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PROXIMAL FEMORAL FRACTURES

FUNCTIONAL OUTCOME, QUALITY OF LIFE AND MORTALITY

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Greatfulness

We who have two legs must not forget to be grateful.
We walk for ourselves, and we walk for those that cannot walk.
We walk for all living beings – past, present and future.

Thich Nhat Hanh

TABLE OF CONTENTS

ABSTRACT

A hip fracture in the elderly is one of the most devastating consequences of osteoporosis and has a high rate of complications, including death and a serious threat to the patient's future mobility, social functioning, quality of life and autonomy.

The aim of this thesis was to gain a better knowledge of the functional outcome after treatment with an intramedullary (proximal femoral nail;PFN) or an extramedullary (Medoff sliding plate; MSP) fixation device in patients with unstable trochanteric and subtrochanteric fractures. The purpose was also to report on the long-term outcome for the health-related quality of life in patients with stable trochanteric fractures treated with a sliding hip screw and patients with subtrochanteric fractures treated with a cephalo-medullary nail. A further intention was to identify factors associated with mortality in hip fracture patients and to create a predictive model to assess the mortality risk.

In *Study I* patients with a trochanteric or subtrochanteric fracture were assessed with regard to walking ability, rising from a chair, the curb test and abductor strength. The ability to walk 15 metres at 6 weeks was significantly better in the PFN group with no difference in other functional parameters. The major complication rate, 8% in the PFN group and 4% in the MSP group, did not differ statistically but reoperations were more frequent in the PFN group.

Studies II and *III* evaluated the patients with regard to function, HRQoL and mortality. Among patients with a stable trochanteric fracture, 55% had regained their prefracture walking ability, 66% had regained their prefracture level of ADL function and almost their prefracture HRQoL level 2 years after surgery. Among patients with a subtrochanteric fracture, 46% had regained their prefracture walking ability and 48% their prefracture level of ADL function but showed a substantial and persistent deterioration in their HRQoL at 2 years.

Study IV focused on predictors of mortality among patients with hip fractures. 1944 patients were assessed with regard to gender, age, type of hip fracture, smoking habits, comorbidities, the ASA classification and cognitive function according to the SPMSQ. A predictive model was created based on factors that were significantly associated with death and were all readily accessible upon admission. The mortality rate was 4% during the acute hospitalisation period, 16% at 4 months, and 38% at 24 months. High ASA scores, low SPMSQ scores, advanced age and male gender were the most prominent factors associated with mortality. The analyses showed that the combination of ASA and SPMSQ could effectively identify patients at risk for increased mortality.

In conclusion, the PFN contributed to a better walking ability in the early rehabilitation period but also caused more reoperations than the MSP. There was an obvious deterioration in the HRQoL in the early rehabilitation phase after both stable trochanteric and subtrochanteric fractures. However, in patients with subtrochanteric fractures this deterioration persisted over time. A combined use of ASA and SPMSQ and a predictive model, also including age and gender, can be used to identify patients with an increased risk of mortality.

Keywords: functional outcome, trochanteric fracture, subtrochanteric fracture, elderly, fracture fixation, treatment outcome, quality of life, hip fracture, mortality.

LIST OF PAPERS

I. Functional outcome in treatment of unstable trochanteric and subtrochanteric fractures with the proximal femoral nail and the Medoff sliding plate
Ekström W, Karlsson-Thur C, Larsson S, Ragnarsson B and Alberts K-A
Journal of Orthopaedic Trauma, 2007;21(1):18-25

II. Quality of life after a stable trochanteric fracture - a prospective cohort study on 148 patients
Ekström W, Miedel R, Ponzer S, Hedström M, Samnegård E and Tidermark J
In press, Journal of Orthopaedic Trauma, 2008

III. Quality of life after a subtrochanteric fracture – a prospective cohort study on 87 elderly patients
Ekström W, Németh G, Samnegård E, Dalen N and Tidermark J
In press, Injury (2008), doi:10.1016/j.injury.2008.09.010

IV. Prediction of mortality in elderly patients with hip fractures – a two-year prospective study on 1944 patients
Söderqvist A, Ekström W, Ponzer S, Petterson H, Cederholm T, Dalen N, Hedström M and Tidermark J
Accepted for publication, Gerontology, 2008

LIST OF ABBREVIATIONS

ADL	Activities of daily living
ASA	American Society of Anesthesiologists
CHAID	Chi-squared automatic interaction detector
DCS	Dynamic condylar screw
DHS	Dynamic hip screw
EQ-5D	The 5-dimensional scale of the EuroQoL
EQ-5D index score	The utility score generated from the EQ-5D
Fx	Fracture
GN	Gamma nail
HRQoL	Health-related quality of life
J-M	Jensen-Michaelsen classification for trochanteric fractures
LGN	Long Gamma nail
LPFN	Long proximal femoral nail
MSP	Medoff sliding plate
PFN	Proximal femoral nail
QALYs	Quality-adjusted life years
QoL	Quality of life
RCT	Randomised controlled trial
ROC	Receiver operating characteristics
SAHFE	Standardised Audit of Hip Fractures in Europe
SGN	Standard Gamma nail
SHS	Sliding hip screw
SPMSQ	Short Portable Mental Status Questionnaire
TAD	Tip-apex distance
TGN	Trochanteric Gamma Nail
THR	Total hip replacement
TTO	Time trade-off
VAS	Visual Analogue Scale

INTRODUCTION

GENERAL BACKGROUND

Over 200 million individuals are estimated to suffer from osteoporosis in a global perspective.[1,2] A hip fracture in the elderly is one of the most devastating consequences of osteoporosis demanding acute surgery with a high rate of complications including death and a serious threat to the patient's future mobility, social functioning, quality of life and autonomy. There has been a persistent increase in the number of hip fractures in the world since 1990 and, according to the latest calculations, the number will rise further to 2.6 million hip fractures a year in 2025 and 6.25 million a year in 2050.[2-4] The most dramatic increase will be seen in Asia and Latin America, but at the present time citizens in the Scandinavian countries have the highest 10-year risk to contract a hip fracture.[5,6] Even though the overall number of hip fractures is increasing, the increase is not equally distributed among the different types of hip fracture. Over the last three decades there has been an increase in the trochanteric fracture/femoral neck fracture incidence ratio and a further substantial increase, especially in male trochanteric fractures, is expected.[7,8]

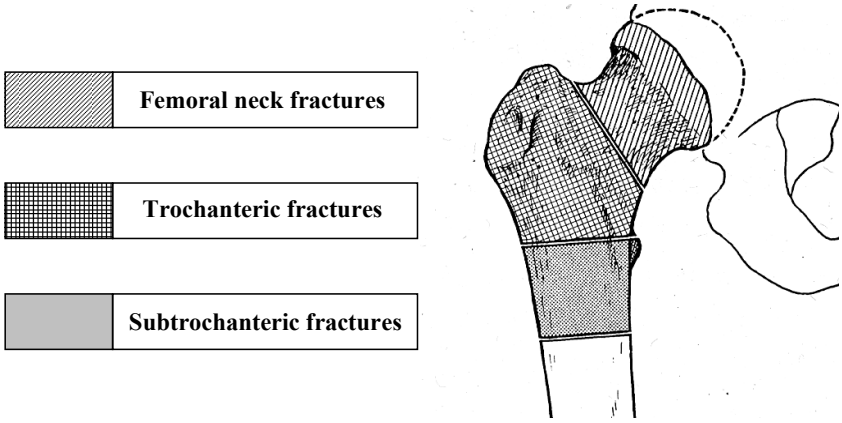
Consequently, there will be a major challenge to cope with the future demands from patients with proximal femoral fractures and it will be necessary to optimise both the surgical treatment and rehabilitation in order to improve the outcome. In order to do this, we need instruments to identify patients at risk for serious complications and, moreover, we need to continuously evaluate our surgical methods with regard to hip complications, the need for revision surgery, functional outcome and the health-related quality of life (HRQoL).

TROCHANTERIC AND SUBTROCHANTERIC FRACTURES

CLASSIFICATION

Proximal femoral fractures, i.e. hip fractures, are classified as femoral neck fractures (51%), trochanteric fractures (38%) and subtrochanteric fractures (8%) (RIKSHÖFT 2007) (Fig. 1). The basocervical fracture is a rare fracture in the transition zone between the femoral neck and the trochanteric region that constitutes only 3% of all hip fractures (RIKSHÖFT 2007).

Figure 1. Proximal femoral fractures.



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One of the most frequently used classifications for trochanteric fractures is the Jensen-Michaelsen (J-M) classification.[9] According to this classification, the undisplaced two-part fracture and the displaced two-part fracture (J-M 1 and 2) are defined as stable. The three- and four-part fractures including the greater trochanter, the lesser trochanter or both trochanters (J-M 3-5) are defined as unstable (Figure 2).

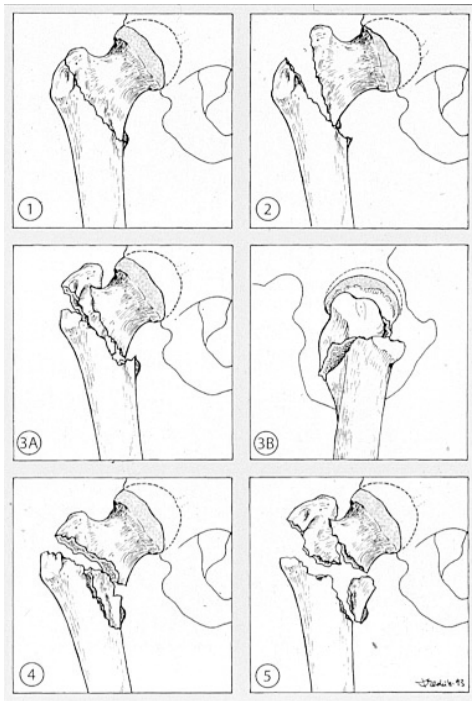

Figure 2.
The Jensen-Michaelsen classification for trochanteric fractures (J-M 1-5).[9]

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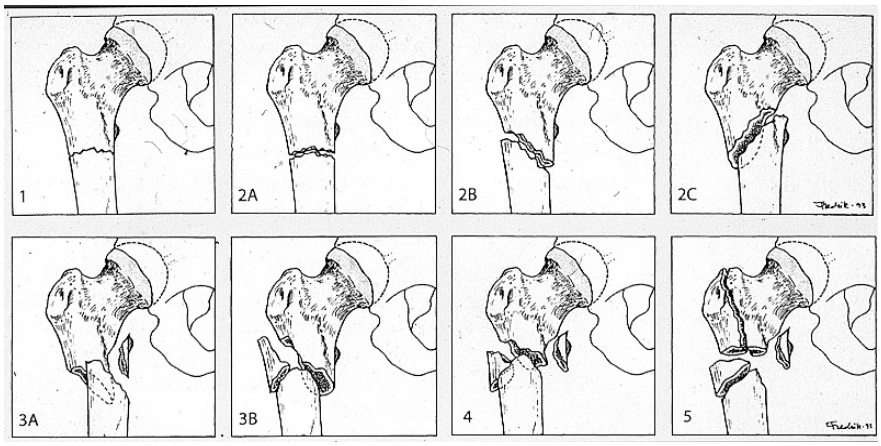
The Seinsheimer classification[10] is a widely accepted classification for subtrochanteric fractures. These fractures, all considered unstable, are classified in eight categories according to the number of major fragments, the location and the shape of the fracture (Figure 3).

Figure 3. The Seinsheimer classification[10] for subtrochanteric fractures.



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SURGICAL TREATMENT AND IMPLANTS

A wide variety of implants have been utilised in the efforts to improve fracture fixation and outcome in patients with trochanteric and subtrochanteric fractures. The treatment of stable trochanteric fractures (J-M 1 and 2) is uncontroversial and good results can be expected with different implants.[11] Most authors favour the sliding hip screw (SHS) and recent studies on this method have shown rates of failure below 2%[12,13] (Figure 4). In the case of unstable trochanteric fractures (J-M 3−5) and subtrochanteric fractures, the treatment is more controversial and the rate of failure for the SHS in these fractures is considerably higher, ranging from 4% to 15%.[12-17]

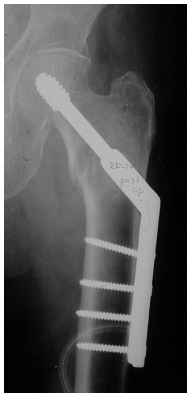


Figure 4.
One type of SHS,the dynamic hip screw (DHS).

The Medoff sliding plate (MSP) is a development of the SHS (Figure 5). Prospective trials have shown very good outcomes in both unstable trochanteric and subtrochanteric fractures with a failure rate of 2% to 4%.[13,17-19] The MSP can be used in a biaxial dynamisation mode, allowing compression along both the femoral neck and shaft, or a uniaxial dynamisation mode, allowing only compression along the femoral shaft. However, uniaxial dynamisation requires frequent radiographic follow-ups and readiness for staged dynamisation in a number of cases to prevent lag-screw penetration.[19] Furthermore, in clinical practice, the differentiation between low trochanteric fractures and high subtrochanteric fractures might be difficult and lead to erroneous uniaxial dynamisation in trochanteric fractures.

Figure 5.
The MSP.

Another way to try to overcome the drawbacks of the SHS in unstable trochanteric and subtrochanteric fractures is the use of cephalomedullary nails. These nails have obvious theoretical advantages owing to the improved biomechanics with a shorter lever arm leading to a more stable fracture construct. Furthermore, the percutaneous insertion technique may result in less soft tissue trauma and thereby reduce bleeding and the incidence of infection. One of the cephalomedullary nails earliest introduced was the standard Gamma nail (SGN) (Figure 6). The main drawback has been intra- and postoperative femoral shaft fractures.

