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THE EPIDEMIOLOGY AND OUTCOME OF FRACTURES IN ELDERLY AND SUPER-ELDERLY PATIENTS

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DECLARATION

I declare that the thesis has been composed by myself and that the work has not be submitted for any other degree or professional qualification. I confirm that the work submitted is my own, except where work which has formed part of jointly authored publications has been included. My contribution and those of the other authors to this work have been explicitly indicated below. I confirm that appropriate credit has been given within this thesis where reference has been made to the work of others.

The work presented in Chapters 3 to 10 has now been published [appendices 1 to 10]. My co-authors, which includes my supervisor, helped with the concept, data collection and analysis, and proofreading the submitted articles. However, I conceived and formulated the study aims and carried out the majority of the data collection and analysis. I wrote and constructed the content of this thesis without the contribution of my co-authors.

Nicholas David Clement

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Last but not the least I would like to thank my family: my wife Jackie, my two wonderful girls Rosie and Abigail, and my parents Yvonne and David for their endless support with my research and composition of this thesis. One day they may thank me should they ever sustain a fracture when they are elderly or super-elderly!

ABSTRACT

Introduction

Over the next decade it is predicted that there will be an increase in the elderly (≥65 years old) population within Western society especially those aged 80 years or more (super-elderly). Associated with this there is an anticipated increase in the number of patients presenting with fractures in these age groups. There is a paucity of literature describing the outcome of fractures in the elderly and super-elderly, other than those affecting the hip.

Aims

To describe the epidemiology and outcome of common fractures in the elderly and super-elderly patients.

Methods

Two prospective fractures databases were used to describe the epidemiology and change in incidence of fractures sustained by elderly and super-elderly patients over a decade for the same patient population. Case-mix and outcome variables for 1310 super-elderly patients sustaining acute fractures were recorded. A cohort of 318 very-elderly (90+ years) patients was compared with a group of 992 elderly (80-89 years) patients. During a three-year period, a prospective consecutive series of 162 elderly patients that underwent internal fixation for an undisplaced intracapsular hip fracture was collected. An established database of proximal humeral fractures was used to describe epidemiology and outcome of these fractures in the elderly. Two hundred and twenty-eight displaced distal radial fractures in super-elderly patients were retrospectively identified from a prospective database of 4024 distal radial fractures. 937 elderly patients with pelvic fractures presenting to the study centre over a 15-year period were identified. Two hundred and thirty-three tibial diaphyseal fractures were prospectively compiled for 225 elderly patients over a ten-year period. One hundred and nineteen (5.1% of all elderly fractures) elderly patients presented with multiple fractures during a one-year period were used to describe the epidemiology and outcome.

Results

More than a third of all fractures occur in elderly (≥65 years) patients, of which half occur in super-elderly (≥80 years) patients. The risk of sustaining a fracture was significantly increased for elderly (odds ratio (OR) 2.3) and super-elderly patients (OR 2.7) relative to those aged 15 to 64 years old. More than 90% of fractures in the elderly were sustained after a fall from standing height. There was a significant increase in

the incidence for the elderly (2025 vs 2318/10^5/yr, $p<0.0001$) and super-elderly (3733 vs 4045/10^5/yr, $p=0.0003$) fractures between the years 2000 and 2010. The elderly and super-elderly population increased during this time but so did the number of fractures which increased disproportionally. There was an increased incidence in distal radial, proximal humeral and ankle fractures for the elderly and super-elderly populations. The very-elderly (≥90 years) group accounted for only 0.6% of the overall population, but they represented 4.1% of all fractures and 9.3% of all orthopaedic admissions. Patients in the very-elderly cohort were more likely to require hospital admission, were less likely to return to independent living. Lower American Society of Anesthesiologists (ASA) grade and the presence of posterior tilt ($p<0.0001$) were significant independent predictors of fixation failure of undisplaced intracapsular hip fracture. More than a quarter of elderly patients sustaining proximal humeral fractures had a poor functional outcome, with those patients not living in their own home ($p=0.04$), participating in recreational activities ($p=0.01$), able to perform their own shopping ($p<0.001$) or ability to dress themselves ($p=0.02$) being at an increased risk of a poor outcome which was independent of fracture severity ($p=0.001$). The pre-manipulation dorsal angulation of distal radial fractures was a significant independent predictor of the degree of improvement in the final dorsal angulation ($p<0.001$) and ulnar variance ($p=0.01$). No significant difference was observed in activities of daily living ($p=0.28$), wrist pain ($p=0.14$), whether the wrist had returned to its normal level function ($p=0.25$), grip strength ($p=0.31$) or range of movement ($p=0.41$) between the malunion group and the non-malunion group. The incidence of pelvic fractures increased from 7.9/10^5/yr to 13.1/10^5/yr, of which the majority were fragility fractures of the pubic rami (84%). Pre-injury independence and mobility, socioeconomic status, associated fractures, energy of injury, and male gender were independent predictors of length of stay, return to original place of domicile and one-year mortality. Tibial diaphyseal fractures in the elderly (≥65 years) predominantly occurred in females (73%) after a fall (61%). The overall standardised mortality ratio (SMR) was significantly increased (4.4 $p<0.0001$) relative to the population at risk and was greatest for elderly female patients (8.1 $p<0.0001$). These frailer patients had more severe injuries with an increased rate of open fractures (30%) and suffered a greater non-union rate (10%). Distal radial, proximal humeral and pelvic fractures were associated with a significantly ($p<0.0001$) increased risk of sustaining associated fractures. 4.5% of patients after a simple fall sustained multiple fractures, but due to the frequency of falls in the elderly this mechanism resulted in 80.7% of all multiple

fractures. The SMR at one year was significantly greater after sustaining multiple fractures which included fractures of the pelvis, proximal humerus and proximal femur ($p<0.001$).

Conclusion

The incidence of elderly and super-elderly fractures increased over the last decade. This increase in incidence was specifically observed for fractures involving the distal radius, proximal humerus, and ankle in the elderly and super-elderly populations. The very-elderly group form a small proportion of the population but are more likely to require hospital admission and are less likely to return to independent living with a longer hospital stay. Lower ASA grade and posterior tilt of the femoral neck were independent predictors of fixation failure of undisplaced intracapsular hip fractures. A poor functional outcome after a proximal humeral fracture was not independently influenced by age and factors associated with social independence were more predictive of outcome. Patients with a high risk of distal radial malunion or poor improvement in the fracture position can be identified pre-manipulation, however malunion does not seem to influence the functional outcome of independent super-elderly patients. The incidence of elderly pelvic fractures is increasing, and patient demographics could be used to predict length of stay, return to domicile, and one-year mortality after a pubic rami fracture. Tibial diaphyseal fractures in the elderly are more common in females after a fall, which are more likely to be open and are associated with a higher prevalence of non-union. There will be financial repercussions associated with the management and ongoing care for these frail elderly patients especially those sustaining multiple fractures, with high admission rates, prolonged length of stay, and the increased level of care needed upon discharge.

