increased from 221 in 1990 to 360 in 2022[28]. According to data from the Organisation for Economic Co-operation and Development (OECD) for the period 2008–2018, the mean annual number of hip replacements performed in OECD countries in 2018 was 191.5 per 100,000 population, representing a 21.7% increase over that period[29]. Concurrently, improvements in implant design and surgical techniques have extended the longevity of hip implants, but they have also led to a proportional increase in revision surgeries and associated complications, most notably PPFF[4,30]. First documented in 1954, PPFF are recognized as one of the leading causes of revision THA, following implant instability, mechanical failure and metallosis[31-32].

The incidence of PPFF varies significantly depending on patient and implant characteristics. Data from the Dutch Arthroplasty Register show that the revision rates due to PPFF in hemi arthroplasty and THA for hip fractures are 0.26% and 0.34%, respectively[33]. Other studies report a risk of 0.07–3.5% for late PPFF, with markedly higher rates in uncemented THA compared to cemented ones[34-38]. These fractures are more common in elderly patients with compromised bone quality and are associated with substantial morbidity and mortality[4]. One-year mortality rates after PPFF surgery range from 8% to 22%, often due to postoperative immobility, increased risk of complications such as pneumonia and delirium and a decline in functional independence[10-12]. Moreover, PPFF management is surgically complex due to altered anatomy and the need to simultaneously address implant fixation and fracture stabilization[23].

Early mobilization after surgery is critical to prevent what is commonly referred to as physiological decline, a transient yet significant deterioration in physical and systemic function that often follows major orthopedic trauma and surgery[39]. This period is marked by muscle atrophy, impaired cardiopulmonary performance, loss of independence and an elevated risk of complications such as pneumonia, thromboembolic events, and delirium[40]. Facilitating early and safe mobilization is therefore essential to improve postoperative recovery trajectories. In this context, the concept of permissive weight bearing (PWB), as introduced by Meys et al., has emerged as a promising, patient-centered strategy[41]. PWB has been proposed as an individualized approach that allows progressive weight bearing based on patient tolerance, guided by clinical assessment and pain levels. It enables early loading of the operated limb within safe biomechanical limits, seeking to leverage the physiological benefits of mobilization while minimizing the risk of implant failure or fracture displacement (Figure 2)[41]. Evidence from other lower extremity fractures suggests that PWB can safely accelerate functional recovery without increasing complication rates[42-43]. However, its application in PPFF care remains limited and insufficiently explored in the literature, highlighting a clear need for further investigation and clinical guidance. Current postoperative protocols for PPFF vary widely, with traditional approaches often involving 6–8 weeks of restricted weight bearing, which may impede mobilization and prolong hospital stays[44-45]. This thesis seeks to further conceptualize and evaluate PWB as a means of enhancing postoperative care and outcomes in patients with PPFF.

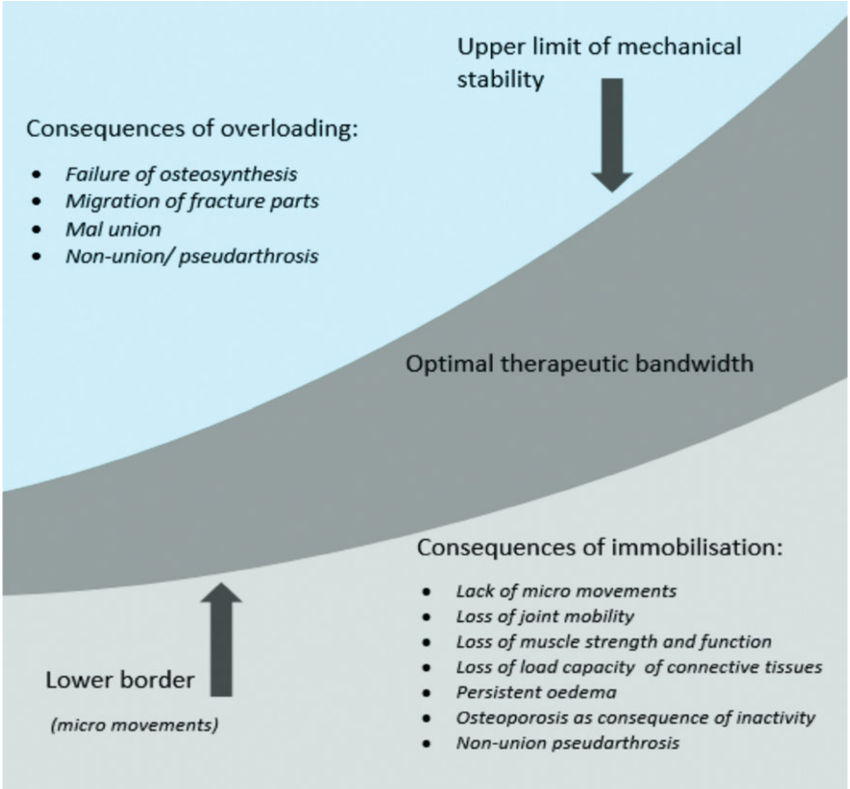

Figure 2: Visual representation of PWB concept[41]

Orthogeriatric challenges; risk-factors for PPFF and mortality

PPFF, are complex and associated with poor bone quality, altered anatomy, and increased surgical difficulty[23]. Data from different previous studies have identified several patient- and surgery-related risk factors for poor outcome, including low Body Mass Index (BMI), advanced age, high American Society of Anesthesiologists (ASA) Physical Status Classification System score, postoperative non weight bearing protocols, pre-existent dementia and delayed surgery[46-50]. Notably, uncemented stems and anterior approaches have been linked to higher revision rates[51-53]. Furthermore, limited guidelines exist for perioperative management of PPFF, and existing classification systems such as the Vancouver classification often overlook modifiable risk factors and comorbidities that influence mortality and complications[25-26]. Comprehensive preoperative assessment and individualized care pathways are critical in improving outcomes and reducing the healthcare burden associated with these complex injuries. This thesis explores key patient- and procedure-related risk factors linked to clinical outcomes and on-year mortality.

PFF including femoral neck and intertrochanteric fractures also represent a serious health burden among the elderly, leading to significant short- and long-term morbidity, reduced quality of life and high mortality rates[8-9]. Due to the ongoing aging of the population, the global incidence of hip fractures is expected to increase substantially in the coming decades[54-55]. These injuries are most commonly treated surgically through hemiarthroplasty or internal fixation using intra- or extramedullary devices[56]. Despite advances in surgical techniques and perioperative care, mortality rates following hip fracture surgery remain alarmingly high, ranging from 20–30% within the first postoperative year, particularly among older and medically frail patients[8-9].

The patient population sustaining PPFF closely resembles that of patients with PFF in terms of demographic and clinical characteristics. Both groups predominantly consist of elderly individuals who are often frail, multimorbid and functionally dependent. These patients are frequently presented with significant comorbidities, such as cardiovascular disease, osteoporosis, and cognitive impairment, that increase their vulnerability to perioperative complications[57]. Furthermore, both PPFF and PFF patients face elevated surgical risks, including a likelihood of postoperative complications, prolonged rehabilitation and increased short- and long-term mortality. Given these shared features, clinical decision-making in both populations requires a similarly cautious and individualized approach, with careful consideration of operative indications, expected outcomes, and the potential burden of treatment.

Accurate risk stratification in this vulnerable population is essential to guide clinical decision-making, including the consideration of nonoperative management in select cases with limited life expectancy. In recent years, there has been growing interest in the critical question of whether surgical intervention is always the most appropriate treatment option for certain frail patient populations. This issue is also addressed in the FRAIL-HIP study, in which the authors suggest that nonoperative management may be a viable alternative for patients with limited life expectancy[58]. Their findings indicate that, in carefully selected individuals, conservative treatment does not necessarily compromise quality of life, highlighting the importance of individualized, goal-directed care in this vulnerable group[58]. They also show that pain management in patients receiving nonoperative treatment remains suboptimal and represents an important area for improvement[58]. Recent advancements, such as the introduction of pericapsular nerve group (PENG) blocks, offer promising alternatives[59-61]. This technique enables chemical denervation of the hip, providing significant pain relief with effects lasting up to six months[62]. As such, PENG blocks may serve as a valuable addition to the treatment arsenal for patients with hip fractures who are not suitable candidates for surgery. To ensure appropriate, patient-centered care, it is crucial to stratify patients according to their mortality risk following the fracture, thereby guiding treatment decisions more effectively. Existing models on mortality prediction, such as the Almelo Hip Fracture Score (AHFS), have demonstrated promise in predicting early mortality, but often rely on a limited follow-up period (e.g., 30 days) and a narrow set of variables[63]. Determining the best treatment option requires a multidisciplinary approach tailored to the individual patient. Identifying patients at high risk of mortality in advance could help improve overall quality of live outcome for this patient population. It enhances the shared decision-making process by offering personalized information into the individual patients' postoperative mortality risk.

Given the complexity and heterogeneity of these patients, one of the central questions is whether surgical intervention will meaningfully benefit the individual in terms of survival and functional recovery. In this light, a substantial component of this research focuses on refining indication criteria for PPFF surgery using predictive modeling based on early mortality risk. Notably, this investigation was conducted in patients with PFF rather than PPFF, primarily because the development and validation of predictive models require large datasets, more readily available in the context of PFF. Therefore, this thesis ends with a model that identifies patients preoperatively who are at increased risk of postoperative mortality to enhance risk stratification and inform clinical decision-making.

THESIS OUTLINE

Despite the rising incidence of PPFF there is currently no universally accepted postoperative guideline for weight bearing management following surgical treatment. *Chapter II* of this thesis aims to address this clinical gap by exploring contemporary postoperative weight bearing practices among orthopedic surgeons in the Netherlands. The first objective was to investigate current postoperative instructions regarding weight bearing in patients with surgically treated PPFF, specifically Vancouver types A, B, and C, while accounting for variation based on fracture classification and chosen surgical intervention. The second objective was to determine whether the concept of *PWB* was already being implemented in Dutch clinical practice, and if so, how frequently it was applied and in relation to which specific PPFF types. Particular attention was given to the perceived safety and practical considerations surrounding the use of PWB as a structured mobilization strategy. A scoping review addressing the gap in existing literature is presented in *Chapter III*. The study conducted a scoping review, using a systematic search strategy, to summarize the current available evidence on postoperative weight bearing protocols in late PPFF around THA, with particular focus on the implementation of PWB in the postoperative management of these patients.

Further this thesis investigates key patient- and surgery-related risk factors associated with PPFF risk and clinical outcomes after surgical treatment of PPFF. By identifying predictors of adverse outcomes, *Chapters IV and V* seek to contribute to more personalized and evidence-based postoperative care strategies. *Chapter IV* presented a nationwide registry-based study with the primary aim of determining the incidence of postoperative stem revision due to PPFF in patients who initially received a primary THA for osteoarthritis. The secondary aim of this study was to examine patient- and surgery-related characteristics associated with the need for stem revision following PPFF. *Chapter V* focused on patients with PPFF requiring surgical treatment. The first aim of this study was to provide a comprehensive overview of the patient population, while the second aim was to identify potential perioperative risk factors that significantly influenced the one-year mortality rate. Together, these studies aim to improve clinical decision-making and outcome prediction in the surgical treatment of PPFF around HA.

In *Chapter VI,* the newly proposed Zuyderland Hip Inference for Survival and Lifetime Expectancy (ZHISLE) model expanded on previously identified limitations in existing prediction models for PFF by incorporating a broader range of clinical, demographic, and biochemical variables to predict mortality over a longer follow-up period. Thereby offering improved preoperative guidance in elderly patients undergoing hip fracture surgery. The aim of this study was to propose a novel model, that identifies patients preoperatively who are at increased risk of postoperative mortality. This model extended the follow-up period to six months and included a comprehensive set of predictors, such as comorbidities, blood metabolite concentrations, demographic characteristics, and vital signs, to enhance risk stratification and inform clinical decision-making.

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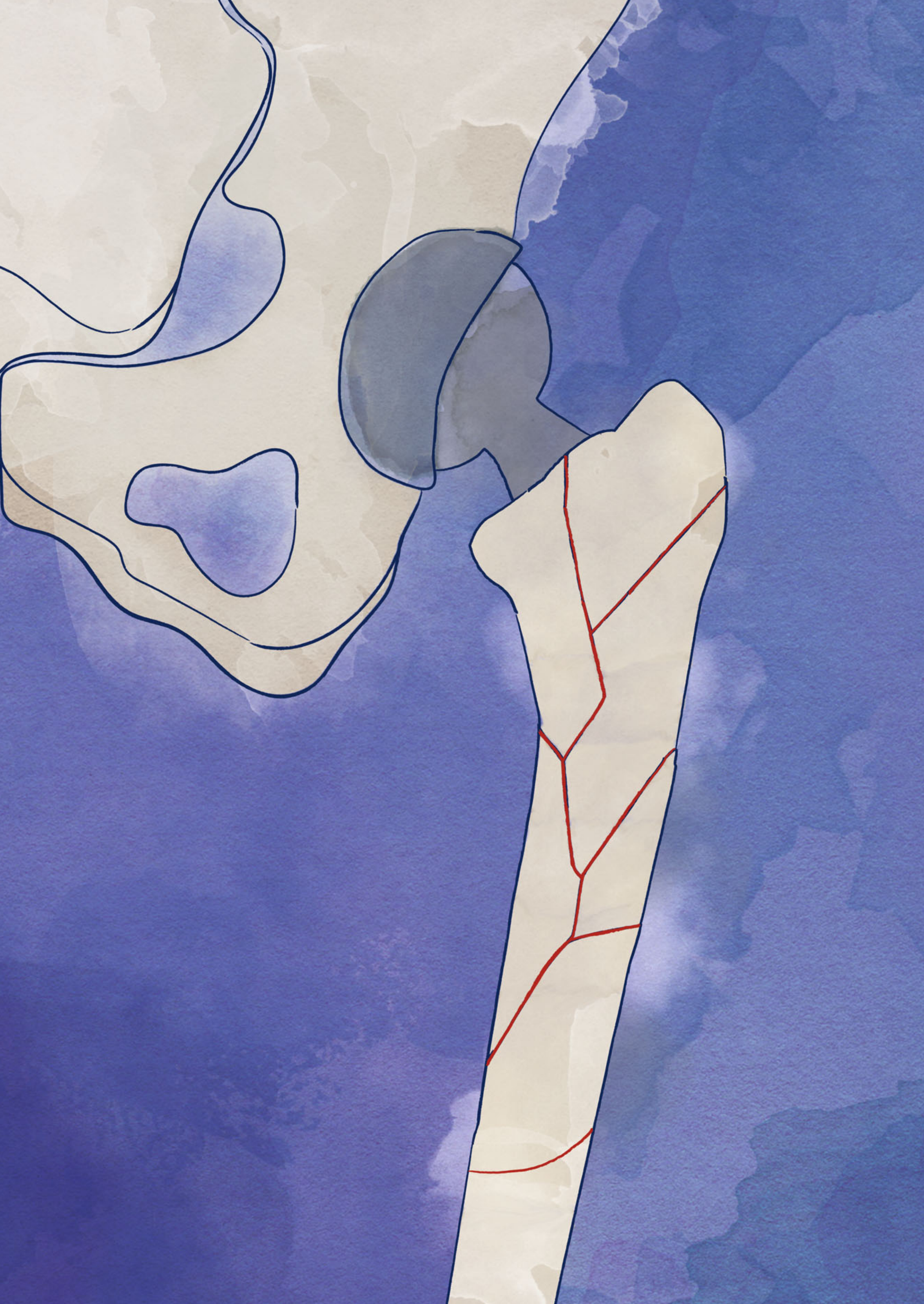
Part 2

Optimizing in-hospital care for the orthogeriatric patient



Chapter II

Postoperative Load Bearing in Periprosthetic Femoral Fractures Around Hip Arthroplasty: A Survey Among Orthopedic Surgeons in The Netherlands

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ABSTRACT

Introduction

Permissive weight bearing (PWB) has relatively recently been implemented to optimize rapid clinical recovery and restoration of function in patients suffering lower extremity fractures. PWB shows outcome advantages in this patient category. Currently, there are no decisive recommendations on postoperative load-bearing management after surgically treated periprosthetic femoral fractures (PPFF) around hip arthroplasty. The objective is to investigate the current postoperative practice of weight-bearing instructions for patients with surgically treated PPFF, accounting for differences in types of periprosthetic fractures and treatment options among Dutch orthopedic surgeons.

Materials and methods

An online survey was distributed among the members of the hip and trauma working groups of the Dutch Orthopedic Association.

Results

The response rate was 13% (n=75). The main finding was that postoperative load bearing regimes in Vancouver A, B, and C PPFFs differed greatly among Dutch orthopedic surgeons, and there was no decisive guideline or consensus in postoperative load bearing regimes after surgically treated PPFF was used in the Netherlands.

Conclusion

In the absence of decisive guidelines or consensus, more research is needed to explore the efficacy of PWB after surgically treated PPFF.

Keywords

Trauma, survey, orthopedic surgery, permissive weight bearing, periprosthetic femoral fractures

I INTRODUCTION

In 1891, the first recognized hip replacement was performed[1]. Periprosthetic femoral fractures (PPFF) after total hip arthroplasty (THA) were first reported in 1954[2]. The aging population results in a higher prevalence and incidence of osteoarthritis and, therefore, primary THA[3-4]. In addition, implant designs have improved, which increases their lifetime. Consequently, numbers of PPFF are also rising[4-5]. A wide range is observed in the probability of PPFF after primary THA. Lindahl et al. found a probability of 0.6% for late traumatic PPFF, whereas Schwartz et al. reported rates ranging from 4.1% to 28% (half were diagnosed intraoperatively) after uncemented hip replacement, compared with less than 3% when cemented stems were used[6-8].

High morbidity and mortality rates are observed in patients with PPFF. Mortality rates start at 9% at 90-day follow-up, 21% at one-year follow-up, and might increase to a total of 60% at five-year follow-up[9]. Immobility among older (in)patients is related to higher mortality rates[10]. Whereas early postoperative mobilization of surgically treated patients with a variety of medical diagnoses and surgical conditions may improve patient outcomes[11]. In the literature, different postoperative load-bearing protocols are described[12]. Current practice in patients with surgically treated PPFF mostly includes a postoperative period of non-, restricted-, or partial load bearing for 6-8 weeks[12]. This generally leads to a loss of mobilization and independence and, subsequently, a prolonged length of hospital stay with increased costs of healthcare services[13].

Permissive weight bearing (PWB) has been designed as a new aftercare mobilization regimen to optimize rapid clinical recovery and restoration of functionality[14]. PWB has been proven to be successful (in cases of non-union, wound infection, early removal of implant, implant fracture, and secondary dislocation) in different kinds of lower extremity fractures (pelvic/acetabular, distal femur, tibial plateau, distal tibia/ankle, and foot) without raising post-operative complications when compared to non-load-bearing protocols[14]. In addition, it ensures patients fully mobilize four weeks earlier (12 weeks versus 16 weeks) compared to AO guidelines[14]. Also, in the case of uncemented THA, early postoperative load bearing is proven to be safe and does not increase the incidence of postoperative complications[15].

To the best of our knowledge, no postoperative clinical guidelines after PPFF exist. Therefore, the question was postulated on how orthopedic surgeons deal with postoperative load bearing in the management of surgically treated PPFF. The first aim is to investigate the current postoperative practice of weightbearing instructions for patients with surgically treated PPFF (Vancouver A, B, and C[16]), accounting for differences in types of periprosthetic fractures and treatment options among Dutch orthopedic surgeons. The second aim was to determine whether PWB was already applied in the Netherlands and, if so, how often and for which types of PPFF (Vancouver A, B, and C[16]).

This article was previously presented as a meeting abstract at the 22nd European Congress of Trauma and Emergency Surgery on May 7, 2023, and at the European Federation of National Associations of Orthopedics and Traumatology Congress on May 24, 2023.

II MATERIALS AND METHODS

An online survey was developed (Appendix 1) and distributed among Dutch orthopedic surgeons using online software (Momentive Inc. (formerly SurveyMonkey Inc.), San Mateo, California, United States). This survey contained general questions regarding daily practice, questions on load bearing in postoperative management, and case-specific questions. The survey was presented by e-mail to members of the hip and trauma subgroups, including arthroplasty surgeons, of the Dutch Orthopedic Association on July 19th, and a reminder was sent on August 30th, 2021. The survey was online until September 27th, 2021.

PWB was defined as described by Kalmet et al.[17]. In their definitions, patients are instructed and trained to start load-bearing as tolerated. The limitation of load bearing is dependent on the patient's perception of pain, a feeling of instability, and redness or swelling at the fracture site. The primary objective was to quantify the proportion of physicians prescribing certain intensities of load-bearing. For the purpose of secondary analysis (prescription of PWB in high-volume surgeons vs. low-volume surgeons and fellows vs. consultants), a high-volume surgeon was defined as someone who operated more than 10 PPFF annually, and a low-volume surgeon was defined as someone who operated less than 10 PPFF annually.

Statistical analyses were performed using IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp. Descriptive statistics were used to describe the demographic data and baseline characteristics. Results are presented as frequencies and percentages (%). A one-way ANOVA test was used to assess a difference in postoperative management between fellows and consultants and between high-volume and low-volume surgeons.

III RESULTS

III.I Group characteristics

The survey was sent to 569 orthopedic surgeons, of whom 75 responded (13%). Group characteristics are shown in Table 1. From the respondents, nine (12%) were fellows (subspecialty training), and 66 (88%) were consultants. Half of all respondents (51%) worked at a non-academic teaching hospital. There was a good distribution among the cohort in terms of experience, ranging from zero to five years to >20 years, and based on the number of interventions regarding PPFF annually. Nearly all respondents (95%) used the Vancouver classification system[16]. The concept of PWB was already known by 61 respondents (81%).

Table 1: Group characteristics

Total n (%)	75 (100)
Hospital n (%)	8 (10.7)
- **Academic hospital**	38 (50.7)
- **Peripheral teaching hospital**	28 (37.3)
- **Peripheral non-teaching hospital**	1 (1.3)
- **Independent treatment center**	
Level of expertise	9 (12.0)
- **Fellow**	66 (88.0)
- **Consultant**	
Number of years working n (%)	21 (28.0)
- **0-5**	22 (29.3)
- **5-10**	13 (17.3)
- **10-15**	15 (20.0)
- **15-20**	4 (5.3)
- **>20**	
Number of interventions regarding PPFF annually n (%)	2 (2.7)
- **None**	12 (16.0)
- **1-3**	14 (18.7)
- **4-6**	16 (21.3)
- **7-9**	18 (24.0)
- **10-13**	5 (6.7)
- **14-15**	8 (10.7)
- **>15**	
Use of classification system n (%)	71 (94.7)
- **Vancouver**	3 (4.0)
- **BABA**	1 (1.3)
- **UCS**	
Use of standard protocol PPFF n (%)	18 (24.0)
- **Yes**	57 (76.0)
- **No**	
Familiar with PWB n (%)	61 (81.3)
- **Yes**	14 (18.7)
- **No**	

n = number of respondents, PPFF = periprosthetic femoral fracture, PWB = permissive weight bearing, UCS = Unified Classification System.

III.II Postoperative load bearing

Results about postoperative load bearing after surgically treated Vancouver A (fracture of lesser or greater trochanter[16]), Vancouver B1 (fracture around a well-fixed implant[16]), Vancouver B2 (fracture with a loose implant[16]), and Vancouver C (fracture well below the tip of the implant[16]) are displayed in Figure 1-5. Most respondents (n=24 (32%) for Vancouver A and n=25 (33%) for Vancouver B1) advised 50% load bearing for six weeks. In the case of Vancouver B2 (plate/screw osteosynthesis, conscious choice in view of vulnerable elderly) and Vancouver C, most respondents (n=32 (43%) and 26 (35%) advised plantar contact for six weeks, and for Vancouver B2 (stem revision), most respondents (n=21, 28%) advised full load mobilization or immediate load bearing. PWB was advised by 28% (n=21) for Vancouver A, 24% (n=18) for Vancouver B1, 19% (n=14) for Vancouver B2 (plate/screw osteosynthesis), 20% (n=15) for Vancouver B2 (stem revision), and 23% (n=17) for Vancouver C.

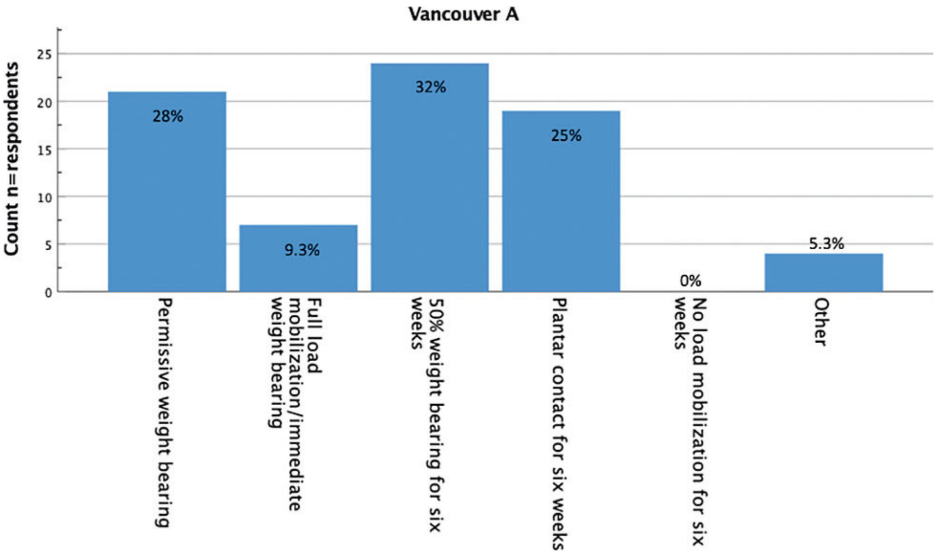

Figure 1: Vancouver A (n=75)
You perform a trochanter refixation for a Vancouver A periprosthetic fracture. The fracture is non-comminuted, and with osteosynthesis, there is good reposition and a stable fixation. What is your policy regarding postoperative loading of the operated leg? (Assuming a well-instructed patient). n = number of respondents.

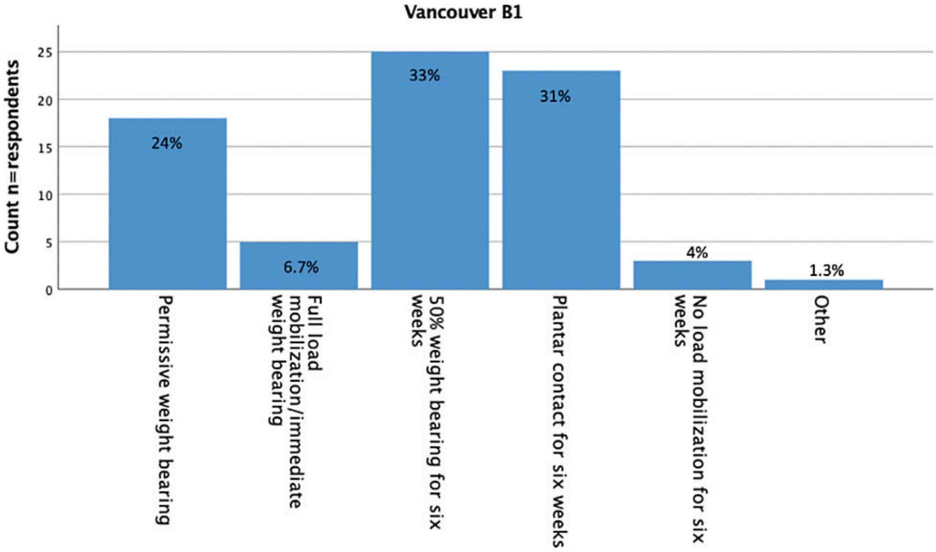

Figure 2: Vancouver B1 (n=75)
You are performing plate screw osteosynthesis on a Vancouver B1 (stem-fixed) periprosthetic femoral fracture. The fracture is non-comminuted, and in osteosynthesis, there is good reposition and a stable fixation. What is your policy regarding postoperative loading of the operated leg? (Assuming a well-instructed patient). n = number of respondents.

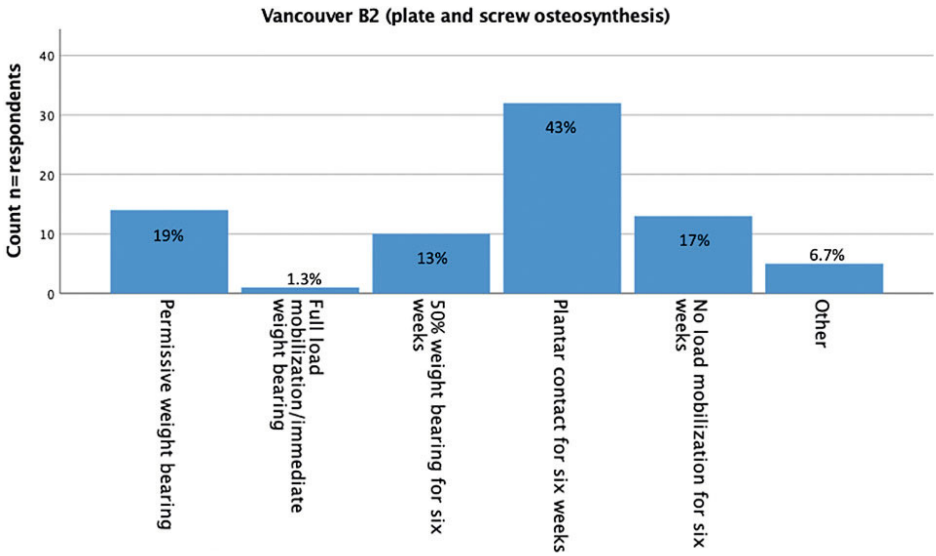

Figure 3: Vancouver B2 (plate/screw osteosynthesis) (n=75)
You perform a plate screw osteosynthesis on a Vancouver B2 (stem loose) periprosthetic femoral fracture (cemented stem) (conscious choice due to, for example, patient comorbidity). The fracture is non-comminuted, and in osteosynthesis, there is good reposition and a stable fixation. What is your policy regarding postoperative loading of the operated leg? (Assuming a well-instructed patient). n = number of respondents.

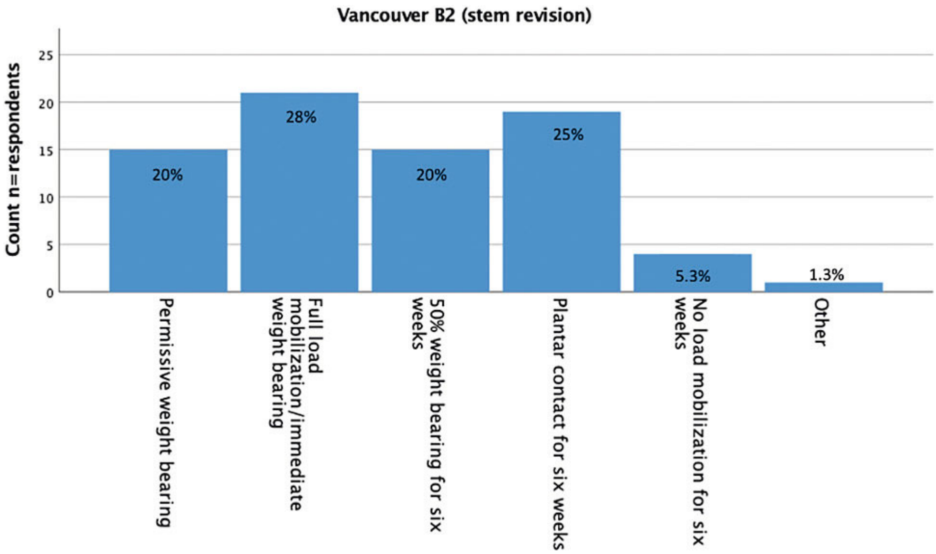

Figure 4: Vancouver B2 (stem revision) (n=75)
You perform a stem revision in combination with plate screw osteosynthesis/cerclages. The fracture is non-comminuted, and in osteosynthesis, there is good reposition and a stable fixation. What is your policy regarding postoperative loading of the operated leg? (Assuming a well-instructed patient). n = number of respondents.

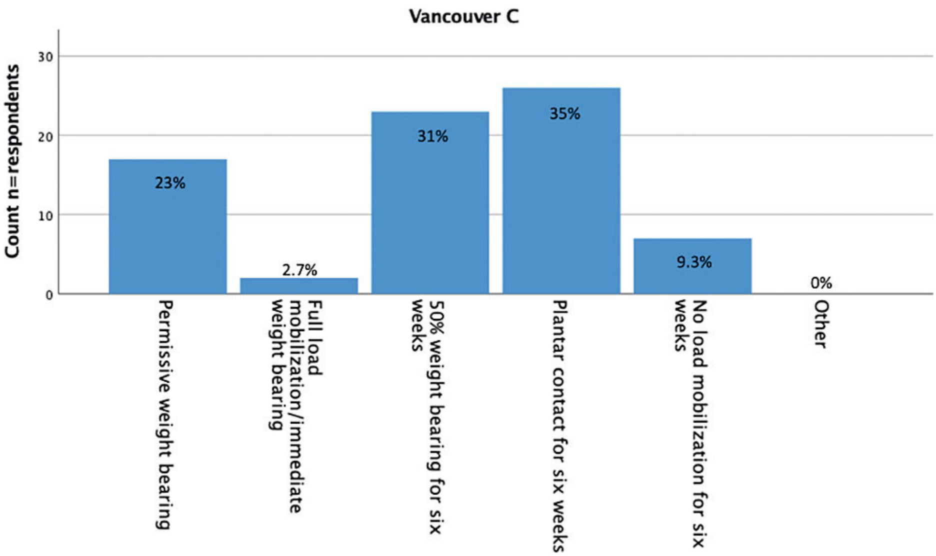

Figure 5: Vancouver C (n=75)
You perform plate screw osteosynthesis on a Vancouver C periprosthetic fracture. The fracture is non-comminuted, and in osteosynthesis, there is good reposition and a stable fixation. What is your policy regarding postoperative loading of the operated leg? (Assuming a well-instructed patient). n = number of respondents.