Figure 6.
The SGN.

The design of the nails has improved, however. The SGN had a length of 200 mm and a valgus-bend of 10º creating a three-point fixation of the non-elastic implant within the proximal femur and leading to a stress concentration at the distal part of the implant.[20,21]

Figure 7.
The short Gamma 3 nail.

Later, the trochanteric Gamma nail (TGN) was introduced and subsequently the short Gamma 3 both with a length of 180 mm and a valgus bend of only 4º (Figure 7), which reduced the number of femoral fractures.[22-24] In contrast to the SGN, which could be used to treat high subtrochanteric fractures, these modern short nails are recommended exclusively for trochanteric fractures. For subtrochanteric fractures, the long Gamma nail (LGN) is recommended (Figure 8).

Figure 8.
The LGN (Gamma 3).

Another representative of the cephalomedullary nails is the proximal femoral nail (PFN) (Figure 9) utilising an additional anti-rotational screw (hip pin) placed in the femoral neck to avoid rotation of the head-neck fragment during weight bearing.[25] Recently a further development of the PFN has been introduced, the PFNA utilising a spiral blade in the femoral head and a new antirotational principal.

Figure 9.
The PFN.

Over the years there has been a substantial increase in the use of intramedullary nails in preference to the extramedullary plate fixation system. The intramedullary nails theoretically contribute to an improvement of the biomechanical conditions in the proximal femur and have advantages especially in elderly osteoporotic patients in whom the primary treatment goal is immediate full weight-bearing mobilisation. So far, the evidence for the advantages of the intramedullary nail procedure has not been convincing. In the latest Cochrane review[26] comparing Gamma and other cephalomedullary nails with extramedullary implants for extracapsular hip fractures, the authors conclude that, given the lower complication rate of the SHS in comparison with intramedullary nails, the SHS appears to be superior for trochanteric fractures. Further

studies are required to determine whether different types of intramedullary nail produce similar results, or whether intramedullary nails have advantages for selected fracture types, e.g. subtrochanteric fractures. However, many of the trials included in the reviews have been performed in institutions not experienced in the surgical technique and thus include the learning curve in the results.[27-31] The technique for cephalomedullary nails is quite different as the procedure starts with inserting a nail with a fixed neck angle and then inserting the lag-screw. If an optimal guide-wire position is not achieved after proper insertion of the nail, the surgeon has to improve the reduction or change to a nail with a different neck angle. This may induce some surgeons to accept a suboptimal lag-screw position. Furthermore, the improved design of the nails and the modern insertion technique, i.e. gently by hand without using a hammer, almost eliminated the initial problem with per-and postoperative shaft fractures. In summary and in conformity with the latest Cochrane review, further studies comparing modern intramedullary and extramedullary implants inserted using a modern technique are necessary in order to establish indications and improve outcomes.

FRACTURE COMPLICATIONS

The most frequent fracture complications after trochanteric fractures are lag-screw penetration (cut-out) due to varus collapse of the fracture (Figure 10) and excessive medialisation of the femoral shaft, the latter being seen in unstable trochanteric and subtrochanteric fractures treated with extramedullary fixation devices (Figure 11). Non-union after a trochanteric fracture is a rare complication, but it is seen more often in subtrochanteric fractures (Figure 12).

Figure 10. Cut-out.

Figure 11. Medialisation.

Figure 12. Non-union.

FUNCTIONAL OUTCOME

There have been several studies reporting functional outcomes after subtrochanteric (Table 1) and trochanteric fractures (Table 2) with regard to walking ability, need for walking aids and returning to previous living conditions,[14,19,32-37] while information regarding activities of daily living (ADL) function is reported more seldom.[38,39] The outcomes in these respects are highly dependent on the study inclusion criteria with regard to age, prefracture walking ability and co-morbidities, which make a direct comparison between the outcomes in individual studies difficult. Another interesting way to evaluate hip function more objectively after hip fracture treatment is to investigate the isometric abductor strength. Wachtl et al.[40] reported significantly lower abductor strength on the operated side compared to the non-operated side in patients with trochanteric fractures treated with the MSP. To the best of our knowledge, the isometric abductor strength has not been evaluated previously in patients with trochanteric and subtrochanteric fractures within the context of a randomised controlled trial (RCT) comparing an intramedullary and an extramedullary implant (*Study 1).*

Table 1. Functional outcome, pain and living conditions of patients with subtrochanteric fractures in prospective studies only. The colons indicate the different results for the surgical methods in the study.

Study	Year	Method	No	Age	F-U period, months	No walking aids, %	ADL	No pain %	Own home %
Parker	1997	SHS	74	74	12	50	-	71	80
Ceder	1998	MSP	32	77	12	37	-	97	84
Rantanen	1998	GN:IMHS	50:37	71:68	4:12	60:57	-	-	66:74
Lunsjö	1999	MSP uniaxial	55	81	12	47	-	-	72
Lunsjö	1999	DHS, DCS DHS/TSP	52	80	12	35	-	-	81
Sadowski	2002	PFN:DCS	20:19	80:77	12		Slightly dependent 2.5:2.6 of 4	No-mild 1.44:1.77 of 4	45:50
Pakuts	2004	DCS:GN	15:11	70	16:14	77	-	90	-
Robinson	2005	LGN	302	78.5	12	28	-	58.3	57
Sarenpää	2006	GN:DHS	43:15	77:74	4	20:8	-	-	37:80

Blanks indicate unreported data.

Table 2. Functional outcomes, pain and living conditions of patients with stable and unstable trochanteric fractures in prospective studies only. The colons indicate the different results for the surgical methods in the study.

First author	Year	Method	Stable/ unstable	Age	No	F-U period, months	No walking aids %	ADL A and B %	No pain %	Own home %
Bridle	1991	Gamma:DHS	Stable + Unstable	81:83	49:51	6	29	-	-	72:79
Leung	1992	Gamma:DHS	Stable	81:78 all	30:20	6-12	40:40	-	73:75	-
Leung	1992	Gamma:DHS	Unstable	81:78 all	63:73	6-12	35:32	-	78:60	-
Lunsjö	1995	MSP uniaxial	Stable + Unstable	81	104	12	49	-	-	83
Lunsjö	1996	MSP biaxially	Stable + Unstable	82	108	12	43	-	-	82
Olsson	1997	MSP	Unstable	80	94	12	58	-	-	80
Baumgaertner	1998	SHS:IMHS	Stable + Unstable	79	68:67	24	71	74:54 Barth-el ≥90	-	70
Madsen	1998	Gamma:SHS :DHS/TSP	Unstable	78	55:35:85	6	50:54:58	-	-	70:86:66
Simmermacher	1999	PFN	Stable + Unstable	77	191	4	40	-	-	-
Lunsjö	2001	MSP:DHS:DHS/TSP:DCS	Unstable	81:81: 83:81	268:238: 49:14	12	36:46: 69:60	-	-	73:78: 71:67
Adams	2001	Gamma:SHS	Stable + Unstable	81:81	203:197	12	56:55	-	-	75:76
Olsson	2001	MSP:CHS	Stable + Unstable	84:84	54:60	4	24:26	-	-	75:69
Harrington	2002	IMHS:SHS	Unstable	84	50:52	12	-	-	-	-
Ahrengart	2002	SGN:CHS	Selected unstable	82:81	210: 216	4	29:30	-	47:68	65:62
Miedel	2005	SGN:MSP	Unstable + Subtroch	85:83	109: 108	12	2.8: 2.9 of 6	57:63	5.3: 5.2 of 6	-

Blanks indicate unreported data.

QUALITY OF LIFE

There is a growing opinion that measures of quality of life should be used to evaluate health-care interventions.[41] It is argued that what really matters is how the patient feels, rather than how doctors think they ought to feel on the basis of clinical measurements. The quality of life assessment serves as a complement to such conventional outcome measures in orthopaedic surgery as fracture-healing complications, reoperations and mortality, and also as a complement to disease-specific outcome instruments, e.g. scores evaluating hip function. Some quality of life instruments, e.g. the EQ-5D, also allow combining of different dimensions of health to form an overall index, as required for health care evaluations[42] and for constructing quality-adjusted life years (QALYs),[43] a measure frequently used in cost-effectiveness analyses.

In contrast to the field of research on patients with femoral neck fractures,[44-47] there have been few studies evaluating the health-related quality of life (HRQoL) in patients with trochanteric and subtrochanteric fractures. To the best of our knowledge, HRQoL after a stable trochanteric fracture has not previously been reported in a prospective study using a validated quality of life instrument (*Study II)*. The negative influence on HRQoL after an unstable trochanteric and subtrochanteric fracture has been reported by Miedel et al.[38] However, in that study, the HRQoL was not reported separately for patients with subtrochanteric fractures (*Study III).*

MORTALITY

Hip fracture patients are reported to have an increased mortality rate compared to the general population[48-50] (Table 3). The mortality is high in the immediate postfracture period and decreases after about 6 months but still remains higher than in the general population.[48,51,52] The specific cause of the increased mortality after a hip fracture is unclear but co-morbidities are likely to contribute and the hip fracture may increase the likelihood of dying from these co-morbidities. Previous studies have also indicated that hip fracture patients with impaired cognitive function have a further increased risk for general and fracture-related complications[53] as well as an increased mortality rate and a poorer functional outcome.[54] Moreover, a recent study demonstrated that age, male sex, and the presence of three or more co-morbidities on admission were associated with a high rate of postoperative complications and an increased mortality rate.[55] Similar to the effect on functional outcome, the mortality rate in various studies on hip fracture patients is completely dependent on the study inclusion criteria, the most important ones being age, gender and co-morbidities. These differences make comparisons between mortality rates in individual studies difficult. The best approach is to include a large number of consecutive patients from a defined catchment area.

In order to be able to reduce the morbidity and mortality after a hip fracture, our efforts to identify the patients at risk already upon admission to hospital need to be increased. For such a risk assessment, robust, validated and reproducible criteria are mandatory. Furthermore, these criteria must be based on factors that are easy to assess in the acute clinical setting in routine health care (*Study IV*).

Table 3. Studies reporting the mortality rate in patients with hip fractures.

First author	Year	Age	No	Mortality, %	
				1 year	2 year
Kenzora	1983	70.5	406	14.3	-
Aharanoff	1997	≥65	612	12.7	-
Kitamura	1998	77	1 169	11	19
Richmond	2003	79.8	836	11.5	16.9
Jonell	2003	78.6	1 143	22	31
Gdalevic	2004	>60	651	18.9	-
Roche	2005	82	2 448	33	-
Paksima	2008	>65	1 050	11.9	18.5

Blanks indicate unreported data.

AIMS OF THE STUDIES

STUDY I

To compare functional outcome as well as assessments of abductor strength, pain, living conditions and complications in patients with unstable trochanteric and subtrochanteric fractures randomised to either a proximal femoral nail or a Medoff sliding plate.

STUDY II

To report the long-term outcome for patients with stable trochanteric fractures treated with a sliding hip screw with special regard to the health-related quality of life.

STUDY III

To report the long-term outcome for patients with subtrochanteric fractures treated with a cephalomedullary nail with special regard to the health-related quality of life.

STUDY IV

The primary aim of this study was to identify factors that are associated with mortality within 24 months and are possible to assess upon admission to hospital. The secondary aim was to evaluate the combined use of the ASA classification and the SPMSQ as tools to identify patients with a high risk of mortality and to create a predictive model to assess the mortality risk.

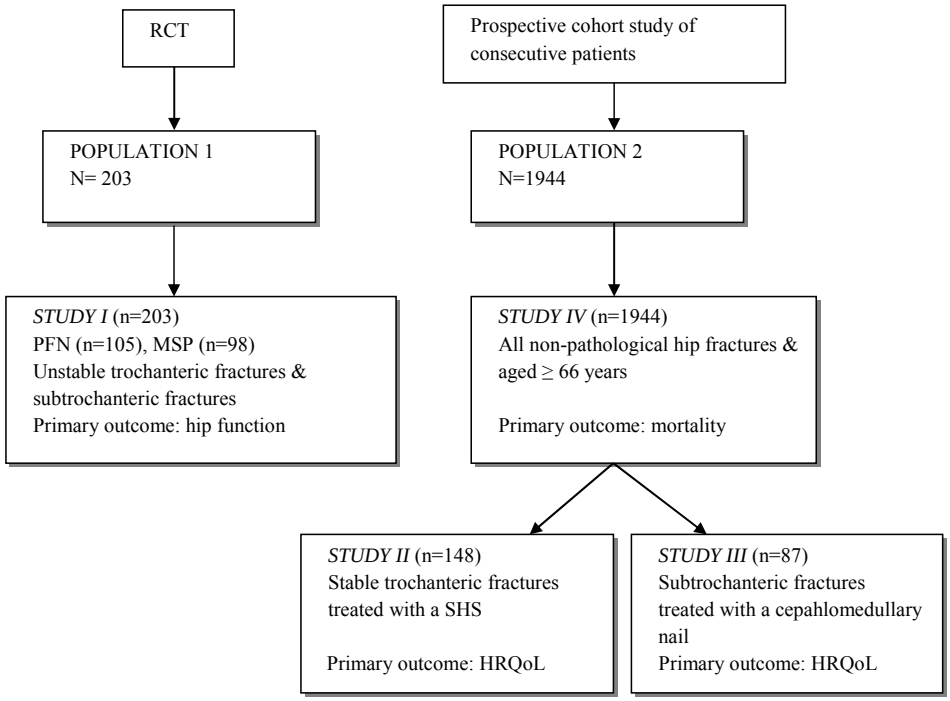
PATIENTS

The completion of this thesis is the result of a collaboration between four orthopaedic units in Stockholm County: the Karolinska University Hospital Solna and Huddinge sites, Danderyd Hospital, Stockholm Söder Hospital, and the Orthopaedic Unit at Uppsala University Hospital.