LAY SUMMARY

The number and overall incidence of fractures increased over the last decade, which is due to the increasing number of fractures in the elderly (≥65 years) and super-elderly (≥80 years) populations. Very-elderly (≥90 years) patients have a similar number of co-morbidities relative to elderly patients aged 80 to 89 years, but they are less likely to be independently mobile or to live in their own home prior to injury. They are more likely to require admission to hospital, have a longer length of stay, and are less likely to return to independent living.

Comorbidity and grade of displacement were independent predictors of fixation failure of minimally displaced hip fractures. Age was not a predictor of poor outcome, nor of mortality or function of shoulder fractures in the elderly. Factors associated with social independence, such as living in their own home, pursuing recreational activities, and being able to shop for themselves are more influential upon outcome. Most super-elderly patients with a displaced distal radial fracture managed with manipulation alone will not heal in the correct position, however there was no functional deficit if it healed in a suboptimal position. This questions whether a surgical intervention should be offered after a displaced distal radial fracture in this population. Elderly patients with pelvic fractures have multiple comorbidities and a prolonged costly length of stay with a high mortality rate where they receive minimal orthopaedic intervention and may benefit for physician assessment early in their admission. The epidemiology of tibial shaft fractures has changed, with a greater proportion occurring in elderly females after a low energy fall. These frailer patients had more severe injuries, with an increased rate of open fractures and suffered a greater non-union rate. The mortality associated with these fractures is equal to that of a hip fracture and therefore these patients should receive the same level of care and prioritisation.

Multiple fractures secondary to low-energy injuries have financial repercussions associated with the management and ongoing care for these frail elderly patients, with high admission rates, prolonged length of stay and the increased level of care needed upon discharge. A large proportion of these patients underwent non-operative management needing only rehabilitation. Hence, these frail patients with an increased mortality risk may benefit from early identification and medical optimization, to facilitate rehabilitation and to provide for their potentially increased care needs and improve their outcome.

KEY MESSAGES

1. The absolute number and overall age adjusted incidence of fractures in the elderly (≥65 years) and super-elderly (≥80 years) has increased over the last decade
2. Within the super-elderly population very-elderly (≥90 years) patients are more likely to require admission to hospital, have a longer length of stay and are less likely to return to independent living relative to those aged between 80 to 89 years
3. Lower level of comorbidity and a posterior tilt on the lateral radiograph are independent predictors of fixation failure of minimally displaced hip fractures
4. More than a quarter of elderly patients sustaining a proximal humeral fracture had a poor functional outcome, with those patients not living in their own home, participating in recreational activities, able to perform their own shopping or ability to dress themselves being at an increased risk of a poor outcome
5. Most super-elderly patients with a displaced distal radial fracture managed with manipulation alone will not heal in the correct position, however there was no functional deficit if it healed in a suboptimal position
6. Elderly patients with pelvic fractures have multiple comorbidities and a prolonged costly length of stay with a high mortality rate
7. The epidemiology of tibial shaft fractures has changed, with a greater proportion occurring in elderly females after a low energy fall who have more severe injuries, with an increased rate of open fractures, non-union and mortality
8. Multiple fractures secondary to low-energy injuries in elderly patients result in high admission rates, prolonged length of stay and the increased level of care needed upon discharge, with an associated increased mortality risk

RESEARCH METHODLOGIES USED

Study design

Prospective cohort study

- Sections 2.1, 2.2, 2.3 and 2.8

Retrospective cohort study

- Sections 2.4, 2.5, 2.6 and 2.7

Statistical analysis

Descriptive statistics

- All studies: sections 2.1 to 2.8

Simple statistical tests (parametric non-parametric)

- All studies: sections 2.1 to 2.8

Logistic regression analysis

- Sections 2.2, 2.4, 2.5 and 2.6

Multivariate regression analysis

- Sections 2.2, 2.4, 2.5, 2.6 and 2.7

Standardised mortality ratios

- Sections 2.3, 2.4 and 2.7

Kaplan Meier survivorship

- Sections 2.3, 2.4, 2.7 and 2.8

Cox regression analysis

- Sections 2.3, 2.4, 2.6 and 2.7

PUBLISHED PAPERS FROM THIS THESIS

The changing epidemiology of fall-related fractures in adults

Court-Brown CM, Clement ND, Duckworth AD, Biant LC, McQueen MM

Injury. 2017 Apr;48(4):819-824. doi: 10.1016/j.injury.2017.02.021.

Appendix 1

Manipulation of displaced distal radial fractures in the super-elderly: prediction of malunion and the degree of radiographic improvement.

Clement ND, Duckworth AD, Court-Brown CM, McQueen MM.

Adv Orthop. 2014;2014:785473. doi: 10.1155/2014/785473.

Appendix 2

The outcome of proximal humeral fractures in the elderly: predictors of mortality and function.

Clement ND, Duckworth AD, McQueen MM, Court-Brown CM.

Bone Joint J. 2014 Jul;96-B(7):970-7. doi: 10.1302/0301-620X.96B7.32894.

Appendix 3

Distal radial fractures in the super-elderly: does malunion affect functional outcome?

Clement ND, Duckworth AD, Court-Brown CM, McQueen MM.

ISRN Orthop. 2014 Mar 4;2014:189803. doi: 10.1155/2014/189803.

Appendix 4

Elderly pelvic fractures: the incidence is increasing and patient demographics can be used to predict the outcome.

Clement ND, Court-Brown CM.

Eur J Orthop Surg Traumatol. 2014 Dec;24(8):1431-7. doi: 10.1007/s00590-014-1439-7.

Appendix 5

The spectrum of fractures in the elderly.

Court-Brown CM, Clement ND, Duckworth AD, Aitken S, Biant LC, McQueen MM.

Bone Joint J. 2014 Mar;96-B(3):366-72. doi: 10.1302/0301-620X.96B3.33316.

Appendix 6

The outcome of tibial diaphyseal fractures in the elderly.

Clement ND, Beauchamp NJ, Duckworth AD, McQueen MM, Court-Brown CM.

Bone Joint J. 2013 Sep;95-B(9):1255-62. doi: 10.1302/0301-620X.95B9.31112.

Appendix 7

Undisplaced intracapsular hip fractures in the elderly: predicting fixation failure and mortality. A prospective study of 162 patients.

Clement ND, Green K, Murray N, Duckworth AD, McQueen MM, Court-Brown CM.

J Orthop Sci. 2013 Jul;18(4):578-85. doi: 10.1007/s00776-013-0400-7.

Appendix 8

Multiple fractures in the elderly.

Clement ND, Aitken S, Duckworth AD, McQueen MM, Court-Brown CM.

J Bone Joint Surg Br. 2012 Feb;94(2):231-6. doi: 10.1302/0301-620X.94B2.27381.

Appendix 9

The outcome of fractures in very elderly patients.

Clement ND, Aitken SA, Duckworth AD, McQueen MM, Court-Brown CM.

J Bone Joint Surg Br. 2011 Jun;93(6):806-10. doi: 10.1302/0301-620X.93B6.25596.