In all cases, half of the respondents (range 43%-53%, n=32-40) answered that their policy regarding postoperative load bearing of the operated leg would change for a patient who is poorly instructed to mostly no load bearing mobilization for six weeks (range 73%-83%, n=27-33) and to PWB in a few cases (8%-14%, n=3-5). In the case of a poorly instructed patient for Vancouver B1, out of the five respondents who initially advised full load mobilization, two (40%) changed to no load mobilization for six weeks. For Vancouver B2, out of the 21 respondents who initially advised full load mobilization, six (29%) changed to no load mobilization for six weeks. For Vancouver C, out of the two respondents who initially advised full load mobilization, one (50%) changed to no load mobilization for six weeks.

III.III Case specific

In the case of a stem revision with an uncemented modular stem and trochanteric hook plate with cable grip and additional dual-mobility cup (Case A; Figures 6-10) most respondents (n=23, 32%) advised PWB (Table 2). In the case of plate and screw osteosynthesis and placement of cerclages after the femoral stem was determined to be well fixed (Case B; Figures 11-15), most respondents (n=32, 45%) advised plantar contact for six weeks, and 18 (25%) respondents advised PWB (Table 2). In the case of a stem revision with an uncemented revision stem and placement of cerclages (Case C; Figures 16-20), most respondents (n=25, 35%) advised PWB (Table 2).

Table 2: case specific reactions (n=71)

	Case A	Case B	Case C
Permissive weight bearing (PWB)	n=23, 32.4%	n=18, 25.4%	n=25, 35.2%
Full load mobilization/immediate weight bearing	n=11, 15.5%	n=1, 1.4%	n=16, 22.5%
50% weight bearing for six weeks	n=19, 26.8%	n=15, 21.1%	n=19, 26.8%
Plantar contact for six weeks	n=15, 21.1%	n=32, 45.1%	n=7, 9.9%
No load mobilization for six weeks	n=3, 4.2%	n=5, 7.0%	n=4, 5.6%
Other	n=0, 0.0%	n=0, 0.0%	n=0, 0.0%

n = number of respondents, PWB = permissive weight bearing.

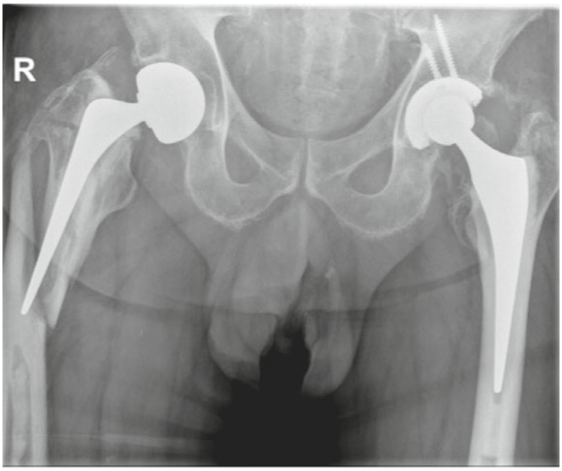

Figure 6: Case A, X-pelvis pre-OR
X-ray showing a periprosthetic femoral fracture of the right femur, Vancouver B2 type of fracture

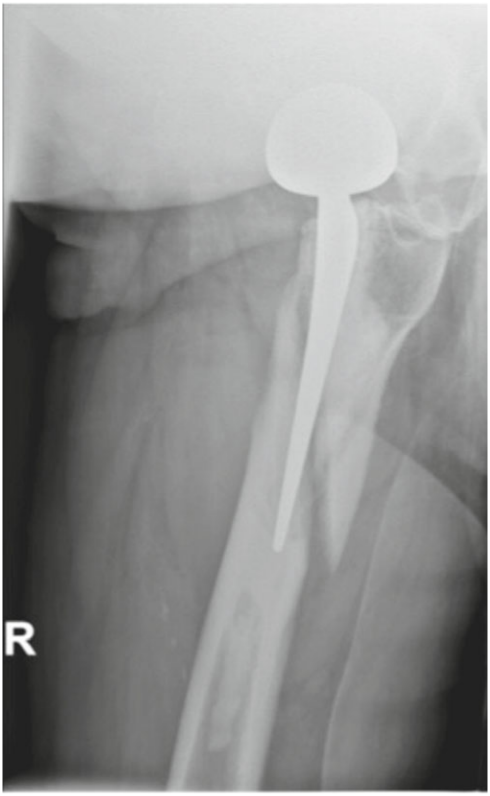

Figure 7: Case A, X-hip-axial pre-OR
X-ray showing a periprosthetic femoral fracture of the right femur, Vancouver B2 type of fracture

Figure 8: Case A, right X-thigh-axial post-OR
The choice was made for a stem revision with an uncemented modular stem and trochanter hook plate with cable grip (and an additional dual-mobility cup)

Figure 9: Case A, right X-hip-axial post-OR
The choice was made for a stem revision with an uncemented modular stem and trochanter hook plate with cable grip (and an additional dual-mobility cup)

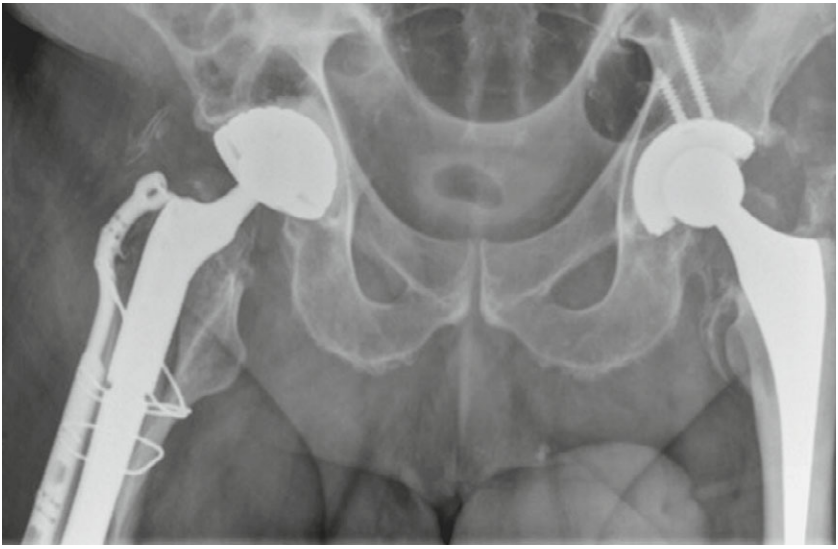

Figure 10: Case A, X-pelvis post-OR
The choice was made for a stem revision with an uncemented modular stem and trochanter hook plate with cable grip (and an additional dual-mobility cup)

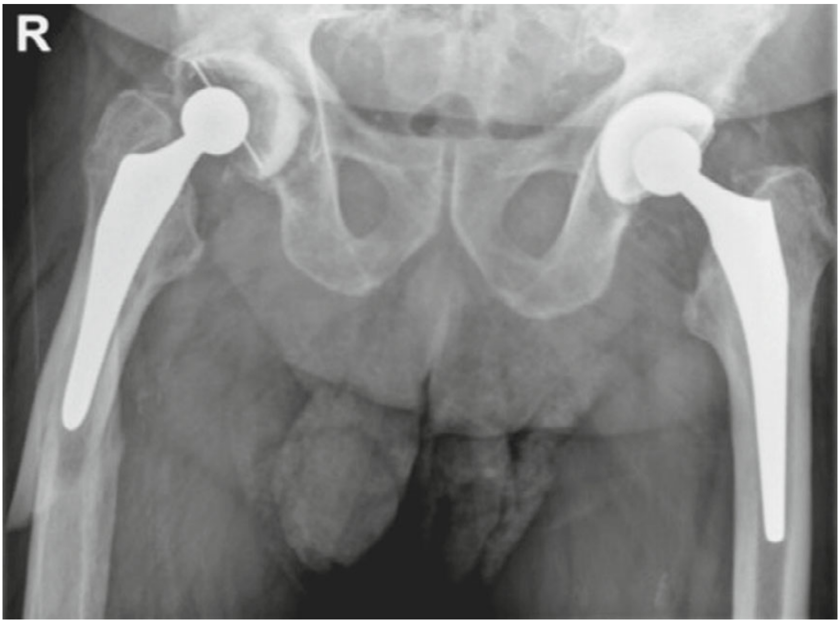

Figure 11: Case B, X-pelvis pre-OR
X-ray showing a periprosthetic femoral fracture of the right femur, Vancouver B1 type of fracture

Figure 12: Case B, right X-hip-axial pre-OR
X-ray showing a periprosthetic femoral fracture of the right femur, Vancouver B1 type of fracture

Figure 13: Case B, right X-thigh-AP post-OR
The choice was made for plate screw osteosynthesis with the placement of cerclages

Figure 14: Case B, right X-hip-axial post-OR
The choice was made for plate screw osteosynthesis with the placement of cerclages

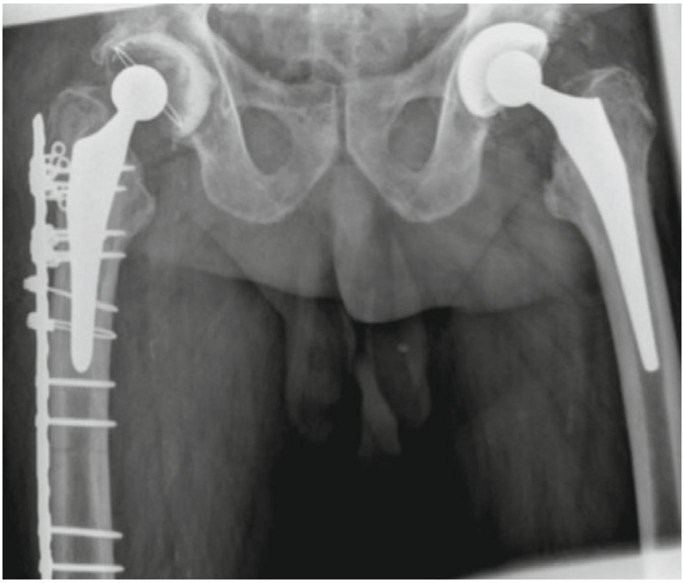

Figure 15: Case B, X-pelvis post-OR
The choice was made for plate screw osteosynthesis with the placement of cerclages

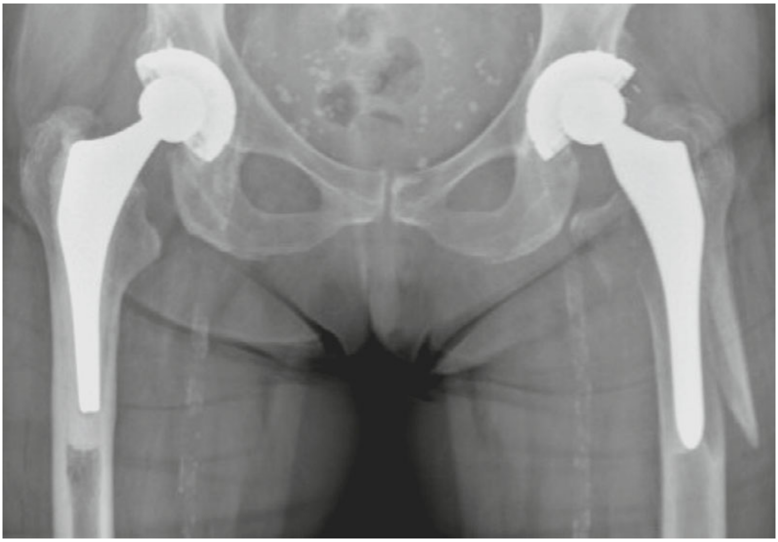

Figure 16: Case C, X-pelvis pre-OR
X-ray showing a periprosthetic femoral fracture of the left femur, Vancouver B2 type of fracture

Figure 17: Case C, left X-hip-axial pre-OR
X-ray showing a periprosthetic femoral fracture of the left femur, Vancouver B2 type of fracture

Figure 18: Case C, left X-thigh-axial post-OR
The choice was made for a stem revision with an uncemented revision stem and the placement of cerclages

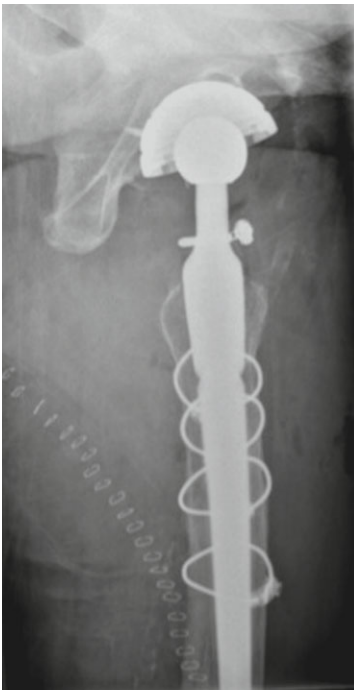

Figure 19: Case C, left X-hip-axial post-OR
The choice was made for a stem revision with an uncemented revision stem and the placement of cerclages

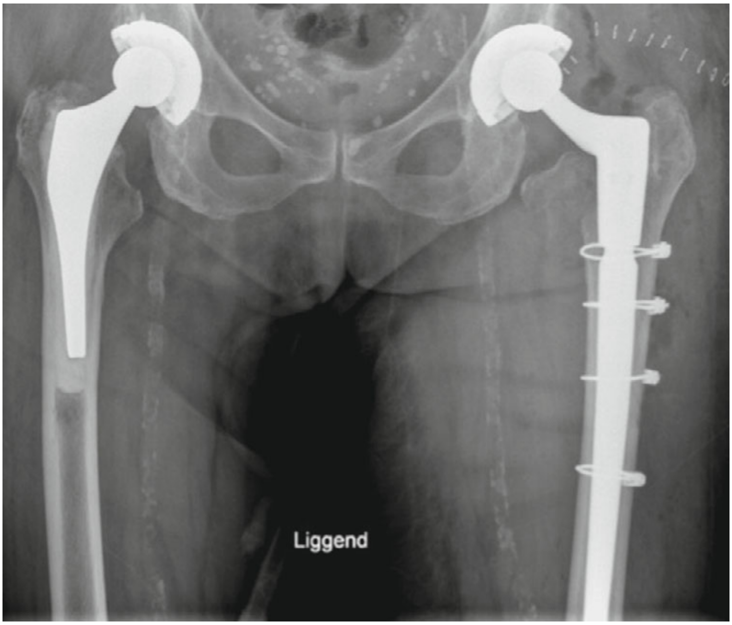

Figure 20: Case C, X-pelvis post-OR
The choice was made for a stem revision with an uncemented revision stem and the placement of cerclages

III.IV Differences in postoperative load bearing management
Fellows (n=5, 56%) used PWB significantly more often than consultants (n=12, 18%) in postoperative load bearing for Vancouver C PPFF (P=0.04). High-volume surgeons (n=7, 23%) prescribed significantly (P<0.05) more PWB for Vancouver B2 (stem revision) than low-volume surgeons (n=7, 15%).

IV DISCUSSION

The main finding of the present study was that postoperative load-bearing regimes differed greatly among Dutch orthopedic surgeons. Additionally, there are no decisive guidelines or consensus in the postoperative load-bearing regime after surgically treated PPFF is used in the Netherlands. Despite a good reposition and stable fixation in well-instructible patients and with non-comminuted fractures obtained with surgery in Vancouver A, B, and C PPFF, PWB was never the first choice in the postoperative load-bearing regime. In contrast, in cases of stem revision (cases A and C), PWB was the first choice as the postoperative load-bearing regime. In the case of Vancouver B2 (plate/screw osteosynthesis, conscious choice in view of the vulnerable elderly), five respondents (6.7%) would not consider performing only open reposition and internal fixation in cases of this type of fracture.

However, there is no evidence in the current literature to restrict patients to postoperative load bearing in the case of PPFF.

Only a few studies have been published about PWB in lower extremity fractures. In their retrospective cohort study, Kalmet et al. concluded that PWB is a safe postoperative load-bearing regime after surgically treated tibial plateau fractures with regards to complication rates[18]. In the PWB group, one non-union and one superficial wound infection were observed versus three non-unions, two superficial wound infections, and one deep infection in the restricted load-bearing group (6.5% vs. 10%). The time to full load bearing was significantly shorter with PWB than with restricted load bearing (15 weeks vs. 21 weeks). PWB was related to reduced time to full load bearing with no differences in quality of life or pain[18]. PWB has also been proven to be successful in other kinds of lower extremity fractures (pelvic/acetabular, distal femur, tibial plateau, distal tibia/ankle, and foot). Meys et al. showed that PWB, despite being the more aggressive rehabilitation regimen, does not lead to increased post-operative complications (non-union, wound infection, early removal of implant, implant fracture, secondary dislocation) when compared to non-load bearing protocols, and it ensures patients have earlier full load bearing mobilization compared to the AO guidelines (12 weeks vs. 16 weeks)[14]. Cunningham et al. conclude in their study that immediate postoperative load bearing as tolerated in patients with intramedullary fixation for subtrochanteric fractures results in reduced length of hospital stay (7.4 days vs. 9.7 days) with no significant differences in re-operations (in case of infection, hardware failure, non-union, or malunion) and complications (11% vs. 11% in non-load bearing)[19]. Also, Lieder et al. found similar results in surgically treated patients with extra-articular distal femoral fractures with similar rates of early adverse events requiring reoperation (11% in load bearing as tolerated vs. 19% in toe touch load bearing)[20]. In addition, no differences between length of stay, malunion, or patient-reported outcomes were observed[20]. These findings are in line with expectations of PWB in the postoperative load-bearing regime for PPFF with good postoperative reposition and stable fixation, given the fact that early mobilization in surgically treated patients leads to improvements in patient outcomes in terms of complications, morbidity, and mortality[11]. In conclusion, the literature clarifies the safety and effectiveness of PWB for lower extremity fractures.

In literature about load bearing after THA, early load bearing is also proven to be safe. Tian et al. performed a meta-analysis looking at partial load bearing versus early full load bearing[15]. No significant differences were found in postoperative complications (prosthetic loosening, femoral subsidence, radiolucent lines). They concluded that early load mobilization after uncemented THA is safe and does not increase the incidence of postoperative complications.

Thaler et al. also performed an online survey study to investigate the current treatment of PPFF by members of the European Hip Society (EHS)[21]. They first looked at treatment differences in cases of different PPFF. Secondary, they looked at load-bearing restrictions after surgically treated PPFF. They found strong variations regarding postoperative load-bearing protocols for all Vancouver PPFF. This is also in line with our results. This endorses the need for more standardized protocols for the management of PPFF.

Still literature lacks studies focusing on postoperative load bearing in general after PPFF. But, given the fact that it is proven to be safe and effective in different kinds of lower extremity fractures, it is likely that this will also be the case in PPFF. Therefore, more research is needed to confirm this hypothesis[22].

In secondary analysis, fellows were keener to prescribe PWB as a postoperative load-bearing regime for Vancouver C PPFF. This might be explained by the fact that PWB is a fairly new concept and has only been described as a protocol for lower extremity fractures since 2019[14]. Hypothetically, fellows may be more familiar with PWB. High-volume surgeons prescribed more PWB compared to low-volume surgeons. This can be due to the fact that high-volume surgeons are more experienced with PPFF management and are, therefore, less reluctant to prescribe PWB as a postoperative load-bearing regime. This study shows that there is currently a lot of variability in postoperative load-bearing regimes. There is a lack of knowledge about the optimal load-bearing treatment after PPFF, and dissemination of this knowledge is slow (results regarding fellows vs. consultants). Concluding PWB can possibly solve two great problems: one is that it is a more effective postoperative treatment option, resulting in less physiological decline in vulnerable patients without increasing complications, and the second is that it will lead to uniformity in postoperative treatment strategy, which is essential for good outcome measurements.

The main limitation of this study was the response rate of 13%. With 23 questions, the survey took up to 15 minutes to complete, which could have led to an unwillingness to participate. We believe the extensive analysis and questionnaire were necessary to address all aspects of PWB and postoperative management of PPFF. The use of case-specific questions, including pre- and postoperative X-rays, mimicked clinical practice as closely as possible. Nevertheless, there was a homogenous distribution of respondents based on the type of hospital in which they were working, the number of interventions regarding PPFF annually performed, and their years of experience as orthopedic surgeons. For this reason, we believe this study is useful as a baseline with regards to load bearing in postoperative settings of surgically treated PPFF in the Netherlands. Therefore, the results may logically apply mainly to the situation in the Netherlands and are not necessarily extrapolated to other parts of the world.

V CONCLUSIONS

With this study, we intended to give an overview of the current postoperative practice of weight-bearing instructions for patients with surgically treated PPFF, accounting for differences in types of periprosthetic fractures and treatment options and whether PWB was already applied in the Netherlands among Dutch orthopedic surgeons. The present study shows that postoperative load-bearing regimes after surgically treated patients suffering PPFF (Vancouver A, B, and C) differed greatly among Dutch orthopedic surgeons. In the absence of decisive guidelines or consensus, there is a great need for scientific evidence and research on this topic. We would recommend further research to explore the effectiveness of early postoperative mobilization, possibly with PWB, as a postoperative load-bearing protocol in surgically treated PPFF.

APPENDIX I: QUESTIONNAIRE

Part 1: general questions

1. To which department do you belong?
   a. Orthopedics
   b. Trauma surgery

2. Is there a joint transfer/indication discussion/distribution of specific injuries (such as the Multidisciplinary Trauma Unit; MDTU) between the orthopedic department and the trauma surgery department in your center?
   a. Yes
   b. No

3. What is the percentage distribution of trauma between orthopedics and trauma surgery in your center?

4. What kind of hospital do you work at?
   a. University hospital
   b. Non-academic teaching hospital (training for orthopedics and traumatology)
   c. Non-academic non-teaching hospital
   d. Independent treatment center

5. What is your level of expertise?
   a. Fellow
   b. Consultant

6. How many years have you been working as a medical specialist?
   a. 0-5
   b. 5-10
   c. 10-15
   d. 15-20
   e. >20

7. How many procedures for periprosthetic hip fractures do you perform on an annual basis?
   a. 0-3
   b. 4-6
   c. 7-9
   d. 10-13
   e. 13-15
   f. >15

8. What surgical techniques do you master to treat periprosthetic hip fractures?
   a. Stem revision
   b. Plate screw osteosynthesis (with/without cerclages)
   c. Bridging nail
   d. Cerclages
   e. Conversion to total hip replacement
   f. All of the above

9. Which classification system for periprosthetic hip fractures do you routinely use in practice?
   a. Vancouver
   b. Baba
   c. Unified Classification System

10. Does your center have a standard protocol for perioperative care for patients with periprosthetic hip fractures?
   a. Yes
   b. No

11. Are periprosthetic hip fractures treated by a select club within your department?
   a. Yes
   b. No

12. If yes to question 11, by whom will the periprosthetic hip fractures be handled?
   a. Trauma surgeon
   b. Orthopedic surgeon with a focus on hip prosthesis
   c. Orthopedic traumatologist

13. Are you familiar with the principle of permissive weight bearing (PWB)?
   a. Yes
   b. No

Part 2: specific questions regarding load bearing in postoperative management

14. You perform a trochanter refixation for a Vancouver A periprosthetic fracture. The fracture is non-comminuted, and with osteosynthesis there is good reposition and a stable fixation. What is your policy regarding postoperative loading of the operated leg? (Assuming a well-instructed patient).
   a. Mobilize without load for 6 weeks

b. Touching/plantar contact (10%) for 6 weeks
c. 50% load bearing for 6 weeks
d. Full load mobilization/immediate load bearing
e. Permissive weight bearing in accordance with the mentioned definition
f. Other, namely:

15. You are performing a plate screw osteosynthesis on a Vancouver B1 (stem fixed) periprosthetic femoral fracture. The fracture is non-comminuted, and in osteosynthesis, there is good reposition and a stable fixation. What is your policy regarding postoperative loading of the operated leg? (Assuming a well-instructed patient).
a. Mobilize without load for 6 weeks
b. Touching/plantar contact (10%) for 6 weeks
c. 50% load bearing for 6 weeks
d. Full load mobilization/immediate load bearing
e. Permissive weight bearing in accordance with the mentioned definition
f. Other, namely:

16. You perform a plate screw osteosynthesis on a Vancouver B2 (stem loose) periprosthetic femoral fracture (cemented stem) (conscious choice due to, for example, patient comorbidity). The fracture is non-comminuted, and in osteosynthesis, there is good reposition and a stable fixation. What is your policy regarding postoperative loading of the operated leg? (Assuming a well-instructed patient).
a. Mobilize without load for 6 weeks
b. Touching/plantar contact (10%) for 6 weeks
c. 50% load bearing for 6 weeks
d. Full load mobilization/immediate load bearing
e. Permissive weight bearing in accordance with the mentioned definition
f. Other, namely:

17. You perform a stem revision in combination with plate screw osteosynthesis/cerclages. The fracture is non-comminuted, and in osteosynthesis, there is good reposition and a stable fixation. What is your policy regarding postoperative loading of the operated leg? (Assuming a well-instructed patient).
a. Mobilize without load for 6 weeks
b. Touching/plantar contact (10%) for 6 weeks
c. 50% load bearing for 6 weeks
d. Full load mobilization/immediate load bearing
e. Permissive weight bearing in accordance with the mentioned definition
f. Other, namely:

18. You perform a plate screw osteosynthesis on a Vancouver C periprosthetic fracture. The fracture is non-comminuted, and in osteosynthesis, there is good reposition and a stable fixation. What is your policy regarding postoperative loading of the operated leg? (Assuming a well-instructed patient).

a. Mobilize without load for 6 weeks
b. Touching/plantar contact (10%) for 6 weeks
c. 50% load bearing for 6 weeks
d. Full load mobilization/immediate load bearing
e. Permissive weight bearing in accordance with the mentioned definition
f. Other, namely:

19. Does the degree of consolidation determine the time of full load bearing?

a. Yes
b. No

20. Previous questions relate to patients who can be instructed properly. Do you change your postoperative loading protocol for patients who are poorly instructible?

a. Yes/No
b. If yes, how
i. In connection with Vancouver A:
ii. In connection with Vancouver B1:
iii. In connection with Vancouver B2/3:
iv. In connection with Vancouver C:

Part 3: case-specific questions

21. View Figures 1-5. The choice has been made for a stem revision with an uncemented modular stem and trochanter hook plate with cable grip (and additional dual-mobility cup). In view of the above intervention and treatment, what would your policy be regarding postoperative loading? (assuming a well-instructed patient)

a. Mobilize without load for 6 weeks
b. Touching/plantar contact (10%) for 6 weeks
c. 50% load-bearing for 6 weeks
d. Full load mobilization/immediate load bearing
e. Permissive weight bearing in accordance with the mentioned definition
f. Other, namely:

22. View Figures 6-10. The stem was fixed per operatively, a plate screw osteosynthesis was chosen with the placement of cerclages. In view of the above intervention and treatment, what would your policy be regarding postoperative loading? (assuming a well-instructed patient)

   a. Mobilize without load for 6 weeks
   b. Touching/plantar contact (10%) for 6 weeks
   c. 50% load-bearing for 6 weeks
   d. Full load mobilization/immediate load bearing
   e. Permissive weight bearing in accordance with the mentioned definition
   f. Other, namely:

23. View Figures 11-15. A stem revision with an uncemented revision stem and placement of cerclages has been chosen. In view of the above intervention and treatment, what would your policy be regarding postoperative loading?

   a. Mobilize without load for 6 weeks
   b. Touching/plantar contact (10%) for 6 weeks
   c. 50% load-bearing for 6 weeks
   d. Full load mobilization/immediate load bearing
   e. Permissive weight bearing in accordance with the mentioned definition
   f. Other, namely:

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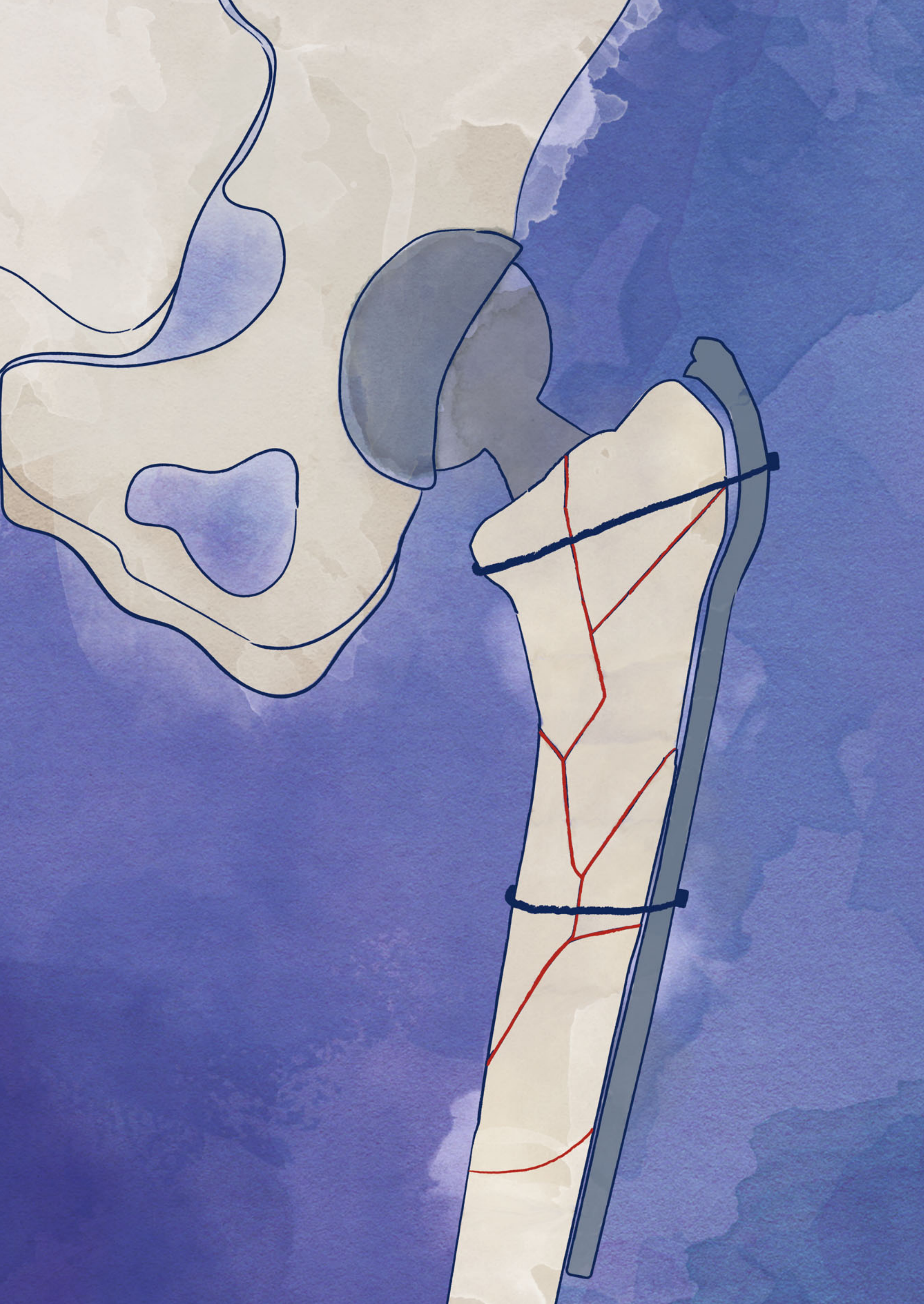

Chapter III

Permissive Weight Bearing in Patients with Surgically Treated Periprosthetic Femoral Fractures Around Total Hip Arthroplasty: A Scoping Review

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ABSTRACT

Periprosthetic femoral fractures (PPFF) around total hip arthroplasty (THA) are one of the leading causes of hip revision. High mortality rates are observed after revision in case of PPFF around THA. To modify risk factors, early postoperative mobilization is necessary. Permissive weight bearing (PWB) is designed to optimize clinical recovery in aftercare. This study aimed to perform a scoping review to summarize the current available evidence on postoperative weight bearing in late PPFF around THA and the implementation of PWB in aftercare. A systematic search was performed on the Cochrane Library, Web of Science, Ovid MEDLINE, EMBASE, and CINAHL databases on January 26th, 2023. Articles were screened in two stages by two independent reviewers. Studies describing adult patients with a history of primary THA who were surgically treated for late PPFF and mentioning prescribed postoperative weight-bearing protocols with relevant outcome measures were included. Seven studies were included, reporting data on 22 patients (age range 47-97 years, BMI range 19-32 kg/m2, ASA classification range 2-3). No studies used PWB in aftercare. The non-weight-bearing group showed no complications. The restricted weight-bearing group had one death and one implant failure. The full weight-bearing group experienced one deep infection and one plate removal because of impingement. The main finding was that, after an extensive systematic search, no articles could be included focusing on PWB in patients with a late PPFF after THA. Addressing this gap in the literature is essential to advancing the understanding of postoperative weight-bearing protocols and PWB for late PPFF around THA.

Keywords
Permissive weight bearing, weight-bearing protocols, surgery, trauma, PPFF, periprosthetic femoral fractures, PWB

I INTRODUCTION AND BACKGROUND

The incidence of primary total hip arthroplasty (THA) is rising, and subsequently, more periprosthetic femoral fractures (PPFF) around THA occur[1]. These PPFFs can occur intra- or postoperatively[2]. A late PPFF is considered a PPFF that occurs after new trauma, and therefore, it does not refer to a PPFF that occurred during the operation or in the immediate days following index surgery without new trauma. The incidence of late PPFF ranges between 0.07% and 3.5%[3-4]. The average mean age at which late PPFF is reported in the existing literature is within the range of 60-77 years[5]. PPFF is one of the leading causes of THA revision, following mechanical implant failure, metallosis, and implant instability[6]. Higher mortality rates are observed after THA revision in the case of a PPFF: one in 13 patients is deceased within two years after surgery compared to revision based on infection or recurrent dislocation (both one in 20 patients)[7]. This is significantly higher compared to the overall mortality rate of one in 51 patients[7]. Decreased mobility leads to a higher risk of pneumonia and delirium and subsequently increases mortality rates[8-9].