The population in *Study I* was recruited in a collaboration between the Karolinska University Hospital Solna site and the Uppsala University Hospital. This study included patients with unstable trochanteric and subtrochanteric fractures.

In 2001 a group of clinicians and research nurses in the fields of orthopaedics, geriatrics and endocrinology established the Stockholm Hip Fracture Group (SHFG) with representatives from the four teaching hospitals, the Karolinska University Hospital Solna and Huddinge sites, Danderyd Hospital and Stockholm Söder Hospital. During 2003, the SHFG included 2213 consecutive patients with a hip fracture admitted to any of the above-mentioned hospitals. The patients in *Studies II-IV* are cohorts of this population. *Study II* included patients with a stable trochanteric fracture treated with SHS and *Study III* patients with a subtrochanteric fracture treated with a cephalomedullary nail. All patients with a non-pathologic hip fracture aged 66 or older were included in *Study IV*. The study populations of the thesis are displayed in (Figure 13).

Figure 13.



ETHICS

The included studies were all conducted in conformity with the Helsinki Declaration and the separate protocols were approved by the local Ethics Committee. In *Study I* all patients gave their written consent to participate in the study. Patients in *Studies II-IV* also gave their informed consent. In *Study IV* where we included patients with severe cognitive dysfunction, the informed consent was given by a close relative or caregiver.

AGE AND GENDER

Study I included adult patients aged 16 or older. The mean age was 82 (48−96) years for both treatment groups. There were 76% women in the PFN group and 75% in the MSP group. *Studies II, III* and *IV* included patients aged 66 or older. In *Study II* and *III* the mean age was 83 (range 68−101 and 66-101, respectively) with 74% and 75%, respectively, being females. The mean age in *Study IV* was 84 (66−103) with 75% of the patients being females.

STUDY I

In a prospective randomised controlled trial, 203 patients with an unstable trochanteric (J-M 3−5)[9] or a subtrochanteric fracture were included and treated either with the PFN or the MSP. Inclusion criteria were adult patients with a closed growth plate and an unstable trochanteric fracture or a subtrochanteric fracture with the most distal part of the fracture ending less then 5 cm distal to the lesser trochanter. Exclusion criteria were a two-part fracture, high-energy trauma, pathological fracture, previous surgery of the proximal femur, daily intake of steroids exceeding 10 mg of prednisolone, ongoing chemotherapy or irradiation treatment due to malignancy and presence of degenerative osteoarthrosis/arthritis in the injured hip. Randomisation was stratified according to a trochanteric or subtrochanteric fracture location. There were 105 patients in the PFN group and 98 in the MSP group.

BASELINE DATA

Baseline data for all patients included are displayed in Table 4.

Table 4. Baseline data.

	Proximal femoral nail	**Medoff sliding plate**
No	105	98
Mean age, years (range)	82 (48-96)	82 (52-97)
Sex (%)		
Female	76	75
Male	24	25
Trochanteric fracture type (%)		
Jensen-Michaelsen 3	16	11
Jensen-Michaelsen 4	10	19
Jensen-Michaelsen 5	56	57
Subtrochanteric fracture type (%)		
Seinsheimer 1	0	0
Seinsheimer 2	0	0
Seinsheimer 3	1	5
Seinsheimer 4	8	1
Seinsheimer 5	9	7
Living conditions (%)		
Own home	81	74
Nursing home	8	16
Institution	11	10
Need for walking aid (%)		
Without aid/one crutch	65	62
Two crutches/Zimmer frame	34	35
Two-person support	1	3

FOLLOW-UP

The patients were followed up at 6 weeks, 4 months and 12 months. Twelve out of 203 patients (6%) were deceased at 6 weeks and the corresponding figures for 4 and 12-month follow-ups were 22 (11%) and 33 patients (16%), respectively.

Twenty-nine out of 191 patients (15%) were lost to the 6-week follow-up while 34 out of 180 (19%) and 49 out of 169 (29%) were lost at the 4 and 12-month follow-up, respectively.

STUDY II

148 patients with an acute stable trochanteric fracture (J-M 1 and 2)[9] and treated with a SHS were included in the study. The inclusion criteria were an acute stable trochanteric fracture, absence of severe cognitive dysfunction and independent walking capability with or without walking aids before the fracture.

BASELINE DATA

Baseline data for all patients included are displayed in Table 5.

Table 5. Baseline data for all patients included.

Mean (SD) age in years		83	(6.5), range 68-101
Gender, female, n (%)		109	(74)
ASA classification, n (%)	1	5	(3)
	2	68	(46)
	3	72	(49)
	4	3	(2)
Mean (SD) cognitive function		7.6	(2.1), range 3-10
Mean (SD) EQ-5D $_{index}$ score prefracture		0.69	(0.29), range 0.0-1.0
Walking aids, n (%)	none	60	(41)
	stick or crutches	33	(22)
	walking frame	55	(37)
ADL A and B, n (%)		129	(89)*
From independent living, n (%)		134	(91)

* Three missing values.
ADL A and B indicate independence in all six functions and independence in all but one, respectively.

FOLLOW-UP

The patients were followed up at 4, 12 and 24 months. Sixteen out of 148 patients (11%) were deceased at 4 months and the corresponding figures for the 12 and 24-month follow-ups were 23 (16%) and 43 patients (29%), respectively.

Eight out of 132 patients (6%) were lost to the 4-month follow-up while 13 out of 125 (10%) and 13 out of 105 (12%) were lost at the 12 and 24-month follow-ups, respectively.

STUDY III

Eighty-seven patients with an acute subtrochanteric fracture of the femur and treated with a cephalomedullary nail were include in the study. The inclusion criteria were an acute subtrochanteric fracture, absence of severe cognitive dysfunction and independent walking capability with or without walking aids before the fracture.

BASELINE DATA

Baseline data for all patients included are displayed in Table 6.

Table 6. Baseline data for all patients included.

Mean (SD) age in years		83	(SD 7.8), range 66-101
Gender, female, n (%)		65	(75)
ASA classification, n (%)	1	3	(3)
	2	35	(40)
	3	44	(51)
	4	5	(6)
Mean (SD) cognitive function		7.8	(SD 2.1), range 3-10
Mean (SD) EQ-5D $_{index}$ score prefracture		0.73	(SD 0.27), range 0.0-1.0
Walking aids, n (%)	none	38	(44)
	stick or crutches	17	(19)
	walking frame	32	(37)
ADL A and B, n (%)		80	(94)*
From independent living, (%)		82	(94)

*Two missing values.
ADL A indicates independence in all six functions and B independence in all but one function.

FOLLOW-UP

Seven out of 87 patients (8%) were deceased at 4 months and the corresponding figures for the 12 and 24-month follow-ups were 12 (14%) and 22 (25%), respectively. Three out of 80 patients (4%) were lost to the 4-month follow-up, 3 out of 75 (4%) at 12 months and 5 out of 65 (8%) at 24 months.

STUDY IV

During the study period a total of 2213 patients with a hip fracture were admitted to the four participating hospitals. Patients with pathological fractures (n=71) and those under the age of 66 (n=198) were excluded, leaving 1944 patients in the study population.

The overall mean age was 84 years (SD = 6.9, range 66−103 years); the mean age for women was 84 years (SD = 6.7, range 66−103 years) and, for men, 82 years (SD = 7.3, range 66−101 years). Seventy-five per cent of the patients were females. Fifty per cent of the fractures were femoral neck fractures, 43% trochanteric and 7% subtrochanteric.

An assessment of the ASA classification was available for 1924 (99%) patients. Thirty-seven per cent had an ASA score of 1−2, 54% a score of 3, and 9% a score of 4−5. Only one patient in the study was classified as ASA 5.

An assessment of cognitive function according to the SPMSQ was available for 1647 (85%) of the included patients, 45% of whom were lucid (SPMSQ 8−10), 32% had mild to moderate cognitive dysfunction (SPMSQ of 3−7), and 24% had severe cognitive dysfunction (SPMSQ 0−2). Consequently, data on cognitive function were missing for 297 (15%) patients. Among these, 137 (46%) had been diagnosed earlier as suffering from dementia. The reason for the lacking data on the SPMSQ was that individual research nurses opted to abstain from assessing the SPMSQ in some patients with previously diagnosed dementia. There were also some patients who, according to the nurse, were not in an optimal condition, e.g. due to pain medication, to answer the questionnaire.

Eighty-three per cent of the patients reported at least one co-morbidity. Thirty-nine per cent had one co-morbidity, 30% had two and 13% had three or more co-morbidities.

Factors associated with mortality constituted the main outcome measurement and are reported in the Results Section.

METHODS

OVERVIEW

Study I-IV comprised methods to assess baseline data (patient characteristics) and main outcomes. Table 7 summarises the different methods of assessment used in the thesis.

Table 7. Assesment methods.

Outcome area	Method used	Study I	Study II	Study III	Study IV
Co-morbidity	According to: SAFHE		X	X	X
	ASA		X	X	X
Smoking	Current smoker/Non-smoker				X
Cognitive function	SPMSQ		X	X	X
Living conditions	Questionnaire	X	X	X	
ADL	Katz		X	X	
Functional outcome	Need for walking aids	X	X	X	
	Rising from a chair	X			
	Curb test	X			
	Abductor strength	X			
Pain	VAS	X			
	Charnley score		X	X	
Quality of Life	EQ-5D		X	X	
Surgery	Fracture complications	X	X	X	
	General complications	X		X	
Mortality	Registration	X	X	X	X

FRACTURE CLASSIFICATION

In *Studies I* and *II* the Jensen and Michaelsen classification[9] was used to classify the trochanteric fractures. Please see Introduction: Trochanteric and Subtrochanteric Fractures; Classification (page 5). In *Study I* the AO/OTA classification[56,57] was added as a complement. It divides the trochanteric fractures (31 A2) into three groups: A1 fractures (stable) and A2 and A3 fractures (unstable). The subtrochanteric fractures (32 A1.1, B1.1) are all assessed as unstable fractures.

In *Studies I* and *III* the Seinsheimer classification[10] system was used to classify the subtrochanteric fractures. Please see Introduction: Trochanteric and Subtrochanteric Fractures; Classification (page 6).

In *Study IV* the hip fractures were classified as femoral neck fractures, trochanteric fractures or subtrochanteric fractures. Femoral neck fractures were further classified as undisplaced or displaced.[58] Trochanteric fractures were classified according to the Jensen-Michaelsen classification as stable (J-M 1 and 2) or unstable (J-M 3−5).[9] The subtrochanteric fractures were not further subclassified.[10]

CO-MORBIDITY

In *Studies II, III* and *IV* the patient's physical status was assessed by the attending anaesthetist at each hospital according to the American Society of Anestesiologists (ASA) classification.[59] ASA 1 indicates a completely healthy person; ASA 2, a person with a mild systemic disease; ASA 3, a person with a severe systemic disease that is incapacitating; ASA 4, a person with an incapacitating disease that is a constant threat to life; ASA 5, a moribund patient who is not expected to live 24 hours with or without surgery. There were no ASA 5 patients in *Studies II* and *III* and only one in *Study IV*. In *Study IV* the following co-morbidities according to the Standardised Audit of Hip Fractures in Europe (SAHFE)[60]were recorded: cardiovascular disease, stroke, respiratory disease, renal disease, diabetes, rheumatoid disease, Parkinson's disease and malignant disorders.

SMOKING

In *Study IV* the patients' smoking habit status was recorded as current smoker or non-smoker.

COGNITIVE FUNCTION

In *Studies II, III* and *IV* the patient's cognitive function was assessed using the Short Portable Mental Status Questionnaire (SPMSQ).[61] The SPMSQ is a 10-item test (Table 8) that categorises the patients in four subgroups: intact cognitive function (8−10 correct

answers), mild cognitive impairment (6−7 correct answers), moderate cognitive impairment (3−5 correct answers) or as having severe cognitive dysfunction (0−2 correct answers).

In *Studies II* and *III* only patients without severe cognitive dysfunction (SPMSQ ≥ 3) were included. In *Study IV* all patients were included and a comparison was made between three groups: intact cognitive function (SPMSQ 8−10), mild or moderate cognitive impairment (SPMSQ 3−7) and severe cognitive dysfunction (SPMSQ 0−2).

Table 8. The Short Portable Mental Status Questionnaire. (SPMSQ).[61]

1. What is the date today?	Right / Wrong
2. What day of the week is it?	Right / Wrong
3. What is the name of this place?	Right / Wrong
4. What is your telephone number or alt. street address?	Right / Wrong
5. How old are you?	Right / Wrong
6. When were you born?	Right / Wrong
7. Who is the prime minister now?	Right / Wrong
8. Who was the prime minister before him?	Right / Wrong
9. What was your mother's maiden name?	Right / Wrong
10. Substract 3 from 20 and keep subtracting 3 from each new number all the way down.	Right / Wrong

LIVING CONDITIONS

In *Study I* the patient's living condition was categorised as own home, nursing home or institution. In *Studies II* and *III* living conditions were categorised as independent (living in one's own home or in housing for the elderly) or as institutionalised (living in a nursing home or a hospital).

FUNCTIONAL OUTCOME

MOBILITY AND HIP FUNCTION

In *Study I*, only patients that were able to walk with or without walking aids or human support before the fracture were included. Three test parameters reflecting functional capacity were: walking ability defined as the patient's ability to walk or not walk 15 metres (the distance measured indoors on a regular floor) when instructed to walk at a pace at which he/she felt safe and with his/her preferred walking aid, the ability to rise from a chair without arm support and the ability to climb a curb measuring 15 cm in height.