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Abbreviations

ANOVA	Analysis of variance
ASA	American Society of Anesthesiologists
db	Direct blow
CI	Confidence interval
CS	Constant score
CT	Computer tomography
DA	Dorsal angulation
DASH	Disabilities of Arm Shoulder and Hand
OR	Odds ratio
RCT	Randomised controlled trial
ROM	Range of movement
RTA	Road traffic accident
SIMD	Scottish Index of Multiple Deprivation
SMR	Standardised mortality ratio
SD	Standard deviation
UK	United Kingdom
UV	Ulna variance

CHAPTER 1:

INTRODUCTION AND LITERATURE REVIEW

CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

1.1 The elderly

An ‘elderly’ person is generally defined by age, with those aged 65 years and older being assigned ‘elderly’ status. This chronological definition is related to policies and social norms concerning retirement and legislation.[1] In contrast, a physiological definition of aging is more complex, and would vary depending on individual well-being, relative to the society in which the person lives.

In the United States of America, the retirement age was introduced in the 1930s as a way of encouraging people to leave the labour force to be replaced by younger people, thereby lowering the unemployment rate. Such legislation made it ‘customary’ to ‘finish working’, thus giving people an expectation of retirement at 65 years. A survey in Manitoba Canada revealed that nearly 80% of people aged 65 and over who considered themselves retired, stated that they had done so voluntarily, although health also entered into the equation for about a third of those questioned.[2]

The elderly population is commonly subdivided into three groups that show marked physiological variation. Thus, young–old (65–69), middle–old (70–74) and old–old (over 75) cohorts are often identified. Sometimes the age divisions vary and being over 80 or over 85 years may define the ‘oldest-old’ category. The terminology also changes with oldest-old and super-elderly being used to define the oldest patients. The term “super-elderly” has been used in orthopaedics for both elective and trauma patients. The definition, however varies from those patients greater than 80 years old to those greater than 90 years old.[3, 4] For the purpose of this thesis the super-elderly population will be define as those patients 80 years old or more. This group of patients is thought to be more vulnerable to the physical and social challenges that are associated with old age, such as widowerhood, worsening health, and an increasing difficulty completing the activities of daily life without assistance.[2]

1.2 Incidence and epidemiology of fractures in the elderly

The world’s population is expected to increase by two billion over the next 30 years to nearly 10 billion by the year 2050 according to current United Nations estimates.[5] However, by 2100 the population of the world is estimated to peak at approximately 11 billion, with an annual growth of less than 0.1%.[5] By 2050 the United Nations estimate that one in six (17%) people in the world will be elderly, aged over 65 years, where the current ratio is one in eleven (9%) people.[5] However, this ratio is estimated

to potentially be even lower in Europe and North America where one in four (25%) will be elderly by 2050.[5] The world's population of super-elderly is projected to increase from a current estimate of 143 million to 426 million by 2050.[5] The elderly population is on the threshold of a boom.[6] According to United States Census Bureau projections, a substantial increase in the number of older people will occur during the 2010 to 2030 period, after the first "Baby Boomers" have turned 65 years old.[7] The older (65 years or more) population in 2030 is projected to be twice as large as it was in 2000, growing from 35 million to 72 million, which will represent nearly 20% of the total United States population.[7] The median age rose from 22.9 years in 1900 to 35.3 years in 2000 and is projected to increase to 39.0 years by 2030.[7] In 2000, the number of people in the oldest-old, defined as those 85 years and older, was 34 times greater than that recorded in 1900, whereas the elderly population aged between 65 and 84 years was only 10 times as large.[7] In 2000, 420 million people in the world were at least 65 years of age which constitutes 7% of the world's population.[7] However, this number is projected to more than double by 2030, reaching 974 million.[7] This changing population demographic is affecting developing countries at a rapid rate; in the year 2000 60% of the world's elderly population lived in developing countries. This is projected to increase to 70% by 2030.[7]

People in developed countries are not only living longer but they are enjoying increasingly healthier lifestyles than ever before. However, the effect of the obesity epidemic on longevity is yet to peak. The average life expectancy in the United States at birth rose from 47.3 years in 1900 to 76.9 years in 2000.[7] Furthermore, disability among the older population is declining, with studies over the past two decades demonstrating a substantial decline in the rate of disability and functional limitation. The growth of this more active and physically fitter elderly population is challenging policy makers, families, businesses, and health care providers to meet the needs of aging individuals. This will have major repercussions upon the type and severity of fragility fractures presenting to orthopaedic surgeons. Fracture management in elderly (≥65 years) and super-elderly (≥80 years) patients will consume a greater proportion of the trauma workload and expense in the future with an increasing elderly population being at risk of trauma.

1.3 Life expectancy of the super-elderly

There is evidence that increases in the population of centenarians over the twentieth century were largely a result of increases in survival between 80 and 100 years and

at birth, as well as increases in the size of the birth cohorts available to survive.[6] The increases in survival from birth to 80 years, combined with the increases in survival from 80 to 100 years seen over the second half of the twentieth century, are expected to continue.[8] This suggests that considerable extension to length of life has been, and will continue to be, achieved in the super-elderly. Table 1.1 presents the life expectancy at age 80 for cohorts born between 1901 and 1961 in England and Wales and the estimated and projected population aged 80 between 1981 and 2041.[8] Life expectancy at age 80 for females born in England and Wales at the beginning of the twentieth century was about eight years.[8] The estimated mid-year population of females aged 80 years in 1981 was 152 thousand.[8] The cohort of females born in England and Wales in 1961 are expected to live, on average, for a further 13 years after their 80th birthday in 2041.[8] The population of females aged 80 in 2041 is projected to be twice the size of that of the same age in 1901. Remaining life expectancy at age 80 for men born during the twentieth century has increased and is expected to increase at a greater pace than that of women. Life expectancy at age 80 for the cohort of men born in 1901 was six years but will be 12 years for those born in 1961. The population of men aged 80 in 1901 was 74 thousand, half that of women of the same age. The population of men aged 80 years projected to be alive in 2041 is 3.5 times larger than that in 1901. The super-elderly population is growing and is projected to continue to grow. In addition, expectation of life at older ages is expected to continue to increase.

Table 1.1. Life expectancy and population for super-elderly population in England and Wales according to year of birth and gender.[8]

Birth cohort	**Year aged 80**	**Life expectancy at 80 (yrs.)**		**Population ≥80 years old**	
		Male	Female	Male	Female
1901	1981	6	8	74,000	152,000
1911	1991	7	8	96,000	172,000
1921	2001	8	9	127,000	202,000
1931	2011	9	11	136,000	180,000
1941	2021	11	12	157,000	187,000
1951	2031	12	13	207,000	244,000
1961	2041	12	13	252,000	295,000

1.4 Falls and fractures

A simple fall from standing height is the commonest cause of injury in the elderly (≥65 years) population.[9, 10] Out of all fall-related injuries needing medical attention in older people, every second injury is reported to be a fracture.[11] In 2000, the worldwide occurrence of fragility fractures in adults aged 50 years or older was estimated to be approximately 9 million.[12] In Finland, the annual number of hip fractures has remained static at approximately 7000 fractures per year in patients aged 50 years or older between 1997 and 2004.[13] However, due to increasing longevity and a growing elderly population the number of fractures presenting to orthopaedic surgeons is estimated to double[14] and the number of hip fractures to double or even triple by the year 2030.[13]

The cost of fracture care in the elderly (≥80 years) is relatively high compared with younger patients.[15, 16] In Finland, the average total cost of a patient with a hip fracture during the first post-operative year was $17,750 in 2003.[15] More recently Nikitovic et al[17] demonstrated the costs to be far greater reaching nearly $40,000 in the first year. This continued into the second post-operative year with a further $10,000 of costs being recorded. This was mainly due to the cost of institutional care after injury, with 24% of females and 19% of males who were living independently in the community before their fracture needing long-term postoperative care. In the United States, the medical expenditures have been reported to be two to three times greater for women compared to men.[10] It is predicted however, that in the future the number and the costs of fall-related injuries will rise more rapidly in older men relative to women.[14, 18] The insult of the fracture upon the functional status of elderly patients can be serious[12] and can lead to excess morbidity and mortality and foreshorten the frailty trajectory.[19] In addition to altering physical performance and the management of activities of daily living tasks, hip fractures may seriously affect health-related quality of life.[16, 20] Thus, fracture prevention is an important public health issue.