With the use of early postoperative mobilization, risk factors leading to higher postoperative mortality rates can be reduced[8-9]. Potential risk factors should be addressed as soon as PPFF is diagnosed. This apparent vulnerable patient group is in need of early and pain-free mobilization. To achieve these treatment goals and to optimize rapid clinical recovery and restoration of function, permissive weight bearing (PWB) has been introduced as a relatively new aftercare mobilization regimen[10]. The initial studies on PWB in different types of lower extremity fractures have shown successful outcomes without raising the number of complications[10]. PWB enables patients to mobilize earlier compared to patients who follow a non-weight-bearing protocol, aiming for a lower risk of mortality[11]. However, PWB is not a commonly used postoperative weight-bearing protocol, and there is no consensus on its use in the aftercare of PPFF around THA[12].

The term PWB was first described by Kalmet et al.[13] and is now increasingly described in the literature and applied in clinical postoperative weight-bearing treatment protocols[14]. PWB involves advancing the weight-bearing process based on the patient's and therapist's subjective observations, such as pain levels and the patient's ability to tolerate weight-bearing, while also taking into account objective factors like limb temperature, swelling, and gait metrics[13].

This study aims to perform a scoping review, with the use of a systematic search, to summarize the current available evidence on postoperative weight bearing in late PPFF around THA and the implementation of PWB in aftercare regarding PPFF in THA patients.

II REVIEW

II.I Material and methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist was used to draft the protocol and to perform this review[15]. The study protocol was registered in the Prospero database with registration number CRD42021230271.

II.II Selection criteria

The suitability of articles was assessed in two stages. Inclusion criteria were adult patients (age >18 years) with a history of primary THA with a surgically treated late PPFF (Vancouver classification A, B, or C). Articles were suitable for inclusion when describing postoperative weight-bearing protocols with relevant outcome measures (time of hospital stay, resuming activities of daily living, time to fracture union, time to first mobilization, time to full weight bearing, range of motion, quality of life, pain, postoperative complications, readmission, and mortality rate). Studies were included in different groups based on the postoperative weight-bearing protocols. Non-weight bearing (NWB) group; restricted weight bearing (RWB) group, which also includes partial weight bearing and toe touch weight bearing; permissive weight bearing (PWB) group, also including weight bearing as tolerated; and full weight bearing (FWB) group, encompassing also immediate weight bearing. Exclusion criteria were animal studies, editorial articles, and abstracts of congresses. Studies reported in another language than English or Dutch were also excluded. There were no restrictions on study quality, year of publication, or study origin.

II.III Search and screening process

An extensive systematic literature search was conducted by two reviewers (MV and MH) on January 26th, 2023, using the Cochrane Library, Web of Science, Ovid MEDLINE, EMBASE, and CINAHL. The search strategy was reviewed by the other reviewers in this study. No search limitations or filters were used. Search terms are presented in Tables 1-6.

Table 1: Cochrane Library

#5	**#2 AND #4**	**442**
#4	#1 OR #3	10.501
#3	((fracture* AND (periprosthetic* OR ‘peri implant*’ OR femoral OR femur OR ‘periprosthetic femoral’ OR ‘periprosthetic femur’ OR hip OR trochanteric OR intertrochanteric OR subtrochanteric OR ‘peri prosthetic*’ OR ‘peri prosthetic femoral’ OR ‘peri prosthetic femur’ OR ‘femur torsion’))):ti,ab,kw	9.533
#2	(‘weight bearing’ OR weightbearing OR loadbearing OR ‘load bearing’ OR ‘axial load*’ OR pwb OR ‘permissive weight*’ OR ‘permissive load’ OR ‘load carry*’):ti,ab,kw	6.064
#1	(‘revision arthroplast*’):ti,ab,kw	1.147

ti.ab.kw: title word, abstract word, keywords (MeSH and other), and word variations have been searched

Table 2: Web of Science

#5	**#3 AND #4**	**3.001**
#4	TS=("weight bearing" OR weightbearing OR loadbearing OR "load bearing" OR "axial load*" OR pwb OR "permissive weight*" OR "permissive load" OR "load carry*")	66.576
#3	#1 OR #2	96.048
#2	TS=(revision arthroplast*)	22.379
#1	TS=(((fracture* AND (periprosthetic* OR "peri implant*" OR femoral OR femur OR "periprosthetic femoral" OR "periprosthetic femur" OR hip OR trochanteric OR intertrochanteric OR subtrochanteric OR "peri prosthetic*" OR "peri prosthetic femoral" OR "peri prosthetic femur" OR "femur torsion")))) AND TS=(((fracture* AND (periprosthetic* OR "peri implant*" OR femoral OR femur OR "periprosthetic femoral" OR "periprosthetic femur" OR hip OR trochanteric OR intertrochanteric OR subtrochanteric OR "peri prosthetic*" OR "peri prosthetic femoral" OR "peri prosthetic femur" OR "femur torsion"))))	77.850

TS: topic; searched for topic terms in the following fields within a record: title, abstract, author keywords, and Keywords Plus®

Table 3: Ovid MEDLINE

#10	**#6 AND #9**	**3.163**
#9	#7 OR #8	44.103
#8	(weight bearing or weightbearing or loadbearing or load bearing or axial load* or pwb or permissive weight* or permissive load or load carry*).mp.	44.103
#7	exp Weight-Bearing/	21.767
#6	#1 OR #2 OR #3 OR #4 OR #5	66.138
#5	(Fracture* and (Periprosthetic* or Peri Implant* or femoral or femur of periprosthetic femoral or periprosthetic femur or Trochanteric or Intertrochanteric or Subtrochanteric or peri prosthetic* or peri prosthetic femoral or peri prosthetic femur or femur torsion)).mp.	51.713
#4	exp Periprosthetic Fractures/	1.541
#3	exp Hip Fractures/	28.172
#2	exp Femoral Fractures/	44.387
#1	revision arthroplasty.mp.	2.268

TS: mp.: title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms. exp: "explodes" controlled vocabulary term (e.g., expands the search to all more specific related terms in the vocabulary's hierarchy)

Table 4: EMBASE

#9	**#5 AND #8**	**5.304**
#8	#6 OR #7	51.589
#7	'weight bearing':ti,ab,kw OR weightbearing:ti,ab,kw OR loadbearing:ti,ab,kw OR 'load bearing':ti,ab,kw OR 'axial load':ti,ab,kw OR pwb:ti,ab,kw OR 'permissive weight*':ti,ab,kw OR 'permissive load':ti,ab,kw OR 'load carry':ti,ab,kw	32.559
#6	'weight bearing'/exp	33.622
#5	#1 OR #2 OR #3 OR #4	109.702

Table 4: Continued

#4	Fracture:ti,ab,kw AND (periprosthetic*:ti,ab,kw OR 'peri implant*':ti,ab,kw OR femoral:ti,ab,kw OR femur:ti,ab,kw OR 'periprosthetic femoral':ti,ab,kw OR 'periprosthetic femur':ti,ab,kw OR hip:ti,ab,kw OR trochanteric:ti,ab,kw OR intertrochanteric:ti,ab,kw OR subtrochanteric:ti,ab,kw OR 'peri prosthetic*':ti,ab,kw OR 'peri prosthetic femoral':ti,ab,kw OR 'peri prosthetic femur':ti,ab,kw OR 'femur torsion':ti,ab,kw) OR 'revision arthroplasty*':ti,ab,kw	76.835
#3	'femur fracture'/exp	46.153
#2	'hip fracture'/exp	56.158
#1	'periprosthetic fracture'/exp	4.216

exp: "explodes" controlled vocabulary term (e.g., expands the search to all more specific related terms in the vocabulary's hierarchy). ti,ab,kw: title, abstract, and authentication keywords

Table 5: CINAHL

#9	**#5 AND #8**	**808**
#8	#6 OR #7	14.447
#7	TI ((("Weight Bearing" OR Weightbearing OR Loadbearing OR "Load Bearing" OR "Axial Load*" OR PWB OR "permissive weight*" OR "permissive load" OR "load carry*"))) OR AB ((("Weight Bearing" OR Weightbearing OR Loadbearing OR "Load Bearing" OR "Axial Load*" OR PWB OR "permissive weight*" OR "permissive load" OR "load carry*")))	8.934
#6	MH weight-bearing	8.258
#5	#1 OR #2 OR #3 OR #4	23.128
#4	TI ((("Periprosthetic Fracture*" OR "Peri Implant Fracture*" OR "femoral fracture*" OR "femur fracture*" OR "periprosthetic femoral fracture*" OR "periprosthetic femur fracture*" OR "Hip fracture*" OR "Trochanteric Fracture*" OR "Intertrochanteric Fracture*" OR "Subtrochanteric Fracture*" OR "fracture of the hip*" OR "revision arthroplast*" OR "peri prosthetic fracture*" OR "peri prosthetic femoral fracture*" OR peri prosthetic femur fracture* OR femur torsion fracture*))) OR AB ((("Periprosthetic Fracture*" OR "Peri Implant Fracture*" OR "femoral fracture*" OR "femur fracture*" OR "periprosthetic femoral fracture*" OR "periprosthetic femur fracture*" OR "Hip fracture*" OR "Trochanteric Fracture*" OR "Intertrochanteric Fracture*" OR "Subtrochanteric Fracture*" OR "fracture of the hip*" OR "revision arthroplast*" OR "peri prosthetic fracture*" OR "peri prosthetic femoral fracture*" OR peri prosthetic femur fracture* OR femur torsion fracture*)))	16.744
#3	MH periprosthetic fractures	322
#2	MH femoral fractures	5.658
#1	MH hip fractures	12.380

MH: search the exact CINAHL® subject heading and search both major and minor headings, TI: title, AB: abstract

Table 6: Summary

1	Cochrane Library	442
2	Web Of Science	3.001
3	OVID Medline	3.163
4	EMBASE	5.304
5	CINAHL	808
	Total	12.718

The results of the literature search were collected in a reference management program (RefWorks, ProQuest LLC). All exact duplicates were marked and deleted until one original article remained. All close duplicates were marked and screened by one reviewer (MV); if these appeared to be exact duplicates, they were also deleted until one original article remained. First, all articles were screened on title and abstract (TiAb) independently by two reviewers (MV and BH). Studies that did not meet the inclusion criteria were excluded. Second, the remaining articles went through a second independent selection for full-text screening by the same two reviewers. No automation or artificial intelligence tools were used for article selection and/or inclusion. Any disagreement between the two reviewers was resolved by a third reviewer (MS). When a systematic review was identified, it was screened for missing studies in the present initial search, and if present, they were included in the present review. A flowchart of the selection process is presented in Figure 1.

II.IV Data collection

A data-charting form was developed by two reviewers (MV and BB) to determine which variables to extract. One reviewer (MV) independently extracted data from the included studies. The extracted data was put in an Excel charting form (Microsoft Excel, Version 6.77, 2023 Microsoft). The following study characteristics were collected if present: study ID (author, year), country, study design, number of patients (n), age in years (mean), sex (female, male), medical morbidities (e.g., American Society of Anesthesiologists (ASA) physical status classification, body mass index (BMI), smoking), fracture classification (Vancouver classification A, B, or C), surgical intervention details, postoperative weight-bearing protocol, and earlier described relevant outcome measures. This was checked by all the other reviewers. The final version of the charting form is available in Table 7.

II.V Results

Search results based on the number of studies are presented in Tables 1-6. The search resulted in a total of 12,718 records, and 4,571 records were removed before screening based on duplicates. Eight thousand one hundred forty-seven (8,147) records were screened on TiAb, and 8,038 records were excluded based on the inclusion and exclusion criteria. The remaining 109 reports were assessed for eligibility. Based on full-text screening, 102 reports were excluded for the following reasons: no clear description of the prescribed weight-bearing protocol (n=35), no clear description of relevant outcome measures (n=30), biomechanical analysis (n=16), femoral replacement (n=4), and other reasons (n=17). This left seven primary studies including 22 patients (age range 47-97 years, BMI range 19-32 kg/m2, ASA classification range 2-3) between 2006 and 2021 for final inclusion[17-23]. The flowchart of the screening process is presented in Figure 1.

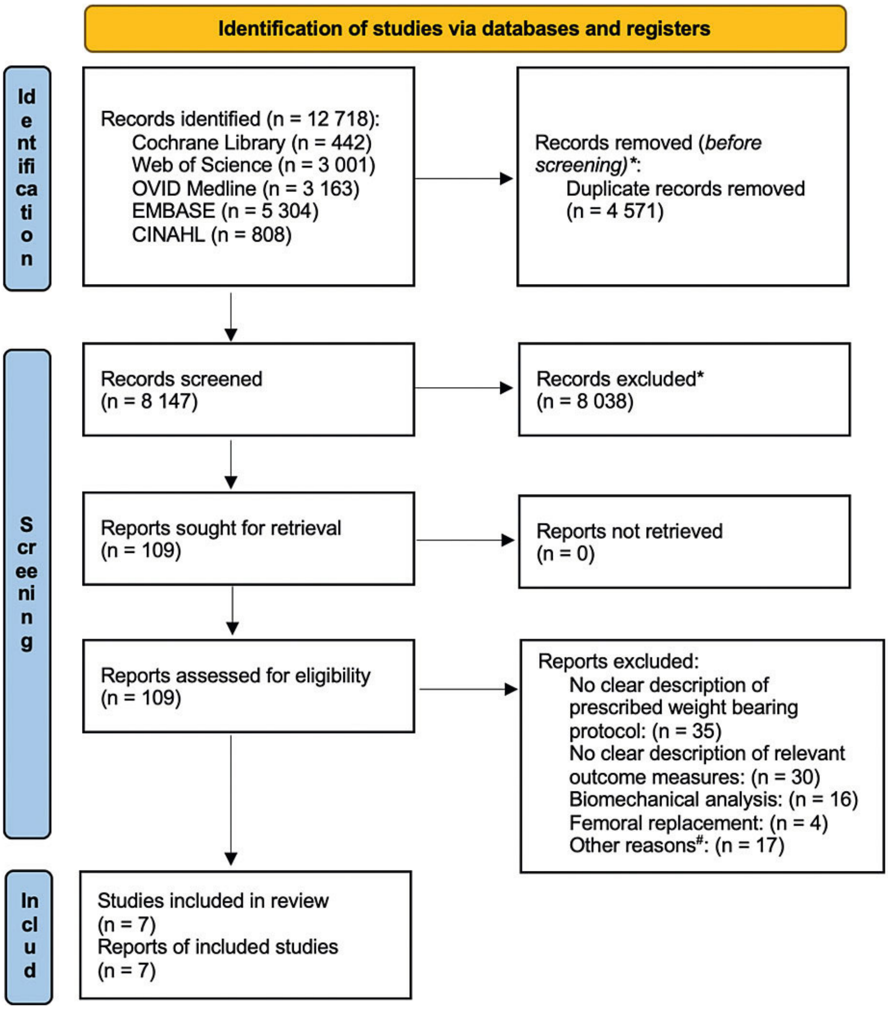

Figure 1: PRISMA flowchart

* Without the use of automation tools or artificial intelligence,

Other reasons: neglected femoral neck fracture of the other side wherefore ambulated with partial weight bearing (n=1), atypical femoral fractures because of long-time bisphosphonate use (n=4), implant failure (n=7), open PPFF (n=1), bilateral Vancouver A PPFF within short postoperative time wherefore multiple operations followed (n=1), in combination with uncontrolled infection (n=1) and combination with acetabulum fracture (n=2)

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses, PPFF: periprosthetic femoral fractures

Image Credit: Page et al. (2021)[16]

A study by Martinov et al.[17] was included in two different postoperative weight-bearing protocol groups because of the different management of postoperative weight-bearing for each specific patient. One study reported outcome data on the treatment of late PPFF within the NWB group[17]. Six studies adhered to the RWB group[17-22]. No studies were included in the PWB group. One study presented results after surgical treatment of late PPFF in the FWB group[23]. No studies reported outcomes on Vancouver type A (OTA 32A1[IV.3A12][24]), four studies on Vancouver type B1 (OTA 32A1[IV.3B1][24])[19-21,23], two studies on Vancouver type B2 (OTA 32A1[IV.3B2][24])[17,22], one study on Vancouver type B3 (OTA 32A1[IV.3B3][24])[18], and one study on Vancouver type C (OTA 32A1[IV.3C][24]) fractures[23].

Open reduction and internal fixation (ORIF) was the most commonly used technique in the included studies[17-21,23] with the use of different postoperative weight-bearing regimes, including patients in the NWB group[17], RWB group[17-22], and FWB group[23]. This surgical technique led to one deep infection in the FWB group (time frame not mentioned)[23], one death at a two-month follow-up in the RWB group[20], one plate fracture at a 12-month follow-up needing revision in the RWB group[21], and one plate removal due to impingement in the FWB group (time frame not mentioned)[23]. One stem revision was done in the RWB group without any complications mentioned[22].

More detailed information on study characteristics of interest and relevant outcome measures is summarized in Table 8.

Table 7: Final version of the charting form

Author	Year of publication	Origin/country of origin	Study design	Study population	Medical morbidities	Type of fracture	Surgical intervention details	Weight bearing protocol	Outcomes
First author of the paper included.	The year that the paper was published first.	The country where the study was originally conducted.	The study design which was used in the study.	Relevant characteristics of the study population.	Relevant comorbidities for the included patients.	Type of periprosthetic femoral fracture with the use of the Vancouver classification.	Details on the operative technique used to treat the mentioned periprosthetic femoral fracture.	Clear description of the prescribed postoperative weight bearing protocol.	Relevant outcome measures mentioned in the paper.

Table 8: Overview of the included studies

Author	Year of publication	Origin/ country of origin	Study design	Study population	Medical morbidities	Type of fracture	Surgical intervention details	Weight bearing protocol	Outcomes
NWB-group									
S Martinov, et al. [17]	2021	Belgium and Canada	Retrospective study design.	1 patient; 84yo female.	BMI of 19 and ASA 2.	Vancouver B2.	Hook plate with screws and cerclage wires.	Weight bearing was not allowed for 12 weeks after surgery.	Hospital stay of 6 days, at final follow-up at 3-years there were no complications besides subsidence and varus migration of the stem and the proximal cerclage wires cut through the medial cortex, FJS of 72 and OHS of 32.
RWB-group									
S Martinov, et al. [17]	2021	Belgium and Canada	Retrospective study design.	2 patients: Patient 1; 70yo male. Patient 2; 94yo female.	Patient 1; BMI of 32 and ASA 3. Patient 2; BMI of 22 and ASA 3.	Patient 1: Vancouver B2. Patient 2: Vancouver B2.	Patient 1: ORIF with two plates and cerclage wires. Patient 2; hook plate with screws and cerclage wires.	Patient 1: 8 weeks partial weight-bearing. Patient 2: toe-touch walking for 6 weeks.	Patient 1: hospital stay of 4 days, at final follow-up at 4.5-years there were no complications, FJS of 92 and OHS of 42. Patient 2: hospital stay of 7 days, at final follow-up at 5-years there were no complications besides slight radiolucency of the lateral cortex and greater trochanter, FJS of 82 and OHS of 34 and she was walking without a walking aid.
HE Matar, et al. [18]	2021	United Kingdom.	Retrospective study design.	2 patients: Patient 1; 89yo female. Patient 2; 68yo female.	Not mentioned.	Vancouver B3.	Patient 1: ORIF with plate and strut anterior. Patient 2: ORIF with plate and strut anterolateral.	Protected weight-bearing for 6 weeks.	Patient 1: time to union 6 months, at final follow-up at 4.2-years there were no complications. Patient 2: time to union 5 months, at final follow-up at 4-years there were no complications.
RR white. [19]	2013	United States of America.	Case report.	1 patient; 84yo female.	Dementia, cardiovascular disease, atrial fibrillation.	Vancouver B1.	ORIF with plate and screw fixation.	Allowed protected weight bearing and full weight bearing at 8 weeks.	First mobilization on day 1. At 3-months the patient was able to walk without pain and x-rays at 8-months showed solid union.

Table 8: Continued

Author	Year of publication	Origin/ country of origin	Study design	Study population	Medical morbidities	Type of fracture	Surgical intervention details	Weight bearing protocol	Outcomes
T Apivatthakakul, et al. [20]	2012	Thailand.	Retrospective study design.	7 patients: Patient 1; 84yo female. Patient 2; 74yo male. Patient 3; 47yo male. Patient 4; 80yo female. Patient 5; 79yo female. Patient 6; 80yo female. Patient 7; 78yo female.	Not mentioned.	Vancouver B1.	Closed percutaneous cerclage wiring with internal fixation with MIPO utilizing a long LCP Synthes bridging plate.	Partial weight bearing of 10-15 kg in the first week. Afterwards gradually weight bearing as tolerated.	Patient 1: time to union 16 weeks, at final follow-up at 15-months there were no complications. Patient 2: time to union 20 weeks, at final follow-up at 12-months there were no complications. Patient 3: time to union 20 weeks, at final follow-up at 18-months there were no complications. Patient 4: time to union 18 weeks, at final follow-up at 12-months there were no complications. Patient 5: time to union 20 weeks, at final follow-up at 12-months there were no complications. Patient 6: died two months after operation due to cardiovascular problems. Patient 7: time to union 18 weeks, at final follow-up at 12 months there were no complications.
MA Buttaro, et al. [21]	2007	Argentina.	Retrospective study design.	3 patients: Patient 1; 85yo male. Patient 2; 80yo female. Patient 3; 88yo male.	Not mentioned.	Vancouver B1.	LCP fixation.	Early mobilization and walking with two crutches or a walker and toe-touch weight-bearing on the involved side for forty-five days. In the absence of pain and radiographic findings patients were progressed to 20% weight-bearing until the ninetieth day. Afterwards gradually weight bearing was tolerated, and a cane was used.	Patient 1: time to union 6-months, plate pull out at 6-months, at final follow-up at 20 months there were no complications. Patient 2: time to union 12 months after re-operation, plate fracture at 12-months and had revision with locking compression plate and struts, at final follow-up at 12 months there were no further complications. Patient 3: time to union 6-months, at final-follow-up at 12-months there were no complications.

Table 8: Continued

Author	Year of publication	Origin/ country of origin	Study design	Study population	Medical morbidities	Type of fracture	Surgical intervention details	Weight bearing protocol	Outcomes
JM Ferrara, et al. [22]	2006	United States of America.	Case report.	1 patient; 78yo male.	Not mentioned.	Vancouver B2.	Fully coated femoral stem revision implant.	Toe touch weight bearing on the affected extremity, at 2-months advanced to weight bearing as tolerated.	Fracture union was achieved without any complications. Time frame or final follow-up period was not mentioned.
PWB-group									
.	.	.	.	.	.	.	.	.	.
FWB-group									
RE Anakwe, et al. [23]	2008	United Kingdom.	Retrospective study design.	5 patients: Patient 1; 72yo male. Patient 2; 77yo female. Patient 3; 89yo female. Patient 4; 81yo female. Patient 5; 97yo male.	Patient 4 had medical treatment for osteoporosis.	Patient 1: Vancouver B1. Patient 2: Vancouver C. Patient 3: Vancouver B1. Patient 4: Vancouver C. Patient 5: Vancouver B1.	LISS plate fixation.	Mobilize touch weight bearing initially in post-operative phase. In practice, many of these elderly patients found this difficult and full weight bearing was accepted.	Patient 1: time to union 28-weeks, regained pre-injury mobility, no complications. Patient 2: time to union 16-weeks, went from stick mobilization to hoist mobilization, plate removed because of knee pain/ impingement. Patient 3: time to union 26-weeks, went from independent mobilization to in house mobilization, plate removed because of deep infection. Patient 4: time to union 18-weeks, went from independent mobilization to stick mobilization, no complications. Patient 5: time to union 50-weeks, went from in house mobilization to hoist, no complications. Time frame or final follow-up period was not mentioned.

yo: years old, BMI: body mass index, ASA: American Society of Anesthesiologists physical status classification, FJS: Forgotten joint score, OHS: Oxford hip score, ORIF: open reduction and internal fixation, MIPO: minimally invasive plate osteosynthesis, kg: kilogram, LCP: locking compression plate, LISS: less-invasive stabilization system, FWB: full weight bearing, NWB: non-weight bearing, RWB: restricted weight bearing, PWB: permissive weight bearing

II.VI Discussion

The present study aimed to summarize the currently available literature regarding postoperative weight-bearing regimes in patients with a surgically treated late PPFF after THA, with a special focus on PWB during aftercare. The main finding of this scoping review was that, after an extensive systematic search, no literature was available focusing on PWB aftercare in patients with a late PPFF after THA.

PWB in aftercare for late PPFF can offer several advantages, which are in line with studies reporting on PWB for other lower extremity fractures. First, it can lead to reduced complication rates[10-11]. PWB allows patients to start weight bearing on the affected limb earlier than traditional NWB protocols[13]. This can help reduce the risk of complications associated with prolonged postoperative immobilization, such as pneumonia and delirium[8-9]. Second, PWB promotes improved mobility and functional recovery[10-11]. Patients can regain independence more quickly, which can lead to a positive impact on their overall quality of life[14]. Third, controlled weight bearing can stimulate bone healing and remodeling by promoting physiological stress on the fracture site[25-26]. This may lead to faster bone healing outcomes. Fourth and last, PWB can therefore theoretically facilitate shorter hospital stays, reducing healthcare costs and the burden on both patients and healthcare systems.

Weight bearing is typically measured using percentages of body weight or categorized as NWB, RWB, and FWB. These methods can make it challenging for therapists to accurately gauge the amount of weight being applied at the fracture site during rehabilitation and daily activities[10]. Consequently, clinical practice may inadvertently involve excessive or insufficient weight bearing, potentially resulting in complications or prolonged recovery periods[10]. PWB entails gradually progressing the weight-bearing protocol by considering both subjective assessments made by the patient and therapist, including pain thresholds and the patient's capacity to endure weight bearing[13]. Additionally, objective factors such as limb temperature, swelling, and gait measurements are taken into careful consideration during the rehabilitation process[13].

The current literature search showed that PWB is not widely used as a postoperative aftercare regimen in surgically treated late PPFF. First and foremost, the lack of evidence-based PWB protocols in the literature underscores a prevailing trend toward more traditional weight-bearing regimens, such as NWB and RWB. These conventional approaches have been the norm in the management of PPFF. However, the limited inclusion and exploration of PWB in current literature suggest that this approach has not yet gained widespread recognition or acceptance. Also, in general, prescribed postoperative weight-bearing regimes were not always clearly described. Furthermore, the terminology used for weight-bearing regimens is not standardized across studies. In this review, we found multiple studies describing postoperative care regimes similar to PWB (e.g., weight bearing as tolerated), but not explicitly using the term PWB. Therefore, it is challenging to identify and assess studies that incorporate this aftercare regimen. This lack of consistent terminology contributes to an underrepresentation of PWB in the literature.

Further research is warranted to elucidate the optimal balance between early weight bearing and the risk of complications in this patient population. Clinical studies should aim to systematically investigate the efficacy and safety of PWB protocols, with a focus on defining and standardizing the terminology. By doing so, the involved practitioners can gain a more comprehensive understanding of the potential advantages and drawbacks of PWB, ultimately informing evidence-based practices and improving patient outcomes in the management of late PPFF around THA.

II.VI.I Strengths and limitations

There are some strengths and limitations to this scoping review. Strengths of the present systematic scoping review, which centers on postoperative weight-bearing regimes in patients undergoing surgical treatment for late PPFF, include first that this review distinguishes itself as the inaugural study to comprehensively analyze and present findings concerning postoperative weight-bearing regimes in this patient category. It stands as a trailblazer in the field, shedding light on a crucial but previously underexplored aspect of late PPFF management. Second, we delved into the subject of postoperative weight bearing, with a particular emphasis on PWB protocols. By synthesizing existing literature, this scoping review provides an up-to-date overview of the knowledge in the field of postoperative weight-bearing regimes for surgically treated late PPFF within the scope of this review. Third, the comprehensive nature of this review and its emphasis on PWB may pave the way for the development of evidence-based guidelines for postoperative weight-bearing management in late PPFF. The focus on PWB is particularly valuable, as it addresses a critical aspect of postoperative care that can significantly impact patient outcomes. Such guidelines, which, to our knowledge, still do not exist, can improve the consistency and quality of care provided to patients in this category.

The first limitation was that there were only retrospective studies and case reports available in the included literature. Second, multiple studies clearly described their unique population, including the type of late PPFF and postoperative weight-bearing regime, but did not stratify results on the different types of fractures or based on the postoperative weight-bearing regime. For that reason, we were unable to extract relevant data from these studies. Third, because of the limited number of included studies, it is nearly impossible to draw valid conclusions with great certainty from the data obtained.

III CONCLUSIONS

The present systematic scoping review stands as a contribution to the field, offering a unique and valuable perspective on postoperative weight-bearing regimes in surgically treated late PPFF with a specific focus on PWB. Within the scope of this review, we were not able to include any literature concerning surgically treated late PPFFs focusing on PWB as an aftercare regimen. Therefore, we cannot conclude that PWB is a safe and viable option in this patient category. Addressing this gap in the literature is essential to advancing the understanding of postoperative weight-bearing protocols and PWB for late PPFF around THA.

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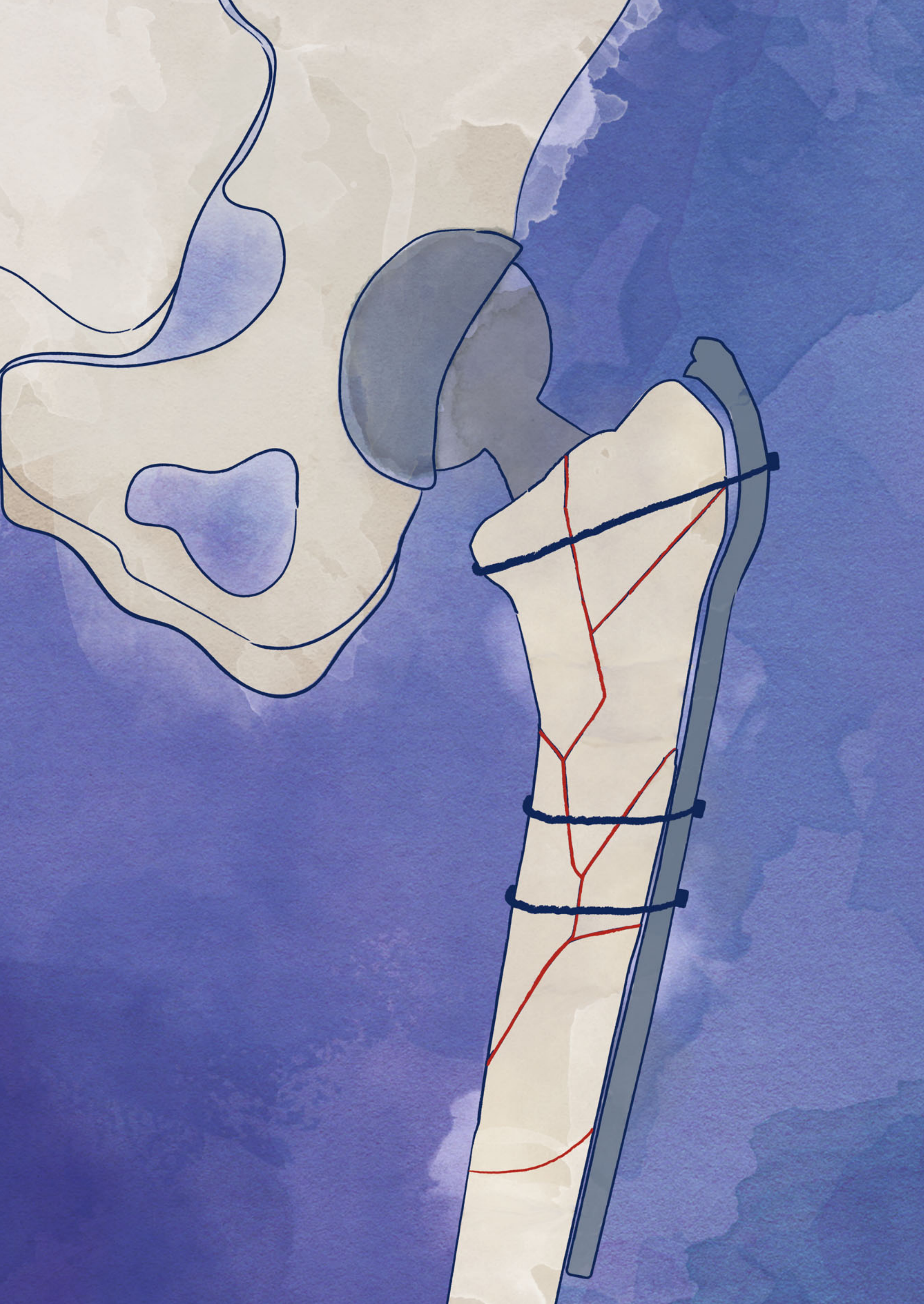

Chapter IV

Risk Factors for Postoperative Stem Revision in Patients with Periprosthetic Femoral Fractures after Primary Total Hip Arthroplasty: Nationwide Outcomes Based on the Dutch Arthroplasty Registry

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ABSTRACT

Purpose

This study aimed to determine the incidence of postoperative primary total hip arthroplasty (THA) stem revision due to periprosthetic fractures (PPF) and analyze related patient and surgical factors.

Materials and methods

Utilizing the Kaplan-Meier analysis and Cox regression method to identify risk factors for stem revision due to PPF, this study analyzed 331,009 primary THA procedures from the Dutch Arthroplasty Register performed between 2007 and 2021.