Isometric hip abductor strength was measured at each follow-up visit with a dynamometer. The dynamometer was calibrated before each test. With the patient lying supine and with the foot in a vertical position, the dynamometer was placed at the level of the lateral femoral condyle 5 cm proximal to the knee joint space. The patient applied a force against the dynamometer by performing active isometric abduction. The muscular contraction was gradually increased for at least 2 seconds. Three consecutive tests were done with a short break in between and with the patient remaining in the same testing position. The non-operated leg was tested first and the results were given as the average abduction strength for the three tests. The ratio of operated/non-operated was calculated and used as the value for comparisons between the study groups.

In *Studies II* and *III*, all patients had independent walking ability with or without walking aids before the fracture. They were interviewed about their walking ability and need for walking aids at each follow-up.

ADL

In *Studies II* and *III* the activities of daily living (ADL) status was assessed according to Katz. The Katz index[62] status is based on an evaluation of the functional dependence or independence of patients in bathing, dressing, going to the toilet, transferring, continence and feeding. ADL index A indicates independence in all six functions, and index B independence in all but one of the six functions. Indexes C− G indicate dependence in bathing and at least one additional function.

PAIN

VAS

In *Study I* pain in the hip region at rest and after the walking test was assessed by a physiotherapist using the Visual Analogue Scale (VAS 0−100).[63] 0 represents no pain and 100 represents the worst possible pain.

CHARNLEY SCORE

In *Studies II* and *III* pain at the hip was assessed using the pain score from Charnley´s numerical classification,[64] which grades the pain from 1 to 6 with 1 = severe and spontaneous and 6 = no pain (Table 9). The assessment was performed by a research nurse.

Table 9. Scoring of pain at the hip according to Charnley´s numerical classification of the clinical state of the affected hip joint.

Score	Description
1	Severe and spontaneous
2	Severe on attempting to walk, prevents all activity
3	Tolerable, permitting limited activity
4	Only after some activity, disappears quickly with rest
5	Slight or intermittent, pain on starting to walk but getting less with normal activity
6	No pain

QUALITY OF LIFE

In *Studies II* and *III* the EuroQoL (EQ-5D)[65] was used to assess HRQoL. The EQ-5D is a non-disease-specific self-reported questionnaire consisting of the EQ-5D self-classifier, the EQ VAS and the EQ SDQ (standard set of demographic questions). The EQ-5D was used in both studies. The EQ-5D evaluates the quality of life in five dimensions: mobility, self-care, usual activities, pain/discomfort and anxiety/depression (Table 10). Within each dimension there are three levels of severity: no problems, moderate problems and severe problems.

Table 10. The EQ-5D self-classifier.

By placing a tick in one box in each group below, please indicate which statements best describe your own health state today.	
Mobility	
I have no problems in walking about	□
I have some problems walking about	□
I am confined to bed	□
Self-care	
I have no problems with self-care	□
I have some problems washing and dressing myself	□
I am unable to wash and dress myself	□
Usual activities (e.g. work, study, housework, family or leisure activities)	
I have no problems with performing my usual activities	□
I have some problems with performing my usual activities	□
I am unable to perform my usual activities.	□
Pain/Discomfort	
I have no pain or discomfort	□
I have moderate pain or discomfort	□
I have extreme pain or discomfort	□
Anxiety/Depression	
I am not anxious or depressed	□
I am moderately anxious or depressed	□
I am extremely anxious and depressed	□

Preferences were measured using time trade-off (TTO)[66] values for a subset of health states from a large sample of the UK population (UK EQ-5D Index Tariff) when calculating the scores in the studies. An EQ-5D index tariff assigns a single weighted index value, a health state score (EQ-5D $_{\text{index score}}$) to each of the 245 (3^5+ unconciousness and death) possible health states classified by the EQ-5D. A value of 0 indicated the worst possible state of health and a value of 1 the best possible. This is a divergence from the UK EQ-5D Index Tariff where some health states were given negative scores. The appropriate scaling of negative scores is controversial and the same approach has been used when generating the values for the Swedish age-matched reference population (Table 11).[67] The assessments of the prefracture HRQoL was based on the quality-of-life conditions the week before the fracture. The EQ-5D also allows combining different dimensions of health to form an overall index, as required for health care evaluations[42] and for constructing quality-adjusted life years (QALYs),[43] a measure frequently used in cost-effectiveness analyses.

Tabel 11. EQ-5D index scores for relevant age groups of the age-matched Swedish reference population.

	EQ-5D$_{index}$ scores		
Age, years	**60-69 (n=387)**	**70-79 (n=338)**	**80-88 (n=122)**
Total	0.80	0.79	0.74
Male	0.83	0.81	0.74
Female	0.78	0.78	0.74

SURGICAL PROCEDURES AND IMPLANTS

The MSP and PFN were used in *Study I*. Either the four- or six-hole MSP plates were used for the trochanteric fractures, whereas only the six-hole plate was used for the subtrochanteric fractures. The locking set screw in the MSP was used in all subtrochanteric fractures to prevent compression along the femoral neck (uniaxial dynamisation mode). No locking set screw was used in the trochanteric fractures (biaxial dynamisation mode). The PFN was inserted according to the surgical technique recommended by the manufacturer. Fracture reduction and fixation was carried out with the patient lying supine on a fracture table. Surgery was undertaken by 43 different surgeons employed as regular staff at the two hospitals and reflected a typical clinical setting. Two senior consultants, with extensive experience and familiar with both surgical methods, gave similar theoretical and practical instructions before the start of the study.

In *Study II*, the SHS used in all cases was a DHS. Fracture reduction and fixation was carried out with the patient lying supine on a fracture table. The surgeon was a certified specialist in orthopaedic surgery (post-registrar or consultant) in 97 cases (66%) and a registrar in the remaining 51 (44%).

In *Study III*, a short cephalomedullary nail (the TGN/Gamma 3 or the PFN) was used in 37 patients and a long cephalomedullary nail (the LGN or the long PFN) in 50 patients. The surgeon was a certified specialist in orthopaedic surgery (post-registrar or consultant) in 59 cases (68%) and a registrar in the remaining 28 (32%).

COMPLICATIONS AND REOPERATIONS

In *Study I* major fracture fixation complications were defined as: femoral shaft or neck fracture during surgery (fracture detected by fluoroscopy control or a new fracture at postoperative radiographic control), cut-out of the implant (migration of the hip pin or the femoral screw through the femoral head), implant breakage, deep infection (positive cultures and need for debridement) and non-union (non-bridging callus formation at the final follow-up at 1 year).

In *Studies II* and *III* wound complications, indications for reoperation and type of reoperation were recorded.

MORTALITY

In *Study I* the mortality was recorded using information from patient records and relatives. In *Studies II, III* and *IV* the mortality was recoded using the Swedish personal registration number system.

STATISTICAL METHODS

In *Study I* the statistical analyses were conducted using Statistica 6.1 and the SAS System 8.2. Power was calculated for the primary outcome, i.e. the ability to walk 15 metres. We wanted to detect a 10% difference (population SD 25%) with an 80% power and a significance level of 5%. The required sample was 100 patients per group. To compare the results for the two investigated surgical methods, the chi-square test and Fisher's exact test were used to analyse variables measured on a nominal or ordinal scale. The Mann-Whitney U test was used to analyse the VAS measurements and the continuous data that were not normally distributed. A two-way factorial analysis of variance (ANOVA) was performed to compare the differences between abductor strengths with regard to fracture type and surgical method. For comparisons over time, an ANOVA for repeated measures was performed for both binary/ordinal and continuous responses (Procedure GENMOD and MIXED in SAS).

In *Studies II* and *III* the statistical software used was SPSS 15.0 for Windows. A Wilcoxon signed-ranks test was used to compare median EQ-5D values between prefracture and 4, 12 and 24 months after surgery. The results were considered significant at $p < 0.05$.

In *Study IV* all statistical analyses were performed using SPSS 15.0. The Cox regression analysis was used to identify factors associated with mortality within 24 months after arrival at the hospital.[68] The variables were divided in demographic, pre- and postoperative factors. As a complement, the Chi-squared Automatic Interaction Detector (CHAID) algorithm was used to visually identify factors associated with high or low mortality. A CHAID analysis is a type of decision tree technique. It can be used for prediction or for detection for interaction between variables. Using this method a

relationship could be established between a dependent variable (mortality within 24 months) and other explanatory variables such as age, ASA, gender and SPMSQ.

The estimated cox model was used to identify patients with an increased risk to die based on the factors that were significantly associated with death and were clinically easy to use. The sensitivity of the predictive model to classify the patients correctly (true deceased, i.e. the proportion of patients predicted to be deseased among those that did die) and specificity (true alive, i.e. the proportion of patients predicted to be alive among those that were alive) was calculated. The Receiver Operating Characteristic (ROC) method was used to measure the ability of the prediction model to correctly classify the patients. The ROC curve is a graphical plot of the sensitivity vs the specificity of the test for different cut points. The area under the ROC curve is reflection of how good the estimated model is at distinguishing between patients with a risk to die or to be alive. The greater the area under the curve the better predictive model. The best possible prediction method would set a point in the upper left corner (coordinate 0, 1) of the ROC space representing 100% (all true positives are found) and 100% specificity (no false positive found). An area under the curve equal to 0.5 suggests no discrimination, 0.7 to less than 0.8 being acceptable, 0.8 to 0.9 being excellent, and above 0.9 being outstanding discrimination.[68] Points above and below the diagonal line in the ROC space indicate a good and bad prediction respectively.

RESULTS

STUDY I

SURGICAL OUTCOME

There were 12 major and 4 minor complications. Ten patients in total required a reoperation. Significantly more secondary surgery was needed in the PFN group, 9% (9/105) compared to the MSP group 1% (1/98) during the study period (p= 0.02) (Table 12).

Table 12. Complications and reoperations. The figures within brackets represents the number of reoperations.

	Proximal femoral nail (n=105)		**Medoff sliding plate (n=98)**	
Fracture type	**Trochanteric**	**Subtrochanteric**	**Trochanteric**	**Subtrochanteric**
Patients (n)	87	18	85	13
Major complications				
Femoral fracture	1 (1)	0	0	0
Cut out	5 (2)	1 (1)	1 (1)	1
Femoral neck fracture	0	1 (1)	0	0
Nonunion	0	0	1	1
Minor complications				
Misplaced locking screw	1 (1)	1 (1)	0	0
Lateral displacement hip pin	1 (1)	0	0	0
Hematoma	1 (1)	0	0	0
Total number	9 (6)	3 (3)	2 (1)	2

FUNCTIONAL OUTCOME AND PAIN

The ability to walk 15 m at 6 weeks was significantly better in the PFN group compared to the MSP group with an odds ratio 2.2 (p = 0.04, 95% confidence limits 1.03–4.67). At 4 months 59% in the PFN group and 56% in the MSP group had regained their prefracture ambulatory status (p = 0.69) and 35% and 25 % respectively, walked without any aid. After 1 year, 63% in the PFN group and 57% in the MSP group were back to their former ambulatory status (p = 0.55) and 41% and 38%, respectively, walked without aid (Table 13).

At 6 weeks, the median value for pain at rest was 0 for both groups and while walking the median value increased to 30 in both treatment groups. At 12 months, the median value decreased to 0 both in rest and at walking for both the PFN and MSP group. There were no significant differences between the treatment groups or fracture types.

At 6 weeks, 49% of the patients in the PFN group had returned to their prefracture living conditions compared to 41% in the MSP group. At 4 and 12 months the number increased to 70% and 69% respectively in the PFN group and 64% and 77% respectively in the MSP group.

Table 13. Functional outcome and pain.

		PFN		MSP	
		Trochanteric	**Subtrochanteric**	**Trochanteric**	**Subtrochanteric**
Walk 15 m, %					
	6w	86	94	72	77
	4 m	91	100	86	92
	12m	87	100	89	75
Rise from a chair,%					
	6w	25	35	19	31
	4 m	46	56	40	23
	12 m	50	60	53	50
Climb a curb,%					
	6w	5	24	6	8
	4 m	17	22	24	25
	12 m	20	27	32	38
Pain,VAS, rest/walk	6w	0/30	0/30	0/30	0/25
	4 m	0/20	0/0	0/20	0/20
	12 m	0/0	0/0	0/0	0/0.5

ABDUCTOR STRENGTH

The isometric abductor strength did not differ significantly between the treatment groups ($p = 0.93$) or fracture types ($p = 0.62$) at any of the follow-up occasions (Table 14).

Table 14. Isometric abductor strength of the injured side divided with the abductor strength of the uninjured side at 6 weeks, 4 months and 12 months.

		PFN		MSP	
		Trochanteric	**Subtrochanteric**	**Trochanteric**	**Subtrochanteric**
Abductor strength,%					
	6w	84	76	79	73
	4 m	88	81	92	90
	12 m	94	98	95	91

STUDY II

SURGICAL OUTCOME

There were no deep infections. Five patients (3%) had superficial infections requiring antibiotic therapy. Four patients (3%) were reoperated upon during the two-year follow-up period. All reoperations were performed within 6 months and the most common indication was lag screw penetration due to a varus collapse of the fracture. In two of the reoperated patients the initial lag screw position was suboptimal, i.e. cranial and extremely dorsal, respectively. The details for the reoperations are displayed in Table 15.

Table 15. Data on the 4 patients that were reoperated.

Indication	Reoperation/reoperations	Time (months)
L-S penetration	1/ HA	1.3
	2/ First dislocation – closed reduction	1.5
	3/ Second dislocation – Girdlestone arthroplasty	1.5
Redisplacement	Reosteosynthesis	2.1
L-S penetration	THR	3.0
L-S penetration	THR	5. 3

Time = time elapsed from the primary operation
L-S penetration = lag-screw penetration
HA = hemiarthroplasty
THR = Total Hip Replacement

FUNCTIONAL OUTCOME AND PAIN

Pain at the hip, walking ability and ADL function for all patients available at each follow-up is displayed in Table 16. At the final follow-up 81% of the patients reported no or only slight or intermittent pain at the hip (Charnley score 5−6).[64]
55% had regained their prefracture walking ability, 66% had the same level of ADL function and 89% of the patients that were living independently before the fracture were still living independently after 24 months.