Falls and associated fractures can potentially be prevented.[21, 22] The aim of an intervention to prevent a fall is to reduce modifiable associated risk factors for falling and to avoid associated injuries such as fractures.[23] This can be accomplished using multifactorial interventions that are mainly based on exercise prescription to reduce the rate and risk of older people falling.[23] There is inconsistency regarding the role of fall-related factors and bone fragility in predicting whether a person will sustain a fracture.[24] Factors associated with an increased risk of falls differ according to gender.[25] Thus, more detailed information about the gender-specific predictors of fractures are needed in order to make prevention of fractures more effective.

1.5 The Super-elderly

Twenty-three percent of all fractures occur in patients greater than 75 years of age, where the predominant fracture is of the proximal femur.[26] Only a single study has described the epidemiology of all fractures in patients aged 90 years or more.[27] The majority of literature focuses upon proximal femoral fractures for this age group, which has major repercussions for the patient, their family, social and other health care services. These patients have an increased age and gender adjusted mortality rate when compared to the general population.[28] The outcome with increasing age deteriorates; mortality increases and the patient is less likely to return to independent living and mobility after the fracture.[29] Whether these outcomes relate to all fractures in the elderly population is unknown.

It is predicted that there will be an increase in the elderly population within Western society over the next decade.[30] It is anticipated that there will be an 81% increase in the Scottish population aged 75 years of more by 2031.[31] Currently, patients at the extreme of old age represent a small subgroup of those presenting with fractures, but they do account for nearly 8% of acute orthopaedic trauma surgery.[27] The elderly will form a greater proportion of the trauma workload in the future due to their increasing population and will place a major burden upon medical resources both acutely and for the ongoing care of these frail patients.[32, 33] The term "super-elderly" has been used in orthopaedics for both elective and trauma patients. The definition, however varies from those patients greater than 80 years old to those greater than 90 years old.[3, 4]

1.6 Incidence of osteoporosis and changing fracture epidemiology

Osteoporosis is a systemic skeletal disease characterised by low bone mass and microarchitectural deterioration of bone tissue, which results in bone fragility and increased fracture risk.[34] The incidence of osteoporosis is increasing at a rate faster than would be predicted simply by the increasing longevity of the population.[35] The increasing rate of osteoporosis may be one aspect of the increasing rate of fragility fractures that have been observed in Scotland. The estimated prevalence of osteoporosis in Europe varies, in Denmark approximately 20% of men and 40% of women aged 50 years or more have osteoporosis[36], whereas in southern European countries such as Spain, the prevalence is lower but still significant, the condition affecting one in four Spanish women who are at least 50 years of age.[37] Over two million people are affected by osteoporosis in Australia[38], with one in ten men and one

in four women aged over 60 years being diagnosed with osteoporosis.[39] In China, osteoporosis affects almost 70 million people over the age of 50 years, while, in India, bone mineral density at all the skeletal sites showed a high prevalence of osteopenia (52%) and osteoporosis (29%).[40] The prevalence of osteoporosis in the Japanese female population aged 50–79 years has been estimated to be about 35% in the spine and 9.5% in the hip.[41] This considerable global rate of osteoporosis, which seems to be accelerating, may explain the increasing incidence of fractures observed in the elderly population over the last decade. This makes elderly fractures one of the most important groups to understand as this growing group of patients will constitute more of the orthopaedic trauma workload of the future.

There is a paucity of epidemiological data relating to the incidence of fractures and the distribution with regard to fracture type, age and gender.[42] Recent epidemiological study of fractures in England demonstrated that the overall incidence is far greater than prior studies had suggested[42-45], with an annual incidence of 3.6% being calculated from 2002 to 2004.[46] However, this study relied upon patient recall and self-diagnosis of their fracture, inclusive of whether medical attention or diagnosis was sort, which may have led to an overestimation in the incidence they demonstrated. This increase may also be explained by an increase in the incidence of fragility fractures in the elderly, despite the incidence of hip fractures reaching a plateau both in the UK[47] and Europe[48], other fractures may be increasing. Epidemiological data from other countries demonstrate that fractures of the proximal humerus[49], distal radius[50], ankle[51], and pelvis[13] have increased in the elderly. To date there has been no epidemiological study from the UK comparing the incidence of fractures over the last decade or describing the epidemiology of fragility fractures.

The studies that have demonstrated an increase in the incidence of fragility fractures have also illustrated that the rate is increasing most rapidly in the super-elderly.[52-55] The outcome after fractures has been demonstrated to be different for the super-elderly compared to that of an elderly (65 to 79 years old) cohort, which is thought to be related to increasing frailty with age.[56, 57]

1.7 Fractures the proximal femur

Hip fractures account for 12% of all adult fractures presenting to orthopaedic trauma surgeons[26], and are a major cause of morbidity and mortality for elderly patients.[58] Although the reported annual incidence of hip fractures during the last decade may have plateaued[13], the population at risk however continues to increase.[59] Hence,

elderly patients will continue to form an increasing proportion of the orthopaedic trauma workload in the future.

Approximately 60% of hip fractures are intracapsular[58, 60], of which 32% to 38% are undisplaced.[61, 62] The conventional management of an undisplaced intracapsular hip fracture is by internal fixation, however, there is a reported revision rate of between 12% to 17% at one year.[63, 64] Gjertsen et al[62] demonstrated that the outcome of displaced intracapsular hip fractures managed with a hemiarthroplasty had a better outcome when compared to patients with an undisplaced intracapsular hip fracture managed with internal fixation. If patients with a high risk of revision surgery could be identified prior to fixation of their undisplaced intracapsular hip fracture, they may benefit from a primary hemiarthroplasty or potentially a total hip replacement.[65] Parker et al[63] identified that age, mobility, and the lateral Garden angle to be risk factors for non-union after fixation of undisplaced intracapsular hip fractures. Whether these or other factors, such as social deprivation, are independent predictors of failure of fixation is unknown.