Results

At 10-years follow-up, the incidence rate was 0.7%. Patient specific factors with significant incidence probabilities were higher age higher age (Hazard Ratio (HR) 1.29 per 10 years, 1.22-1.36), female sex (HR 1.30, 1.16-1.45), ASA class II (HR 1.56, 1.27-1.93) and ASA class III-IV (HR 2.07, 1.59-2.71), Charnley score B2 (HR 1.46, 1.23-1.72), Charnley score C (HR 1.81, 1.26-2.59) and higher BMI (HR 1.02 per kg/m2, 1.00-1.03). Surgery specific factors with significant incidence probabilities were interventions with an uncemented stem (HR 4.55, 3.85-5.26), and anterior approach compared to posterolateral approach (HR 1.25, 1.03-1.52).

Conclusion

The highest risk of PPF in THA requiring stem revision was found in older female patients with high ASA class, Charnley score and BMI as well as uncemented implants. This result may prompt surgeons to strive for cemented stem fixation in patients with declining bone stock when feasible. Furthermore, care should be taken when using anterior approaches for patients with specific risk factors.

Keywords

Periprosthetic fractures, stem revision, nationwide registry-based study, Landelijke Registratie Orthopedische Interventies

I INTRODUCTION

Although the first hip replacement was performed in 1891, periprosthetic fractures (PPF) after a THA weren't initially reported until 1954[1-3]. The incidence of THA procedures and subsequent PPF have steadily increased since then. Contributing factors for this are the broadened indications for THA, the increased lifetime of implants in combination with ageing of the population and the subsequent increase in prevalence and incidence of osteoarthritis[2-5].

There is much heterogeneity in reported risk for PPF in the first ten years after primary THA. Lindahl et al. reported an incidence of 0.64%, ranging from 0.07% among low-risk patients to 2.25% in high-risk patients[6]. In contrast, Schmidt et al. reported PPF rates ranging from 4.1% to 27.8% in cases involving uncemented hip replacement, while cases involving cemented stems registered less than 3% of total PPF incidence[7]. Notably, patients who sustain a PPF are at high risk of morbidity and mortality, underscoring the need to investigate risk factors associated with PPF occurrence and enhance the quality of patient care[8-9]. Other studies have indicated that patient-related characteristics like increased Body Mass Index (BMI, >25), American Society of Anesthesiologists (ASA) class (≥3) and age (>80yrs), as well as specific surgical characteristics, such as uncemented THA and anterior surgical approach, can be marked as potential risk factors for stem revision in cases of PPF in patients with primary THA[8,10-11]. High ASA class, which reflects greater preoperative comorbidity and poorer overall health status, can be associated with increased risks of complications. Charnley score classifies patients based on functional mobility and the presence of comorbid conditions, with higher scores indicating greater disability and higher risk of complications.

The primary aim of this nationwide registry-based study was to determine the incidence of postoperative stem revision due to PPF in patients with primary THA for osteoarthritis. The secondary aim was to study patient- and surgery- related characteristics associated with stem revision due to PPF after primary THA.

II MATERIALS AND METHODS

Data for this retrospective cohort study were obtained from the Dutch Arthroplasty Register, Landelijke Registratie Orthopedische Interventies (LROI). This database was established by the Dutch Orthopedic Association (NOV) in 2007. Since 2012, Dutch hospitals have been successful in full reporting coverage, encompassing 100% of all primary THAs with a completeness of 98% and 99%, respectively, for primary THAs and revision arthroplasties[12-13]. The LROI database includes information related to patient demographics, prosthetic devices and surgical procedures for both primary and revision arthroplasties. Prosthetic component details are sourced from an implant library, which relies on product numbers to compile data such as prosthesis type, brand, designation, and material, as provided by the manufacturer. Any procedure involving the replacement, removal, or addition of one or more components within the implant system was classified as a revision arthroplasty[12]. As osteosynthesis for fracture fixation is not registered in this database, these procedures were excluded from the scope of this study.

II.I Population

The study population for this study consisted of all primary THAs for osteoarthritis registered in the LROI between 2007 and 2021. This included people aged 18 years or older (331,009 procedures; 284,543 patients). A patient could possibly be recorded in the database twice if right-sided and left-sided THA procedures were performed (Figure 1).

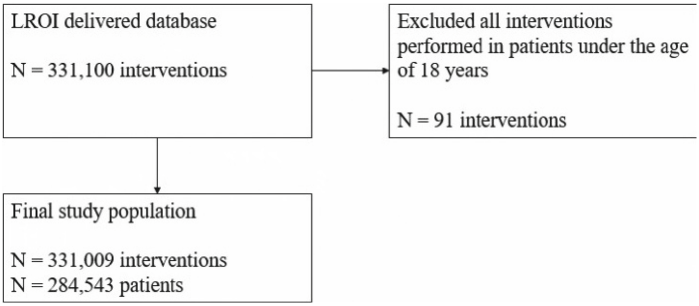

Figure 1: Flowchart for study cohort
The study cohort included 331,009 primary THAs for osteoarthritis registered in the LROI from 2007 to 2021, involving 284,543 patients aged 18 or older.

II.II Data collection

Data were collected and delivered by the LROI. The following patient data were available: sex, age, ASA class, BMI, previous surgeries, Charnley score and diagnosis related to primary THA. The following procedural information was available: year, side, type of implant, fixation method, approach, articulation, and femoral head size. Since 2014, BMI, smoking status and Charnley score have also been registered. Type and reason(s) for the first revision were recorded.

II.III Outcome measures

The primary aim was to determine the incidence of postoperative stem revision due to PPF in patients after primary THA for osteoarthritis. Secondary analyses were performed to identify potential patient and surgical characteristics associated with stem revision due to PPF.

II.IV Statistical analysis

Baseline characteristics of the patient cohort were reported as mean with standard deviation (SD), count (n) with percentage (%) or median with interquartile range (IQR). Using Kaplan–Meier analysis, PPF incidence in the context of primary THA necessitating femoral stem revision was explored. Survival time was defined as duration from initial THA to either the first revision, patient death or end of follow-up period (January 1st, 2022).

This study conducted univariable multilevel Cox proportional hazards regressions to analyze the association between both patient and surgical related characteristics and stem revision for PPF, adjusted for the clustered nature of the data (as some patients contribute multiple revisions). Multivariable multilevel Cox regression analyses were performed to explore the combined association of multiple risk factors among patient and surgical related characteristics by including those risk factors that were significant in univariable analysis. Among recorded patient related characteristics, BMI, age, sex, ASA class, Charnley classification, and smoking status were considered as potential risk factors. Type of procedure, year of operation, implant type, fixation method, and surgical approach were considered among surgical related characteristics as potential risk factors.

The percentage of variable data missing was considerable since some characteristics were not recorded until 2014. As these are unrelated to other patient related characteristics, we chose not to impute missing data. Instead, we used all available cases per analysis. All statistical computations were conducted using R (version 4.0.4, R Foundation for Statistical Computing, Vienna, Austria). We established statistical significance at p-value < 0.05.

II.V Ethics, data sharing, funding and disclosures

The data used for this study was completely anonymized. It was sourced from the LROI, and used specifically for this research project under a licensed agreement.

III RESULTS

III.I Baseline characteristics

Table 1 presents patient demographic and clinical characteristics of this large cohort of THA procedures (n = 331,009) performed for primary osteoarthritis. Median follow-up time was 5.6 years (IQR 2.8 – 9.0). Mean age was 69.7 years (SD 9.7), and 66% of patients were female. Based on BMI, 0.4% were underweight (BMI ≤ 18.5), 15.0% were obese (BMI >30–40) and 0.8% were morbidly obese (BMI >40). Seventy-eight percent of procedures were performed in patients with ASA levels II-IV and 37% had Charnley scores of B1 or higher. In 69% of procedures, an uncemented stem was used while a cemented stem was used in 31% of cases. The most common surgical approach was posterolateral (56%). Primarily, ceramic-on-polyethylene articulations (54%) and 32 mm femoral head sizes (52%) were used.

Table 1: Baseline characteristics of all included primary THA procedures

Characteristics		**Total *n* (331,009)**	**Percentage %**
Age (years)	Mean (SD)	69.7 (9.7)	
	Unknown	284	0.1
Sex	Female	219,658	66.4
	Male	110,892	33.5
	Unknown	459	0.1
ASA class	I	65,414	19.8
	II	206,209	62.3
	III-IV	51,916	15.7
	Missing	7,470	2.3
Charnley class[1]	A	93,390	28.2
	B1	66,375	20.1
	B2	49,739	15.0
	C	5,693	1.7
	Unknown	115,812	35.0
Smoking[1]	No	187,042	56.5
	Yes	20,748	6.3
	Unknown	123,219	37.2
BMI[1]	Underweight (≤ 18.5)	1,351	0.4
	Normal weight (>18.5–25)	69,104	20.9
	Overweight (>25–30)	91,132	27.5
	Obesity (>30–40)	49,770	15.0
	Morbid obesity (>40)	2,576	0.8
	Unknown	117,076	35.4
Previous surgeries at affected hip	No	313,667	94.8
	Yes	6,324	1.9
	Unknown	11,018	3.3
Procedure side	Left	150,976	45.6
	Right	180,033	54.4
Fixation method	Cemented stem	100,508	30.4
	Uncemented stem	227,981	68.9
	Unknown	2,520	0.8

Table 1: Continued

Characteristics		**Total *n* (331,009)**	**Percentage %**
Surgical approach	Anterior	71,704	21.7
	Anterolateral	19,379	5.9
	Posterolateral	185,503	56.0
	Straight lateral	49,339	14.9
	Direct superior	1,714	0.5
	Trochanter Osteotomy	53	0.0
	Unknown	3,317	1.0
Articulation	Ceramic-on-ceramic	22,076	6.7
	Ceramic-on-metal	77	0.0
	Ceramic-on-polyethylene	179,068	54.1
	Metal-on-ceramic	6	0.0
	Metal-on-metal	5,233	1.6
	Metal-on-polyethylene	85,735	25.9
	Oxidized zirconium-on-polyethylene	23,048	7.0
	Unknown	15,766	4.8
Femoral head size	22-28 mm	81,021	24.5
	32 mm	172,246	52.0
	36 mm	65,329	19.7
	≥ 38 mm	3,889	1.2
	Unknown	8,524	2.6

[1]Registered in the LROI since 2014
SD: Standard Deviation; ASA: American Society of Anesthesiologists; BMI: Body Mass Index; mm: millimeter; LROI: Dutch Arthroplasty Register.

III.II Incidence of stem revision due to periprosthetic femoral fractures

The cumulative incidence of postoperative stem revision based on PPF in primary THA was 0.4% at five years (95% confidence interval [CI]: 0.4-0.4) and 0.7% at ten years (95% confidence interval [CI]: 0.7-0.7) (Figure 2).

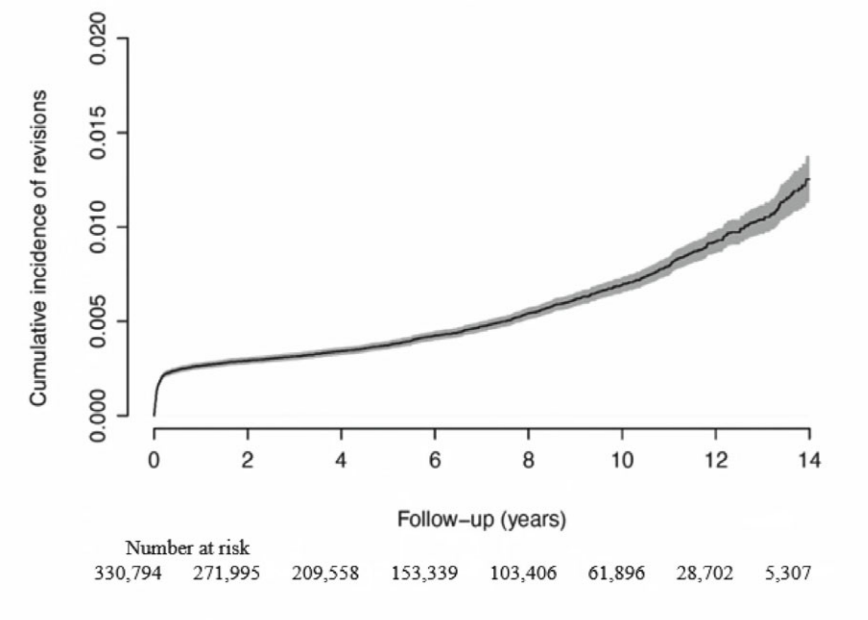

Figure 2: Incidence of stem revision
Cumulative incidence of stem revision due to PPF in primary THA was 0.4% at five years and 0.7% at ten years, with 95% confidence intervals of 0.4-0.4 and 0.7-0.7, respectively.

III.III Factors associated with stem revision due to periprosthetic femoral fractures

Univariable analyses of patient factors demonstrated that patients of increased age (Hazard Ratio (HR) 1.29 per 10 years, 95% CI 1.22-1.36) and female sex (HR 1.30, 95% CI 1.16-1.45) had significantly higher odds of revision due to PPF after primary THA. In addition ASA class II compared to ASA class I (HR 1.56, 95% CI 1.27-1.93) and ASA class III-IV compared to ASA class I (HR 2.07, 95% CI 1.59-2.71), Charnley score B2 compared to Charnley score A (HR 1.46, 95% CI 1.23-1.72), Charnley score C compared to Charnley score A (HR 1.81, 95% CI 1.26-2.59), and higher BMI (HR 1.02 per kg/m2, 95 CI 1.00-1.03) had significantly higher odds of revision due to PPF after primary THA. Univariable analysis of surgery specific factors showed that procedures performed with an uncemented stem (HR 4.55, 95% CI 3.85-5.26) and anterior approach as compared to a posterolateral approach (HR 1.25, 95% CI 1.03-1.52) had significantly higher odds for stem revision due to PPF after primary THA.

Based on PPF after primary THA, multivariable analyses showed that increased age (HR 1.05 per 10 years, 1.04-1.05), female sex (HR 1.47, 95% CI 1.27-1.72), higher BMI (HR 1.02, 95% CI 1.00-1.03), ASA class II (HR 1.43, 95% CI 1.14-1.79), ASA class III-IV (HR 1.62, 95% CI 1.24-2.13), Charnley score B2 (HR 1.34, 95% CI 1.13-1.59) and Charnley score C (HR 1.77, 95% CI 1.23-2.55) were significant independent predictors for revision. In the multivariable analysis model of surgery specific factors, only uncemented stem (HR 7.14, 95% CI 5.56-9.09) remained as an independent predictor of stem revision due to PPF after primary THA (Table 2).

Table 2: Uni- and multivariable associations between patient- and surgery-related characteristics and stem revision rate.

	Univariable		**Multivariable**	
	HR (95% CI)	p-value	HR (95% CI)	p-value
Age (per 10 years)	1.29 (1.22 - 1.36)	<0.001	1.05 (1.04 - 1.05)	<0.001
Sex (male)	0.77 (0.69 - 0.86)	<0.001	0.68 (0.58 - 0.79)	<0.001
BMI (kg/m²)	0.98 (0.97 - 1.00)	0.013	0.98 (0.97 - 1.00)	0.015
Smoking	1.18 (0.95 - 1.46)	0.130	-	-
ASA class				
I (reference)	1.0	-	1.0	-
II	1.56 (1.27 - 1.93)	<0.001	1.43 (1.14 - 1.79)	0.002
III-IV	2.07 (1.59 - 2.71)	<0.001	1.62 (1.24 - 2.13)	<0.001
Charnley score				
A (reference)	1.0	-	1.0	-
B1	1.15 (0.98 - 1.36)	0.096	1.09 (0.92 - 1.29)	0.310
B2	1.46 (1.23 - 1.72)	<0.001	1.34 (1.13 - 1.59)	<0.001
C	1.81 (1.26 - 2.59)	0.001	1.77 (1.23 - 2.55)	0.002
Previous surgery	1.17 (0.85 - 1.61)	0.327	-	-
Stem cemented	0.22 (0.18, 0.26)	<0.001	0.14 (0.11 - 0.18)	<0.001
Approach				
Anterior (reference)	1.0	-	-	-
Anterolateral	0.98 (0.73 - 1.31)	0.870	-	-
Direct superior	1.78 (0.65 - 4.87)	0.270	-	-
Posterolateral	0.80 (0.66 - 0.97)	0.026	-	-
Straight lateral	0.88 (0.70 - 1.11)	0.280	-	-
Other	0.56 (0.13 - 2.42)	0.440	-	-

BMI: body mass index; ASA: American society of anesthesiologists; HR: hazard ratio; CI: confidence interval. The multivariable analysis incorporates all significant associations found in the univariable analysis. They have been mutually adjusted to discern the independent risk factors.

IV DISCUSSION

The aim of this nationwide registry-based study was to determine the incidence of stem revision due to PPF in patients with primary THA for osteoarthritis. The secondary aim was to study both patient- and surgery- related characteristics as potential risk factors for stem revision due to PPF after primary THA. As aforementioned in the introduction, research has reported great variations in incidence rates, ranging from 0.07 to 27.8%. In this study, an overall cumulative incidence rate was determined for stem revision based on PPF in primary THA of 0.4% and 0.7% at five and ten years, respectively. Risk factors associated with increased stem revision rates due to PPF in patients with primary THA include female sex, increased age, ASA class II-IV, Charnley score B2-C, higher BMI, uncemented stem fixation and anterior approach. The overall stem revision incidence in cases of PPF after THA in this study was low and similar to previous research findings[14-15].

IV.I Patient related factors

Consistent with prior findings, advanced age was associated with a significantly increased risk of stem revision based on PPF[14,16-17]. Physiological condition, lifestyle, and medical conditions of elderly patients could influence the incidence of PPF. This was also described in a systematic review by Xu et al. in which they concluded that older age, polypharmacy, malnutrition, single status, rural living, smoking, and alcohol consumption were all significant factors associated with increased fall risk among elderly individuals[18]. Furthermore, advancing age is expected to correlate with a decline in bone mass and lack of mechanical support provided by the bone cortex, an escalation in medical comorbidities, and increased fall risk[19-21]. Correspondingly, as indicated in previous research, female patients exhibited a significantly increased risk of stem revision based on PPF after THA[11,22-23]. Dale et al. reported an 11x increased risk of revision due to PPF after reverse hybrid THA in females as compared to males[23]. The implication is that there is a noteworthy interest in the influence of age- and sex-related changes like osteoporosis affecting bone quality in the femora of females[19]. Fracture risk could be mitigated through the use of cemented fixation, serving as a load-sharing device, that has the potential to alleviate point-loading stress on the femur[24].

Indicative of potential implications for diminished bone quality and an increased susceptibility to falls, ASA class serves as a valuable surrogate marker for frailty[25-27]. In this study, and consistent with earlier investigations, high ASA class (II and III-IV) was associated with a substantially increased risk of stem revision due to PPF after THA[11]. Similarly, a high Charnley score (B2 and C) was associated with increased risk. Peters et al. also found that high Charnley score was also found to be associated with increased risk for revision three years after primary THA[28]. One hypothesis is that multiple surgical interventions may be associated with a more extensive osteoarthritic burden across multiple joints, thus leading to a decline in mobility and muscle strength over time, which is consistent with the osteoarthritic profile. An increased risk of falls occurs as a consequence. Impaired balance control and proprioception may persist despite surgical intervention, further exacerbating the risk of falls.

This study found that high BMI correlated significantly with an increased risk of stem revision based on PPF around primary THA. Previous studies reported no significant correlation between BMI (high or low) and the occurrence of PPF after THA[11,22]. Following THA, elevated BMI may contribute to increased mechanical loading on both the implant and surrounding bone structures. This heightened mechanical stress has the potential to exacerbate the likelihood of bone microfractures or cement mantle failure and subsequent late PPF. Also, when falling, individuals with high BMI, or increased body mass, experience greater mechanical forces exerted on the bone around the prosthetic joint, leading to a higher risk of potential PPF.

IV.II Surgery related factors

The association between the selected implant, surgical approach, and fixation method on PPF risk after THA is of great importance for surgical decision-making. In this study, a significantly increased risk of stem revision based on PPF after THA was observed in patients with uncemented stem fixation. Furthermore, Dale et al. found that, as compared to cemented THA, the risk of revision in females due to PPF after uncemented THA was increased 19-fold in the postoperative first year[23]. This finding is consistent with previous published literature on both THA and hemiarthroplasty[22-23,29-32]. Moreover, the increased risk of postoperative PPF after uncemented stems was shown to be independent of age or sex[33]. Uncemented THA relies on biological fixation, where the implant is designed to encourage bone ingrowth into its porous surface for stability[34]. However, this process may result in stress shielding where the implant bears a disproportionate amount of load. Stress shielding may potentially lead to weakening of the surrounding bone and increasing risk of fracture, especially after falls in the fragile elderly[35].

Consistent with earlier research, anterior approach was found to be associated with an increased risk of PPF after primary THA[36-37]. However, the anterior approach is commonly performed using uncemented THA. Therefore, the uncemented THA can affect the likelihood of anterior approach as a risk factor for stem revision due to PPF. Furthermore, hypothetically, the stem may impinge against the medial femoral cortex, causing it to protrude in relation to the femoral neck cut during intra-operative broaching and stem implantation in varus positioning while performing an anterior approach. This protrusion can create a stress concentration point or an occult fracture at the location of the fracture apex site. During the perioperative period, repetitive axial loading and rotational forces prior to the establishment of bony ingrowth into the implant may further weaken this region of bone and predispose it to fracture at the medial femoral cortex just proximal to the stem tip. Another potential risk factor for proximal femoral fracture akin to coronal malalignment is a disparity in sagittal alignment of the stem[38]. Previous research suggests that the anterior approach mainly causes intra-operative or early postoperative PPF due to disproportionate proximal femoral canal fill, while post-operative PPF around THA anterior approaches are mostly related to other patient specific risk factors as previously discussed and not specifically related to the type of approach used[39].

The parallels between frailty fractures in native hips and PPF after primary THA are noteworthy. Literature has demonstrated the value of multidisciplinary trauma units in managing frailty fractures, highlighting improved outcomes through comprehensive care involving orthopedic/trauma surgeons, geriatricians, physiotherapists, and other healthcare professionals[40-42]. At-risk patients for stem revision based on PPF after primary THA are fragile and vulnerable. Therefore, it stands to reason that these patients would benefit from the same type of multidisciplinary care. Implementing such an approach could potentially enhance patient outcomes by addressing the multifaceted needs of this at-risk group.

IV.III Strengths and limitations

The main strength of this study is the real-world population-based cohort sourced from the LROI with a database completeness exceeding 95%. This cohort encompasses the vast majority of patients who underwent THA in the Netherlands during that specific time period, including patients of all ages, health conditions, and socio-economic statuses. Given the comparable demographic attributes observed across the scrutinized groups, the likelihood of selection bias is deemed to be minimal. Furthermore, this nationwide registry-based study has a considerable cohort including 331,009 procedures.

One limitation to mention is that PPF treatment after THA can consist of a conservative or surgical approach. Surgically, a PPF can be managed using osteosynthesis with or without stem revision. Only stem revisions are included in the LROI. As a result, valid conclusions can only be made in this specific subset of patients suffering from a PPF. Causality could not be examined as this study was conducted using observational data. Moreover, due to our large cohort of primary procedures, we were able to demonstrate how minor differences become highly significant. It remains a matter of inquiry as to how clinically relevant these findings are.

V CONCLUSION

This study, with over 300,000 procedures, showed that the incidence risk of stem revision due to PPF after primary THA was 0.4% after five years and 0.7% after ten years. Older female patients, with high ASA class (II-IV), high Charnley score (B2-C), high BMI, uncemented stem fixation and anterior approach have significant higher risks for revision due to PPF after primary THA. Primarily, this highlights the fact that these fractures occur in a frail population. Currently, substantial focus exists on how to treat patients suffering from these fractures from a mechanical point of view. The results of this study emphasize the importance of a more patient-centered approach, much like frail elderly suffering from frailty fractures of the proximal femur. We advocate approaching these patients in the same, multidisciplinary way. Aligned with these findings, caution is advised when employing uncemented stem fixation methods and anterior approaches in older female patients with high ASA class, Charnley score, and BMI. Further research is recommended to explore all surgically treated PPF around THA, not only the stem revision cases. This aspect warrants further investigation and could be important for subsequent study.

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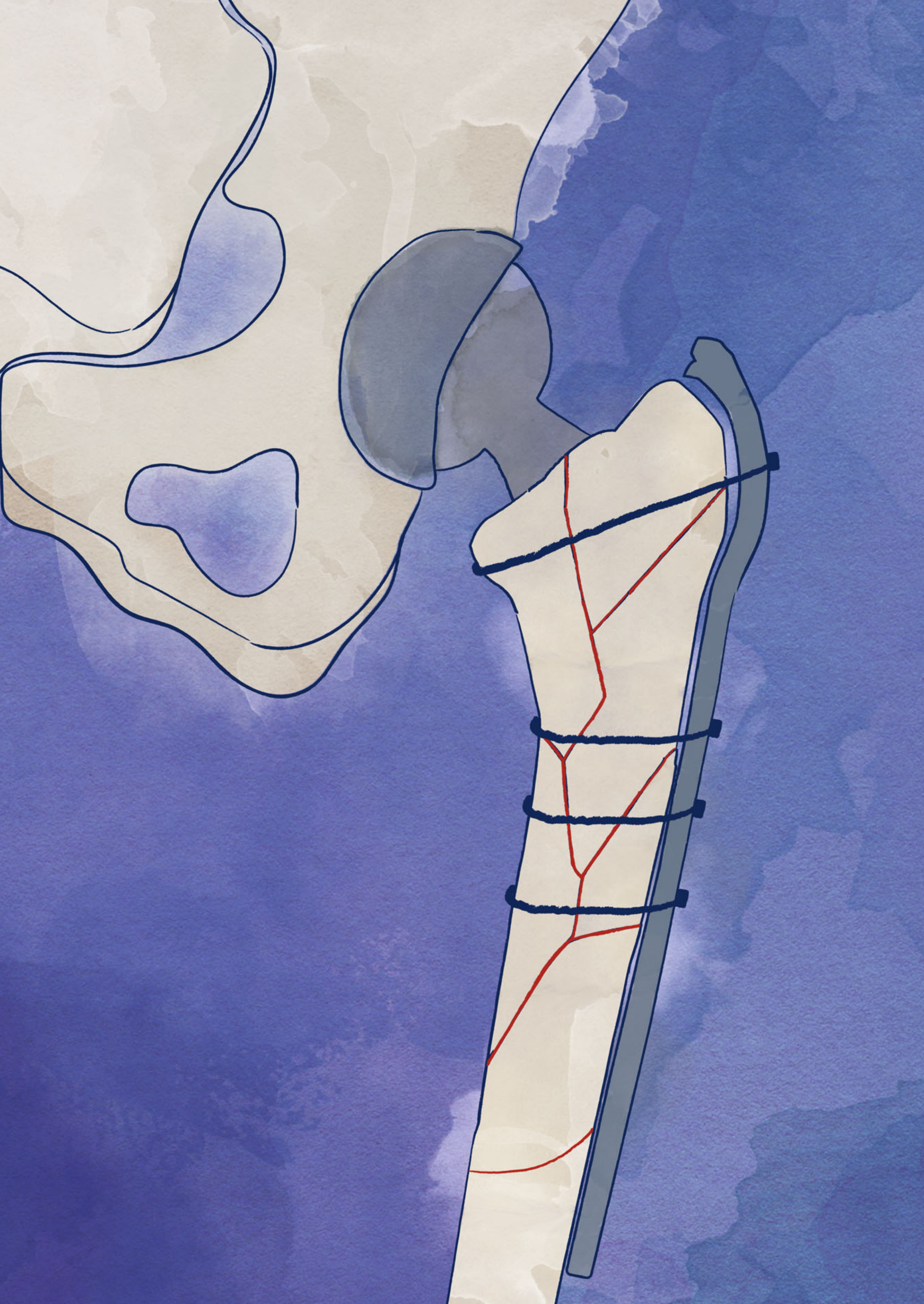

Chapter V

Identifying Risk Factors for One-Year Mortality After Surgical Treatment of Periprosthetic Femoral Fractures Around Hip Arthroplasty

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ABSTRACT

Background

The increasing number of hip arthroplasties (HA) worldwide, including hemi- and total hip arthroplasties, has led to a rise in periprosthetic femoral fractures (PPFF). These fractures are technically complex, linked to high morbidity and mortality, and impose a burden on healthcare systems. However, clinical guidelines for managing PPFF are lacking, and data on factors affecting postoperative outcomes remain limited. This study aimed to identify risk factors for one-year mortality in surgically treated PPFF patients.

Methods

A retrospective single-center cohort study was conducted on patients with surgically treated PPFF. Data on patient-, implant-, fracture-, surgical- and perioperative characteristics were collected. Univariate and multivariable logistic regression analyses were used to identify independent predictors of one-year mortality.

Results

Among 157 patients (median age was 83 years, 59.2 % ASA III), the one-year overall mortality rate was 16.6 %. Multivariable analyses suggested that residency in a nursing home [OR 4.1 (95 %CI 1.20–14.25) p = 0.025], use of a walking aid [OR 3.6 (95 %CI 1.07–12.36) p = 0.039], initial uncemented stem fixation [OR 4.08 (95 %CI 1.25–13.35) p = 0.020], preoperative urinary bladder catheter (UBC) [OR 4.5 (95 %CI 1.33–15.25) p = 0.016] and lower Body Mass Index (BMI) (Kg/m2) [OR 0.87 (95 %CI 0.75–1.00) p = 0.049) were independently associated with one-year mortality.

Conclusion

PPFF patients are frail and highly comorbid. Risk factors such as low BMI, nursing home residency, walking aid use, uncemented stem fixation, and preoperative UBC highlight the need for targeted strategies to improve outcomes.

Keywords

Periprosthetic fractures, reoperation, mortality, retrospective studies, arthroplasty, replacement, hip

I INTRODUCTION

Hip arthroplasties (HA), first performed in 1891, are among the most common and successful orthopedic procedures worldwide[1-2]. The number of HA, including hemi-arthroplasty and total hip arthroplasty, has risen significantly, with data from the UK, Sweden, and New Zealand showing a 37 % increase between 2008 and 2017[2-3]. This trend is likely similar in other developed nations and is attributed to aging populations, increasing demand for improved quality of life, and expanded indications for younger, more active patients[4-5]. However, the growing number of HA has led to a parallel rise in revision surgeries and traumatic events increasing the incidence of periprosthetic femoral fractures (PPFF)[2,4,6].

PPFF around HA represent the most common type of PPFF. The reported risk of a PPFF following HA is about 0.4–3.5 %[2,5]. The incidence of PPFF is 3–18 % in HA with uncemented stems and 0.1–1 % in cemented stems[6–11]. PPFF are challenging complications and are associated with high morbidity and mortality rates[2,6]. They can occur either intra-or postoperative. The surgical management of PPFF is known to be complex due to the altered anatomy, poor bone quality, and the need to manage both fracture and implant stability[12]. They often occur in older patients with medical comorbidities and require technically complex operations, resulting in a prolonged hospital stay and increased use of hospital resources[12-13]. The associated costs and necessary care are high, placing a significant burden on hospital systems[13].

Currently there are no established guidelines for the perioperative management of PPFF, and while the Vancouver classification system is useful for classification, it neglects patient- and surgery-related factors that impact outcomes[14-15]. In previous research older age, higher American society of Anaesthesiologists classification system (ASA) scores, and delayed surgeries have been independently suggested to increase one-year mortality rates after PPFF[12,16-17]. However, the primary object of these studies was not to identify potential risk factors and therefore a lack in knowledge remains. Due to the high morbidity and mortality associated with PPFF, it is essential to consider these factors in the perioperative management. Limited data regarding patient- and surgical related factors with their influence on the perioperative management of PPFF is available. Therefore, it is needed to get insight into this population to optimize the hospital treatment care path and to ensure patient safety. The first aim of this study was to provide an insight into the patient population suffering PPFF needing surgical management. Second aim was to identify potential risk factors in the perioperative management that have a significant influence on the one-year mortality rate.

II METHODS

A retrospective single-center cohort study was conducted investigating all patients who underwent surgical treatment in case of a PPFF around HA between June 2015 and December 2022. Center specific codes for the surgical treatment of PPFF around HA were used extracting our patients of interest. Patients with primary knee arthroplasties, resurfacing prosthesis, PPFF around primary trauma fixation devices such as plates, nails and screws and patients who initially underwent conservative treatment were excluded (Figure 1).

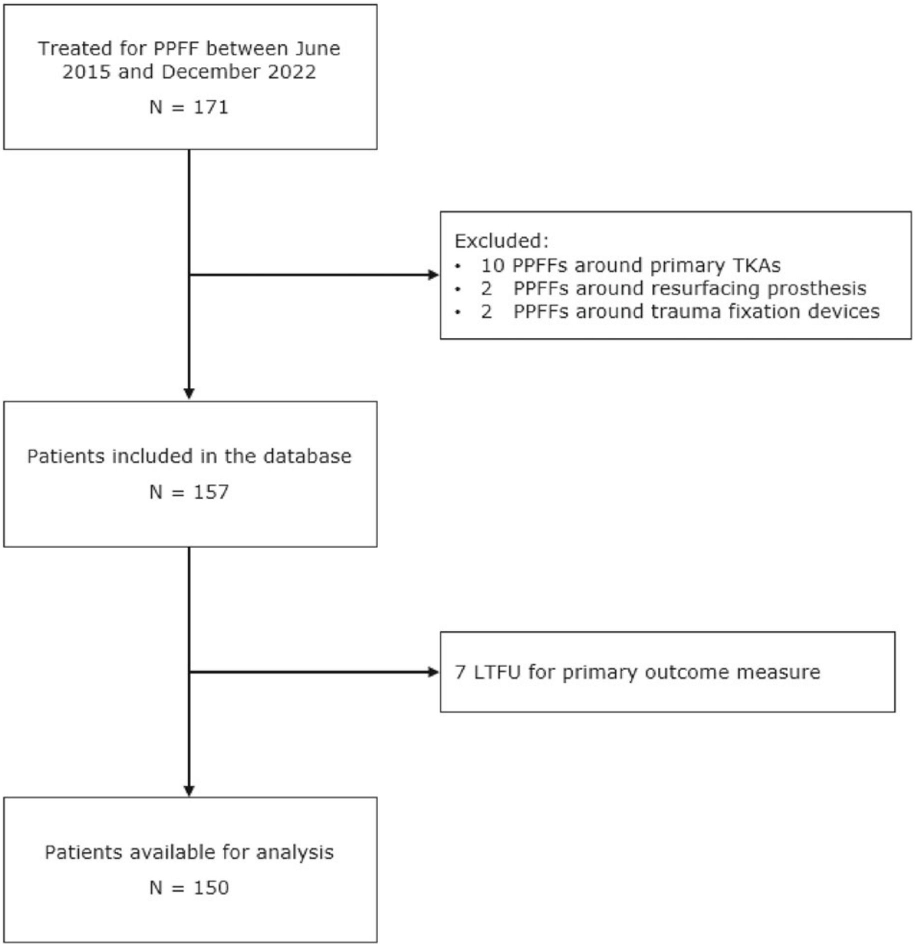

Figure 1: Flowchart PPFF data
LTFU, lost to follow up; TKA, total knee arthroplasty.