Table 16. Pain at the hip, walking ability and ADL function for all patients available at each follow-up (4 months n=124; 12 months n=112; 24 months n=92).

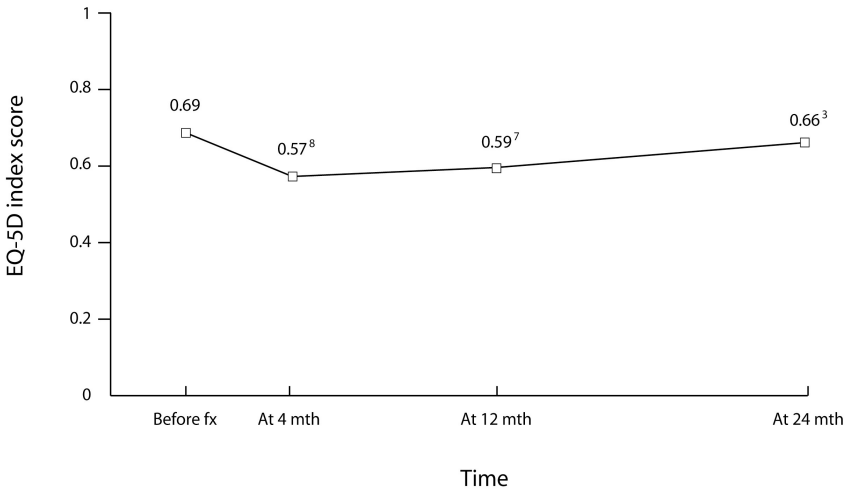
Pain, mean (SD) Charnley score	4 months	5.1 (1.4)[5]
	12 months	5.3 (1.3)[8]
	24 months	5.4 (1.0)[4]
Pain, Charnley score 5 or 6, n (%)	4 months	86 (72)[5]
	12 months	80 (77)[8]
	24 months	71 (81)[4]
At least similar walking ability as prefracture, n (%)	4 months	58 (46)[0]
	12 months	58 (52)[1]
	24 months	50 (55)[1]
At least similar level of ADL function as prefracture, n (%)	4 months	74 (62)[5]
	12 months	67 (63)[5]
	24 months	59 (66)[3]
Still independent living, n (%)*	4 months	103(89)[1]
	12 months	87(85)[5]
	24 months	76 (89)[2]

[0] to[8] refers to the number of missing values.
Charnley hip score: best possible score = 6 and worst possible score = 1.
* The calculation is based on the number of patients available at each follow-up that were independently living before the fracture.

HRQOL

The HRQoL (EQ-5D $_{index}$ score)[65] decreased from 0.69 before the fracture to 0.57 at 4 months ($p < 0.001$) and 0.59 at 12 months ($p < 0.05$). At 24 months the EQ-5D $_{index}$ score, 0.66, did not differ from the prefracture level ($p = 0.522$) (Figure 14).

Figure 14. HRQoL according to the EQ-5D (EQ-5D $_{index}$ score) for all patients with stable trochanteric fractures (J-M 1 and 2) available at each follow-up (at inclusion, n=148; at 4 months, n=124; at 12 months, n=112; at 24 months, n=92). Best possible score = 1 and worst possible score = 0.



The superscript figures refer to the number of missing values at each follow-up.
Fx = Fracture.

STUDY III

SURGICAL OUTCOME

There were 7 patients (8%) with superficial infections that healed after antibiotic therapy and 1 patient (1%) with a suspected deep infection who had wound revision surgery. At surgery there were no signs of deep infection and the bacterial cultures were all negative. This patient deceased at 18 months after surgery from causes not related to the fracture.

In total, 7 patients (8%) were reoperated upon during the study period, including the patient explored for a suspected deep infection (Table 17). One patient had early revision surgery due to excessive internal malrotation. The reoperation was complicated by a deep infection and the patient underwent two subsequent wound revisions and finally extraction of the nail after the fracture had healed. Two patients had lag-screw penetrations, in one of which a total hip replacement (THR) was performed and, in the other, a successful reosteosynthesis with a new LGN. Two patients sustained fractures close to the tip of the nail after new falling accidents. In one of these patients the distal fracture was stabilised with a longer LGN and, in the other one, the LGN was left in situ and the distal fracture was stabilised with a dynamic condylar screw (DCS). All fractures healed in both patients. Finally, in one patient there were radiological signs of delayed union indicating dynamisation, after which the fracture healed.

Table 17. Data on all patients reoperated upon (n=7).

Implant	Indication	Reoperation/s	Time, months
GN	1/ Malrotation	Revision with new lag-screw	0.1
	2/ Deep infection	Wound revision	0.4
	3/ Deep infection	Wound revision	1.7
	4/ Local pain	Extraction of the nail	12.5
LGN	L-S penetration	New LGN	1.8
LGN	L-S penetration	THR	1.9
LGN	Fx close to the tip of the nail	Longer LGN	2.1
LGN	Suspected deep infection	Wound revision	3.0
LGN	Fx close to the tip of the nail	LGN left in situ, fixation with a DCS	3.6
LPFN	Delayed union	Dynamisation	8.6

Fx = fracture; Time = time elapsed from the primary operation; L-S = lag-screw
GN = Gamma nail; LGN = long Gamma nail; LPFN = long proximal femoral nail
DCS = dynamic condylar screw; THR = total hip replacement

FUNCTIONAL OUTCOME

Pain at the hip, walking ability and ADL function for all patients available at each follow-up are displayed in Table 18. At the final follow-up 80% of the patients reported no or only slight or intermittent pain at the hip (Charnley score 5−6), 46% had regained their prefracture walking ability, 48% had the same level of ADL function and 71% of the patients living independently before the fracture were still living independently after 24 months.

Table 18. Pain at the hip, walking ability and ADL function for all patients available at each follow-up (4 months, n=77; 12 months, n=72; 24 months, n=60).

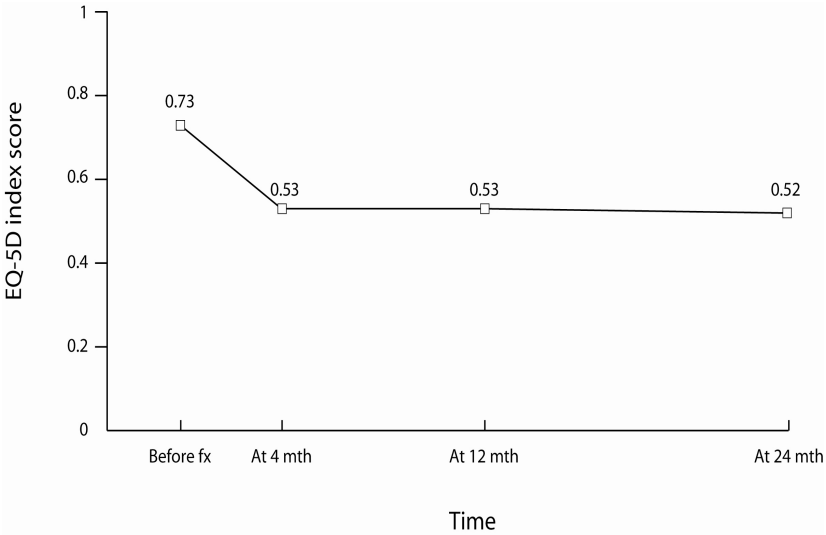
Pain, mean (SD) Charnley score	4 months	4.9 (1.5)[4]
	12 months	5.1 (1.4)[2]
	24 months	5.4 (1.0)[4]
Pain, Charnley score 5 or 6, n (%)	4 months	47 (64)[4]
	12 months	49 (70)[2]
	24 months	45 (80)[4]
Walking ability at least similar to prefracture, n (%)	4 months	33 (43)
	12 months	34 (47)
	24 months	27 (46)[1]
Level of ADL function at least similar to prefracture, n (%)	4 months	35 (46)[1]
	12 months	31 (44)[1]
	24 months	28 (48)[2]
Living conditions similar to prefracture, n (%)*	4 months	58 (74)
	12 months	53 (74)
	24 months	42 (71)[1]

The superscript figures refer to the number of missing values at each follow-up.
Charnley hip score: best possible score = 6 and worst possible score = 1.
*The calculation is based on the number of patients available at each follow-up who were living independently before the fracture.

HRQOL

The HRQoL (EQ-5D $_{index}$ score)[65] decreased from 0.73 before the fracture to 0.53 at 4 months ($p < 0.001$) and remained at the same level at the 12 and 24-months follow-ups, 0.53 ($p < 0.001$) and 0.52 ($p < 0.05$), respectively (p values are given for the difference between follow-ups and before fracture) (Figure 15).

Figure 15. HRQoL according to the EQ-5D for the patients with subtrochanteric fractures available at each follow-up. Best possible score = 1 and worst possible score = 0.



Fx = Fracture.

STUDY IV

FACTORS ASSOCIATED WITH MORTALITY WITHIN 24 MONTHS

The mortality rate during the acute hospitalisation period was 4% (71/1944), at 4 months 16% (310/1944) and at 24 months 38% (732/1941). Between the 4-month assessment and the 24-month assessment, 2 patients had moved abroad and 1 opted to abstain from further participation in the study. These 3 patients were excluded from the 24-month analysis (n = 1941).

The factors associated with the 4- and 24-month mortality are reported in Table 19 and 20, respectively.

The crude analysis showed a strong correlation between the 4-month mortality and a high (3 and 4−5) ASA score (HR 1.8; 6.5) as well as a low score (3−7 and 0−2) on the SPMSQ (HR 2.9; 5.8) (Table 19). This correlation was attenuated but still high in the adjusted model. Other factors associated with a higher risk of mortality within 4 months after the hip fracture were male gender and age over 80 years.

The factors associated with the 24-month mortality were similar to those after 4 months (Table 20), i.e. a high ASA score (HR 2.2; 3.4), as well as a low score on the SPMSQ (HR 2.0; 3.4). The number of co-morbidities was included in the multivariable analysis since it was also significantly associated with the 24-month mortality after adjustments for age, gender, ASA and SPMSQ. The result from the adjusted model did not differ from the 4-month result.

The classification tree analysis indicated that the most important factors for mortality among elderly patients within 24 months after the hip fracture were the combined ASA and SPMSQ scores (Figure 16). The patients with the lowest mortality, 11%, had ASA scores of 1−2 and SPMSQ scores of 8−10. In contrast, the group with the highest mortality, 86%, consisted of patients with a high ASA score and a low SPMSQ score. Furthermore, patients with missing values on the SPMSQ were associated with a higher mortality than those who had available scores.

Table 19. Factors associated with mortality within 4 months (n=1944).

		Univariable Crude measures				**Multivariable** Adjusted for age, gender, ASA and SPMSQ	
		n [a]	% Dead	HR	95 % CI	HR	95 % CI
Demographics							
Gender	Female	1453	13	Ref		Ref	
	Male	491	24	1.9	1.5 – 2.4	1.8	1.4 – 2.4
Age	66−79	497	9	Ref		Ref	
	80−89	1034	16	1.8	1.3 – 2.5	1.7	1.1 – 2.5
	>90	413	51	2.6	2.0 – 3.2	2.2	1.4 – 3.4
Hip fx type	Undisplaced femoral neck	256	15	Ref		Ref	
	Displaces femoral neck	708	15	1.0	0.7 – 1.5	0.9	0.6 – 1.4
	Stable trochanteric	344	16	1.1	0.7 – 1.6	1.0	0.6 – 1.7
	Unstable trochanteric	497	18	1.2	0.8 – 1.8	1.2	0.7 – 1.9
	Subtrochanteric	139	14	0.9	0.5 – 1.6	0.7	0.3 – 1.5
Current smoker	No	1424	12	Ref		Ref	
	Yes	271	13	1.0	0.7 – 1.5	1.1	0.7 – 1.7
Baseline data (preoperative)							
SPMSQ score	8−10	733	5	Ref		Ref	
	3−7	525	15	2.9	2.0 – 4.2	2.4	1.6 – 3.5
	0−2	389	27	5.8	4.6 – 8.4	4.5	3.1 – 6.5
ASA score	1 and 2	712	9	Ref		Ref	
	3	1041	16	1.8	1.4 – 2.5	1.4	1.0 – 1.9
	4 and 5	171	45	6.5	4.7 – 9.1	4.4	3.0 – 6.6
Number of co-morbidities	0	333	11	Ref		Ref	
	1	755	13	1.3	0.9 – 1.9	1.0	0.6 – 1.6
	2	579	19	1.9	1.3 – 2.7	1.3	0.8 – 2.0
	>3	252	25	2.6	1.7 – 3.9	1.7	1.0 – 2.8

HR = Hazard ratio

[a] The total number of patients does not always add up to 1944 for all factors owing to partly missing data.

Table 20. Factors associated with mortality within 24 months (n=1941).