The one year mortality after a hip fracture is approximately 30%.[66] Independent patients surviving beyond this time may benefit from a total hip replacement when compared to a hemiarthroplasty.[65, 67] Isolated independent predictors of survival have been identified for hip fractures, but these are inclusive of intra- and extra-capsular fractures.[66, 68] Holt et al[58] specifically identified intra-capsular fractures to be associated with a decreased early mortality rate relative to other hip fracture patterns. Predictors of patient survival after sustaining an undisplaced intracapsular hip fracture have not previously been described. If such predictors were available, patients at a high risk of fixation failure of their undisplaced hip fracture and are likely to survive beyond one year may benefit from an arthroplasty.

Social deprivation influences the outcome of orthopaedic interventions.[69, 70] Quah et al[70] demonstrated that social deprivation was associated with an increased incidence of hip fractures in elderly patients. Socially deprived patients were younger, had a greater level of comorbidity, and suffered a higher unadjusted mortality rate relative to more affluent patients.[70] The effect of social deprivation upon the outcome of specific hip fracture patterns, such as intracapsular fractures, remains unknown.

1.8 Fractures the proximal humerus

The incidence of proximal humeral fractures has increased during the last 40 years in both Europe[71] and the United States[72], and is one of the most common fractures presenting to orthopaedic surgeons.[26] These fractures have a unimodal older male and female distribution curve and are acknowledged to be an osteoporotic fracture.[26] The elderly population in the UK continues to rise[73], and the management of proximal humeral fractures will be an increasing burden upon orthopaedic trauma services in the future. Recent epidemiological data has illustrated the incidence of proximal humeral fractures to be increasing, which seems to be doing so most rapidly in the super-elderly female population.[52, 74]

Neer estimated that approximately 20% of patients may benefit from surgery according to his classification.[75, 76] Hence, most proximal humeral fractures are managed non-operatively; despite this the majority of the literature regarding the outcome of such fractures focuses upon operative interventions.[77-79] There is a paucity of literature reporting the outcome of proximal humeral fractures in the elderly especially that of non-operative management with only small cohort studies reported.[80] In addition, it would seem, the current literature does not support operative intervention for such fractures in the elderly, with no significant difference in the functional outcome between operative and non-operative management for three and four part proximal humeral fractures.[81] Alternatively, this may be due to case-mix variables of the reported cohorts, and some elderly patients may benefit from surgical intervention, but predictors of outcome in this patient group have not been described previously. Hence, it would be beneficial to be able to predict which elderly patients have the greatest longevity, to benefit from an intervention, and have a poor predicted outcome to aid decision making early after their injury.

1.9 Fractures the distal radius

Fractures of the distal radius account for 16% of all fractures, and are the most prevalent fracture that orthopaedic surgeons have to manage.[26] Stable fractures can be managed conservatively with the expectation of a good functional outcome.[82, 83] The management of unstable fractures of the distal radius in the elderly remains controversial.[84] The functional outcome of displaced fractures is generally accepted to correlate with the anatomical reduction of the fracture.[82, 83, 85] Super-elderly patients account for approximately 20% of distal radial fractures[86], which may increase in the future due to their growing population and form a greater proportion of patients.

The primary management of displaced distal radial fractures is close manipulation.[87] However, increasing age, fracture comminution, and dependency are predictors of fracture instability, and if present, are more likely to lead to malunion.[88] These predictors are more likely to be present in the super-elderly population, and hence are more likely to fail non-operative management by close manipulation alone. If the risk of malunion and degree of improvement offered by closed manipulation of the fracture could be calculated prior to manipulation, super-elderly patients with a high risk of malunion could be identified. These patients may benefit from early operative intervention, avoiding delay and the inconvenience of a failed manipulation.

The effect of a malunion after a distal radial fracture upon functional outcome has been demonstrated to diminish with increasing age.[89] Most studies reporting the outcome of distal radial fractures in the elderly, being defined as greater than 60 or 65 years of age, include low demand patients only.[90-92] The question remains as whether malunion results in an inferior outcome in super-elderly patients whom have a lower physical demand, because of their age. Furthermore, the reduction of distal radial fractures has been shown to be of minimal benefit in frail elderly patients[90-92], and same could be asked of surgical intervention.

1.10 Fractures the pelvis

Although the predominant fracture in the elderly and super-elderly is of the proximal femur 73% of all pelvic fractures occur in elderly patients.[26] Currently pelvic fractures are three times less common than proximal femoral fractures.[93] However, a recent epidemiologic study from Europe demonstrated a threefold increase of pelvic fractures in the elderly from 1970 to 1997.[49] The predominant pelvic fracture in the elderly is that of the isolated pubic rami[86], which is associated with considerable morbidity and increased mortality.[94-98] The predicted increase in the elderly population has been predicted to have major repercussions on the trauma workload in the future, placing a major burden on medical resources both acutely and for the ongoing care of these frail patients after discharge.[32, 33, 94, 98]

The majority of what modest literature exists, regarding pelvic injuries in the elderly, focuses on pubic rami fractures.[94-97, 99] However, there is limited literature describing the incidence, epidemiology, demographics, or outcome of elderly patients with pelvic fractures over the last decade, or whether these differ according fracture configuration. In addition, no published study to date has described factors that independently influence length of hospital stay, return to place domicile, and one-year

mortality for patients with pubic rami fractures. These factors could be used to identify patients early in their admission that may be at risk of a long hospital stay, failure to return home, and a greater mortality and may benefit from prompt interventions in during their admission that may improve their outcome.

1.11 Fractures the tibial diaphysis

Tibial diaphyseal fractures currently account for 2% of all fractures presenting to orthopaedic surgeons.[26] The epidemiology of these fractures has changed in the developed world significantly during the last 20 years, which is thought to be related to improved road safety.[86] The overall incidence of tibial diaphyseal fractures is declining, nearly halved in number from 27 per 100,000 in 1990[100] to 14 per 100,000 in 2008.[86] The gender distribution, although predominately male[86], has demonstrated a change with increasing incidence of elderly female patients during the latter half of the last century.[101, 102] The mean age of these fractures has also increased during this same time period, with a current average age of 40 years.[86] Furthermore the mechanism of injury has also changed, with most occurring after a road traffic accident (38%) or a sports injury (31%) in 1990[100], whereas in 2008 most occurred after a low energy fall from standing height.[86] This change in epidemiology suggests the tibial diaphyseal fracture that may be classically associated with a young male after high energy trauma is now becoming a fracture of the elderly sustained after a low energy fall. This is also supported by the fracture distribution curve for tibial diaphyseal fractures, with a unimodal curve for younger males and older females[26], so with increasing mean age an elderly female predominance occurs.

There is limited literature regarding the outcome elderly patients after tibial diaphyseal fractures, with only a small cohorts reported.[103, 104] The elderly population are likely to form an increasing proportion of an orthopaedic surgeons workload in the future, due to the changing epidemiology of tibial diaphyseal fractures and the increasing elderly population at risk. The demographics and outcome of these fractures may differ in the elderly patients relative to their younger counterparts, which may require a different management approach.