Data were abstracted from electronic medical records, including information on patient demographics, initial surgery, fracture characteristics, revision surgery, perioperative management, treatment complications (postoperative meaning within two weeks after surgery and after 90 days) and mortality (at 90-days and one-year). An overview of all variables included in the database is given in Appendix 1. The primary outcome was defined as one-year mortality after surgical treatment for PPFF around HA.

Fractures were classified by the operating surgeons using the Vancouver Classification system[18]. The initial stem implants were categorized according to their mode of fixation (cemented or uncemented). Patients of which primary outcome measures were available were included in the analyses for one-year mortality. Due to the large variety, complications were categorized into groups. Patients could have multiple complications. Due to the small numbers, ASA-score I (n = 4) and II (n = 50) were grouped together in the multivariable analyses. For the same reason the 'wheelchair bound' subgroup (n = 3) and the weight bearing protocol subgroup 'other' (n = 11) were excluded from the multivariable analyses.

Statistical analyses were performed using SPSS software (IBM Corp. Released 2021. IBM SPSS Statistics for Mac, Version 29.0. Armonk, NY, USA: IBM corp). Equal distribution was tested using Kolmogorov-Smirnov analyses. Descriptive statistics were used to describe the total patient population (n = 157). Categorical variables were reported as numbers (n) and percentages (%). Continuous variables were, if normally distributed, reported as mean with standard deviation (±SD and range), or as median with interquartile ranges (IQR) if non-normally distributed. Univariate analyses were performed to compare variables in survivors and non-survivors (n = 150). Patients who were loss to follow up (n = 7) were not included in the univariate analyses. Statistical analysis consisted of an Independent-Samples Median Test for continuous variables and a Chi-square test (X2) for categorical variables. Independent variables that showed potential association with one-year mortality in the univariate analyses (defined as $P < 0.10$) where thereafter used to develop a multivariable logistic regression model to assess their correlation with the dependent variable, one-year mortality after surgical treatment. The multivariable analysis was constructed with binary logistic regression, using two blocks; the first one for pre-operative variables and the second one for post-operative variables. The 'Backward: Conditional' method was used to run the analyses, with variables retained based on a backward stepwise approach (conditional $P < 0.1$). Missing data was coded in SPSS and not used in the analysis for the primary outcome measure. Statistical significance in the multivariable analyses was defined as $p < 0.05$.

This study was approved by the institutional review board, with code of approval METCZ20230085. It was performed in compliance with the 1975 Declaration of Helsinki, as revised in 2013 and conducted in accordance with the guidelines for Good Clinical Practice.

III RESULTS

III.I Demographics

III.I.I Patient demographics

Out of 171 patients surgically treated for PPFF after HA, a total of 157 patients were considered eligible to participate in our study (Figure. 1). The majority of the population was female (62.4 %), the median age was 83 years (SD ± 12, range 51–95), and the median Body Mass Index (BMI) was 25.6 kg/m2 (SD ± 5.4, range 18–41.5). A total of 26 patients (16.6 %) died within one year after surgery for PPFF around HA (Figure. 2). A complete overview of patient demographics is presented in Table 1. Univariate analyses showed that compared to survivors, non-survivors were older (p = 0.049), scored higher on the ASA-classification (p = 0.046), had pre-existing mobility disorders (p = 0.01), and were more likely to suffer from dementia (p = 0.01).

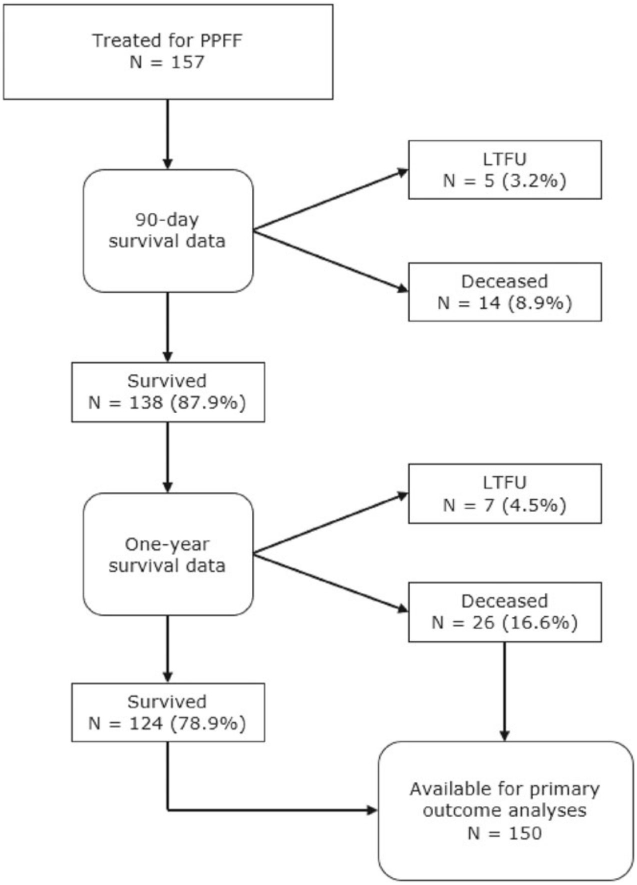

Figure 2: 90-day and one-year survival

PPFF, periprosthetic femoral fracture; LTFU, lost to follow up.

Table 1: Patient demographics

	Value N (%)	Survival N (% within category)	Deceased N (% within category)	P-value
Total no. of patients	157			
Sex				0.227
Male	59 (37.6)	49 (87.5)	7 (12.5)	
Female	98 (62.4)	75 (79.8)	19 (20.2)	
#	0 (0.0)			
Age	83.0 ±12, 51 - 95	81.0 ±11.0, 51 - 95	87 ±7, 61 - 93	0.049*
#	0 (0.0)			
BMI	25.6 ±5.4, 18 - 41.5	26.0 ±5.1, 18.0 - 41.5	23.1 ±5.9, 18.6 - 33.7	0.018*
Underweight	2 (1.3)	2 (100)	0 (0.0)	
Healthy weight	69 (43.9)	47 (72.3)	18 (27.7)	
Overweight	61 (38.9)	54 (93.1)	4 (16.0)	
Obese	25 (15.9)	21 (84.0)	4 (16.0)	
#	0 (0.0)			
Place of residence				0.003*
Own home	113 (72.0)	97 (88.2)	13 (11.8)	
Nursing home	25 (15.9)	15 (60.0)	10 (40.0)	
Residential home	11 (7.0)	8 (88.9)	1 (11.1)	
#	8 (5.1)			
ASA classification				0.046*
ASA I	4 (2.5)	4 (100)	0 (0.0)	
ASA II	50 (31.8)	45 (93.8)	3 (6.3)	
ASA III	93 (59.2)	67 (76.1)	21 (23.9)	
ASA IV	9 (5.7)	8 (88.9)	1 (11.1)	
#	1 (0.6)			
Preexistent mobility status				0.010*
Independent	77 (49.9)	68 (93.2)	5 (6.8)	
Walking aid	59 (37.6)	41 (71.9)	16 (28.1)	
Use of a stick	13 (8.3)	9 (75.0)	3 (25.0)	
Wheelchair bound	3 (1.9)	2 (66.7)	1 (33.3)	
#	5 (3.2)			
Pre-existent dementia	22 (14.0)	14 (63.6)	8 (36.4)	0.011*
#	0 (0.0)			
Osteoporosis	29 (18.5)	24 (85.7)	4 (14.3)	0.637
#	1 (0.6)			

Table 1: Continued

	Value N (%)	Survival N (% within category)	Deceased N (% within category)	P-value
Initial diagnosis				0.742
Coxarthrosis	96 (61.1)	80 (83.3)	16 (16.7)	
Femoral neck fracture	33 (21.0)	26 (83.9)	5 (16.1)	
Other^	3 (1.9)	3 (100)	0 (0.0)	
#	25 (15.9)			

BMI, Body Mass Index; ASA, American Society of Anaesthesiologists.
* Statistically significant value of $p < 0.10$.
^ Avascular necrosis after intramedullary osteosynthesis (2), epiphysiolysis.
# Missing data.

III.I.II Fracture and implant characteristics

Table 2 shows an overview of characteristics of the PPFF in the population. The majority of the population suffered from a PPFF caused by low-energy trauma (92.4 %). Most patients sustained a PPFF around total hip arthroplasty (THA) (85.4 %) and the initial method of fixation being uncemented (58.6 %). Fractures classified as Vancouver type B2 were most common in this population (47.8 %). In the univariate analyses, method of stem fixation showed a potential association with one-year mortality ($p = 0.087$).

III.I.III Fracture and implant management

An overview of PPFF management in given in Table 3. The median time of surgery was 107.4 min (IQR 46.5). Most of the patients were treated with open reduction and internal fixation (ORIF) (60.5 %). 64 % (n = 18) of the patients with a Vancouver type B2 fracture treated with ORIF had a cemented HA. Stem revision was done in 62 patients (39.5 %) of which 57 (91.9 %) were treated with uncemented stem fixation. Permissive weight bearing (PWB) was prescribed in the largest proportion after surgery (27.4 %) and full weight bearing was only prescribed in 16 cases (10.2 %). Univariate analyses revealed that patients who were prescribed ‘no weight bearing for six weeks’ after surgery had a higher risk for one-year mortality ($p = 0.04$).

Table 2: Fracture characteristics

	Value N (%)	Survival N (%within category)	Deceased N (% within category)	P-value
Initial intervention				0.767
THA	135 (86.0)	107 (82.3)	23 (17.7)	
HA	22 (14.0)	17 (85.0)	3 (15.0)	
Initial stem fixation				0.087*
Cemented stem	65 (41.4)	56 (88.9)	7 (11.1)	
Uncemented stem	92 (58.6)	68 (78.2)	19 (21.8)	
#	0 (0.0)			
Time till fracture (years)	8 ±11.0, 0 - 29	8 ±11, 0 - 29	10 ±13, 0 - 29	0.484
#	23 (14.6)			
Mechanism of trauma				0.777
Low- energy	145 (92.4)	113 (81.9)	25 (18.1)	
High- energy	2 (1.3)	2 (100)	0 (0.0)	
Intra- operative	6 (3.8)	5 (83.3)	1 (16.7)	
Spontaneous	3 (1.9)	3 (100)	0 (0.0)	
#	1 (0.6)			
Fracture side				0.572
Right	83 (52.9)	64 (81.0)	15 (19.0)	
Left	74 (47.1)	60 (84.5)	11 (15.5)	
#	0 (0.0)			
Vancouver classification				0.278
Type A	4 (2.5)	4 (100)	0 (0.0)	
Type B1	32 (20.4)	29 (93.5)	2 (6.5)	
Type B2	75 (47.8)	58 (79.5)	15 (20.5)	
Type B3	11 (7.0)	7 (70.0)	3 (30.0)	
Type C	35 (22.3)	26 (81.3)	6 (18.8)	
#	0 (0.0)			

THA, Total Hip Arthroplasty; HA, Hemiarthroplasty.
* Statistically significant value of $p < 0.10$.
# Missing data.

Table 3: Fracture management

	Value N (%)	Survival N (% within category)	Deceased N (%within category)	P-value
Treatment				0.408
Revision	2 (1.3)	2 (100)	0 (0.0)	
Revision + ORIF	60 (38.2)	46 (78.0)	13 (22.0)	
ORIF	95 (60.5)	76 (85.4)	13 (14.6)	
#	0 (0.0)			
Surgical approach				0.649
Straight lateral	112 (71.3)	87 (82.1)	19 (17.9)	
Anterior	4 (2.5)	4 (100)	0 (0.0)	
Posterolateral	41 (26.1)	33 (82.5)	7 (17.5)	
#	0 (0.0)			
Surgery time (minutes)	107.4 ±46.5, 43.6 - 290.0	107.9 ±46.7, 43.6 - 290.0	91.2 ±42.8, 58.1 - 174.6	0.518
#	0 (0.0)			
Perioperative use of TXA	77 (49.0)	60 (80.0)	15 (20.0)	0.324
#	3 (1.9)			
Blood loss	500 ±500, 100 - 4050	500.0 ±550.0, 100 - 4050	500 ±300, 100 - 1700	0.427
#	4 (2.5)			
Method of wound closure				0.714
Staples	100 (63.7)	78 (83.0)	16 (17.0)	
Monocryl intracutaneous	41 (26.1)	32 (80.0)	8 (20.0)	
V-loc intracutaneous	10 (6.4)	9 (90.0)	1 (10.0)	
Ethilon intracutaneous	2 (1.3)	2 (100)	0 (0.0)	
Ethilon transcutaneous	4 (2.5)	3 (75.0)	1 (25.0)	
#	0 (0.0)			
Postoperative weight bearing				
PWB	43 (27.4)	35 (85.4)	6 (14.6)	0.040*
Full weight bearing	16 (10.2)	11 (68.8)	5 (31.3)	
50% weight bearing**	34 (21.7)	29 (87.9)	4 (12.1)	
No weight bearing**	19 (12.1)	9 (52.9)	8 (47.1)	
Plantar contact**	34 (21.7)	30 (90.9)	3 (9.1)	
Other^	11 (7.0)	10 (100)	0 (0.0)	
#	0 (0.0)			

ORIF, open reduction internal fixation; TXA, tranexamic acid; PWB, permissive weight bearing.
^No weight bearing for two weeks, no weight bearing for eight weeks (2), PWB in combination with hip brace, bed/chair mobilization until full consolidation, 20–30 kg for six weeks (2), no weight bearing until full consolidation, 10 % weight bearing for six weeks, no weight bearing for six weeks with 4 weeks extension brace, 50 % weight bearing for four weeks.
* Statistically significant value of $p < 0.10$.
# Missing data.
** For a period of six weeks

III.I.IV In-hospital patient management

Table 4 shows the in-hospital patient management. The median time from hospitalization until surgery was three days (SD ± 3, range 0–14). The median time for hospital discharge after surgery was six days (SD ± 5, range 1–70) and the median clinical follow-up period was five months (SD ± 9, range 2–36). Univariate analyses showed that the independent variables pre-operative urinary bladder catheter (UBC) ($p < 0.001$), geriatrics consultation ($p = 0.016$), post-operative UBC ($p = 0.032$), and blood transfusion ($p = 0.038$) showed potential of being a predictor for one-year mortality.

Table 4: In-hospital patient management

	Value N (%)	Survival N (% within category)	Deceased N (% within category)	P-value
Time hospitalization till surgery (days)	3.0 ±3.0, 0 - 14	3.0 ±4.0, 0 - 13	3.0 ±3, 1 - 14	0.727
#	0 (0.0)			
Preoperative DOS-score	1.3 ±4.0, 0 - 11	1.3 ±3.0, 0 - 10	2.7 ±5, 0 - 11	0.782
#	92 (58.6)			
Preoperative pain-score	2.0 ±2.0, 0 - 9	2.0 ±2.0, 0 - 9	2.0 ±3, 0 - 7	0.951
#	21 (13.4)			
Preoperative UBC	79 (50.3)	55 (72.4)	21 (27.6)	<.001*
#	0 (0.0)			
Geriatrics in consultation	99 (63.1)	74 (77.1)	22 (22.9)	0.016*
#	0 (0.0)			
Postoperative DOS-score	1.0 ±4.0, 0 - 9	1.3 ±3.0, 0 - 10	1.7 ±4.0, 0 - 9	0.818
#	93 (59.2)			
Postoperative pain score	2.0 ±3.0, 0 - 7	2.0 ±3.0, 0 - 7	2.0 ±3.0, 0 - 7	0.619
#	6 (3.8)			
Postoperative UBC	121 (77.1)	90 (78.9)	24 (21.1)	0.032*
#	0 (0.0)			
Number of days wound leakage	1.0 ±4.0, 0 - 18	1.0 ±5.0, 0 - 18	1.0 ±3.0, 0 - 10	0.693
#	3 (1.9)			
Blood transfusion	93 (59.2)	68 (77.3)	20 (22.7)	0.038*
#	0 (0.0)			
Days till first mobilization	1.0 ±1.0, 0 - 5	1.0 ±1.0, 0 - 5	2.0 ±1.0, 1 - 4	0.220
#	0. (0.0)			
Complication rate				
Post-op	60 (38.2)	42 (75.0)	14 (25.0)	0.060*
#	1 (0.6)			
90 days	22 (14.0)	19 (86.4)	3 (13.6)	0.620
#	5 (3.2)			

V

Table 4: Continued

	Value N (%)	Survival N (% within category)	Deceased N (% within category)	P-value
Hospital discharge after surgery (days)	6.0 ±5.0, 1 - 70	6.0 ±5.0, 1 - 70	7.0 ±2.0, 3 - 17	0.438
#	3 (1.9)			
Follow up (months)	5.0 ±9.0, 2 - 36	5.0 ±9.0, 2 - 36	4.5 ±3.0, 3 - 7	0.263
#	73 (46.5)			

DOS, Delirium Observation Screening; UBC, Urinary Bladder Catheter.
* Statistically significant value of p<0.10
# Missing data

III.I.V Complications

An overview of complications developed postoperative and at 90 days after surgical treatment in given in Table 5. Most of the complications postoperatively were of urogenital nature, accountable for 14.0 %. The complication rate at 90 days postoperatively was mostly defined by dislocations of the hip (7.0 %, n = 11). Univariate analyses showed that patients with post-operative complications had a higher risk for one-year mortality (p = 0.06). Out of the 11 patients with a dislocation within 90-days, mortality was 27.3 % (n = 3).

Table 5: Complications

Postoperative (Total 83 = 52.87%)	Group	Value N (% within category, % total group)
	Cardiovascular	21 (25.3, 13.4)
	Pulmonal	7 (8.4, 4.5)
	Urogenital	22 (26.5, 14.0)
	Neurological	5 (6.0, 3.2)
	Gastrointestinal	3 (3.6, 1.9)
	Dermatological	13 (15.7, 8.3)
	Hip dislocation	5 (6.0, 3.2)
	Other*	7 (8.4, 4.5)
90-days (Total 24 = 15.29%)		
	Hip dislocation	11 (45.8, 7.0)
	Surgical site infection	8 (33.3, 5.1)
	Dermatological	2 (8.3, 1.3)
	Other[#]	3 (12.5, 1.9)

* COVID (2), bacteremia, electrolyte imbalance (2), bone fissure, insufficient fracture reduction
# Non-union, cable failure, trochanteric bursitis

III.II Multivariable analysis

Displayed in Table 6 are the independent variables used to create a multivariable logistic regression model. After accounting for multiple independent variables, analyses showed the odds of mortality to be four times higher for patients with initial uncemented stem fixation compared to cemented stem fixation [4.08 (95 %CI 1.25–13.35)] (p = 0.020). Patients who lived in a nursing home had a four times higher risk of one-year mortality in comparison to patients who lived independently [4.13 (95 %CI 1.20–14.25)] (p = 0.025) and patients that mobilized using a walking aid pre-trauma had a 3.6 times higher risk for one-year mortality compared to patients who mobilized independently [3.63 (95 %CI 1.07–12.36)] p = 0.039). Additionally, patients having a UBC preoperative showed 4.5 times higher odds for mortality in comparison to patients who did not [4.50 (95 %CI 1.33–15.25)] (p = 0.016). An increase of 1 kg/m2 in BMI, however, independently correlates with a 13 % decrease in relative odds of mortality [0.87 (95 %CI 0.75–0.99)] (p = 0.049). At the same time, older age, higher ASA-score, post-operative non weight bearing, and pre-existent dementia were shown not to be independent predictors for one-year mortality.

Table 6: Predictors of one-year mortality after PPFFs

	Adjusted Odds Ratio (95%CI)	**P-value**
BMI (kg/m^2)	0.87 (0.75 – 1.00)	0.049*
Place of residence		
Own home (reference)		0.075
Nursing home	4.13 (1.20 – 14.25)	0.025*
Residential home	1.03 (0.08 – 13.62)	0.982
Preexistent mobility status		
Independent (reference)		0.081
Walking aid	3.63 (1.07 – 12.36)	0.039*
Use of a stick	5.07 (0.70 – 36.86)	0.109
Preoperative UBC	4.50 (1.33 - 15.25)	0.016*
Initial stem fixation		
Cemented stem (reference)		
Uncemented stem	4.08 (1.25 – 13.35)	0.020*

BMI, Body Mass Index; UBC, Urinary Bladder Catheter.
* Statistically significant value of p<0.05

IV DISCUSSION

This single-center retrospective cohort study aimed to provide insights into the frail patient population requiring surgical treatment for PPFF around HA and to identify risk factors for one-year mortality. The median age was 83 years, and most patients were classified as ASA-score III, indicating severe comorbidities, consistent with previous research[16,19-20]. Independent predictors for one-year mortality included initial uncemented stem fixation, preoperative UBC use, walking aid dependence, nursing home residency, and low BMI (<25.6 kg/m2).

This study did not identify older age, higher ASA-score, post-operative non weight bearing, or pre-existent dementia as independent predictors of one-year mortality, contrasting with prior studies suggesting these factors, along with male sex, as significant predictors in PPFF management[16,17,21–23]. Similarly, Khassawna et al. also found no association between ASA-score (III/IV vs I/II) and mortality, aligning with our findings[19]. Surgical delay has been debated as a predictor. Bhattacharyya et al. reported that delays beyond two days significantly increased one-year mortality in PPFFs around THA[12]. However, Finlayson et al. found no correlation between delays exceeding 48 h and mortality in PPFF around HA, consistent with our results[16]. The discrepancies in the literature may stem from small sample sizes and low statistical power. This study utilized a robust database and multivariable analysis accounting for data dependencies, which were often unaddressed in prior research. Therefore, our findings offer a reliable perspective on mortality predictors in PPFF management.

In the current study we observed a one-year mortality rate of 16.6 %, slightly higher than in previous reports (10.7 %–13.2 %)[12,16,19,21-22]. An increase of 1 kg/m2 in BMI was associated with a 13 % reduction in relative odds of mortality, aligning with Drew et al., who found a significant link between low BMI (<25 kg/m2) and increased mortality[21]. However, other studies found no correlation, likely due to small sample sizes and unequal BMI subgroup distributions[20,22]. By adjusting for factors like age and ASA-score, our analysis provides a clear understanding of BMI's role. Research on elderly hip fracture patients supports our findings, indicating that a BMI of 25.0–29.9 kg/m2 significantly reduces one-year mortality risk[24].

Patients with uncemented stem fixation had a fourfold higher risk for one-year mortality than those with cemented stem fixation. Previous studies reported no significant correlation between stem fixation method and mortality[19,22]. This discrepancy may be due to the higher incidence of PPFF around uncemented stems and differences in surgical management. Vancouver B2 fractures involving uncemented stems often require stem revision due to compromised fixation, whereas fractures around cemented stems can sometimes be treated with ORIF, depending on cement integrity. In this study, stem revision was more common in uncemented stems (n = 51) than cemented stems (n = 11). Revision procedures, linked to longer operative time, greater blood loss and higher physiological stress, may contribute to increased complications and mortality. Additionally, uncemented stems are typically used in younger, more active patients, but PPFF in this group may indicate poor bone quality, leading to severe fractures and complex surgeries. Conversely, cemented stems, often chosen for older, frailer patients, provide immediate stability and may lower early postoperative risks. While prior research has not consistently found a mortality difference based on fixation type, our findings underscore the need for further investigation into surgical management and patient outcomes.

Patients residing in nursing homes and those who used a walking aid for mobility prior to treatment were at higher risk of one-year mortality. This outcome corresponds to the findings of Nassar et al., who also found a significant difference in these variables in the univariate analyses between survivors and non-survivors[22]. These results are inconclusive as it is not clear if these variables were accounted for in the multivariable analyses in their study.

Preoperative UBC use was associated with a four and a half fold increase in mortality risk. To our knowledge, no prior research has examined this variable, preventing direct comparison with other studies. Previous studies on UBC use in hip fracture surgery patients has linked indwelling catheters to higher rates of urinary tract infections (UTI) and postoperative urine retention (POUR), which may increase the risk of chronic renal insufficiency and urosepsis[25–27]. these complications could contribute to the elevated mortality observed in patients with preoperative UBC use.

Our study found that one-year mortality was influenced by patient-related factors (preoperative UBC and low BMI) rather than fracture-, implant- or surgery-related factors. While variables like BMI, use of a walking aid, initial uncemented stem fixation and residency in a nursing home by admission are non-modifiable, they help identify high-risk patients requiring closer in-hospital management. Preoperative UBC, however, is modifiable, and intermittent catheterization or early removal of indwelling catheters may reduce UTI and POUR risks, potentially improving outcomes[25]. However, further research is needed for definitive recommendations.

Univariate analyses identified a ‘no-weight-bearing’ protocol as potential predictor of one-year mortality. Despite adjustment in multivariable analysis, early weight-bearing should be prioritized unless contraindicated. Immobilization increases the risk of complications such as pressure ulcers, UTIs, pneumonia and delirium. Weight-bearing as tolerated promotes bone healing, independence, and shorter hospital stays. Early mobilization is therefore recommended post-surgery.

Furthermore, the present study did not investigate the pre-operative nutritional status of the included patients. Seeing as lower BMI has shown to be an independent predictor of mortality and the population is described to be frail and of older age, it might be interesting for future research on this topic to assess nutritional status, start with protein-enriched diet and see its effect on the rehabilitation process and mortality rates.

The study population, characterized by old age and high ASA-scores, aligns with research on proximal femoral fractures; an extremely vulnerable population[28]. Prior studies have recommended optimizing in-hospital care, including delirium prevention, early geriatric consultation, minimal surgical delay and rapid mobilization[29]. Given the similarities, these strategies should also be integrated into PPFF treatment guidelines.

A strength of this study is its large patient population from a high-volume trauma center, making it one of the first to examine mortality predictors in PPFF around HA. However, limitations include potential confounding due to its retrospective design, missing data on in-hospital management, and grouping of complications without assessing severity.

This retrospective study highlights the frailty of PPFF patients after HA, characterized by old age and poor health (ASA-score III). Independent predictors of one-year mortality include low BMI, preoperative UBC, nursing home residency, walking aid use, and uncemented stem fixation. Further research with larger cohorts is needed to refine clinical guidelines and optimize perioperative management.

V LEARNING POINTS AND CLINICAL INFERENCES

- Patient frailty and risk factors for mortality
    - This study highlights that patients with PPFF around HA are generally frail, with a median age of 83 years and a high prevalence of comorbidities (ASA-score III).
    - Clinical Inference: Identifying high-risk patients (e.g., those in nursing homes, those who use walking aids, and those with a low BMI) allows for targeted perioperative strategies to improve outcomes.
- Preoperative UBC and mortality
    - Patients with preoperative UBC had a four and a half fold higher risk of one-year mortality, potentially due to complications like UTI and sepsis.
    - Clinical Inference: Avoiding prolonged catheter use and implementing early removal strategies can help reduce postoperative complications and improve survival.

- Weight-bearing and early mobilization
  - A ‘no-weight-bearing’ postoperative protocol was associated with increased mortality risk. Encouraging early mobilization can reduce complications like pressure ulcers, pneumonia, and delirium.
  - Clinical Inference: Implementing weight-bearing as tolerated or PWB protocols should be a priority in postoperative care to enhance recovery and reduce hospital stay.
- Nutritional status and BMI as predictors of survival
  - A lower BMI (<25.6 kg/m2) was an independent predictor of increased mortality, with each 1 kg/m2 increase reducing mortality risk by 13 %.
  - Clinical Inference: Preoperative nutritional assessment and interventions, such as protein-enriched diets, should be considered to optimize patient resilience and rehabilitation outcomes.
- Uncemented stem fixation increases mortality risk
  - Patients with initial uncemented stem fixation had a four times higher risk of one-year mortality compared to cemented stem fixation.
  - Clinical Inference: Surgeons may need to reconsider implant selection, particularly in frail elderly patients, to reduce long-term complications and mortality risks.

APPENDIX I: OVERVIEW OF VARIABLES INCLUDED IN THE DATABASE

Patient demographics	**Fracture and implant characteristics**	**Fracture and implant management**	**In-hospital patient management**	**Other**
Sex	Initial intervention	Revision treatment	Time hospitalization till surgery	Difference discharge location from initial place of residence
Age	Date of initial intervention	Revision surgeon	Preoperative DOS-score	Frequent falls before surgery
Zipcode	Date of PPFF	Revision surgical assistant	Preoperative pain-score	Recurrence of falls
Length	Time initial surgery till fracture	Revision surgical approach	Preoperative UBC	Osteoporosis screening done
Weight	Mechanism of trauma	Type of anesthetics used	Geriatrics in consultation	Time till union fracture
BMI	Fracture side	Use of regional anesthetics blocks	Dietetics in consultation	Limitations in mobility after surgery
Place of residence	Vancouver class	Surgery time	Blood transfusion	Other limitations after surgery
ASA	Initial surgical approach	Perioperative use of TXA	Hb decrease	Definite change in place of residence
Preexistent mobility status	Initial implant type	Blood loss	Re-transfusion	Date of death
Preexistent dementia	Initial surgeon	Use of cell saver	Postoperative Dos-score	Consultations postoperative and reason
Osteoporosis yes/no	Initial surgical assistant	Type of implant	Postoperative pain score	Follow-up
Initial diagnosis		Additional use of osteosynthesis material	Postoperative UBC	
Mortality 90-days		Method of wound closure	Number of days wound leakage	
Mortality one-year		Postoperative load bearing protocol	Days till first mobilization	
			Complications postoperative	
			Complications after 90-days	
			Hospital discharge after surgery	

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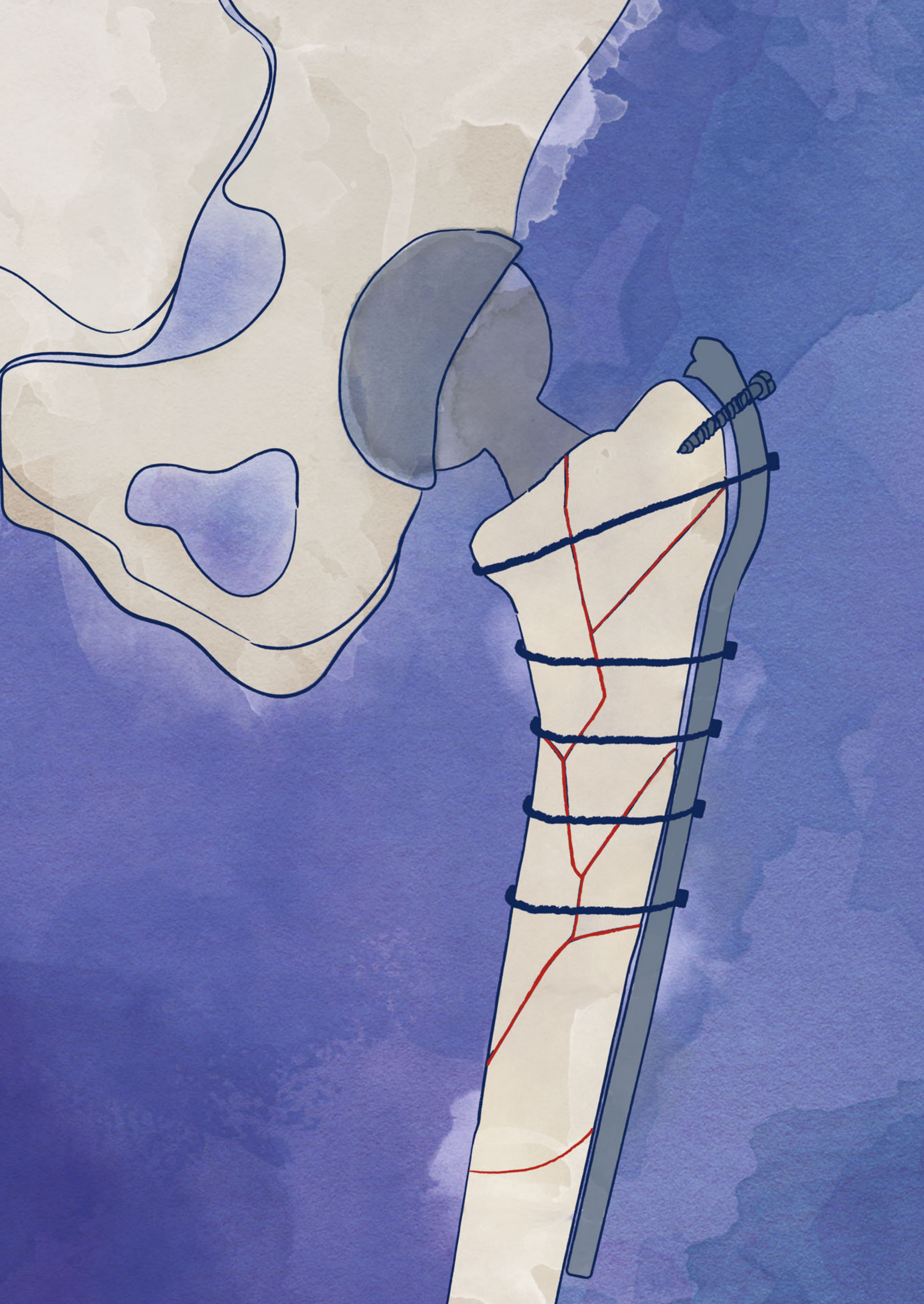

Chapter VI

Zuyderland Hip Inference for Survival and Lifetime Expectancy (ZHISLE) Following Hip Fracture Surgery: Validation of the Model that Demonstrated Good Predictive Power

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ABSTRACT

Purpose

Proximal femoral fractures are common within the elderly population and are associated with a high risk of mortality and reduced quality of life. Hemiarthroplasty or osteosynthesis (extramedullary or intramedullary) is the primary treatment option for these fractures. However, within this fragile patient population many comorbidities, among others dementia, are seen. Therefore, predicting patients with a high mortality risk after surgery may lead to adopting alternative treatment options with less risks. This paper proposes a new model to distinguish patients with high postoperative mortality risk with adequate follow-up time in combination with a wide set of useful and available variables.