		Univariable Crude measures				**Multivariable** Adjusted for age, gender ASA, SPMSQ and co-morbidities		Predictive model with age, gender, ASA, SPMSQ	
		n [a]	% Dead	HR	95% CI	HR	95% CI	HR	95% CI
Demographics									
Gender	Female	1450	33	Ref		Ref		Ref	
	Male	491	49	1.7	1.5 – 2.0	1.7	1.4 – 2.0	1.7	1.4 – 2.1
Age	66−79	495	24	Ref		Ref		Ref	
	80−89	1033	38	1.7	1.4 – 2.1	1.6	1.2 – 2.0	1.5	1.2 – 1.9
	>90	413	51	2.6	2.0 – 3.2	2.3	1.8 – 3.0	2.2	1.7 – 2.8
Hip fx type	Undisplaced femoral neck	256	37	Ref		Ref			
	Displaces femoral neck	706	36	1.0	0.8 – 1.2	0.9	0.7 – 1.2		
	Stable trochanteric	343	38	1.0	0.8 – 1.4	1.1	0.8 – 1.5		
	Unstable trochanteric	497	38	1.1	0.8 – 1.3	1.0	0.7 – 1.3		
	Subtrochanteric	139	37	1.0	0.7 – 1.4	0.9	0.6 – 1.4		
Current smoker	No	1421	34	Ref		Ref			
	Yes	271	34	1.0	0.8 – 1.2	1.1	0.9 – 1.4		
Baseline data (preoperative)									
SPMSQ score	8−10	731	22	Ref		Ref		Ref	
	3−7	524	38	2.0	1.6 – 2.4	1.7	1.3 – 2.0	1.7	1.3 – 2.0
	0−2	389	54	3.4	2.7 – 4.1	2.8	2.2 – 3.4	2.7	2.2 – 3.3
ASA score	1 and 2	711	21	Ref		Ref		Ref	
	3	1039	42	2.2	1.9 – 2.7	1.6	1.3 – 2.1	1.9	1.6 – 2.4
	4 and 5	171	69	3.4	4.2 – 6.9	3.4	2.5 – 4.5	4.2	3.2 – 5.6
Number of co-morbidities	0	332	23	Ref		Ref			
	1	754	33	1.6	1.2 – 2.0	1.3	0.9 – 1.7		
	2	578	43	2.2	1.7 – 2.9	1.6	1.2 – 2.2		
	>3	252	53	3.0	2.2 – 3.9	2.1	1.5 – 2.9		

HR = Hazard ratio

[a] The total number of patients does not always add up to 1941 for all factors owing to partly missing data.

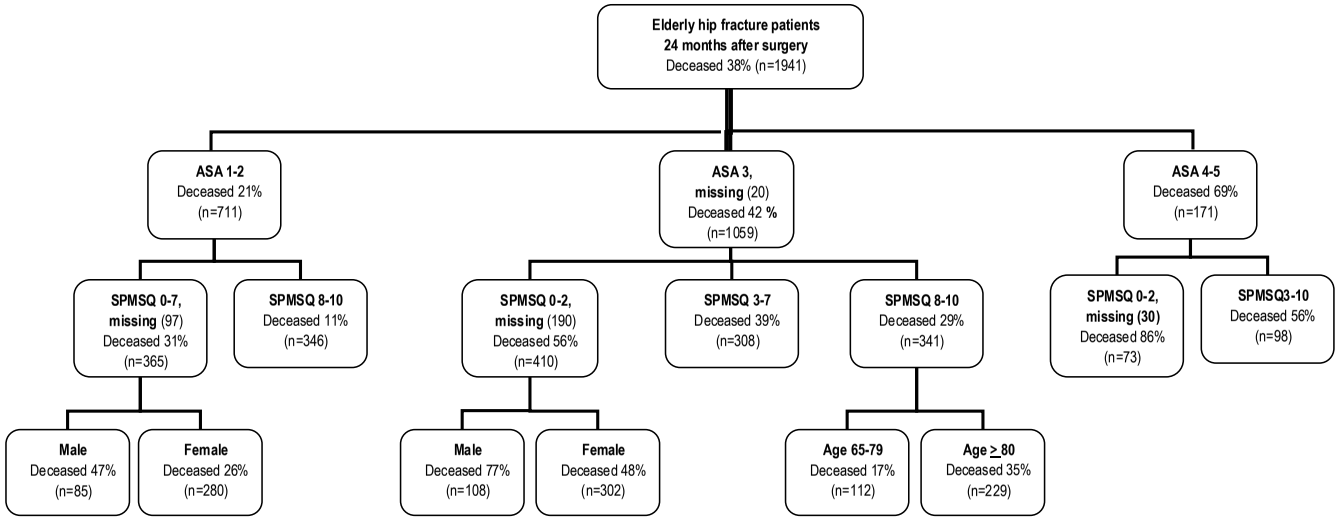


Figure 16. Classification tree showing the factors that had the strongest association with mortality among elderly patients within 24 months after hip fracture surgery (n=1941).

PREDICTING THE RISK OF DEATH

We used age, gender, ASA, and SPMSQ as factors in the predictive model. The risk for a patient to die within 24 months after the surgery was calculated from the estimated hazard ratios for this model (Table 20) as:

$$1-0.93^{EXP(\ln(gender)+\ln(age)+\ln(SPMSQ)+\ln(ASA))}$$

For example, the risk for an 80−89-year-old male with intact cognitive function (SPMSQ 8−10) and no or only mild disease (ASA 1−2) was:

$$1-0.93^{EXP(\ln(1.7)+\ln(1.5)+\ln(1.0)+\ln(1.0))}=0.21$$

Table 21 shows the estimated risk for patients with different characteristics. It shows that the patients' physical (ASA) and mental health (SPMSQ) affect the risk of dying more than age and gender.

Table 21. Estimated risk of death within 24 months after surgery for patients with different characteristics in respect of age, gender, ASA and SPMSQ used as predictive factors in the model.

Gender	Age	SPMSQ	ASA	Estimated risk of death within 24 months
Female	80−89	8−10	1−2	0.13
Female	80−89	0−2	1−2	0.31
Female	80−89	8−10	4−5	0.44
Female	80−89	0−2	4−5	0.80
Male	80−89	8−10	1−2	0.21
Male	80−89	0−2	1−2	0.48
Male	80−89	8−10	4−5	0.64
Male	80−89	0−2	4−5	0.94
Female	66−79	8−10	1−2	0.09
Female	66−79	0−2	1−2	0.22
Female	66−79	8−10	4−5	0.32
Female	66−79	0−2	4−5	0.64
Male	66−79	8−10	1−2	0.15
Male	66−79	0−2	1−2	0.35
Male	66−79	8−10	4−5	0.48
Male	66−79	0−2	4−5	0.83

EVALUATION OF THE PREDICTIVE MODEL

The receiver operating characteristic (ROC) curve shows the possible combination of sensitivity and specificity for predicting the risk of death at different cut-off points (Figure 17). For example, a cut-off point of 0.18 implies that patients with an estimated risk above this point were predicted to die within 24 months while those with a risk equal to or below 0.18 were predicted to be alive. This classification successfully predicted 94% (527/562) of all patients who died (sensitivity) and 33% (348/1069) of the patients who were alive (specificity). With a cut-off point of 0.53, the classification predicted 35% (194/562) of all patients who died (sensitivity) and 92% (983/1069) of the patients who were alive (specificity).

To assess the contribution of ASA and SPMSQ to predicting the risk of death compared to a prediction based solely on gender and age, we measured the area under the ROC curve for these models (Figure 17). The area under the curve increased significantly from 0.64 (95% CI: 0.61−0.67) to 0.74 (95% CI: 0.71− 0.76) when both ASA and SPMSQ were used, compared to when only age and gender were used.

ASA and SPMSQ had a similar predictive ability when used together with age and gender. The area under the curve was 0.71 (95% CI: 0.68−0.74) for ASA and 0.70 (95% CI 0.67−0.72) for SPMSQ.

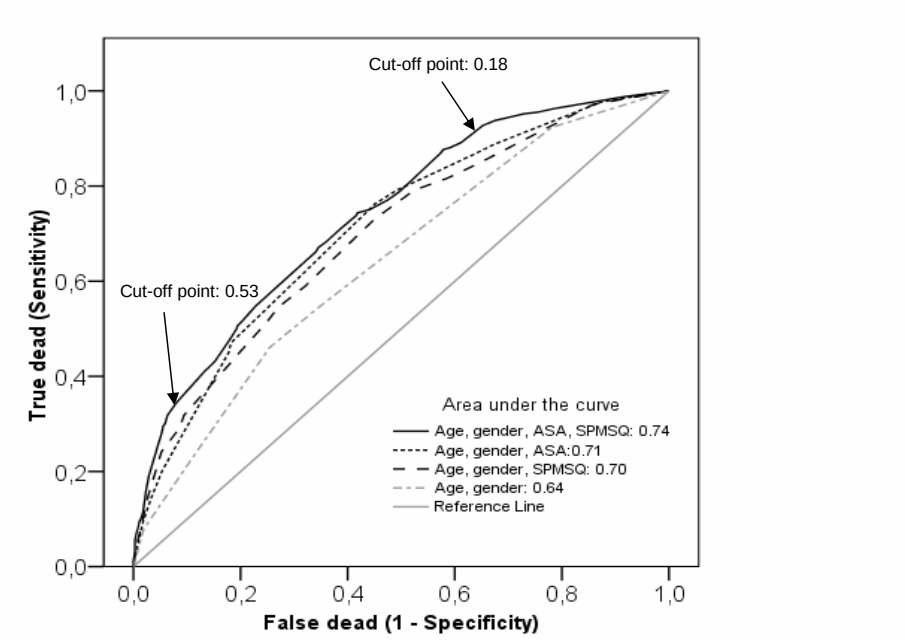


Figure 17. Evaluation of the ability to predict death within 24 months after surgery for models with different factors. Results expressed by the receiver operating characteristic (ROC) curve.

GENERAL DISCUSSION

The overall aim of this thesis was to evaluate the functional outcome *(Studies I-III)* and quality of life after trochanteric and subtrochanteric fractures *(Studies II* and *III).* We also wanted to identify preoperative factors that were associated with mortality and to evaluate the combined use of the ASA classification[59] and the SPMSQ[61] as tools to identify patients at risk *(Study IV).*

FUNCTIONAL OUTCOME

The negative impact on functional outcome following a hip fracture has been documented in a number of studies.[49,69,70] Several factors may contribute to the patients' decline in physical functioning. Fracture healing complications, especially those demanding revision surgery, may of course affect the patient's ability to assimilate rehabilitation measures and in turn also precipitate other acute events. In one study the readmission rate to hospital was found to be as high as 40% and was higher in patients with postoperative complications.[71] The reason for readmission has been shown to relate rather to co-morbidities than to the hip fracture *per se.*[72] Pain is also a factor that may interfere negatively with the rehabilitation process and affect functional outcome along with limited access to appropriate rehabilitation programmes and physiotherapeutic assistance.

As previously mentioned, it is difficult to compare functional outcomes in different studies on hip fracture patients because the outcome is highly dependent on the study inclusion criteria, especially with regard to age, prefracture physical functioning and co-morbidities. However, these difficulties are probably less pronounced when the patients to be compared are recruited from the same cohort of consecutive hip fracture patients from a defined catchment area during a defined period of time as in *Studies II* and *III*. The study populations in *Studies II* and *III* were very similar with regard to age, prefracture walking ability and ASA score. The mean age was 83 (range 66-101) years, 41−44% of the patients did not use any walking aid before the fracture and 43−49% were classified as ASA 1−2. In *Study II,* including patients with stable trochanteric fractures, we found that 46%, 52% and 55% had regained their prefracture walking ability at 4, 12 and 24 months, respectively. The corresponding figures for the patients with subtrochanteric fractures in *Study III* were 43%, 47% and 46%, respectively, indicating that patients with subtrochanteric probably have a worse final outcome with regard to walking ability.

The mixed population of patients with unstable trochanteric and subtrochanteric fractures in *Study I* is somewhat different. Firstly, although the mean age was quite similar to that in *Studies II* and *III,* i.e. 82 years, patients under 66 years of age were also included and more than 60% of the patients were able to walk without walking aids before the fracture. Accordingly, a higher percentage of these patients were able to regain their prefracture walking ability, 56−59% at 4 months and 57−63% at 12 months.

Our overall results regarding walking ability appear to be inferior to those of some previous studies reporting that 40−90% of their patients were able to walk without aids at both 4 and 12 months.[12,34,73] These differences are probably at least partly explained by different patient characteristics. The mean age of our patients was higher than those in previous studies and between 40 and 60% of our patients already used walking aids before the fracture. Another explanation could be the free and easy access to walking frames in our society, which contributes to their popularity even among elderly persons without significant walking disabilities.

Our finding of better walking ability in the early postoperative period in patients treated with the proximal femoral nail is in agreement with the results reported by Pajarinen et al.[74] However, in that particular study the follow up period was too short to evaluate the long-term outcome. Utrilla et al.[75] also showed that patients with unstable trochanteric fractures operated upon using the trochanteric Gamma nail had better walking ability up to 12 months postoperatively than those operated on with a sliding hip screw. Moreover, Simmermacher et al.[25] showed that 40% of their patients in a study including both stable and unstable fractures operated on using the proximal femoral nail had the same unrestricted walking ability 4 months postoperatively. These findings could indicate that intramedullary devices might facilitate the early postoperative rehabilitation, which is of great importance to the elderly patient. One probable explanation could be the percutaneous insertion technique which may result in less pronounced soft tissue trauma and improved muscle function. However, the latter could not be verified by our analysis of isometric abductor muscle strength in *Study I.* This assessment did not demonstrate any significant differences between the PFN and the MSP at any of the follow-ups.

Another aspect of functional outcome, although less frequently reported, is the activities of daily living (ADL) function. Besides walking ability, the ability to perform ADL is very important, not least for the elderly patient whose ADL function may have already been partly impaired before the fracture. A minor deterioration may convert a previously independent elderly person to a dependent and institutionalised patient. In our comparable populations of patients with stable trochanteric fractures *(Study II)* and subtrochanteric fractures *(Study III)*, those with stable trochanteric fractures had a better outcome with regard to ADL. Among patients with stable trochanteric fractures, 62%, 63% and 66% had regained their prefracture ADL function at 4, 12 and 24 months, respectively, compared to 46%, 44% and 48% among patients with subtrochanteric fractures.