1.12 Multiple fractures

The majority of the literature concerning fractures in the elderly has focused on isolated fractures, particularly those of the proximal femur, proximal humerus and distal radius. Elderly patients frequently present with more than one fracture[26], however there is a relatively paucity of data regarding the outcome of multiple fractures in the elderly. However, an elderly patient sustaining multiple fractures may not necessarily be polytrauma patient. Polytrauma can be defined using the Injury Severity Score, where an accepted threshold score of 16 or more is thought to represent a major polytrauma patient which is associate with a mortality risk above 10%.[105] There is a far greater body of evidence regarding the outcome of elderly polytrauma patients[106], with relatively little regarding the outcome of elderly patients sustaining multiple fractures.

CHAPTER 2:

PATIENTS AND METHODS

CHAPTER 2: PATIENTS AND METHODS

2.1 The epidemiology of elderly fractures

A prospective epidemiological study was performed during a one-year period from September 2010 to August 2011 of all adult (15 years of age and greater) patients presenting with a fracture to the study centre. This cohort of patients will be referred to as the 2010 group for the rest of the manuscript. The study centre is the only hospital receiving adult trauma for a predominately urban population from a defined area. All patients from the catchment area and all those receiving their initial management outside the catchment area were included, but patients residing outside the catchment population were excluded from analysis. The adult (15 years and older) population during the study period for 2010 was 564,938, of which 100,562 were 65 years old or more and 29,096 were 80 years old or more (Table 2.1).[31]

Table 2.1. Population of the study catchment area according to time period assessed.[31]

Time period	Total Population	Adult*	Elderly**
2010	665,760	564,938	100,562
2000	615,000	517,555	96,784
1991	615,000	-	96,129

*Adult: 15 years and older
** Elderly 65 years and older

The patient demographics and mechanism of injury was recorded from the patients notes and checked with the patient at the index episode, either as a new patient presenting to an outpatient clinic or as a new orthopaedic trauma admission, by a dedicated trauma fellow (Table 2.2). All fractures presenting to the study centre are either admitted to the trauma unit directly or referred to the outpatient clinic by the Accident and Emergency department or their general practitioner. The fracture was identified and classified according to anatomical location, whether it was open or closed, and if there was an associated fracture as previously described[26], by the trauma fellow. Only radiographically diagnosed fractures were included, with all soft tissue injuries and other diagnoses being excluded. All fractures compiled within the database were then checked for accuracy, which was found to have less than a 1% error rate. Patients who failed to attend the outpatient clinic as a new patient were offered a further appointment where upon the data was acquired, however if they did not attend again data relating to their fracture was obtained from their notes and if missing were contacted via telephone to complete the database.

Table 2.2. Study chapter and time period assessed with stated person collecting data and the population time period used to assess epidemiology and incidence of fractures.

Study chapter	Time period	Date collection	Time period used for population
3. Epidemiology of elderly fractures	2000 and 2010	Ben Caesar Myself	2000 and 2010
4. Super-elderly fractures	July 2007 to June 2008	Stuart Aitken Myself	N/A
5. Undisplaced femoral neck fractures	2008 to 2010	Myself	N/A
6. Proximal humeral fractures in the elderly	June 1988 to May 1996	Professor Court-Brown Liz Will Myself	1991
7. Distal radial fractures in the super-elderly	June 1988 to December 1993	Professor McQueen Liz Will Myself	N/A
8. Pelvic fractures in the elderly	1. 2007 to 2008 2. 1996 to 2010	Stuart Aitken Myself	2010
9. Tibial diaphyseal fractures in the elderly	January 1990 to December 1999	Professor McQueen Professor Court-Brown Myself	2000
10. Multiple fractures in the elderly	July 2007 to June 2008	Stuart Aitken Myself	N/A

N/A: not applicable

The same epidemiology study was performed, using the same methodology as described above, for a one year period during the year 2000 that has previously been described.[26] The catchment area for this time period was identical to that used for the 2010 cohort, however the adult population during this study period was less at 517,555, of which 96,784 were 65 years old or more and 24,910 were 80 years old or more (Table 2.1). This cohort was used to compare the fracture incidence over a period of a decade, according to age and anatomical location.

Statistical analysis

All data were analysed using Statistical Package for Social Sciences version 17.0 (SPSS Inc., Chicago, IL, USA). Simple descriptive statistical analysis was undertaken for patient demographics, mode of injury, whether the fracture was open or closed, and for associated fractures were performed for the 2010 cohort. In addition for the purpose of describing the epidemiology and incidence of fractures in the elderly and super-elderly patients were categorised into the those who were 65 years old or more (elderly) and 80 years old or more (super-elderly). The fracture incidence in 2010 was

compared to that identified in the year 2000. Dichotomous variables were assessed using a Chi square test. A p-value of <0.05 was used to define statistical significance.

2.2 The outcome of Super-elderly fractures

All non-spinal fractures presenting to the Royal Infirmary of Edinburgh from July 2007 to June 2008 were analysed (Table 2.2). All in-patients and out-patients were included. This hospital receives all adult orthopaedic trauma from the City of Edinburgh, Midlothian and East Lothian from which previous epidemiological studies have been reported.[26, 27] However the hospital also treats patients from other parts of central Scotland and in this study all patients managed as in patients have been included. A standard core dataset was prospectively collected, which consisted of patient demographics, date of injury, hospital admission, fracture type and mechanism. This data was collected by an experienced trauma fellow.

All super-elderly patients were analysed. Of these identified patients a retrospective review of case notes and the hospital patient database were carried out for all in-patient admissions: patient domicile, mobility, co-morbidities, diagnosis of dementia, length of stay, management of fracture, time to theatre (if applicable), and place of discharge were recorded. Nursing home residents were not included in the length of stay analysis as these patients already had a maximum care packages in place and this may conceal a true delayed in discharge of the patients. Mortality at 30 and 120 days from injury was obtained from the General Register Office for Scotland.[31] These two time points were chosen to enable comparison with published hip fracture data from the same country.[29]

Two patient cohorts were used for comparison, both of which sustained an acute skeletal fracture. The very-elderly cohort was defined as all patients aged 90 years or older. The epidemiology and outcomes of the very-elderly cohort was compared with a typical elderly cohort. The average age of patients sustaining a hip fracture in Scotland is currently 83 years[107], and therefore an 80 to 89 year old age group was thought to be representative of the typical elderly fracture population to enable a comparison.

Statistical Analysis

Variables were studied in two groups: (1) Case-mix variables included age, gender, prefracture mobility, prefracture residence, co-morbidity, and fracture type, (2) Outcome variables were operative management, time to theatre, length of the hospital stay (excluding nursing home residence), place of residence at 120 days post fracture

if patient lived at home, and 30 day and 120 day unadjusted mortality rates. The commonest fractures (n=>5) were segregated into four cohorts (1. upper limb, 2. lower limb excluding hip, 3. pelvis, and 4. proximal femur) to allow for a comparison of operative intervention, time to theatre, and mortality for similar fractures between the two groups. A Chi-square test was used to compare the unadjusted frequencies of case-mix and outcome variables between the two groups. The outcomes in the groups were then compared with use of a multivariable regression model to control for differences in case-mix variables between groups, including co-morbidities, gender, the type of fracture, pre-fracture mobility, and pre-fracture residence.