Methods

Patients treated with hemiarthroplasty or osteosynthesis for proximal femoral fractures were studied, with a follow-up period of 6 months. Patients who died within this follow-up period were compared to survivors, and predicting variables were assessed in logistic regression: The Zuyderland Hip Inference for Survival and Lifetime Expectancy (ZHISLE). The model was validated internally against a held-out dataset. Furthermore, the model performance was compared against the Almelo Hip Fracture Score (AHFS) on the same sample.

Results

Out of 2463 patients undergoing surgical treatment for proximal femoral fractures, 415 (16.8%) died within 183 days. Predictors for early mortality included old age, male sex, high heartbeat, KATZ-ADL and GFI scores, C-reactive protein and urea concentrations and low albumin concentration. Our model showed satisfactory predictive and discriminatory power (ROC curve = 0.81). Internal validation was good (ROC in validation dataset = 0.81), and better than the AHFS (ROC = 0.57).

Conclusions

The ZHISLE model demonstrates good predictive power concerning mortality risk for old patients with a proximal femoral fracture. The model could benefit patients by indicating if a conservative, non-invasive policy might be a better option for those patients.

Keywords

Frail elderly, hip fracture surgery, mortality, orthogeriatric surgery, patient-reported outcome measures, proximal femoral fractures, quality of life, risk prediction

I INTRODUCTION

Proximal femoral fractures are a significant health risk in the elderly population, increasing mortality and reducing quality of life for an extended period[1-3]. Due to aging of the population, the number of femoral neck fractures is only expected to increase[4-5]. The standard treatment options for proximal femoral fractures are hemiarthroplasty or osteosyntheses (intramedullary or extramedullary) dependent on the specific type of hip fracture. These treatment options are major surgeries with a long recovery period, especially for old, fragile and vulnerable patients. Even when surgery is successful, a significant portion of the operatively treated patients dies within a short (30-day) period due to complications or other underlying health conditions. Therefore, recent literature suggests that nonoperative management of proximal femoral fractures is a viable option for vulnerable patients with a limited life expectancy[2].

Being able to predict the outcome of treatment and identify patients at risk for poor outcomes, e.g. mortality and poor quality of life, would allow evidence-based choices for 1 or the other treatment. However, it can be hard to identify patients at risk for early postoperative mortality, as many underlying factors influence the mortality probability. Several models have been developed to assess the early risk mortality for these patients and show promising results[6-7]. Currently, the Almelo Hip Fracture Score (AHFS)[6] shows good discriminatory power, and the results have been validated externally[8]. However, the follow-up period used is relatively short (30 days) and more useful variables could be added to the model[8].

This study proposes a new model to identify patients preoperatively with a potential higher postoperative mortality risk; the Zuyderland Hip Inference for Survival and Lifetime Expectancy (ZHISLE). For this model, a longer follow-up period of 183 days (half a year) and more variables are considered, including comorbidities, blood metabolite concentration, demographic information and vital values.

II PATIENTS AND METHODS

This study was a retrospective investigation of patients who were surgically treated with hemiarthroplasty or osteosynthesis in case of a proximal femoral fracture by the Multidisciplinary Trauma Unit in Zuyderland Medical Center locations Heerlen and Sittard-Geleen between 01 January 2018 and 30 June 2022. Patients were included if full outcome information of the follow-up period (deceased or follow-up completed) was available. The follow-up period was set at 183 days, because deaths after this period are less likely to be related to the surgery and the recovery period after surgery is aligned with this interval[9].

Patients with non-Dutch nationality were excluded from the study, because we did not have certainty on the mortality status of these patients (Dutch Personal Records Database may not apply or may not be complete). Furthermore, patients with 5 or more missing variables were excluded from the study as well.

Data were abstracted from electronic medical records and include demographic information (age, sex assigned at birth), blood values (urea, creatinine, alkaline phosphatase, albumin, C-reactive protein, serum haemoglobin), vital parameters measured pre-surgery (heartbeat, body temperature, blood pressure, saturation), medical history (comorbidities: cardiovascular disease, ICD-10: I20–I52; cerebrovascular disease, ICD-10: I60–I69; diabetes, ICD-10: E10–E14; chronic respiratory disease, ICD-10: J40–J47; renal disease, ICD-10: N00–N19; malignancy, ICD-10: C00–C97)[10] and aggregated medical scores: American Society of Anesthesiologists physical status classification [ASA score][11], Katz Index of Independence in Activities of Daily Living [KATZ-ADL score][12], Modified Early Warning Indicator [MEWS][13], Groninger Frailty Indicator score [GFI score][14] and delirium risk, all measured pre-surgery.

As primary model a multivariate logistic regression using all available variables as predictors is considered to estimate the relation between independent, predicting variables and the dependent outcome, i.e., mortality. As alternative methods, a XGBoost model[15], a penalised regression and support vector machine are fitted[16-17], using a cross-validation procedure to determine the hyperparameters of these models[18]. These models included all assessed variables as predictors. The predictive value of our model was assessed using the area under the curve (AUC) of the receiver operating characteristic (ROC) curve, positive and negative predictive value (PPV and NPV), sensitivity and specificity. Furthermore, interpretability and stability are considered relevant factors to use the model in a clinical setting.

In sensitivity analysis, we considered only significant predicting variables to minimise the risk for collinearity and improve simplicity. The models are compared based on predictive values and stability. A random, stratified sampled subset of the study population (33%) is used for internal validation and is therefore not used in the statistical analysis and model estimation. For this agnostic dataset, we tested the predictive ability of our model.

Lastly, we compared the predictive ability of our model to the AHFS[6]. The AHFS is calculated for all samples in the internal validation set. The follow-up period for both models is not the same, so the comparison is made on both a 30-day and 6-month follow-up period. It should be noted that 2 variables required for the AHFS model are not recorded in our dataset: cognitive frailty and the Parker Mobility Score (PMS). However, the GFI score can serve as proxy for cognitive frailty and KATZ-ADL score is used as a proxy for PMS.

Missing data were handled by imputing the median value for numeric variables and the most frequent value for categorical observations.

All model estimations and data analysis are implemented in Python 3.8 using the scikit-learn library[19].

III RESULTS

III.I Cohort description

The total study population contains 2463 patients, of which 415 (16.8%) individuals died within 183 days post-surgery (Table 1). The patient population had a median age of 82 years and was predominantly female (65%).

Table 1: Variable characteristics

	Total		Early mortality (n = 415)		Survival (n = 2048)		P-value
Albumine (g/l)	40	37.4-42.3	38	34.9-40.2	40.4	38.1-42.5	<0.001
C-Reactive Protein (mg/l)	4	1-19	11	3-43	3	1-15	<0.001
Serum Hemoglobin (mmol/l)	7.8	7.1-8.5	7.4	6.7-8.2	7.9	7.2-8.5	<0.001
Serum Hemoglobin ≥ 6.21 mmol/l	2244	91.1	345	83.1	1899	92.7	<0.001
Creatinine (μmol/l)	75	61-96	84	65-116	74	60-93	<0.001
Urea (mmol/l)	6.8	5.3-9.0	8.4	6.2-11.3	6.6	5.2-8.6	<0.001
Alkaline Phosphatase ≥ 150 U/l	125	5.1	51	12.3	74	3.6	<0.001
36.5 ≤ Body temperature (°C) ≤ 38.5	2091	84.9	353	85.1	1738	84.9	0.92
Oxygen supplied	2254	91.5	385	92.8	1869	91.3	0.29
ASA Score	3	2-3	3	2-3	3	2-3	0.51
Katz-ADL Score	1	0-3	3	1-5	1	0-3	<0.001
GFI Score	3	1-5	5	3-7	2	1-5	<0.001
Heartbeat (beats/minute)	79	70-89	81	72-91	78	70-88	0.001
Delirium risk	801	33.7	215	53.9	586	29.6	<0.001
Diabetes	131	5.3	36	8.7	95	4.6	0.006
Cardiovascular disease	558	22.7	143	34.5	415	20.3	<0.001
Respiratory disease	168	6.8	39	9.4	129	6.3	0.04
Cerebrovascular disease	166	6.7	37	8.9	129	6.3	0.08
Renal disease	113	4.6	35	8.4	78	3.8	0.001
Malignancy	384	15.6	96	23.1	288	14.1	<0.001
Dementia	102	4.1	28	6.7	74	3.6	0.02
Number of comorbidities ≥ 2	228	9.3	68	16.4	160	7.8	<0.001

Table 1: Continued

	Total		Early mortality (n = 415)		Survival (n = 2048)		P-value
Male sex	870	35.3	177	42.7	693	33.8	<0.001
Not living at home	407	16.5	120	28.9	287	14	<0.001
Age (years)	82	73-88	87	80-91	81	72-87	<0.001

Data are presented as median (IQR), or as frequency (n (%)). P-value refers to the unpaired comparison between patients in the early mortality- and survival-group.

Patients in the early mortality group were on average older, had more underlying diseases and were less likely to live at home at the time of admission. Significant differences were also observed for patient-reported outcome measures (PROMs) and labs, but not on vitals (Table 1).

III.II Model development

The primary, full model was developed using 1724 patients, of which 290 patients did not survive the follow-up period of 6 months. This model was fitted as multinominal logistic regression and showed a good fit to the data and predictability of mortality. Significant predictors of mortality in this model were old age, male sex, high heartbeat, KATZ-ADL and GFI scores, C-reactive protein and urea concentrations and low albumin concentration (Table 2).

Table 2: Mortality prediction

Predictor	β	P-value
Constant	-0.054	0.96
Katz-ADL Score	0.085	0.08
C-Reactive Protein (mg/l)	0.003	0.07
GFI Score	0.135	< 0.001
Heartbeat (beats/minute)	0.009	0.07
Urea (mmol/l)	0.084	< 0.001
Albumine (g/l)	-0.165	< 0.001
Age (years)	0.030	< 0.001
Male sex	0.477	0.002

Data are presented as coefficients (and significance) of multivariate logistic regression model, with 6-month mortality as dependent outcome variable.

As alternative models, a XGBoost model, a penalised regression and a support vector machine were fitted on the same patient population.

III.III Internal validation

The model is internally validated on 739 patients, of which 125 patients did not survive the follow-up period. These patients were left out of the model estimation phase.

The simplest model in terms of interpretability, the multivariate logistic regression, is not outperformed by the other models in terms of stability and predictive power. The PPV is 0.54 for the multivariate logistic regression, 0.40 for the XGBoost model, 0.58 for the penalised regression and 0.34 for the support vector machine. The NPV is 0.86 for the multivariate logistic regression, 0.88 for the XGBoost model, 0.86 for the penalised regression and 0.95 for the support vector machine. The sensitivity is 0.22 for the multivariate logistic regression, 0.41 for the XGBoost model, 0.24 for the penalised regression and 0.82 for the support vector machine. The specificity is 0.96 for the multivariate logistic regression, 0.87 for the XGBoost model, 0.96 for the penalised regression and 0.68 for the support vector machine.

The area under the ROC curve is 0.82 for the logistic model versus 0.74 for the XGBoost model, 0.82 for the penalised regression and 0.80 for the support vector machine. Penalised regression is in fact a way to do model estimation and variable selection in 1, so it is only natural that the results for these models are very similar.

It should be noted that the predictive power for XGBoost fluctuates significantly over different runs (due to randomisation in the model algorithm) and never outperforms the predictive power of the logistic model.

III.IV Reduced model

In sensitivity analysis, we included only variables with predictive value ($p < 0.2$). The sparse model represents a PPV of 0.48, a NPV of 0.85 a sensitivity of 0.16 and a specificity of 0.96. The area under the ROC curve was 0.81.

III.V Comparison with AHFS

The comparison indicates that our model outperforms the AHFS when the follow-up period is 6 months (area under the ROC is 0.81 vs. 0.60) (Figure 1) and the results are similar when the follow-up period of the ZHISLE model is aligned to the 30-day follow-up period used in AHFS (0.82 for the ZHISLE model, 0.82 for AHFS).

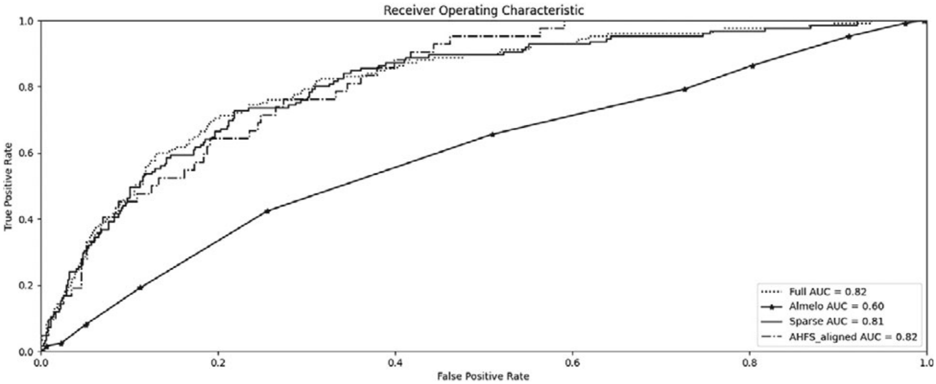

Figure 1: Prediction model performance

IV DISCUSSION

This prospective study greatly illustrates that with a small set of variables it is possible to develop a robust model with excellent performance and which is easy to use in clinical practice. This model can be very easily used in the shared decision-making process. Multiple independent risk factors for early postoperative mortality after proximal femoral fracture surgery are defined. A sparse model with KATZ-ADL and GFI score, heartbeat, C-reactive protein, urea, albumin, age and sex as variables shows adequate predictive values to be used in a clinical setting. Additionally, the area under the ROC curve demonstrates an excellent discriminatory power between both groups for this risk model. These variables are easily measurable without a high burden for the patient and therefore this model can be used at admission. The advantage of a logistic regression over some of the other methods considered is its interpretability, which might indicate clinical guidelines and marginal effects on the treatment of the patient. The overall model performance does not suffer from the choice for simplicity.

As already mentioned earlier, with the aging population, the incidence of proximal femoral fractures is increasing[4-5]. These patients are fragile with most of the time various underlying comorbidities. Therefore, also health costs are increasing. This leads to the point that careful consideration for each individual patient is needed to determine the best treatment option. In the past, almost every proximal femoral fracture patient was treated surgically. The last years there is an increasing interest in the critical question whether surgery is the best treatment option for some of these fragile patients. This topic is also described in the FRAIL-HIP study[2]. In their paper the authors describe that conservative treatment for hip fractures is a viable option in patients with limited life expectancy and that these patients do not compromise on quality of life.

This same FRAIL-HIP study also suggests that pain in the nonoperative management group was undertreated and was a factor in end-of-life care that should be improved. Recent advancements in this field have been made with the introduction of pericapsular nerve group (PENG) blocks[20–22]. Using this technique, chemical hip denervation can be achieved, with effects lasting up to 6 months[23]. This makes it a potential valuable part of the treatment options for patients with hip fractures. In order to provide the right care for the right patients, it is essential to identify patients with high, intermediate and low risk of mortality within 6 months after suffering the hip fracture.

To determine what is the best treatment option there needs to be a multidisciplinary approach specific to each patient. To help with this decision making the ZHISLE model was made. Identifying patients with a high mortality risk a priori could improve overall quality of life outcome for this patient group. It adds value to the shared decision-making discussion because it will provide information about the specific patient and about the prognosis on mortality after surgery. Furthermore, it can identify factors that could indicate further optimisation of the patient condition pre-surgery.

Compared to the AHFS model, the ZHISLE model considers a longer follow-up period and a wider set of variables for the model. The longer follow-up period (6 months) is more practical in a clinical setting in which treatment methods and the post-surgery quality of life are considered.

The comparison between the AHFS and the ZHISLE model is not perfect, as certain indicators (cognitive frailty and PMS) for the AHFS model are missing in our sample and the follow-up periods do not coincide. Proxies for the variables that are missing are used to estimate the AHFS as well. Although the follow-up period is not perfectly aligned, the ROC curve indicates that the discriminatory power of the ZHISLE model is better or equal, even if only a 30-day follow-up period is considered for the ZHISLE model.

The internal validation demonstrates that the model scores from our validation group are similar to the model scores found in the training group. Hence, it can be concluded the model does not suffer from overfitting and the model performs well on internally validated data. Therefore, it can be concluded that the model would generalise well to different cases. However, our model has been developed on a population specific to the region of our hospital. This means the model is at risk to bias the results towards similar patients as in our population group.

Unfortunately, missing observations are part of our sample. In some cases, for either practical or administrative reasons, variables are not recorded. Furthermore, there are certain limitations to the registration of underlying diseases, as underlying diseases can only be observed given the patient's history in our hospital. However, as the number of missing values is limited and they occur at random, it is decided to keep these observations in our data if the number of missing variables is < 5 for each individual. Prior to fitting the model, these missing values are replaced with the median value (continuous variables) or with the most frequent value (categorical variables). In addition, a limitation of our study is that the ZHISLE model was developed using data from a single hospital, which may introduce biases due to regional differences in healthcare practices, patient demographics, and access to care. These factors could limit the model's generalisability to other populations. To enhance its applicability, external validation is essential. Testing the model on independent datasets from different populations would assess its performance and predictive accuracy across diverse settings. If discrepancies are found, recalibration or adaptation may be necessary to account for regional or demographic variations. We recommend conducting multi-centre and international studies to further validate the model and ensure its broader applicability. Collaborative efforts would help refine the model, making it more relevant and effective in diverse clinical contexts.

In conclusion, the ZHISLE model uses all relevant variables to generate excellent clinical performance as a result of which it can be easily used in the clinical decision-making process. We would recommend further research into this field to validate the results from this paper in different populations.

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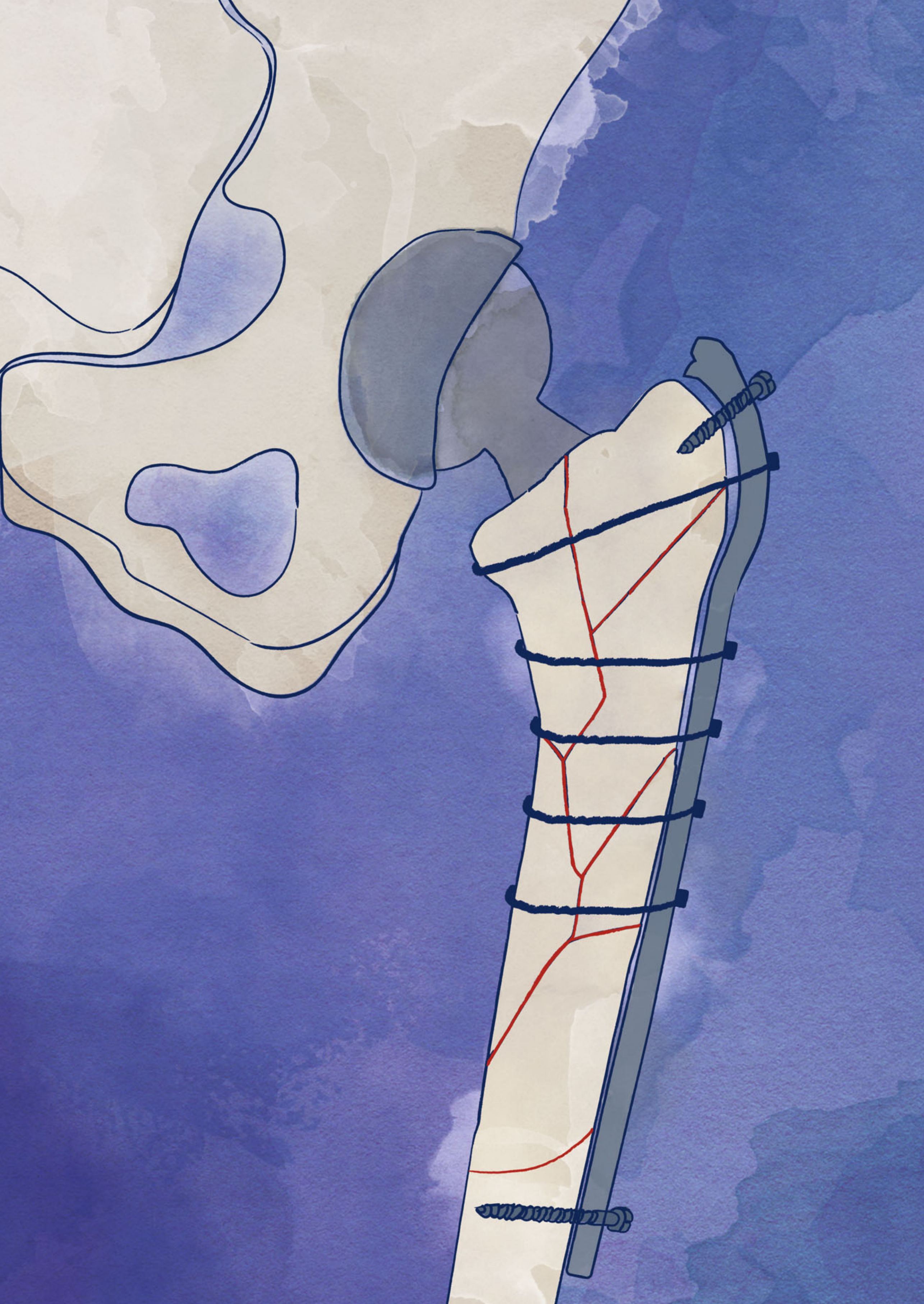
VI

Part 3

Summary, discussion and impact



Chapter VII

Summary, general discussion and future perspectives

OBJECTIVES, MAIN FINDINGS AND FUTURE PERSPECTIVES

This thesis aimed to address several clinically relevant questions in the management of periprosthetic femoral fractures (PPFF), it focused on postoperative weight bearing strategies, particularly permissive weight bearing (PWB), identified risk factors for adverse outcomes focused on mortality, and explored individualized treatment decision-making in frail orthopedic trauma patients utilizing the Zuyderland Hip Inference for Survival and Lifetime Expectancy (ZHISLE) model.

In the first part of this thesis, we explored postoperative care pathways for PPFF, with a particular emphasis on weight bearing protocols. The central research questions focused on the current clinical practices regarding postoperative weight bearing instructions in the Netherlands and the role of PWB as a strategy to facilitate early mobilization while minimizing the risk of complications. Early mobilization is crucial to prevent the physiological decline commonly observed in this vulnerable patient population. This thesis further highlighted the clinical vulnerability of the PPFF population. Using nationwide registry data, key risk factors for stem revision following PPFF were identified. Additionally, important predictors associated with one-year mortality following surgical treatment for PPFF around hip arthroplasty (HA) were also identified using our own retrospective database. These findings reinforce the importance for personalized implant selection and careful perioperative planning.

Building upon this foundation, the thesis expanded its scope to include patients with proximal femoral fractures (PFF), a population that shares many characteristics with those suffering PPFF, namely advanced age, frailty, multiple comorbidities, and high perioperative risk. Traditionally, surgical intervention for PFF has been the default treatment approach for these patients. However, our findings, supported by the emerging literature, suggest that this ‘always operate’ paradigm may not suit all individuals, particularly those with limited physiological reserve and reduced life expectancy. This insight prompted the development of the ZHISLE model, designed to support personalized decision-making by identifying patients at high risk of mortality within six months following hip fracture surgery. In doing so, this thesis contributes to the shift toward more nuanced, individualized trauma-orthopedic care, personalizing treatment strategies not only according to fracture type but also on patient-specific factors such as frailty, comorbidities, and survival prospects.

Orthogeriatric challenges; postoperative mobilization

Chapter II presents a national survey which explored the current postoperative load-bearing strategies utilized by Dutch orthopedic surgeons in the management of PPFF around HA, with a particular focus on the implementation of PWB. The results demonstrated considerable variability in postoperative protocols across Vancouver fracture types, highlighting the absence of a national consensus or standardized guidelines. While PWB was not commonly the first-line recommendation, particular in Vancouver A, B1, and C fractures with good fixation and patients able to comply with instructions, it was more frequently advised in complex revision cases (e.g., Vancouver B2 with stem revision) and case-specific scenarios. Interestingly, fellows and high-volume surgeons were significantly more likely to prescribe PWB, possibly reflecting greater familiarity with newer protocols and increased confidence in managing PPFF. These findings align with prior literature suggesting that PWB is a safe and effective postoperative strategy for various lower extremity fractures, promoting earlier mobilization and reduced length of hospital stays without increasing complication rates[1-4]. Despite growing evidence supporting early mobilization and successful PWB outcomes in similar contexts, the application of PWB in PPFF remains cautious and inconsistent. This is in line with challenges encountered in other field of orthopedic and trauma care, such as the adoption of post-surgical care pathways including weight bearing protocols in lower extremity fractures. Despite the supporting benefits of early weight bearing, the adoption of more liberal weight bearing strategies, like PWB, was initially slow within lower extremity fractures as well, often due to a lack of consensus among surgeons and hesitancy regarding the safety and feasibility of such protocols. However, once protocols were developed a wider adoption was facilitated. This suggests that more robust evidence in the form of clinical trials could accelerate the acceptance of PWB in PPFF management. It underscores the urgent need for further prospective studies to evaluate the clinical outcomes of PWB specifically in PPFF patients. Developing more standardized postoperative protocols based on such evidence could enhance functional recovery, reduced healthcare costs, and promote more uniform care delivery in this increasingly prevalent and high-risk patient population[5-6]. The variability in practice underscores the importance of promoting awareness and knowledge-sharing across the orthopedic community. The challenge of PWB adoption in PPFF, like in other clinical pathways, is not just about evidence, but about changing entrenched clinical practice and behaviors.

The systematic scoping review, as presented in *Chapter III*, investigated the current literature on postoperative weight bearing protocols in patients with surgically treated late PPFF around total hip arthroplasty (THA), with a specific focus on the role and implementation of PWB. Despite an extensive search across five major medical databases yielding over 12,000 records, only seven studies involving 22 patients met the inclusion criteria, and none employed or evaluated PWB as a postoperative strategy. Most included studies adhered to traditional non weight bearing (NWB)[7] or restricted weight bearing (RWB)[7-12] protocols, with limited consistency in terminology and outcome reporting. The review highlights a significant gap in the literature: although PWB has demonstrated promising results in other lower extremity fractures, enhancing early mobilization, potentially shortening hospital stays, reducing complications such as pneumonia and delirium, its application in late PPFF after THA remains unreported and unexplored[1-4]. Furthermore, the lack of standardized definitions and inconsistent documentation of postoperative regimens hinder meaningful comparisons across studies. These findings underscore the need for prospective clinical research to evaluate the feasibility, safety and effectiveness of PWB in this high-risk patient population. To make PWB a successful strategy in PPFF management, several stakeholders within the healthcare chain must be involved. Surgeons alone cannot implement such a strategy effectively it requires the support and commitment of a broader team, also including physiotherapists, nurses, geriatricians and rehabilitation specialists. Training programs to enhance familiarity with PWB protocols across the entire care continuum are essential. Standardization of PWB strategies across hospitals and healthcare networks, possibly through national or regional consensus protocols, could help integrate this innovative approach into routine care.

Orthogeriatric challenges; risk-factors for PPFF and mortality

To determine the incidence and risk factors for stem revision due to PPFF our nationwide, registry-based study, as presented in *Chapter IV*, analyzed over 330,000 primary THA. While the overall incidence of stem revisions for PPFF was relatively low, 0.7% at 10 years, the analysis revealed several important patient- and surgery related risk factors. Advanced age, female sex, high American Society of Anesthesiologists physical status classification (ASA) physical status classification, elevated Body Mass Index (BMI), and a higher Charnley score were all independently associated with an increased risk of stem revision. These findings underscore the multifactorial vulnerability of elderly and frail patients. Among surgical factors, the use of uncemented stems was the most significant independent risk factor for revision, with a hazard ratio exceeding seven, suggesting a strong association between stem fixation method and postoperative fracture risk. Additionally, the anterior approach was associated with a higher risk in univariable analysis. However, this may be confounded by its frequent use in combination with uncemented implants. These findings reinforce existing literature[13-18] which suggests that biological fixation in elderly patients may increase fracture susceptibility to PPFF, due to stress shielding and compromised bone quality[19-20]. The study also highlights the importance of surgical technique and implant alignment, particularly with anterior approaches, as highlighted in previous research[21-22]. These techniques may predispose the proximal femur to localized stress concentrations, increasing the fracture risk[23-24]. Clinically, the results support a more selective approach to implant fixation, advocating for the use of cemented stems in patients with poor bone quality or increased frailty. This underscores the importance of not only technical features such as implant selection and surgical technique, but also broader considerations related to patient management and care pathways. In this context, it is essential to consider how the management of PPFF aligns with existing models used in other high-risk populations with fragility fractures. The parallels drawn between PPFF and fragility fractures suggest that a multidisciplinary approach to care, already well established in the management of hip fractures, may also improve outcomes for PPFF patients management[25-27]. Such an approach typically involves collaboration between orthopedic surgeons, anesthesiologist, geriatrics specialist and rehabilitation teams to tailor treatment strategies based on individual patient profiles, particularly for those who are elderly or frail. These models aim to optimize both the surgical intervention and the perioperative care, enhancing recovery, minimizing the physiological decline and eventually reducing morbidity and mortality. As is the case with fragility fractures, the adoption of personalized approaches to PPFF treatment will require the active involvement of multiple stakeholders across the healthcare system. Supported by training programs and standardized clinical pathways it ensures that the PPFF patient receives the most appropriate care at every stage of the process. Establishing clear network agreements between hospitals to promote evidence-based practices is crucial in ensuring that treatment strategies are applied consistently, ultimately leading to better outcomes for these vulnerable patients.

Resulting in a clear need to explore strategies to personalize implant selection and perioperative management for at-risk individuals and further investigate long-term functional outcomes following revision for PPFF. In addition, enhancements to joint replacements registries to include non-revision treatments such as osteosynthesis, which are currently underreported, would provide a more comprehensive understanding of the full spectrum of PPFF treatment and their associated perioperative management strategies.

The study, discussed in *Chapter V*, sheds light on the significant risk factors associated with one-year mortality following surgical treatment for PPFF around HA. With a one-year mortality rate of 16.6%, the study identified several independent predictors, such as low BMI, preoperative urinary bladder catheter (UBC) use, nursing home residency, walking aid dependence and the use of uncemented stem fixation. These findings underscore the frailty and complexity of the PPFF patient population, which often presents with multiple comorbidities and significant functional limitations[28-29]. Notably, factors commonly associated with poor outcomes, such as older age, higher ASA classification, pre-existing dementia, post-operative non weight bearing and male sex, did not emerge as independent predictors in the multivariable analysis. This contrasts with findings from previous studies[30-34]. This study also highlighted the potential impact of preoperative UBC use, a factor that has not been thoroughly explored in prior studies. The association between UBC use and increased mortality is concerning, as indwelling catheters are linked to higher rates of urinary tract infections and postoperative complications such as urinary retention, which may contribute to mortality[35-37]. These issues may contribute to poorer recovery and higher mortality, underscoring the need to re-evaluate perioperative management protocols. Uncemented stem fixation, identified as an independent risk factor, may reflect a combination of greater surgical complexity, poorer bone quality and higher patient frailty, all of which could contribute to poorer outcomes[19-20]. In contrast, cemented stems, can offer improved stability and facilitate earlier mobilization potentially contributing to better postoperative outcomes. These findings support a more cautious and individualized decision-making process regarding primary implant selection, particularly in vulnerable patients. Furthermore, these findings suggest that appropriate early weight bearing protocols, could be beneficial in reducing mortality risks. Although the multivariable analysis did not identify a direct association, the univariate analysis pointed to an NWB protocol as a potential risk factor for one-year mortality.

As orthopedic surgeons, our responsibility is not only to stabilize the fracture but also to ensure that early weight bearing, or even PWB, is made possible. This requires proper fixation, as well as careful planning around implant selection, surgical technique and rehabilitation. Early mobilization can mitigate risks such as pressure ulcers, pneumonia and delirium, all of which are common in immobilized patients[38-39]. These complications contribute to a longer hospital stay and increased mortality, further supporting the need for earlier mobilization strategies in PPFF treatment[40-41]. The findings emphasize the need for a more personalized approach to patient management, focusing on identifying high-risk individuals, such as those with low BMI, preoperative UBC use, and nursing home residency, who may require closer monitoring and targeted interventions. Subsequent research should consider the role of nutritional status, particularly the effect of a protein-enriched diet, which could support rehabilitation and potentially reduce mortality rates in this frail population. Moreover, further investigation into the impact of stem fixation type, particularly uncemented stems, could help refine surgical strategies to mitigate the higher mortality risks observed in these patients. This retrospective study provides valuable insights into the clinical factors influencing outcomes in PPFF surgery and emphasizes the importance of refining perioperative care. With an increasing elderly population undergoing hip arthroplasties, it is crucial to develop evidence-based guidelines that address the unique needs of patients sustaining PPFF. Research, ideally with larger cohorts and prospective data, will be essential to validate these findings and optimize treatment protocols to improve survival and quality of life in this high-risk population. However, we are not yet at the optimal level of care. There are several areas that still require attention and optimization. For instance the use of single-patient rooms, combined with the presence of a caregiver, could help reduce the risk of delirium, which is a major concern in this vulnerable population. On the softer side it is also essential to explicitly communicate the surgery goals to both the patient and their care team. While pain management is often a primary goal, we must also address the realistic expectations regarding postoperative mobility. Will the patient be able to walk again? If so, what kind of functional recovery can we expect? These discussions should begin as early as possible in the treatment process, allowing us to establish clear and personalized goals. Addressing there expectations early on has also implications for post-hospital care, including the potential need for rehabilitation, changes to the patient's living situations and the involvement of family or caregivers in the recovery process. The earlier we identify the goals, the better we can guide the patient through their recovery trajectory, ensuring a smoother transition from hospital to rehabilitation and eventually to home and thereby improving patient outcomes.