The differences in pain at the hip were less pronounced, especially at the final two-year follow-up. Among patients with stable trochanteric fractures 72%, 77% and 81% reported no or limited pain at 4, 12 and 24 months, respectively, compared to 64%, 70% and 80% of those with subtrochanteric fractures.

The importance of regaining the prefracture walking ability and level of ADL function is reflected in the outcome regarding returning to independent living conditions. Among patients with stable trochanteric fractures who were living independently before the fracture, 89%, 85% and 88 % had returned home at 4, 12 and 24 months, respectively. The corresponding figures for patients with subtrochanteric fractures were worse: 74%, 74% and 71%.

The overall worse outcome for patients with subtrochanteric fractures is probably a reflection of the fracture type being more complex and associated with a more severe soft tissue injury and thereby resulting in a more difficult rehabilitation for these elderly patients. However, the results in all three studies *(I, II* and *III),* including all types of trochanteric and subtrochanteric fractures, underline the fact that this patient group should be offered multidisciplinary rehabilitation during their stay on the orthopaedic ward and, if necessary, be referred to dedicated rehabilitation units after the initial postoperative course and also be offered outpatient rehabilitation after discharge from the hospital or rehabilitation unit. It is likely that these measures could contribute to an improved recovery of function in these patients and decrease the costs to society.

QUALITY OF LIFE

Does a quality of life assessment add any valuable information in orthopaedic outcome studies? Most orthopaedic surgeons in this field of research would agree. The quality of life assessment certainly serves as a complement to conventional outcome measures in orthopaedic surgery, such as fracture-healing complications, reoperations and mortality, and also as a complement to disease-specific outcome instruments, e.g. scores evaluating hip function. Moreover, since HRQoL is a patient-reported outcome measure, it gives us valuable information on how the injury/illness influences all areas of the patient's life and thereby enhances our ability to improve future health care programmes. Up to now, there has been a very limited number of papers evaluating the HRQoL after trochanteric fractures and even fewer using a validated quality of life instrument in the assessment.

Comparing outcomes with regard to HRQoL between different studies on hip fracture patients has the same limitations as for other outcome measures, i.e. the result is very much dependent on the study inclusion criteria. Furthermore, since most HRQoL assessments are self-reported, the results are also dependent on the patients' cognitive function. This was the reason for using a validated instrument for assessing cognitive function in *Studies II* and *III.* The Short Portable Mental Status Questionnaire (SPMSQ)[61] was used and only patients without severe cognitive dysfunction were included (SPMSQ ≥ 3).

The EQ-5D, which is brief and easy to use in elderly patients,[46,76] has been validated in hip fracture patients.[77-79] Moreover, it also allows combining different dimensions of health to form an overall index, as required for health care evaluations[42] and for constructing quality-adjusted life years (QALYs),[43] a measure frequently used in cost-effectiveness analyses.

The patients with stable trochanteric fractures *(Study II)* experienced a deterioration in their HRQoL during the first postoperative year, but at two years the survivors had almost regained the same level of quality of life as before the fracture. The patients with subtrochanteric fractures *(Study III)* showed a different pattern with a substantial negative effect upon their quality of life although the number of fracture-related complications was limited. There was a clear deterioration in the HRQoL, which was established as early as at 4 months and persisted without any positive development during either the first or

second year after the fracture. This is probably a reflection of the functional outcome with impaired walking ability and ADL function.

The HRQoL was not assessed in *Study I.* However, the HRQoL determined by the same instrument, the EQ-5D, in a randomised controlled trial with a one-year follow-up in patients with unstable trochanteric fractures (J-M 3−5)[9] and high subtrochanteric fractures[10] has been reported previously.[38] Patients with unstable trochanteric fractures in that study satisfying the same inclusion criteria as for our patients in *Study II* reported significantly more pain and a more pronounced deterioration in HRQoL at both 4 and 12 months, with EQ-5D $_{index}$ scores of 0.44 and 0.51, respectively, compared to patients with stable trochanteric fractures.

The HRQoL according to the EQ-5D has also been reported for patients with femoral neck fractures, both after internal fixation and different types of arthroplasties.[44-47,80] In studies using nearly the same inclusion criteria as in the present study, patients with femoral neck fractures were, compared to those with trochanteric fractures, approximately three years younger and their quality of life before the fracture was generally better. Our results regarding the HRQoL of patients with stable trochanteric fractures are comparable to the favourable outcome after internal fixation of undisplaced femoral neck fractures (Garden I and II) or after primary arthroplasty in patients with displaced femoral neck fractures (Garden III and IV).[44-46,58]

In summary, patients with stable trochanteric fractures have a favourable outcome with regard to HRQoL while patients with unstable trochanteric fractures and subtrochanteric fractures have a significant deterioration in HRQoL. The data on HRQoL obtained in *Studies II* and *III* can be used in future health care evaluations and to calculate quality-adjusted life-years (QALYs).

MORTALITY

An increased mortality rate in hip fracture patients compared to the general population seems inevitable, especially during the first year after the fracture. As for other outcome measures, the magnitude of the mortality rate is highly dependent on the inclusion criteria and therefore is not readily comparable between individual trials. Moreover, the follow-up period in most previous prospective studies is limited to 6 or 12 months. Several factors can interfere with the patients' risk of dying after a hip fracture. Earlier studies have shown that diagnosed dementia as well as severe cognitive dysfunction in elderly patients markedly increases the risk of dying compared to other citizens.[54,81] Lately, there has been an increasing awareness that male gender appears to be a factor associated with mortality as men have approximately double the mortality rate after hip fracture compared to women and that this difference persists up to 2 years after the fracture.[82,83] This is partly explained by more frequent and severe co-morbidities in men.

One problem in a clinical setting is to identify the patient who has an increased mortality risk. The American Society of Anesthesiologists (ASA) classification[59] for assessing the patient's general health and the Short Portable Mental Status Questionnaire (SPMSQ)[61] for assessing the patient's cognitive function fulfil these requirements and

both instruments have been evaluated separately in clinical trials and have been shown to identify hip fracture patients with increased mortality rates.[54,84,85] However, combined use of the ASA classification and the SPMSQ to identify patients at risk has not been evaluated previously in a large prospective cohort study of consecutively admitted hip fracture patients.

Our results showed that there was a clear relationship between the ASA score and the mortality rate, which is in conformity with previously published studies.[84,85] Even though the number of co-morbidities and the ASA score can be considered to be two ways of describing the patient's current health status, our multivariable analysis implied that the ASA score is more strongly related to mortality − perhaps because it focuses on the severity of the patient's physical status.[86] Therefore, the ASA score appears to be useful not only for surgery-related short-term mortality assessments, but also for predictions of the long-term mortality in a hip fracture population.

The problems involved in making a correct assessment of the patient's cognitive function without a validated instrument have been highlighted previously[87] and the use of the SPMSQ at admission to the orthopaedic unit can identify patients with severe cognitive dysfunction and predict a poor outcome with regard to walking ability, ADL function and mortality.[54] We have continued our use of the validated SPMSQ questionnaire as the assessment tool because it is both quick and easy to use, which are important factors in an emergency care facility.[61,88,89] The results of the present study confirm previous results[54] showing that patients with a low SPMSQ at admission had a significantly higher mortality rate than those with normal cognitive function.

It is important to keep in mind that cognitive dysfunction is a symptom seen both in dementia and delirium. Although the SPMSQ gives good information about the patient's present cognitive status, it is of major importance for the patient's future care to diagnose as soon as possible the underlying cause of the cognitive dysfunction. However, it is not always possible to obtain this information in the acute setting, i.e. before surgery. According to previous studies, a delay of the operation of more than 48 hours is associated with an increased complication and mortality rate.[90,91] Therefore, giving priority to a swift appraisal of hip fracture patients is of major importance and a delay of surgery should be avoided.

The reason why patients with impaired cognitive function have an increased mortality rate is probably multifactorial. Firstly, as shown in our study, impaired cognitive function is associated with poorer general health. Moreover, recent data indicate that patients with cognitive impairment do not have the same possibilities for adequate rehabilitation as cognitively intact patients.[92] However, by adopting a multifactorial intervention programme, it may be possible to reduce the complication rate and shorten the hospital stay.[93] Whether a different rehabilitation regimen may reduce the mortality rate remains to be analysed.

Our analysis indicated that the combined preoperative use of the ASA classification and the SPMSQ identified patients at risk more effectively than when each of the instruments was used separately. In particular, patients with a severe or incapacitating disease (ASA 3−4) combined with severe cognitive impairment (SPMSQ 0−2) have a high mortality rate and should be identified early on during the acute hospitalisation to prevent, if possible, fatal complications. The ASA and the SPMSQ scorings are both

quick and easy to perform in clinical practice and can serve as a valuable aid in the planning of the operative treatment, medical care, nursing, and rehabilitation of the individual patient.

Advanced age and male gender are known risk factors for an increased mortality rate after a hip fracture,[54,55] but, used as predictors alone, they have limited ability to predict death. Based on our results, the outcome seems to be more dependent on the patients´ physical and mental health. However, when age and gender are used in combination with ASA and SPMSQ, the ability to predict the risk of death is improved. As previously demonstrated, an increasing number of co-morbidities was associated with a higher mortality rate.[55] However, we opted not to include the number of co-morbidities in the predictive model. Assessing the number and relevance of co-morbidities is difficult, especially in the acute setting. Additionally, the inclusion of co-morbidities in the model did not improve its predictive value.

There are studies reporting the role of preoperative functional status in predicting the mortality for patients with hip fractures.[94] We opted not to include the preoperative functional status in our analysis. Although this information has proven its value in clinical studies, it may be difficult to acquire useful information regarding functional status in the acute setting of routine health care, especially in patients with severe cognitive dysfunction.

Although it is well known that patients with poor general health (high ASA score) and cognitive dysfunction (low SPMSQ score) have a higher mortality rate, this information is rarely used in clinical practice to identify patients at risk. Our model combining four predictors, all readily accessible upon admission, can be used by clinicians as a tool to assess the individual patient's mortality risk. Our evaluation of the model indicates that it is most accurate in predicting the mortality risk for patients with the highest and lowest risk levels, i.e. those with an increased risk of dying and those with a high chance of survival. Moreover, our analysis indicated that the combined preoperative use of the ASA classification and the SPMSQ identified patients at risk more effectively than when each of the instruments was used separately. In particular, patients with a severe or incapacitating disease (ASA 3−4) combined with severe cognitive impairment (SPMSQ 0−2) have a high mortality rate and should be identified early on during the acute hospitalisation phase to prevent fatal complications, which is of the greatest importance, as it appears to be the only variable that can be influenced in the hospital care setting to decrease the mortality rate. The main purpose for using an instrument like this is to prevent and decrease mortality in this fragile group of patients. It could also be useful for the clinicians when counselling the patients and their family so they may be able to prepare for changed needs in the future. Moreover, it can be used to identify patients with increased life expectancy. This is, for instance, an important factor in the decision-making process when choosing the type of arthroplasty, i.e. HA or THR, in elderly patients with displaced femoral neck fractures.

The question is, can we change the prognosis for the individual with a hip fracture? We believe that this is possible and a recent study supports this notion.[92,93] An instrument like the one presented in this thesis can help the clinician to identify patients at risk. Besides an early anaesthesiological assessment, the patient should be assessed by a specialist in internal medicine or geriatrics during the stay on the orthopaedic ward or

already in the emergency ward, and the necessary measures should be implemented. The patient should be operated on as soon as possible in a fast-track setting. With this raised level of precaution, the circumstances during the hospital stay could be optimised and hopefully the patients could be discharged from the orthopaedic ward, not only optimally treated purely surgically but also optimally treated with regard to their co-morbidities and any possible complications. With this increased awareness, we would also have the opportunity to improve the nursing care in such areas as nutrition and prevention of decubital ulcers, delirium and pain. To be able to implement these improvements in the treatment of hip fracture patients, it is necessary to inform policy-makers and hospital managements and seek their support in the development of new preventive strategies.

SURGICAL OUTCOME

Our finding of a 3% reoperation rate in patients with stable fractures *(Study II)* is in conformity with previous studies.[12,13] The main reason for revision surgery was lag-screw penetration, which has also been shown to be the predominant reason for revision in most other studies on stable trochanteric fractures.[12,14,15,73] This was also the most frequent reason for revision surgery on patients with unstable trochanteric fractures in *Study I.* The overall reoperation rate for these patients was 4%, i.e. 7% in the PFN group and 1% in the MSP group. In this study the overall reoperation rate for patients with subtrochanteric fractures was higher, 10%, with all reoperations in the PFN group. We found a lower revision rate, 8%, in patients with subtrochanteric fractures treated with short or long cephalomedullary nails in *Study III.* In contrast to the situation after a trochanteric fracture, only 2.3% of the patients with subtrochanteric fractures in that study were reoperated upon due to cut-out, a finding at par with the 1.7% reported by Robinson et al.[35] However, in contrast to Robinson and co-workers, we found only one patient with a delayed union resulting in reoperation (dynamisation). On the other hand, three of the eight patients (3.1%) reoperated on for suspected non-union in the study by Robinson and co-workers had a healed fracture at the time of exploration. A finding also in conformity with this previous study was that a fracture close to the tip of the nail was another major cause of reoperation, 2.3% in our study compared to the 1.7% reported by Robinson et al.,[35] all in patients with long nails. Owing to the natural antecurvation of the femur nail, impingement upon the anterior cortex of the distal femur has been a problem, especially with the use of earlier generations of cephalomedullary nails. This problem is less pronounced in later generations with reduced stiffness and a smaller radius of curvature. However, both of our patients sustained their distal fractures after falling accidents more than two months after the index operation and this particular complication probably cannot be completely eliminated. In an elderly patient with a femur implant sustaining a significant trauma, the stress concentration and eventual fracture will most probably occur at the distal end of the implant regardless of its length or type, i.e. nail or plate. As expected, the number of fractures distal to the short cephalomedullary nail was low in our studies, i.e. only 1 patient in *Study I* treated with a PFN, supporting the notion

that improved nail design and modern atraumatic surgical technique have reduced, but not eliminated, the risk of this particular complication.