2.3 Predicting the outcome of undisplaced femoral neck fractures in the elderly

During a three year period (2008 to 2010) a prospectively compiled database of a consecutive series of 162 elderly (≥65 years old) patients that underwent internal fixation for an undisplaced (Garden stage I or II[108]) intracapsular hip fracture was collected (Table 2.2). The study centre is the only hospital receiving adult in patients trauma for a predominately urban population of (East Lothian, Mid Lothian, West Lothian, and the City of Edinburgh), of which 14.7% are aged 65 years old or more.[31] All patients from the catchment area who were treated in the study centre, but who resided outside these areas were excluded from analysis. All patients receiving their initial management outside the catchment area but resided within it were included. All data was prospectively collected and recorded.

The patients' demographic details, socio-economic status, and American Society of Anesthesiologists (ASA) grade were recorded. The patients socio-economic status was assigned using the Scottish Index of Multiple Deprivation (SIMD).[109] Each patient's postcode was used to allocate their social quintile, with the first quintile being the most deprived and the fifth quintile being the least deprived. The radiographs were assessed by a single researcher and were classified according to the Garden[108] and Pauwels[110] classification. Garden's lateral angle was also measured[111], and if there was an angle of less than 170° patients were defined to have posterior tilt which has previously been shown to be associated with non-union (Figure 2.1).[63] Screw positioning was considered adequate if: parallel (<5° deviation), at least two within 5mm of the subchondral bone, had both posterior and calcar contact for support, and there was at least one screw in the posterior and one in the inferior aspect of the femoral head, in an inverted triangle position.[64]

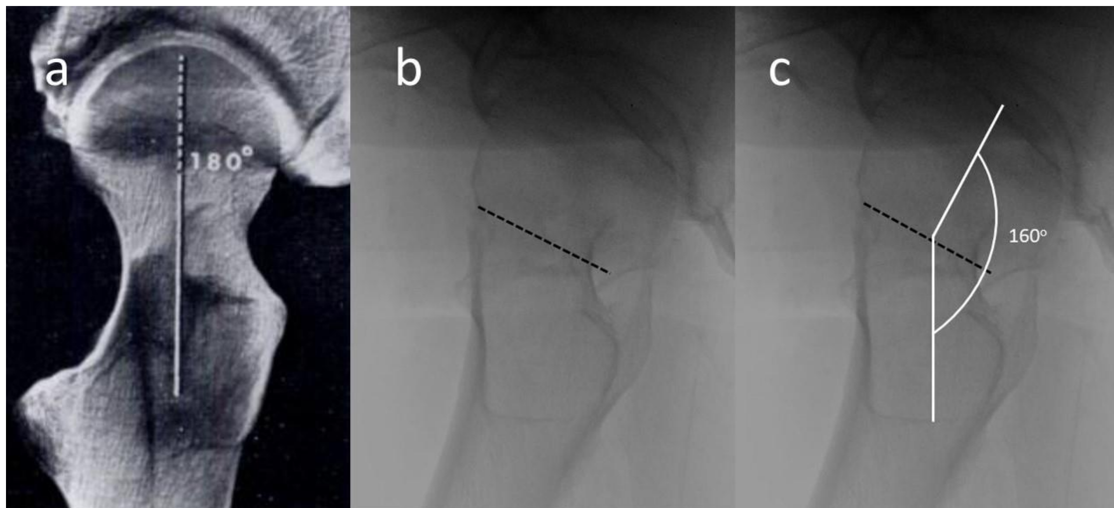

Figure 2.1. Lateral radiograph of the hip demonstrating normal alignment of the femoral head and neck (a) and posterior tilt due to an intracapsular hip fracture (b), with a Garden lateral angle of 160 degrees (c).

All patients were managed according to hip fracture protocols established by the Scottish Intercollegiate Guidelines Network.[112] The study centre has eleven orthopaedic trauma surgeons who were responsible for care of the patients. No intra-operative reduction manures were performed. Either a direct mini lateral approach or a percutaneous approach was used to insert 6.5mm AO (Stratec Medical Ltd, Welwyn Garden City, Hertfordshire, England) cannulated screws under fluoroscopy guidance. Three screws were used for all cases, with most screws being placed in an inverted triangle configuration, depending on surgeons' preference. Patients were encouraged to weight bear as able from the first post-operative day.

Patients were followed-up to a minimum of one year to a maximum of 3.6 years, with a mean follow-up of 1.7 years. No patient was lost to follow-up. Failure of the fixation was defined as revision of the screws for any reason, or if there was any intension to revise. Forty-three patients (27%) died during the study period, and the exact date was retrieved from the General Register Office for Scotland.[31]

Statistical analysis

SPSS version 16.0 software was used for statistical analysis (SPSS Inc., Chicago, IL, USA). Unpaired t-tests or an analysis of variance (ANOVA) were used to compare linear variables and a chi square test or a Fishers exact test (if <10) were used to compare dichotomous variables between groups. Age and gender standardized mortality rate (SMR) was calculated using life expectancy data held by the Scottish Office for the population at risk.[31] Kaplan-Meier methodology was used to investigate

survival. Cox regression analysis, using forward conditional methodology entering all case-mix variables, was used to identify significant independent predictors of failure of fixation and one-year mortality. A p-value of ≤0.05 determined statistical significance.

2.4 Predicting the outcome of proximal humeral fractures in the elderly

The study cohort was identified retrospectively from a prospectively compiled trauma database, specific to proximal humeral fractures, presenting to the study centre during a four-year period (June 1992 to May 1996) (Table 2.2). The study centre is the only hospital receiving adult outpatient trauma for a predominately urban population of 615,000 East Lothian, Mid Lothian and the City of Edinburgh) during the period of the study, and during the study period the elderly population (≥65 years old) accounted for 96,129 of the adult population according to the 1991 census data (Table 2.1).[31] All patients from the catchment area and all resident patients receiving their initial management outside the catchment area were included, but patients residing outside the catchment population were excluded from analysis.

There were 637 proximal humeral fractures in 629 elderly (≥65 years old) patients recorded during the study period. Demographic details were available from the database. The Carstairs score was used to assign the socioeconomic status of each patient.[113] This score has been used to measure social deprivation for the Scottish population since the year 1981, with each postcode sector (n=1010) within Scotland being assigned a standardised deprivation score.[114] The patients were divided into five quintiles, according to their postcode, with one being the most affluent and five the least affluent. Markers of physical and social independence were also recorded: were they living in their own home, did they live alone, were they employed, did they participate in recreational activities, can they do their own shopping, were they ability to dress themselves, were they able to do their own housework, and did they need home help? The Neer[75] classification was used to assess fracture severity, which was assigned by Professor Court-Brown. Concomitant fractures sustained at the time of the index fractures were also recorded.