The ZHISLE model, developed and validated in the study presented in *Chapter VI*, offers a powerful and clinically applicable tool for predicting six-month mortality in elderly patients undergoing surgery for PFF. Using a carefully selected set of readily available preoperative variables, including age, sex, Katz Index of Independence in Activities of Daily Living (KATZ-ADL)[42] and Groninger Frailty Indicator score (GFI)[43] scores, vital signs like heart frequency, and key laboratory markers (C-reactive protein, albumin, urea), to achieve excellent discriminatory performance (ROC AUC = 0.81). Importantly, the model maintains simplicity and interpretability by utilizing multivariate logistic regression. This makes the model well-suited for use in shared decision-making at the point of care, especially when weighing surgical versus nonoperative treatment strategies. In line with the growing literature, including findings from the FRAIL-HIP study[44], these results support a more individualized approach. When compared to other well-established frailty and mortality prediction models, such as the FRAIL-HIP score, the ZHISLE model shows slightly better performance in terms of predictive accuracy. While existing models require more complex or less readily available data, the ZHISLE model maintains simplicity and interpretability, using only basic, easily accessible preoperative variables. This makes it particularly suited for shared decision-making, where clinicians need quick, actionable insights to inform surgical versus nonoperative treatment strategies. What the ZHISLE model adds to the existing body of literature is its focus on mortality within a six-month timeframe, providing a more granular prognosis specifically tailored for frail elderly patients undergoing hip fracture surgery. By identifying patients with limited life expectancy, the model enables clinicians to better target conservative, non-invasive treatment options, thereby avoiding unnecessary interventions that could increase the risk of complications[45-48].

Additionally, emerging pain management techniques such as pericapsular nerve group (PENG) blocks, capable of providing long-term analgesia, may further improve quality of life in these high-risk patients[45-48]. Although the internal validation of the model confirmed its stability and freedom from overfitting, there is still room for optimization. External validation across different regions and populations is crucial to further assess the model's generalizability and potential biases inherent in single-center studies. Additionally, refining the model by incorporating more dynamic variables, such as real-time physiological data or patient-reported outcomes during recovery, could enhance its predictive accuracy. There may also be value in integrating socio-environmental factors (e.g., social support, living conditions) to improve the model's ability to predict not just mortality, but also long-term functional outcomes. Future research should prioritize multicenter studies and prospective trials to refine the ZHISLE model and evaluate its broader impact on patient outcomes, resource allocation, and shared decision-making in orthogeriatric care. By extending its validation and incorporating additional data, we can ensure that the model remains a robust and reliable tool in guiding treatment decisions for frail elderly patients necessitating hip fracture surgery.

Concluding remarks

PPFF around HA poses a significant global health concern, with both incidence and prevalence on the rise. It is important to gain insight into this specific patient population, to identify potential risk factors and to formulate universal postoperative weight bearing protocols. Patients suffering PPFF are frail and severely comorbid in line with patients who suffer PFF. This research provides comprehensive tools to support healthcare professionals to improve the perioperative management and care for patients suffering PPFF around HA aiming to optimize better functional outcomes in this specific patient population. In conclusion, the research outlined in this thesis highlights the importance of a multidisciplinary approach.

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Chapter VIII

Impact paragraph

IMPACT PARAGRAPH

Periprosthetic femoral fractures (PPFF) around hip arthroplasty (HA) nowadays represent a big challenge in current practices for orthopedic- and trauma surgeons as the number of patients affected continues to rise and therefore imposing a significant burden on patients and healthcare professionals. Optimizing care for this vulnerable group requires refined, personalized treatment approaches, especially in the context of preoperative risk stratification, individualized treatment plans and standardized care protocols. Also, patients with higher chance of postoperative mortality needs to be recognized pre-operatively to further discuss operative or non-operative management. Against this background, the findings of the studies described in this thesis provide valuable insights into perioperative management, emphasizing the importance of early identification of high-risk patients, personalized decision-making, and the need for consistent postoperative protocols for this vulnerable patient population.

PATIENTS

Orthogeriatric challenges; postoperative mobilization

Postoperative care for patients with PPFF following HA is characterized by significant variability in weight bearing practices. This variability, often driven by individual surgeon preferences rather than evidence-based protocols, directly impact patient outcomes. For elderly and vulnerable patients this inconsistency can affect recovery speed, mobility and overall prognosis. The lack of standardized guidelines means that some patients may not receive optimal care, resulting in prolonged hospital stay, delayed mobilization and a higher risk of complications such as pneumonia, delirium or functional decline due to immobility.

A more uniform progressive postoperative approach, such as PWB, holds significant potential for improving recovery. Evidence from other trauma and orthopedic areas suggests that early mobilization, when safely implemented, accelerates functional recovery and reduces morbidity and mortality. The research presented in this thesis underscores the importance of incorporating PWB as a key component of post-PPFF management, highlighting its effectiveness in promoting faster recovery and minimizing the risks associated with prolonged bed rest. The practical translation of these findings into daily clinical care could mean a reduction in hospital-acquired complications, quicker return to function, and a lower burden on both patients, healthcare providers and hospitals.

However, despite these promising results, there still remains a critical gap in the literature regarding the use of PWB in patients with late PPFF around total hip arthroplasties (THA).

The absence of clear evidence-based guidelines for postoperative load-bearing in this group can delay the adoption of early mobilization protocols, which could prevent the complications mentioned above. This gap in knowledge is particularly troubling given the aging patient population and the increasing number of hip replacement surgeries, leading to a growing number of PPFF cases.

As a direct consequence of this research, it becomes clear that integrating standardized postoperative protocols, such as early PWB, could significantly enhance outcomes for elderly patients. But beyond the clinical setting, several challenges remain in implementing these changes. First, healthcare professionals, particularly physiotherapists in long-term care settings needs to be familiar with the PWB protocol. Simplifying protocols and providing clear, practical guidance will be crucial to ensuring they are followed correctly across different settings. Furthermore, there are broader implications for patient care that need to be addressed. Should we continue to refer patients to a wide range of rehabilitation institutions, or can we selectively guide patients to facilities that are better equipped to handle complex cases? Should family physicians or geriatric specialists be more actively involved in preoperative decision-making to better assess and mitigate risk factors before surgery that can effect postoperative recovery and mobilization? And considering the aging population, should more tailored, individualized care plans be developed, particularly for patients with frailty or comorbid conditions?

As we look at the practical application of these findings, it is clear that there is much room for improvement. Uniform postoperative protocols could help streamline care, but the challenge remains: How can we implement these protocols effectively across diverse healthcare systems? More research is needed to evaluate the feasibility and effectiveness of adopting PWB protocols more widely in patients who suffered PPFF around HA.

Orthogeriatric challenges; risk-factors for PPFF and mortality

Identifying specific patient and surgical risk factors, such as advanced age, female sex, higher ASA class, elevated BMI, high Charnley score and the use of uncemented stems and anterior approach, directly influences how clinical decisions are made. For patients, particularly those with frailty indicators or poor bone quality, the study advocates for a more personalized approach to surgery, which could significantly reduce the risk of complications and the need for stem revision surgery. When healthcare professionals take the time to assess each patient's individual risk profile, rather than adopting a 'one-size-fits-all' approach, the potential for complications, like PPFF, most likely decreases. But there's a key question: How do we ensure these factors are properly addressed in daily practice, especially given the increased volume of elderly patients undergoing THA? Should preoperative assessments become more structured, and should multidisciplinary teams, including geriatricians and rehabilitation specialists, play a larger role within the perioperative care in primary THA surgery? For patients, especially those with frailty indicators or poor bone quality, the study supports a tailored approach, to reduce the likelihood of complications. Ultimately, this evidence can guide personalized perioperative planning and postoperative management strategies, potentially improving outcomes, preserving implant longevity, and reducing the burden of revision surgery.

By addressing additional risk factors in PPFF surgery in the elderly population these insights are extended. Key factors such as low BMI, nursing home residency, preoperative use of urinary bladder catheters (UBC), and dependence on walking aids have been identified as strong predictors of poor postoperative outcomes in terms of PPFF revision surgery. Recognizing these factors allows healthcare providers to better assess which patients may require closer monitoring or more intensive perioperative care, potentially reducing complications and improving survival rates. Furthermore, early intervention in addressing modifiable risk factors, such as managing preoperative UBC use and promoting early mobilization, could significantly enhance postoperative recovery and reduce mortality. This knowledge can guide clinicians in refining their approaches to the treatment of PPFF, improving both short-term and long-term outcomes for affected patients.

The ZHISLE model has the potential to significantly impact patients by guiding clinicians to make more informed and personalized treatment decisions for elderly individuals undergoing surgery for proximal femoral fractures (PFF). By accurately predicting the risk of early postoperative mortality, the model enables healthcare providers to identify patients who may benefit from alternative, less invasive treatments, such as non-operative pain management, rather than undergoing high-risk surgeries. This individualized approach could be a game-changer in improving patient outcomes. For many vulnerable patients, especially those with limited life expectancy, the ZHISLE model could help clinicians avoid unnecessary surgeries that carry high risk. Instead, clinicians could adopt less invasive treatments, potentially improving quality of life and reducing the stress and burden of surgery on both patients and their families. This individualized approach can lead to improved patient outcomes, reduce unnecessary surgeries, and potentially enhance the quality of life for vulnerable patients with limited life expectancy. Additionally, the model's ability to identify modifiable risk factors empowers healthcare professionals to optimize preoperative care, ultimately improving survival rates and overall well-being for patients. The integration of such predictive models into clinical practice can foster more patient-centered care and contribute to better management of healthcare resources.

HEALTHCARE PROFESSIONALS

Orthogeriatric challenges; postoperative mobilization

The observed variability in postoperative weight bearing protocols represents a significant obstacle to delivering consistent, high-quality care to PPFF patients. This emphasizes the need for standardized, evidence-based guidelines to guide decision-making and improve patient outcomes. For surgeons, this inconsistency can lead to uncertainty in postoperative planning and challenges in aligning with best practices. Additionally, the studies in this thesis encourages reflection on individual clinical habits, fosters awareness of emerging concepts like PWB, and may promote continuing education and an interdisciplinary dialogue. Ultimately, the findings emphasize the importance of further research and guideline development to enhance clinical confidence, optimize patient care, and support outcome-based healthcare delivery.

The absence of standardized protocols and outcome data related to PWB underscores a clinical knowledge gap that can limit confidence in postoperative decision-making. By highlighting the need for evidence-based guidance, the study encourages clinicians to critically evaluate current practices, fosters interdisciplinary collaboration in postoperative care planning, and advocates for the development of consistent rehabilitation strategies. Ultimately, this research supports the transition toward individualized, functionally guided aftercare that aligns with modern principles of early mobilization and value-based healthcare delivery.

This variability also underlines a broader challenge in the orthogeriatric field, ensuring that clinical practice keeps pace with emerging evidence on the importance of PWB. For surgeons, physical therapists, and rehabilitation specialists, it may feel like there's no unified approach to postoperative care. This uncertainty can impede the integration of newer practices, such as PWB, into daily clinical routines. Moreover, without standardized guidelines, professionals may find themselves relying more on personal clinical experience than on evidence-based recommendations, which can create gaps in care quality.

The key implication here is the need for evidence-based, universally adopted guidelines. Standardized PWB protocols, backed by robust research, would help clinicians navigate the complexities of postoperative recovery with greater confidence. The push for uniform protocols, however, must also address the nuances of individual patient needs, especially for the growing population of elderly patients with multiple comorbidities. Therefore we strive to develop protocols that are both evidence-based and flexible enough to accommodate individual patient conditions.

Additionally, this calls attention to the potential of interdisciplinary collaboration in improving postoperative mobilization. Surgeons, geriatricians, physiotherapists, and nurses need to work closely together to ensure that patients receive comprehensive, coordinated care throughout their recovery. This approach not only fosters better communication among healthcare teams but also encourages a more patient-centered care model.

In practical terms, the variability in weight-bearing practices may also point to a gap in education. Could regular training sessions on emerging concepts like PWB be integrated into continuing professional development for healthcare workers? What is the role of interdisciplinary dialogues in raising awareness of the benefits of early mobilization for frail patients? By encouraging ongoing education and fostering a culture of open communication, healthcare professionals can better adapt to evolving best practices.

Orthogeriatric challenges; risk-factors for PPFF and mortality
Findings on risk factors for stem revision in patients with PPFF after primary THA, highlights that certain patient- and surgical factors, such as older age, female sex, higher BMI, and uncemented stem fixation, significantly increase the risk of stem revision due to PPFF. These findings emphasize the importance of careful patient assessment, including comorbidities and functional status, to guide surgical decisions. Surgeons may need to consider alternative fixation methods, like cemented stems, especially for frail patients or those with increased risk factors. Additionally, our study suggests a more patient-centered approach for managing PPFF, advocating for a multidisciplinary team involving orthopedic surgeons, geriatricians, and other healthcare professionals to improve patient outcomes. These insights can help clinicians tailor preoperative counseling, surgical planning, and postoperative care for at-risk patients.

Highlighting key predictors of one-year mortality in the management of PPFF around HA such as low BMI, preoperative urinary bladder catheter use, nursing home residency, and walking aid dependence, equips clinicians with the knowledge to prioritize interventions and personalize treatment plans. The findings encourage a more proactive approach in managing frail, elderly patients, emphasizing the importance of early mobilization, careful monitoring of comorbidities, and minimizing complications such as infections or prolonged immobility. This can lead to improved patient outcomes, optimized resource allocation, and better decision-making in surgical and perioperative care.

For clinicians, recognizing these risk factors early allows for more targeted interventions. For instance, a patient with low BMI or who relies on walking aids may require more intensive perioperative care or closer monitoring after surgery. But how do we implement this knowledge effectively? Healthcare providers need to be aware of these indicators and act accordingly. Early intervention in managing these risk factors, such as promoting early mobilization, managing UBC use, or addressing nutritional deficiencies, can significantly improve postoperative recovery, reduce complications, and lower mortality rates after revision surgery.

The practical implication for healthcare professionals is that these risk factors should inform not just surgical decisions but the entire perioperative care process. The idea is to personalize care, ensuring that high-risk patients are managed appropriately at every stage of their journey, from preoperative assessment to postoperative rehabilitation. The challenge remains in how we integrate these risk assessments into the routine clinical workflow. Should we incorporate more structured preoperative screening processes across all healthcare settings to better identify high-risk patients early on? It underscores the need for further education and guidelines on managing PPFF, potentially influencing clinical practices and policy development within orthopedic and geriatric care.

A key question also arising from this discussion is whether every trauma surgeon or orthopedic specialist should be involved in the management of PPFF following HA, or whether this should be reserved for a specialized group of surgeons. Given the complexity of PPFs, which are often associated with multiple comorbidities, frailty, and the need for advanced surgical techniques, it seems prudent to limit the treatment of these fractures to surgeons with expertise in orthogeriatrics and complex revision surgery. A focused, multidisciplinary approach, integrating geriatric care, rehabilitation, and orthopedic expertise, appears to be the optimal model for ensuring the best patient outcomes. This approach would also allow for better alignment of care with the specific needs of the frail elderly population, ultimately improving patient safety and long-term recovery.

The ZHISLE model offers significant benefits to healthcare professionals by providing an evidence-based tool to predict early postoperative mortality risk in elderly patients with PFF. This allows clinicians to make more informed decisions regarding treatment options, balancing the risks of surgery against potential benefits. By integrating predictive analytics into the decision-making process, healthcare providers can identify high-risk patients and consider alternative, less invasive treatments when appropriate, thus enhancing patient safety and optimizing clinical outcomes. Furthermore, the model's simplicity and interpretability make it easy to incorporate into routine practice, ultimately supporting better patient management and improving multidisciplinary collaboration in treatment planning.

Integrating the ZHISLE model into clinical practice has several implications. First, it provides a more accurate way to assess mortality risk, enabling clinicians to personalize treatment plans with greater precision. It also allows for more informed discussions with patients and families about treatment options, ensuring they are fully aware of the risks and benefits. This could be particularly valuable for patients with complex comorbidities or frailty, where the risks of surgery may outweigh the benefits.

But the model's integration into routine practice raises important questions: How can it be scaled to different healthcare settings? Are there enough training and support systems in place to ensure that clinicians are able to use predictive models like ZHISLE effectively? And what role does this model play in helping healthcare professionals collaborate with patients and their families to make more informed, shared decisions about care?

The integration of the ZHISLE model into routine clinical practice certainly presents a set of challenges and opportunities. Scaling the model across different healthcare settings requires careful planning. For the model to be successfully integrated, it must be adaptable to various hospital infrastructures, with considerations for varying levels of technological support, staff expertise, and patient populations. The model's simplicity and interpretability are strengths, but clinical practice usage will still require tailored approaches, potentially through tiered implementation strategies, where larger hospitals could serve as lead sites for dissemination to smaller institutions. Training and support are essential for the effective use of predictive models like ZHISLE. Implementing a robust training program for clinicians, including surgeons, geriatricians, and nursing staff, is critical. This training should not only focus on the technical use of the model but also on understanding the limitations and the broader clinical context, ensuring that it enhances decision-making rather than becoming a stand-alone tool.

As for the model's role in shared decision-making, its impact could be transformative. By predicting early postoperative mortality risk, ZHISLE provides clinicians with concrete, evidence-based data to present to patients and their families, guiding them through complex treatment decisions. This opens the door for more personalized care, with discussions that consider not only clinical outcomes but also quality of life and the patient's values. It allows patients, particularly frail or elderly individuals, to better understand the potential benefits and risks of surgery versus conservative treatment options. This model could empower patients and their families to make more informed, collaborative decisions about their care, enhancing both the patient's autonomy and the clinician-patient relationship.

In conclusion, while the ZHISLE model presents an exciting opportunity to improve clinical decision-making, its integration requires thoughtful planning, adequate training, and an ongoing focus on collaborative, patient-centered care. By addressing these factors, the model could have a meaningful impact on both individual patient outcomes and broader healthcare practices.

SCIENTIFIC RESEARCH

Orthogeriatric challenges; postoperative mobilization
The role of PWB in patients with PPFF is a crucial area of ongoing investigation, which could ultimately enhance patient-centered care and reduce complications associated with prolonged immobility. Validating PWB in the PPFF population could significantly reduce complications associated with prolonged immobility, highlighting the need for evidence-based clinical guidelines. These guidelines would not only enhance clinical confidence but also support patient-centered care, improving recovery, mobility and overall outcomes for elderly, frail patient. This emphasize the importance of continued research and the development of clear clinical guidelines to enhance clinical confidence, optimize treatment strategies, and support consistent, outcome-based healthcare delivery.

The absence of standardized PWB approaches across institutions underscores the need for further clinical research to establish uniform protocols. Evidence suggests that implementing consistent mobilization strategies could lead to faster recovery, greater independence, and a reduction in both morbidity and mortality. However, for such protocols to be effective, they must be adaptable to different healthcare settings. This requires careful consideration of available resources and the unique challenges that various institutions face in implementing these strategies. Ultimately, research should focus on developing protocols that balance clinical best practices with practical feasibility, ensuring that all healthcare providers are equipped to deliver optimal care.

Orthogeriatric challenges; risk-factors for PPFF and mortality
Research into the risk factors for PPFF underscores the need for further investigation into the underlying mechanisms linking patient- and surgical characteristics to PPFF outcomes. Additional research could explore the biological and biomechanical aspects of uncemented stem fixation and anterior approaches, investigating why these factors predispose patients to higher revision rates. Additionally, the study calls for broader studies on all PPFF cases, not limited to stem revisions, to comprehensively understand the full spectrum of PPFF. These directions could lead to refined surgical guidelines and the development of targeted interventions to reduce revision rates and improve long-term outcomes for patients undergoing THA.

While previous studies investigating mortality following surgical treatment of PPFF around HA have explored factors like age and comorbidities, our research adds depth to the existing literature by highlighting variables such as preoperative UBC use, uncemented stem fixation, and mobility aids, which have not been thoroughly investigated in relation to mortality outcomes before within this patient population. The findings challenge some previously held assumptions, particularly regarding the influence of higher ASA scores and delayed surgeries, prompting a reevaluation of these factors in future research. Furthermore, it lays the groundwork for investigations into targeted interventions, such as optimizing perioperative care protocols and patient management strategies, offering a foundation for refining clinical guidelines and advancing scientific inquiry in orthopaedic trauma and geriatric care.

The ZHISLE model contributes significantly to the existing body of scientific research by enhancing the understanding of mortality risk prediction in elderly patients with PFF. By incorporating a wide range of variables and extending the follow-up period to six months, this research improves upon existing models like the Almelo Hip Fracture Score (AHFS) by offering greater predictive accuracy and a more comprehensive approach to patient risk assessment. It also highlights the value of integrating both clinical and biochemical markers into predictive models, encouraging studies to explore multifactorial approaches to risk stratification. Additionally, the validation of the ZHISLE model in clinical practice opens avenues for further research into its applicability across diverse populations and healthcare settings, potentially influencing current guidelines for managing hip fracture patients. For broader adoption, it is critical to ensure that predictive tools like ZHISLE are integrated seamlessly into clinical workflows, making them accessible and actionable for healthcare providers. Equally important is ensuring that the model is understood and accepted by multidisciplinary teams, fostering collaborative care and improving patient outcomes. Further research should explore the applicability of this model across different populations and settings, refining it to meet the needs of diverse patient groups.

Chapter IX

Dutch summary | Nederlandse samenvatting

DE BRUG TUSSEN GERIATRIE EN TRAUMAZORG: OPTIMALISATIE VAN ZIEKENHUISZORG VOOR DE ORTHOGERIATRISCHE PATIËNT

Dit proefschrift onderzocht meerdere klinisch relevante aspecten van de behandeling van patiënten met periprothetische femurfracturen (PPFF) rond heupprothesiologie. De focus lag op postoperatieve belastingstrategieën, met de interpretatie van permissive weight bearing (PWB), op het identificeren van risicofactoren voor ongunstige uitkomsten zoals sterfte en revisie, en op het ontwikkelen van een model voor gepersonaliseerde besluitvorming bij kwetsbare orthopedische traumapatiënten: het ZHISLE-model.

Het eerste deel richtte zich op postoperatieve zorgpaden voor patiënten met PPFF. We analyseerden de huidige belastinginstructies in Nederland en de mogelijke rol van PWB om vroege mobilisatie te bevorderen zonder het complicatierisico te verhogen. Aansluitend toonde dit proefschrift de klinische kwetsbaarheid van PPFF-patiënten aan. Uit landelijke en lokale data werden risicofactoren geïdentificeerd voor steelrevisie en voor 1-jaars mortaliteit na operatieve behandeling van PPFF rond heupprothesiologie. Deze bevindingen benadrukken het belang van een zorgvuldig gepersonaliseerde implantaatkeuze en perioperatieve strategie. Het laatste deel breidde de focus uit naar patiënten met proximale femurfracturen (PFF), die vergelijkbare kenmerken hebben: hoge leeftijd, kwetsbaarheid, multimorbiditeit en een verhoogd operatie risico. Hoewel chirurgie traditioneel de standaardbehandeling is, laat recente literatuur zien dat dit niet voor alle patiënten passend is, vooral bij patiënten met beperkte fysiologische reserve en levensverwachting. Daarom werd het ZHISLE-model ontwikkeld, waarmee patiënten met een hoog zesmaands sterfterisico na heupfractuurchirurgie kunnen worden geïdentificeerd. Hiermee draagt dit proefschrift bij aan een meer individuele aanpak binnen de trauma-orthopedie, waarbij behandeling wordt afgestemd op zowel fractuurkenmerken als patiënt specifieke factoren.

Orthogeriatrische uitdagingen; postoperatieve mobilisatie

Hoofdstuk II presenteert een nationale enquête naar de postoperatieve belastingstrategieën van Nederlandse orthopedisch chirurgen bij patiënten met PPFF rond heupprothesiologie, met speciale aandacht voor de implementatie van PWB. De resultaten toonden een grote variatie in belastinginstructies tussen de verschillende Vancouver-fractuurtypes, wat wijst op het ontbreken van nationale consensus of uniforme richtlijnen. PWB werd zelden als eerste keuze geadviseerd bij Vancouver A-, B1- en C-fracturen met goede fixatie, maar vaker bij complexe revisies (zoals B2-fracturen met steelrevisie) en in casus-specifieke gevallen. Fellows en hoog-volume chirurgen schreven PWB significant vaker voor, mogelijk door meer ervaring met moderne protocollen. Ondanks literatuur die PWB ondersteunt als veilige methode die vroege mobilisatie en kortere opnameduur bevordert, blijft de toepassing bij patiënten met PPFF rondom heupprothesiologie terughoudend en inconsistent. Dit weerspiegelt eerdere uitdagingen bij de invoering van vroeg belastbare protocollen bij andere fracturen van de onderste extremiteit, waar algemene implementatie pas toenam nadat duidelijke protocollen en overtuigend bewijs beschikbaar kwamen. Er is daarom behoefte aan prospectieve studies naar de betrouwbaarheid van PWB specifiek bij PPFF. De hieruit voortkomende gestandaardiseerde protocollen kunnen bijdragen aan betere functionele uitkomsten, lagere zorgkosten en een uniformere behandeling voor deze kwetsbare patiëntengroep.

Hoofdstuk III beschrijft een systematische scoping review naar postoperatieve belastingprotocollen bij chirurgisch behandelde late PPFF rond totale heup prothesiologie, met speciale aandacht voor PWB. Ondanks een brede zoekstrategie in vijf grote databanken, met ruim 12.000 resultaten, voldeden slechts zeven studies, met in totaal 22 patiënten, aan de inclusiecriteria. Geen enkele studie paste PWB toe of evalueerde deze strategie. De geïncludeerde studies hanteerden vooral traditionele non-weight bearing of restricted weight bearing protocollen, waarbij terminologie en uitkomstmaten sterk varieerden. Dit onderstreept het gebrek aan consistentie en maakt vergelijking tussen studies moeilijk. Hoewel PWB in andere fracturen van de onderste extremiteit gunstige resultaten laat zien, zoals vroege mobilisatie, mogelijk kortere opnameduur en minder complicaties, ontbreekt elke vorm van bewijs voor de toepassing ervan bij late PPFF. Deze review benadrukt daarmee een duidelijke lacune in de literatuur en de noodzaak voor prospectieve studies naar de haalbaarheid, veiligheid en effectiviteit van PWB in deze kwetsbare patiëntengroep. Succesvolle implementatie van PWB vraagt bovendien om een multidisciplinaire aanpak: naast chirurgen moeten ook fysiotherapeuten, verpleegkundigen, geriaters en revalidatiespecialisten betrokken worden. Scholing en standaardisatie van PWB-protocollen, bij voorkeur via regionale of landelijke afspraken, zijn essentieel om deze strategie breed te kunnen invoeren.

Orthogeriatrische uitdagingen; risicofactoren voor PPFF en mortaliteit

Hoofdstuk IV beschrijft een landelijke registerstudie naar de incidentie en risicofactoren voor steelrevisie door PPFF bij meer dan 330.000 primaire totale heup prothesen. De incidentie was laag, namelijk 0,7% na 10 jaar, maar verschillende patiënt- en operatie gerelateerde risicofactoren werden geïdentificeerd. Leeftijd, vrouwelijk geslacht, hoge ASA-classificatie, verhoogde BMI en hogere Charnley-score verhoogden het risico, evenals het gebruik van ongecementeerde stelen. De anterieure benadering was in univariabele analyse ook een risicofactor, mogelijk door veelvuldig gebruik bij ongecementeerde implantaten. Dit benadrukt in de eerste plaats dat deze fracturen optreden in een kwetsbare populatie. Momenteel ligt de nadruk vooral op hoe patiënten met deze fracturen mechanisch behandeld moeten worden. De resultaten van deze studie benadrukken het belang van een meer patiëntgerichte aanpak, vergelijkbaar met kwetsbare ouderen met fragiliteitsfracturen van de proximale femur. Wij pleiten ervoor deze patiënten op dezelfde, multidisciplinaire wijze te benaderen. In lijn met deze bevindingen wordt voorzichtigheid geadviseerd bij het gebruik van ongecementeerde steelfixatie en anterieure benaderingen bij oudere vrouwelijke patiënten met hoge ASA-classificatie, Charnley-score en BMI. Verder onderzoek wordt aanbevolen om alle chirurgisch behandelde PPFF rond totale heupprothesiologie te onderzoeken en niet alleen de steelrevisie casussen.

Hoofdstuk V onderzoekt de risicofactoren voor 1-jaars mortaliteit na operatieve behandeling van PPFF rond heupprothesiologie. De 1-jaars mortaliteit was 16,6%. Belangrijke onafhankelijke voorspellers waren een laag BMI, preoperatief gebruik van een urineblaaskatheter (UBC), verblijf in een verzorgingshuis, afhankelijkheid van loophulpmiddelen en het gebruik van ongecementeerde stelen. Deze resultaten benadrukken de kwetsbaarheid van deze patiëntengroep, die vaak meerdere comorbiditeiten en functionele beperkingen heeft. Factoren die in eerdere studies geassocieerd werden met slechte uitkomsten, zoals leeftijd, hogere ASA-classificatie, dementie, postoperatieve non-weight bearing en mannelijk geslacht, waren in deze studie geen onafhankelijke voorspellers. Preoperatief UBC-gebruik is een nieuw geïdentificeerd risicofactor, mogelijk door een hogere kans op urineweginfecties en postoperatieve complicaties. Primair ongecementeerde stelen kunnen het risico verhogen door complexere chirurgie, slechtere botkwaliteit en grotere kwetsbaarheid, terwijl gecementeerde stelen vaak stabieler zijn en vroegere mobilisatie mogelijk maken. De bevindingen ondersteunen een gepersonaliseerde aanpak bij implantaatkeuze, perioperatieve planning en postoperatieve zorg, met speciale aandacht voor hoog risicopatiënten om herstel en overleving te verbeteren. Vroege mobilisatie, inclusief gebruik van PWB, kan complicaties zoals decubitus, pneumonie en delier verminderen en zo bijdragen aan lagere postoperatieve mortaliteit. Daarnaast benadrukt het hoofdstuk het belang van de multidisciplinaire zorg en nauwkeurige planning van chirurgie en revalidatie. Vroege bespreking van realistische functionele doelen en postoperatieve verwachtingen met patiënt en het zorgteam zijn hierbij van belang. Deze inzichten benadrukken de noodzaak van evidence-based richtlijnen en vervolgonderzoek, bij voorkeur met grotere cohorten en prospectieve data, om de zorg voor deze hoog risicopatiënten verder te verbeteren.

Hoofdstuk VI beschrijft de ontwikkeling en validatie van het Zuyderland Hip Inference for Survival and Lifetime Expectancy (ZHISLE)-model, een praktisch hulpmiddel om de 6-maands mortaliteit te voorspellen bij oudere patiënten die chirurgie ondergaan voor proximale femurfracturen (PFF). Het model maakt gebruik van eenvoudig beschikbare preoperatieve variabelen zoals leeftijd, geslacht, Katz Index of Independence in Activities of Daily Living, Groninger Frailty Indicator, vitale functies en laboratoriumwaarden. Hiermee behaalt het model een uitstekende voorspellende waarde (ROC AUC = 0,81) en blijft het eenvoudig, hanteerbaar en interpreteerbaar. Het ZHISLE-model is goed inzetbaar tijdens shared decision-making, bijvoorbeeld bij de afweging tussen chirurgische en conservatieve behandeling bij kwetsbare patiënten met PFF. Het biedt een meer gedetailleerde prognose voor zes maanden en kan helpen hoog risicopatiënten te identificeren die baat hebben bij conservatieve of niet-invasieve behandelingen, waardoor onnodige interventies en complicaties worden vermeden. Hoewel interne validatie de stabiliteit van het model bevestigde, is externe validatie in verschillende regio's en populaties nodig om de generaliseerbaarheid te onderzoeken. Toekomstig onderzoek, bij voorkeur multicenter en prospectief, kan het ZHISLE-model verder verfijnen en de impact op uitkomsten en gedeelde besluitvorming in orthogeriatrische zorg evalueren.

Conclusie

PPFF rond heupprothesiologie vormen een belangrijk wereldwijd gezondheidsprobleem, met toenemende incidentie en prevalentie. Inzicht in deze specifieke patiëntengroep, het identificeren van risicofactoren en het ontwikkelen van uniforme postoperatieve belastingprotocollen zijn essentieel. Patiënten met PPFF zijn kwetsbaar en vaak ernstig comorbide, vergelijkbaar met patiënten met PFF. Dit proefschrift biedt praktische handvatten voor zorgprofessionals om de perioperatieve zorg voor PPFF-patiënten te verbeteren, met als doel betere functionele uitkomsten. Het onderzoek benadrukt daarbij het belang van een multidisciplinaire aanpak, waarin behandeling en zorg worden afgestemd op de individuele kwetsbaarheid en behoeften van de patiënt.

Appendices

Dankwoord

Curriculum Vitae

List of publications and presentations

Chapter X

Dankwoord

DANKWOORD

En dan zijn we eindelijk aangekomen bij de pagina's waar iedereen natuurlijk als eerste naar kijkt. Na de voorgaande hoofdstukken vol met peer-reviewed artikelen, wil ik hier ook een paar woorden vanuit het hart delen. Aan de totstandkoming van dit proefschrift hebben veel mensen op allerlei manieren bijgedragen. Zonder hun steun en hulp was het mij niet gelukt om mijn promotieonderzoek op deze manier af te ronden. Het is daarom een bijzondere eer om hier enkele van hen in het zonnetje te zetten en mijn dank uit te spreken. Want zonder al deze mensen zou dit hele project zeker niet zo geslaagd zijn geweest.