Patients with a cut-out complication in *Study I* had a higher TAD value than patients without cut-out, which is in conformity with previous studies.[95-97] Both the reduction and the fixation are of great importance to obtain a good result. For a reduction to be regarded as good in trochanteric fractures, there has to be a normal or slight valgus alignment on the anterioposterior radiograph with less than 20 degrees of angulation on the lateral radiograph and no more than four millimetres of displacement of any fragment.[95]

On the other hand, the method of fixation must neutralise the forces that tend to displace the fracture. Theoretically, the best implant would be situated in the centre of the axial load, thereby creating a shorter lever arm and a lower bending torque. It is also a great advantage if the system can tolerate immediate weight bearing, especially when used in the elderly. The risk of such complications as cut-out should be minimised and the periostal blood supply should be disturbed as little as possible.[98,99] An intramedullary nail meets these requirements and this could be one explanation for our finding of better walking ability in the early postoperative course in the PFN group *(Study I)*.

An improved walking ability cannot, however, be balanced against the significantly higher reoperation rate we found. We cannot fully explain the significantly higher reoperation rate after the PFN compared to the MSP. There were no differences in TAD between the groups. One explanation could be that there were a higher number of patients who had a reduction in varus in the PFN group than in the MSP group, viz. 19% compared to 9%. Another reason could be that there were slightly fewer patients in the PFN group who had a good position of the lag screw postoperatively (central or caudal in the anteroposterior and central or posterior view in the axial radiography), viz. 83% compared to 86% in the MSP group, and there was also a higher frequency of anterior positioning of the femoral screw in the PFN group, viz. 10% compared to 2% in the MSP group (unpublished data). Moreover, at least 3 of the reoperations in the PFN group were caused by inadequate surgical technique. These explanations may be a reflection of the learning curves of the surgeons involved in the study. Although the PFN had been used at both participating institutions for some time before the study, the extramedullary technique utilised in the MSP group had been in use for a significantly longer period of time. Another question is why the MSP, despite the good results reported for both unstable trochanteric and subtrochanteric fractures,[17,18,34] is not used more frequently. One possible explanation might be that the surgical technique has been found to be demanding and requires a thorough knowledge of fracture classification to enable the surgeon to utilise the implant optimally. For example, erroneous use in the uniaxial dynamisation mode increases the risk of lag-screw penetration and requires a scheduled radiographic follow-up and a readiness for staged dynamisation.

The introduction of intramedullary nails in 1990 produced a dramatic increase in the intramedullary nail fixation rate from 3% in 1999 to 67% in 2006 in the US.[100] On comparing the results of a sliding compression hip screw and a side plate to intramedullary nailing fixation in a total of 18,720 patients, there was a slightly higher overall complication rate in patients operated upon with the intramedullary nail, but without statistical significance.[100] In a meta-analysis by Jones et al., pooled results indicated no statistical significant differences in cut-out rate between the sliding hip

screw and intramedullary nailing, but the total failure rate and the reoperation rate were higher with the intramedullary nail.[101] Recently, a Cochrane review of extracapsular fractures showed that cephalomedullary nails resulted in one extra reoperation in every 50 patients and that the nails are associated with an increased risk of fracture of the femur both during and after operation. No difference was seen in long-term outcomes and mortality between the two methods.[26] The present situation is difficult to comment on as 46% of the included studies were published before the year 2000 and thus include older designs of the cephalomedullary nail and many of them also include the surgeons' learning curves for their patients treated with the cepahlomedullary nail. During recent years the design of the nail and the surgical technique have developed and in a study by Anglen et al., there is a trend over recent years suggesting that the complication rate for intramedullary nailing is declining.[100]

In summary, we believe that there are good reasons to assume that the cephalomedullary nails are superior to extramedullary techniques in elderly osteoporotic patients with subtrochanteric fractures while the benefit of the nails remains to be further evaluated in patients with unstable trochanteric fractures. In patients with stable trochanteric fractures, we do not see any reason yet to change from the extramedullary to the intramedullary technique.

STRENGTHS AND WEAKNESSES

All studies have strengths and weaknesses that need to be addressed.

In *Study I* the strength was its prospective and two-centre design and also its rather large study population. One drawback was the high rate of patients unable to attend follow-up at different times. Many patients had concomitant diseases affecting their general health, thereby making it impossible to participate at follow-up and a number of patients declined further participation in the study, and both reasons are difficult to affect.

In *Studies II* and *III* the multicentre design, with a large study population and relatively few patients lost to follow-up, contributes to their strengths. The drop-out rates at the various follow-ups were acceptable in this fragile age group and not of such a magnitude that the validity of the conclusions would be jeopardised. To be able to assess the influence of the injury on the quality of life, our patients were asked to rate their HRQoL the week before the fracture, which may not be the optimal approach. The patients' ability to correctly recall their health status prior to the hip fracture may be questioned. However, since a prospective collection of HRQoL baseline data for a specific injury population is impossible, the alternative methods often used are preinjury recall, as in this and other trauma studies[44,46,80,102] and/or the use of population figures. Another limitation of *Studies II* and *III* was that at each follow-up the patients were interviewed by phone and only patients reporting problems were scheduled for a follow-up visit including a radiographic examination. Furthermore, we opted not to include patients with severe cognitive dysfunction and patients who were already unable to walk before the fracture as they are difficult to evaluate, especially with regard to HRQoL[103,104] and their quality of life is strongly influenced by their cognitive dysfunction and other co-

morbidities.[105] Another limitation was that we did not use the long nails in all patients with subtrochanteric fractures in *Study III*. Individual surgeons opted to use the short cephalomedullary nails in patients with high subtrochanteric fractures. However, short nails have been shown to be successful in previous studies on patients with high subtrochanteric fractures. Miedel et al.[38] reported no reoperation in 16 patients with high subtrochanteric fractures treated with the short Gamma nail and, in the present study, none of the fracture-related complications occurred in patients operated upon with short nails. The only reoperation after fixation with a short nail was due to a primary malrotation. Therefore, we believe that our results are representative of cephalomedullary nails in general.

The predictive model in *Study IV* needs to be validated in another patient cohort. Although our model showed an acceptable predictive ability, indicating good internal validity, the external validity is unknown and also needs to be evaluated in future studies. Another weakness of the study is the missing data for the SPMSQ in 15% of the patients. However, nearly 50% of the patients with lacking data had previously been diagnosed as suffering from dementia. A consequence of the lacking data is that we have probably underestimated the association between a low SPMSQ and the mortality rate since patients with dementia are known to have a low SPMSQ[61] as well as a shorter life expectancy.[54,106-108] This assumption is supported by the tree analyses in which patients with missing data for the SPMSQ had a higher mortality rate than those with available scores. The major strength of *Study IV* is its multicentre design, allowing the inclusion of a large number of consecutive patients with hip fractures from a well-defined population and with an appropriate follow-up period. The quality of the data was generally high owing to the fact that they were collected by trained research nurses according to a validated protocol (SAHFE) and were assessed with validated instruments. Moreover, thanks to the Swedish personal registration number system, we were able to obtain complete mortality data, except for three patients (1.5 ‰), at the 24-month assessment. Therefore, we have good reason to assume that our conclusions are amenable to generalisation in this patient population.

It is also a strength that all studies were prospective and surgery was performed by a number of surgeons in a standard clinical setting. This makes our results applicable on a general population level.

CONCLUSIONS

STUDY I

There were no major differences in functional outcome or major complications between the PFN and MSP groups, even though the nail group had slightly better results for walking ability in the early rehabilitation period. Subtrochanteric fractures and unstable trochanteric fractures showed equally good results. An advantage of the MSP was the lower reoperation rate.

STUDY II

The outcome after a stable trochanteric fracture treated with a SHS was favourable with a low reoperation rate and a good outcome regarding pain at the hip and only limited deterioration in HRQoL. Even though a number of the patients experienced a deterioration in their walking ability and ADL function, this did not seem to affect their quality of life.

STUDY III

A subtrochanteric fracture in elderly patients had a substantial negative effect on both their short and long-term HRQoL. Although pain at the hip was not a major problem, there was an obvious deterioration in walking ability and ADL function. The rate of revision surgery was comparatively low, which confirms the view that use of the cephalomedullary nail constitutes a safe treatment for elderly patients with a subtrochanteric fracture.

STUDY IV

The combined use of the ASA classification for assessing physical health and the SPMSQ for assessing cognitive function effectively identified hip fracture patients with an increased mortality rate. We suggest a predictive model including age, gender, ASA and SPMSQ which can be used to assess the mortality risk after hip fracture surgery.

OVERALL CONCLUSION

The PFN contibutes to a better walking ability in the early rehabilitation period but also causes more reoperations than the MSP. There was an obvious reduction in HRQoL, after both a stable trochanteric fracture and a subtrochanteric fracture. More attention should be devoted to patients with subtrochanteric fractures as the deterioration in their quality of life appears to persist over time in contrast to after a stable trochanteric fracture. The data on HRQoL obtained in *Studies II* and *III* can be used in future health care evaluations and to calculate quality-adjusted life-years (QALYs). A combined use of ASA and SPMSQ and a predicitive model also including age and gender can be used to identify patients at increased risk of mortality.

CONSIDERATIONS FOR FUTURE RESEARCH

- □ The effect of a multidisciplinary intervention programme on the mortality rate in patients at risk for increased mortality.
- □ The effect of a multidisciplinary intervention programme on the quality of life in patients with subtrochanteric fractures.
- □ Health care evaluations including an assessment of QALYs in patients with fractures of the proximal femur.
- □ The optimal surgical treatment, intramedullary or extramedullary, in patients with an unstable trochanteric fracture.

ABSTRACT IN SWEDISH

En höftfraktur hos en äldre människa är ofta förenad med en hög komplikationsrisk och ökad dödlighet. En höftfraktur innebär även ett allvarligt hot mot patientens framtida gångförmåga, sociala funktion, livskvalitet och autonomi.

Syftet med avhandlingen var att få ökad kunskap om patientens funktionsnivå efter behandling med en intramedullär (proximal femoral nail; PFN) eller extramedullär (Medoff sliding plate; MSP) fixation av en instabil trokantär och subtrokantär fraktur. Målsättningen var också att rapportera hälsorelaterad livskvalitet över en längre tid för patienter med stabil trokantär fraktur opererad med glidskruv och platta (SHS) och för patienter med subtrokantär fraktur opererad med märgspik. Föresatsen var även att identifiera faktorer som var förenade med ökad dödlighet och att skapa en prediktiv modell för att bedöma mortalitetsrisken redan vid inläggningen på sjukhuset.

I *Studie I* bedömdes patienter med trokantär och subtrokantär fraktur avseende gångförmåga, resa sig från en stol utan armstöd, kliva upp på en tröskel och abduktionstest. Förmågan att gå 15 m vid 6 veckor var signifikant bättre i PFN gruppen, dock utan några andra skillnader i övriga funktionstest. Frekvensen av allvarliga komplikationerna, 8% i PFN gruppen och 4 % i MSP gruppen, skiljde sig inte signifikant åt men frekvensen av reoperation var högre i PFN gruppen.

Studierna II och *III* utvärderade patienternas funktion, hälsorelaterad livkvalitet och mortalitet. Bland patienter med stabil trokantär fraktur hade 55% återfått sin gångförmåga, 66% sin ADL funktion och de hade nästan återhämtat sin tidigare nivå av livskvalitet vid 2 år. Bland patienter med en subtrokantär fraktur hade 46% fått tillbaka sin gångförmåga, 48% sin ADL funktion men dessa patienter hade fortfarande en markant och kvarstående försämring av sin livskvalitet efter 2 år.

Studie IV fokuserade på prediktorer för mortalitet bland patienter med höftfraktur. 1944 patienter bedömdes avseende kön, ålder, typ av höftfraktur, komorbiditeter, ASA och kognitiv funktion enligt SPMSQ. En prediktiv modell skapades baserad på faktorer som var signifikant associerade med mortalitet och som var möjliga att bedöma redan vid akutinläggningen. Mortaliteten under vårdtiden var 4%, vid 4 månader 16% och vid 24 månader 38%. Högt ASA värde, lågt SPMSQ värde, hög ålder och manligt kön var de faktorer som var starkast associerade med mortalitet. Analyserna visade att användandet av ASA och SPMSQ i kombination effektivt kunde identifiera patienter med ökad risk för dödlighet.

Sammanfattningsvis visar resultaten i avhandlingen på att PFN bidrog till bättre gångförmåga tidigt i rehabiliteringen men denna metod orsakade även fler reoperationer jämfört med MSP. Patienterna rapporterade en tydlig försämring av den hälsorelaterade livskvaliteten i den tidiga rehabiliteringsfasen både efter en stabil trokantär fraktur och framförallt efter en subtrokantär fraktur. Patienter med subtrokantär fraktur hade dessutom en försämring av livskvalitet som kvarstannade på en låg nivå över tid vilket var i kontrast till situationen hos patienter med stabil trokantär fraktur. Ett kombinerat användande av ASA och SPMSQ och en prediktiv modell även inkluderande ålder och kön kan användas för att identifiera patienter med ökad risk för dödlighet.

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