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Lief ***bestuur van de Wielerronde Orthopedie*** 2024-2026, lieve ***Anouk, Arthur, Daniel, Elisa, Geert, Henriëtte, Jan, Joost, Justin, Koen, Lisa, Martine, Peter***, en ***Tijmen***. Wat een voorrecht was het om deel uit te mogen maken van zo'n hecht en gedreven team. Jaar op jaar zetten we samen een prachtige wielerronde neer voor iedereen die zich verbonden voelt met de orthopedie in Nederland, een evenement dat niet alleen sportiviteit ademt, maar ook kameraadschap, bevlogenheid en onze gedeelde liefde voor het vak. Maar het bleef niet bij organiseren alleen. De fijne dinertjes, de rocycle-lessen, en al die momenten tussendoor hebben ervoor gezorgd dat we als team écht naar elkaar toegroeiden. Ik heb van jullie geleerd wat teamplayerschap écht betekent; samenwerken, vertrouwen, verantwoordelijkheid delen én samen plezier maken. Die vaardigheden komen ook van pas tijdens mijn verdere werk en het onderzoek. Dank jullie wel voor de inspiratie, de energie en de warme samenwerking.

Lief **bestuur van Traumaplatform 2026**, lieve ***Angad***, ***Florine***, ***Floor***, ***Niels***, ***Nine***, ***Noah***, ***Tom*** en ***Veronique***. We zijn nog maar net samen begonnen aan het organiseren van een onvergetelijk avontuur; samen The Green Divide trotseren met een grote groep orthopeden, plastisch chirurgen en traumatologen. Hoewel het in het begin wat stroef op gang kwam, zien we nu langzaam een hechte groep ontstaan waarin we constructief kunnen overleggen en de organisatie steeds vloeiender laten verlopen. We kennen elkaar nog niet zo lang, maar ik ben ervan overtuigd dat we met deze groep een geweldige editie gaan neerzetten. Met zoveel PhD'ers in het team weten we als geen ander hoe zwaar dit soms kan zijn, en dat maakt het des te mooier dat we open kunnen praten, elkaar kunnen ondersteunen en de groepsband zo sterk laten groeien. Op naar een fantastische Traumaplatform-editie in 2026!

Lieve ***collega's van het Honourse programme van de FHML Maastricht***, lieve ***Daniek, Esmee, Sophie, Eveline, Nick, Zenab***, en onze begeleiders ***Chahinda*** en ***Marc***. Met jullie heb ik mijn allereerste stappen binnen het onderzoek mogen zetten, stappen die uiteindelijk bepalend zijn geweest voor alles wat daarna volgde. Onze systematic review en meta-analyse naar man-vrouwverschillen bij het gebruik van cardiovasculaire medicatie vormden een intensief maar ontzettend leerzaam traject. Week in, week uit artikelen screenen, in duo's onderzoeksmeetings plannen, en samen de analyses en resultaten tot in detail bespreken: het was teamwork in de puurste vorm. Wat dit traject extra bijzonder maakte, was ons gezamenlijke doorzettingsvermogen. Ook toen het programma zelf al was afgerond, zijn we stug met z'n allen doorgegaan totdat al onze artikelen daadwerkelijk gepubliceerd waren. Die vasthoudendheid, gecombineerd met jullie kennis, kritisch denken en onderlinge samenwerking, heeft een onuitwisbare indruk op mij achtergelaten. Dank jullie wel voor alles wat ik van jullie heb geleerd. Met deze eerste stappen in het onderzoek heb ik uiteindelijk het fundament kunnen leggen voor dit wetenschappelijk werk waar ik enorm trots op ben.

Lieve ***collega's van compendium geneeskunde*** en ***compendium medicine***. In 2019 begon ik mijn reis bij deze bijzondere organisatie als auteur van het hoofdstuk dermatologie voor de 2.0-versie van Compendium Geneeskunde. Wat toen startte als één hoofdstuk, groeide al snel uit tot veel meer: de pocket Dermatologie, de pocket EHBO, de pocket First Aid, en uiteindelijk mijn rol als editor voor de pocket Orthopedic Surgery. Inmiddels ben ik al zeven jaar betrokken bij dit fantastische collectief. De samenwerking met jullie geeft mij enorm veel energie. Ik heb groot respect voor jullie ambitie, veelzijdigheid en de manier waarop inhoud, kwaliteit en creativiteit samenkomen. Elke samenwerking voelt inspirerend en motiverend, en daagt me uit om steeds het beste uit mezelf te halen zowel binnen compendium als binnen mijn onderzoek. Ik ben ontzettend blij en trots dat ik onderdeel mag zijn van Compendium. Dank jullie wel voor het vertrouwen, de kansen en de fijne samenwerking, ik kijk uit naar alles wat nog komt.

Lieve ***collega's binnen de projectgroep arbeidsomstandigheden van De Jonge Specialist***, lieve ***Phebe, Lucy, Misha, Lotte*** en ***Sari***. Samen werken we aan het in kaart brengen van best practices rondom arbeidsomstandigheden voor arts-assistenten in Nederlandse ziekenhuizen. Wat deze groep zo sterk maakt, is de efficiënte en zelfstandige manier van samenwerken, met inhoudelijke en scherpe uitwisseling tijdens onze meetings. Jullie zijn fijne sparringpartners, met oog voor de organisatorische kant van het ziekenhuis en een duidelijk gezamenlijk doel: verbeteren wat beter kan. Daarnaast is het waardevol om met elkaar te kunnen sparren over onze PhD- en commissietrajecten, en ruimte te hebben om ervaringen te delen. Ik ben blij dat ik deel mag uitmaken van deze commissie en kijk uit naar onze gezamenlijke handreiking.

En dan nu aangekomen bij de meest dierbare personen om mij heen, mijn lieve familie.

Lieve ***Anouk***, ***Bente***, ***Bibi, Celine***, ***Emil***, ***Mees*** en ***Wesley.*** Nu wil ik graag een moment nemen voor mijn schoonfamilie, de aanhangsels, appendixen, wormpjes zoals ik ze ook weleens noem, die ik op geen enkele manier uit mijn leven zou kunnen wegdenken. De een maakt al langer deel uit van de familie, de ander iets korter, maar ieder van jullie is op zijn of haar eigen manier een vaste waarde binnen de Vesseur'tjes en de Deveneijns'en. Met ieder zijn eigen weg en waarden, creëren we samen prachtige discussies en waardevolle gesprekken. Of het nu familieweekendjes zijn, gezellige avondjes uit, of bezoekjes bij elkaar thuis, jullie staan altijd klaar voor een goed gesprek en wijze levenslessen. Ik hoop dat ik datzelfde ook bij jullie kan doen. Dank jullie wel voor jullie onvoorwaardelijke steun, warmte en betrokkenheid.

Lieve ***Mille*** en ***Ninthe***, mijn allerjongste steunpilaren. Jullie brengen een glimlach op mijn gezicht op momenten dat ik het zelf niet doorheb. Met jullie onbevangenheid, nieuwsgierigheid en eindeloze energie herinneren jullie mij eraan wat écht belangrijk is.

Jullie laten zien hoe mooi het is om de wereld met verwondering te blijven bekijken. Dank jullie wel voor de lachjes, de knuffels, de lichtheid die jullie, zonder het te weten, toevoegen aan ons allemaal en de pure liefde die jullie brengen. Ik ben ongelooflijk trots dat ik jullie tante mag zijn.

Lieve ***Janet*** en ***Wim,*** ouders van Mats, (hopelijk) mijn toekomstige schoonouders. Jarenlang kom ik al bij jullie over de vloer, en het voelt bij jullie net zoals thuiskomen. Nooit is iets te veel gevraagd, altijd staan jullie klaar wanneer dat nodig is, met respect, warmte en wijze lessen. Jullie gastvrijheid, betrokkenheid en nuchtere kijk op het leven hebben me altijd geraakt en geholpen. Dank jullie wel voor alles wat jullie voor mij betekenen, voor de steun, de gezelligheid en het vertrouwen dat jullie steeds tonen.

Lieve ***opa*** en ***oma Vesseur.*** Jullie hebben altijd voor mij klaargestaan, mij gesteund en geholpen, en mij wijze lessen meegegeven, vaak op de mooie kaarten die ik van jullie mag ontvangen. Belletjes met verjaardagen of op belangrijke momenten laten altijd zien hoeveel jullie om mij geven. Jullie zijn er altijd wanneer het nodig is, met een warmte die moeilijk in woorden te vatten is. Ook al wordt het ondertussen steeds lastiger voor jullie om op plekken buiten de Reeshof te komen, jullie doen er alles aan om bijzondere momenten met vrienden en familie mee te maken. Ik ben ontzettend dankbaar en trots dat ik jullie nu dit werk mag laten zien.

Lieve ***opa*** en ***oma Smulders***. Hoewel ik jullie maar tot mijn jeugdjaren heb mogen kennen, dragen jullie een blijvende plek in mijn leven en in wie ik ben geworden. De waarden, herinneringen en warmte die jullie hebben meegegeven, neem ik nog altijd met me mee. Ook al kunnen jullie dit bijzondere moment niet meer meemaken, jullie horen onmiskenbaar thuis in dit dankwoord. Dit werk draag ik ook een stukje aan jullie op.

Lieve ***Esmée***, ***Cas*** en ***Lars.*** Mijn verplichte vrienden, de siblings, en Esmée nu ook mijn paranimf, ik zou jullie voor geen goud willen inruilen (tenminste, nu niet meer; vroeger twijfelde ik nog weleens). Lieve schatten, jullie hebben elke periode in mijn leven enorm verrijkt, ieder op jullie eigen bijzondere manier. Zo verschillend als we zijn, in de kern staan we zo dicht bij elkaar, en dat merk ik keer op keer. Soms hebben we nauwelijks woorden nodig om elkaar goed te begrijpen. Het mooiste moment met jullie samen, blijft voor mij de broer/zus-dag met mijn dispuut, toen jullie allemaal afreisden naar het verre Zuid-Limburg. Wat hebben we samen, met de rest van het dispuut en hun broers en zussen, een onvergetelijke dag beleefd. Ik zou willen dat we dit nog eens konden overdoen. We spreken elkaar misschien niet dagelijks, soms zelfs niet wekelijks, maar toch voelen we altijd wat er bij de ander speelt. We weten precies wanneer we naar elkaar kunnen vragen en wanneer even niet. Jullie steun en interesse in mijn werk en onderzoek heb ik altijd enorm gewaardeerd. Ik ben ontzettend trots op ons, op ons vieren, samen, en op alles wat we delen.

Lieve ***papa*** en ***mama,*** *John en Mariëlle*. Ik ben jullie ontzettend dankbaar voor alles wat jullie mij hebben gegeven en gegund. Ik had mij geen beter thuis kunnen wensen om in op te groeien. Nooit was iets te veel gevraagd; altijd stonden jullie klaar voor ons, gaven jullie steun en hielden jullie enorm van ons. Ik denk aan de ontelbare mooie momenten samen, groot en klein: jullie kwamen op bezoek in Maastricht, de vader-dochter dag, jij die altijd naar mijn voetbalwedstrijden kwam kijken, samen met mama winkelen, urenlange wandelingen of fietstochten, onze Lissabon trip, ijs bezorgen voor de Heerenhoeve, feestdagen samen vieren, familie weekendjes weg, helpen in de winkel, en er is nog zoveel meer om op te noemen, al deze herinneringen koester ik, moment voor moment. Jullie steun en vertrouwen hebben mij gebracht tot het punt waar ik nu ben, zowel professioneel als persoonlijk. Door jullie heb ik kunnen groeien en ik had het nooit anders gewild. Vandaag kan ik met ontzettend veel trots deze bijzondere dag met jullie delen.

Lieve ***Mats***, al sinds de middelbare school zijn we samen, en wat een reis is het geweest. Ik weet nog goed hoeveel moeite het me kostte om jouw hart te veroveren, maar gelukkig is het gelukt, en nu laat jij mij gelukkig niet meer los. Al die jaren samen laten me beseffen hoe waardevol het is om iemand zoals jij aan mijn zijde te hebben. Jij geeft me houvast en steun. Jij laat je nooit gek maken en dat siert je enorm. Je hebt altijd in mij geloofd, ook al ben je van mening dat ik soms wat te veel hooi op mijn vork neem. Toch heb je me altijd aangemoedigd om ervoor te gaan als ik iets echt zelf wilde, en dat heb je keer op keer laten zien. Jouw onvoorwaardelijke liefde zal ik altijd koesteren, en ik ben ontzettend dankbaar dat jij in mijn leven bent.

Tot slot wil ik nog graag iedereen bedanken die aanwezig was bij mijn verdediging. Jullie aanwezigheid, steun en betrokkenheid maakten dit bijzondere moment extra waardevol en onvergetelijk. Het was een grote steun om dit hoofdstuk van mijn carrière met jullie te kunnen delen.

Chapter XI

Curriculum Vitae

Maud Vesseur was born on January 8, 1998, in Tilburg, The Netherlands. She completed her secondary education (Atheneum) at Zwin College in 2016. She then pursued her bachelor's degree in medicine (BSc, 2016-2019) at Maastricht University, during which she completed elective internships in Emergency Medicine and Forensic Medicine. As part of the extracurricular Honours Programme FHML (2017-2019), she conducted a meta-analysis on "The effect of anti-hypertensive medication on the cardiovascular system."

Following her bachelor's studies, Maud continued at Maastricht University to obtain her master's degree in medicine (MSc, 2019–2022). Her clinical training included scientific participation in Trauma Surgery (MUMC+), elective internships in Orthopaedics (ZorgSaam) and Trauma Surgery (Zuyderland Medical Center), and a final internship in Orthopaedics at Zuyderland Medical Center.

Alongside her studies, Maud actively engaged in leadership and organizational roles. She served as Secretary of the XIth Board of MSV Pulse (2018-2019) and represented students during clinical rotations in the domains of Mother and Child (2019-2020) and Surgical disciplines (2020-2022) within Pulse Onderwijs. She took place as a General Board Member and Treasurer of Zuydass (2023-2025), Chair of Sporthopedie 2025, Committee Member of the Orthopaedics Cycling Tour and Board Member of Traumaplatform Nederland. Additionally, she mentors medical master's students at Maastricht University.

During her academic years, Maud also gained extensive clinical and research experience. She worked as a student assistant at GGD Zuid-Limburg (2019) and as a research assistant at MUMC+ and Zuyderland Medical Center (2019-2024), contributing to projects in gynaecology, cardiology, orthopedics and traumatology. During the COVID-19 pandemic, she worked as a nurse caretaker at ZorgSaam (2020-2022).

After graduating, Maud broadened her clinical experience as a resident-not-in-training in Orthopaedics at Zuyderland Medical Center (2022-2023) and Emergency Medicine at ZorgSaam (2023). In 2024, she commenced her surgical training as part of the orthopaedic surgery residency program at Zuyderland Medical Center. In 2025, she continued her residency in Orthopaedics in ROGO Zuid.

Beyond her clinical work, Maud has contributed significantly to medical education and communication. She joined the editorial board of 4Bone/4Arthroscopy in early 2023, initially as Editor and, since August 2023, as Editor-in-Chief. She participated in the "Doctor Meets Director" program organized by Stichting Medical Business (2023), further strengthening her interest in healthcare leadership. She is also a long-standing author at Compendium Geneeskunde and recent editor at Compendium Medicine, contributing to medical education resources, and she supports Stichting Sportdokters as a physician, where sports medicine and orthopaedics intersect.

Beyond her medical career, Maud enjoys spending time with family and friends and is passionate about outdoor pursuits such as long distance hiking, running, and road cycling.

Chapter XII

List of publications and presentations

I PUBLICATIONS

I.I Academical publications

I.I.I This Thesis

I. **Vesseur, M.A.M**., Jelsma, J., Most, J., Bemelmans, Y.F.L., Schotanus, M.G.M., van Vugt, R., Boonen, B. (2023). Postoperative load bearing in periprosthetic femoral fractures: A survey among orthopedic surgeons in the Netherlands. Cureus, 15(9), e45122.

II. **Vesseur, M.A.M.**, Heijkens, B., Jelsma, J., Bemelmans, Y.F.L., Heymans, M.J.L.F., van Vugt, R., Boonen, B., Schotanus, M.G.M. (2024). Permissive weight bearing in patients with surgically treated periprosthetic femoral fractures around total hip arthroplasty: A scoping review. Cureus, 16(3), e56374.

III. **Vesseur, M.A.M.**, van Kuijk, S.M.J., van Steenbergen, L.N., Schotanus, M.G.M., van Vugt, R., Boonen, B. (2025). Risk factors for postoperative stem revision in patients with periprosthetic femoral fractures after primary total hip arthroplasty: nationwide outcomes based on the Dutch Arthroplasty Registry. Hip & Pelvis, 2025 Dec 1;37(4):279-288.

IV. **Vesseur, M.A.M.**, van Beurden, E.H.M., Bouwman, L.H., Schotanus, M.G.M., van Vugt, R., Boonen, B. (2025). Identifying risk factors for one-year mortality after surgical treatment of periprosthetic femoral fractures around hip arthroplasty. Journal of Clinical Orthopaedics and Trauma, 66, 103012.

V. **Vesseur, M.A.M.**, Quaedvlieg, L., Schotanus, M.G.M., Most, J., Bouwman, L.H., van Vugt, R., Boonen, B. (2025). Zuyderland Hip Inference for Survival and Lifetime Expectancy (ZHISLE) following hip fracture surgery: Validation of the model that demonstrated good predictive power. HIP International. 2025 Jan. 11207000241312306.

I.I.II Other

VI. Mattsson, V., Ackermans, L.L.G.C., Mandal, B., Pérez, M.D., **Vesseur, M.A.M.**, Meaney, P., Ten Bosch, J.A., Blokhuis, T.J., Augustine, R. (2021). MAS: Standalone Microwave Resonator to Assess Muscle Quality. Sensors (Basel), 21*(*16), 5485.

VII. Mattsson, V., Pérez, M.D., Ackermans, L.L.G.C., **Vesseur, M.A.M.**, Bels, J.L.M., van de Poll, M.C.G., Mandal, B., Sánhez-Gonález, P., Seiffert, A.P., Meaney, P., Ten Bosch, J.A., Blokhuis, T.J., Augustine, R.**(**2022). Muscle Analyzer System: Exploring Correlation Between Novel Microwave Resonator and Ultrasound-based Tissue Information in the Thigh. In 16th European Conference on Antennas and Propagation (EuCAP), 1–5.

VIII. Laven, S.A.J.S., Mohseni-Alsalhi, Z., Meijs, D.A.M., **Vesseur, M.A.M.**, Vaes, E.W.P., Wilmes, N., van Luik, E.M., de Haas, S., Spaanderman, M.E.A., Chossein-Doha, C. (2022). Angiotensin receptor blockers are equally effective in women and men: A systematic review and meta-analysis. European Heart Journal, 43(Supplement_2), Ehac544.2198.

IX. Mohseni-Alsalhi, Z., **Vesseur, M.A.M.**, Laven, S.A.J.S., Vaes, E.W.P., Wilmes, N., Meijs, D.A.M., van Luik, E.M., Dikovec, C.J.R., Wiesenberg, J., Almutairi, M.F., Janssen, E.B.N.J., de Haas, S., Spaanderman, M.E.A., Chossein-Doha, C. (2022). The underrepresentation of females in antihypertensive medication over the years: A scoping review. European Heart Journal, 43(Supplement_2), Ehac544.2511.

X. Koppes, D.M., **Vesseur, M.A.M.**, Schepens-Franke, A.N., Kruitwagen, R.F.P.M., Notten, K.J.B., Scheele, F. **(**2022). Anatomy in the daily practice of the gynecologist, essential or just window dressing? Anatomical Science Education.

XI. **Vesseur, M.A.M.**, van Haasteren, J.C.M., Verstraelen, F.U., Boonen, B. (2023). Osteochondral impression fracture of the patella after sports collision injury. BMJ Case Reports*,* 16, e253825.

XII. Mohseni-Alsalhi, Z., **Vesseur, M.A.M.**, Wilmes, N., Laven, S.A.J.S., Meijs, D.A.M., van Luik, E.M., Vaes, E.W.P., Dikovec, C.J.R., Wiesenberg, J., Almutairi, M.F., Janssen, E.B.N.J., de Haas, S., Spaanderman, M.E.A., Ghossein-Doha, C. (2023). The representation of females in studies on antihypertensive medication over the years: A scoping review. Biomedicines*,* 11(5), 1435.

XIII. Wilmes, N., van Luik, E.M., Vaes, E.W.P., **Vesseur, M.A.M.**, Laven, S.A.J.S., Mohseni-Alsalhi, Z., Meijs, D.A.M., Dikovec, C.J.R., de Haas, S., Spaanderman, M.E.A., Ghossein-Doha, C. **(**2023). Exploring sex differences of beta-blockers in the treatment of hypertension: A systematic review and meta-analysis. Biomedicines, 11(5), 1494.

XIV. van Luik, E.M., Vaes, E.W.P., **Vesseur, M.A.M.**, Wilmes, N., Meijs, D.A.M., Laven, S.A.J.S., Mohseni-Alsalhi, Z., de Haas, S., Spaanderman, M.E.A., Ghossein-Doha, C. (2023). Sex differences in the anti-hypertensive effect of calcium-channel blockers: A systematic review and meta-analysis. Biomedicines, 11(6), 1622.

XV. Laven, S.A.J.S., Meijs, D.A.M., Z., Mohseni-Alsalhi, Vaes, E.W.P., Wilmes, N., van Luik, E.M., **Vesseur, M.A.M.**, de Haas, S., Spaanderman, M.E.A., Ghossein-Doha, C. **(**2023). Sex differences in the efficacy of angiotensin receptor blockers in blood pressure lowering and cardiac remodeling: A systematic review and meta-analysis. Medical Research Archives.

XVI. Laven, S.A.J.S., Meijs, D.A.M., Mohseni-Alsalhi, Z., van Luik, E.M., **Vesseur, M.A.M.**, Vaes, E.W.P., Wilmes, N., de Haas, S., Spaanderman, M.E.A., Ghossein-Doha, C. (2023). Sex differences of angiotensin-converting enzyme inhibitors in blood pressure lowering and cardiac remodeling: A systematic review and meta-analysis. Medical Research Archives.

XVII. 22nd European Congress of Trauma and Emergency Surgery. (2023). European Journal of Trauma and Emergency Surgery, 49(Suppl 1), 1–253.

1. Conservative and postoperative care of proximal humeral fractures regarding permissive weight bearing: a survey among surgeons in the Netherlands. [**1st Author**, Abstract publication]

2. Postoperative load bearing in periprosthetic femoral fractures: a survey among orthopedic surgeons in the Netherlands. [**Last Author**, Abstract publication]

3. The effect of surgical attire usage on the development of surgical site infections. A retrospective study. [**Last Author**, Abstract publication]

XVIII. Vaes, E.W.P., Wilmes, N., Meijs, D.A.M., Laven, S.A.J.S., **Vesseur, M.A.M.**, Mohseni-Alsalhi, Z., van Luik, E.M., de Haas, S., Spaanderman, M.E.A., Ghossein-Doha, C. (2024). Sex differences in the efficacy of diuretics in the treatment of hypertension: A systematic review and meta-analysis. Medical Research Archives.

XIX. **Vesseur, M.A.M.**, van Haaren, E.H., Jelsma, J. (2024). Advanced osteoarthritis of the hip as reason for extensive asymmetric leg edema: A rare case report and review of the literature. Acta Orthopaedica Belgica, 90(1), 142–146.

XX. **Vesseur, M.A.M.**, Dorling, I.M., Boonen, B., Reisinger, K.W., van Vugt, R. (2025). TRUMATCH TM Graft Cage - Long Bone as solution for tibial bone defect in traumatic aseptic non-union: A case report. Acta Chirurgica Belgica. 2025 Feb 13.

XXI. De Cubber, L., **Vesseur, M.A.M.**, Stoot, J., van Bastelaar, J. (2025). Unusual skull metastasis in colorectal adenocarcinoma. BMJ Case Reports, 18(4), e265319.

XXII. 24th European Congress of Trauma and Emergency Surgery. (2025). European Journal of Trauma and Emergency Surgery. Volume 51, article number 282.

1. Perioperative management of periprosthetic femoral fractures around primary hip arthroplasty: An insight into the patient population and identification of potential patient- and surgery related factors affecting one year mortality. [**1st Author**, Abstract publication]

XXIII. **Vesseur, M.A.M.**, van der Burg, T., de Loos, E.R., Pijnenburg, A.M., van Hemert, W.L.W., Schotanus, M.G.M., Boonen, B., van Vugt, R. (2025). Does the type of surgical attire influence surgical site infection rates in intramedullary nailing for proximal femoral fractures? A retrospective analysis. Langenbeck's Archives of Surgery, 410:321.

XXIV. **Vesseur, M.A.M.**, Rochus, I., Yazar, O., Bouwman, L.H. Adrenal tumor bleeding versus ruptured abdominal aortic aneurysm: a diagnostic dilemma in retroperitoneal hemorrhage. Acta Chirurgica Belgica. 2026 Jan 28:1-6.

XXV. Dorling, I.M., **Vesseur, M.A.M.**, Veldman, H.D., in den Kleef, N. Challenges in identifying the underlying cause of extensive osteonecrosis: an illustrative example and clinical guide. Accepted for publication in Acta Orthopaedica Belgica.

XXVI. **Vesseur, M.A.M.**, Jansen, E.J.P., Reisinger, K.W., de Loos, E.R. Isolated traumatic posterior hip dislocation in a paediatric patient. Submitted for publication.

I.II Book publications

I. **Vesseur, M.A.M.**, Plug, S. Dermatologie. In: Snijders, R., Smit, V., editors. Compendium Geneeskunde 2.0. Amsterdam, Nederland: Synopsis BV; November, 2019. p. 26-85.

II. **Vesseur, M.A.M.**, Goijen, L. Pocket Dermatologie. In: Snijders, R., Smit, V., editors. Amsterdam, Nederland: Synopsis BV; May, 2020.

III. **Vesseur, M.A.M.**, Bohnsack, R., van Dam, K., Rabou, J., Wijnands, B. Pocket EHBO. In: Snijders, R., Smit, V., Al-Hassany, L., editors. Amsterdam, Nederland: Synopsis BV; August, 2023.

IV. **Vesseur, M.A.M.**, Bohnsack, R. Pocket First Aid. In: Snijders, R., Smit, V., Al-Hassany, L., editors. Amsterdam, Nederland: Synopsis BV; September, 2024.

V. Borghouts, O., Kahedy, D., Yee, J., **Vesseur, M.A.M.**, Goijen, L. Pocket Dermatology. In: Snijders, R., Smit, V., editors. Amsterdam, Nederland: Synopsis BV; May, 2025.

II PRESENTATIONS

I. **Vesseur, M.A.M.**, Jelsma, J., Most, J., Bemelmans, Y.F.L., Schotanus, M.G.M., van Vugt, R., Boonen, B. Postoperative load bearing in periprosthetic femoral fractures: a survey among orthopedic surgeons in the Netherlands. Presented by M.A.M. Vesseur at Zuyderland Wetenschappelijk Symposium in The Netherlands (June 2022). Poster presentation.

II. Hameleers A., van Vugt, R., Boonen, B., Schotanus, M.G.M., **Vesseur, M.A.M.** Conservative and postoperative care of proximal humeral fractures regarding permissive weight bearing: A survey among surgeons in the Netherlands. Presented by M.A.M. Vesseur at 22nd European Congress of Trauma and Emergency Surgery (ECTES) in Ljubljana, Slovenia (May 2023). Oral presentation.

III. Van der Burg, T., van Vugt, R., Boonen, B., **Vesseur, M.A.M**. The effect of surgical attire usage on the development of surgical site infections: a retrospective study. Presented by M.A.M. Vesseur at 22nd European Congress of Trauma and Emergency Surgery (ECTES) in Ljubljana, Slovenia (May 2023). Oral presentation.

IV. **Vesseur, M.A.M.**, Jelsma, J., Most, J., Bemelmans, Y.F.L., Schotanus, M.G.M., van Vugt, R., Boonen, B. Postoperative load bearing in periprosthetic femoral fractures: a survey among orthopedic surgeons in the Netherlands. Presented by M.A.M. Vesseur at 22nd European Congress of Trauma and Emergency Surgery (ECTES) in Ljubljana, Slovenia (May 2023). Oral presentation.

V. **Vesseur, M.A.M.**, Jelsma, J., Most, J., Bemelmans, Y.F.L., Schotanus, M.G.M., van Vugt, R., Boonen, B. Postoperative load bearing in periprosthetic femoral fractures: a survey among orthopedic surgeons in the Netherlands. Presented by M.A.M.

Vesseur at European Federation of National Associations of Orthopaedics and Traumatology (EFORT) congress in Vienna, Austria (May 2023). Poster presentation.

VI. **Vesseur, M.A.M.**, Heijkens, B., Jelsma, J., Bemelmans, Y.F.L., Heymans, M.J.L.F., van Vugt, R., Boonen, B., Schotanus, M.G.M. Permissive weight bearing in patients with surgically treated periprosthetic femoral fractures around total hip arthroplasty. Presented by M.A.M. Vesseur at Traumadagen 2023 in Amsterdam, The Netherlands (November 2023). Oral Presentation.

VII. **Vesseur, M.A.M.**, Heijkens, B., Jelsma, J., Bemelmans, Y.F.L., Heymans, M.J.L.F., van Vugt, R., Boonen, B., Schotanus, M.G.M. Permissive weight bearing in patients with surgically treated periprosthetic femoral fractures around total hip arthroplasty. Presented by M.A.M. Vesseur at European Congress of Trauma and Emergency Surgery (ECTES) in Lisbon (Estoril), Portugal (April 2024). Poster presentation.

VIII. **Vesseur, M.A.M.**, Heijkens, B., Jelsma, J., Bemelmans, Y.F.L., Heymans, M.J.L.F., van Vugt, R., Boonen, B., Schotanus, M.G.M. Permissive weight bearing in patients with surgically treated periprosthetic femoral fractures around total hip arthroplasty. Presented by M.A.M. Vesseur European Federation of National Associations of Orthopaedics and Traumatology (EFORT) congress in Hamburg, Germany (May 2024). Poster presentation. *Awarded best poster presentation of the session*.

IX. **Vesseur, M.A.M.**, van Kuijk, S.M.J., Jelsma, J., Most, J., van Steenbergen, L.N., Schotanus, M.G.M., van Vugt, R., Boonen, B. Stem revision in patients with periprosthetic femoral fractures after primary total hip arthroplasty: risk-factors for revision based on the dutch arthroplasty register. Presented by M.A.M. Vesseur at European Federation of National Associations of Orthopaedics and Traumatology (EFORT) congress in Hamburg, Germany (May 2024). Oral presentation.

X. **Vesseur, M.A.M.**, Heijkens, B., Jelsma, J., Bemelmans, Y.F.L., Heymans, M.J.L.F., van Vugt, R., Boonen, B., Schotanus, M.G.M. Permissive weight bearing in patients with surgically treated periprosthetic femoral fractures around total hip arthroplasty. Presented by M.A.M. Vesseur at the combined NOV/NOF congress in Rotterdam (June 2024), The Netherlands. Oral presentation.

XI. **Vesseur, M.A.M.**, van Kuijk, S.M.J., Jelsma, J., Most, J., van Steenbergen, L.N., Schotanus, M.G.M., van Vugt, R., Boonen, B. Stem revision in patients with periprosthetic femoral fractures after primary total hip arthroplasty: risk-factors for revision based on the dutch arthroplasty register. Presented by M.A.M. Vesseur at the combined NOV/NOF congress in Rotterdam, The Netherlands (June 2024). Oral presentation.

XII. **Vesseur, M.A.M.**, van Kuijk, S.M.J., Jelsma, J., Most, J., van Steenbergen, L.N., Schotanus, M.G.M., van Vugt, R., Boonen, B. Indentification of risk factors for 1-year mortality after surgically treated periprosthetic hip fractures. Presented by M.A.M. Vesseur at the Traumadagen 2024 in Amsterdam, the Netherlands (November 2024). Poster presentation.

XIII. **Vesseur, M.A.M.**, van Beurden, E., Jelsma, J., Bouwman, L.H., Most, J., Schotanus, M.G.M., van Vugt, R., Boonen, B. Perioperative management of periprosthetic femoral fractures around primary hip arthroplasty: An insight into the patient population and identification of potential patient- and surgery related factors affecting one year mortality. Presented by M.A.M. Vesseur at 24th European Congress of Trauma and Emergency Surgery (ECTES) in Aachen, Germany (April 2025). Oral presentation.

XIV. **Vesseur, M.A.M.**, van Beurden, E., Jelsma, J., Bouwman, L.H., Most, J., Schotanus, M.G.M., van Vugt, R., Boonen, B. Perioperative management of periprosthetic femoral fractures around primary hip arthroplasty: An insight into the patient population and identification of potential patient- and surgery related factors affecting one year mortality. Presented by M.A.M. Vesseur at European Federation of National Associations of Orthopaedics and Traumatology (EFORT) congress in Lyon, France (June 2025). Poster presentation.

XV. **Vesseur, M.A.M.**, Quaedvlieg, L., Schotanus, M.G.M., Most, J., Bouwman, L.H., van Vugt, R., Boonen, B. (2025). Zuyderland Hip Inference for Survival and Lifetime Expectancy (ZHISLE) following hip fracture surgery: Validation of the model that demonstrated good predictive power. Hip International. Advance online publication. Presented by M.A.M. Vesseur at Zuyderland wetenschapssymposium in Sittard-Geleen, The Netherlands (June 2025). Oral presentation. Awarded with the Julie Hoofwijk price, placed 1st.