Functional outcome was recorded using the Constant score.[115] An independent physiotherapist assessed shoulder function using the Constant score at 6, 13, 26, and 52 weeks, but for the purpose of this study only the one year Constant score was used to assess functional outcome. Patients (n=29) who were discharged at 6 months, as their shoulder function was thought to be acceptable, their Constant

score at this point was assumed to be their one-year score. There were 483 (76%) one year Constant scores available for the 637 elderly proximal humeral fractures identified, of those without one year Constant scores 61 died before their one year follow-up, and the remaining 93 were either too frail to return to fracture clinic (n=87) or refused to participate (n=6). A Constant score of 55 or less was defined as a poor outcome, which has previously been used by other authors assessing the outcome of proximal humeral fractures.[116-118]

The choice between operative and non-operative treatment was dictated by the consultant caring for the patient, all of which are experienced orthopaedic trauma surgeons. Operative management was undertaken in 50 patients (hemiarthroplasty n=24, nail n=2, unknown n=1, and open reduction and internal fixation n=23), with the remainder (n=587) being managed by non-operative methods.

Statistical analysis

All data were analysed using Statistical Package for Social Sciences version 17.0 (SPSS Inc., Chicago, IL, USA). Continuous variables (Constant score) were assessed using t-tests and ANOVA to identify significant differences between groups. Dichotomous variables were assessed using a Chi square test. Standardized mortality rates (SMR), matched for age and gender, were calculated using the published expected mortality rates for the study population using data from the General Register Office for Scotland.[31] Kaplan-Meier methodology[119] was used to investigate patient survival. Cox regression analysis was used to identify independent predictors of mortality one year after their proximal humeral fracture. Multivariable linear regression analysis was used to assess the independent effect of case-mix variables on functional outcome, one-year Constant score, using "Enter" methodology. Logistic regression analysis was used to assess the independent predictors of a poor outcome (Constant score of 0-55).

2.5 Predicting the outcome of distal radial fractures in the super-elderly

During a 67-month period (June 1988 to December 1993) 28,376 acute fractures were managed at the study centre, of which distal radial fractures accounted for 4024 (14.2%) (Table 2.2). A distal radial fracture database was prospectively complied, recording demographics, radiographic data, management, and outcome. The mean age for all patients was 59 (14 to 100) years. There were 574 patients aged 80 years or older identified retrospectively who had sustained a distal radial fracture during the study period, of which 228 were displaced and underwent closed manipulation as

their primary intervention. There were 213 (93.4%) females and 15 (6.6%) males with a mean age of 83.7 (80 to 98) years. Two patients sustained bilateral fractures. Fifty-one patients also had outcome data at one year recorded and also lived independently. This group was used to assess functional outcome according to whether there was or was not a malunion. There were 50 females and one male with a mean age of 83.1 (80 to 93) years. Forty-eight patients (94%) were right hand dominant. All fractures were unilateral.

Fracture management followed a standard protocol. The emergency-room staff undertook the initial assessment and treatment. Fractures deemed to be in an acceptable position were managed with a dorsal plaster slab. If the fracture position was thought to be unacceptable, the emergency-room staff, prior to application of a dorsal plaster slab, performed closed reduction using intravenous regional anaesthesia. The patients were evaluated clinically and radiographically by Professor McQueen at one and six weeks after the injury as per the protocol of the study unit.

At approximately one week following the injury, the patients were reviewed by the senior author in a dedicated follow-up clinic. The clinical, demographic, and radiographic data were recorded and entered into a database either by the senior author or a research nurse. The premorbid normal level of function of the patient was categorised as independent if they were able to go shopping without assistance, or dependent if assistance was needed. The dorsal slab was completed to a below-the-elbow forearm cast with the wrist in slight flexion and ulnar deviation at one week. Patients with a fracture that had displaced were admitted to the orthopaedic trauma unit for further intervention, unless the patient had low functional demands and operative intervention was deemed inappropriate.

All radiographs (presentation, time of reduction, one-week, and six-weeks) were measured manually with use of a protractor and a ruler to provide values for the dorsal angle, and ulnar variance (Figure 2.2). The fractures were classified using AO/OTA classification.[120] Metaphyseal comminution was recorded, according to the location, as absent or as involving the dorsal metaphysis, volar metaphysis, or both the dorsal and volar metaphysis. Professor McQueen classified the fractures and assessed the degree of comminution. Adequate reduction was defined as dorsal angle of ≤0 degrees and or ≤3mm of radial shortening.[88] Malunion was defined as a dorsal angle of >10 degrees and or >3mm of radial shortening.[88]

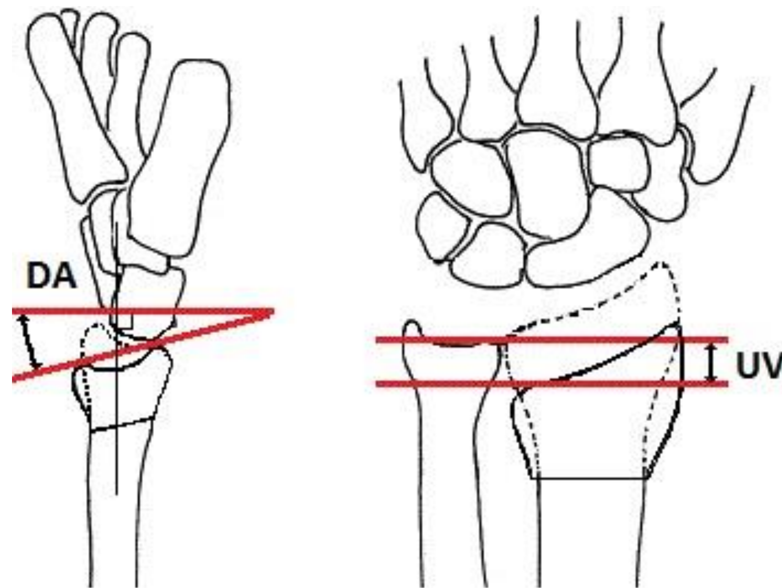

Figure 2.2. The measurement of dorsal angle (DA) and ulnar variance (UV). A relative measurement was used to assess UV, taken as the difference between the UV of the fractured radius and that of the normal, uninjured radius. These measurements were expressed as a negative for volar angulation and a positive for DA, and a positive value for UV if there was radial shortening.

Functional assessment was carried out by a single dedicated research physio at approximately one year from injury. Objective measures made were range of movement (ROM) and grip strength, and subjective measures included presence of pain at the wrist, if the wrist had regained its normal function status for them, and whether they could perform a number of activities of daily living (see below).

ROM measured at the wrist and distal radio-ulnar joints using a standard full circle goniometer.[121, 122] Intra-observer bias was minimised by careful technique and recordings made in triplicate, and the mean of these measurements was recorded. The observer measured flexion, extension, pronation, supination, radial and ulnar deviation for both the injured and uninjured sides. Grip strength was measured using a JAMAR Delux Hand Dynamometer, Model 0030J4 (Therapeutic Equipment Corporation, Clifton, New Jersey).[123-125] In accordance with the guidelines for the use of this device, issued by the American Society for Surgery of the Hand, the mean of three successive readings was taken for each hand.[126] Each patient was examined at a similar time of the day at each assessment in order to minimise the effects of diurnal variation. The grip strength of the non-dominant hand was increased by 10% (as it is thought to be 10% weaker than the dominant hand) for comparative analysis with the dominant side.[123]

The presence or absence of pain was recorded for the injured wrist, and whether they required analgesia because of their injury. Patients were also asked whether they felt their wrist had returned to the pre-injury functional state. In addition, they were asked whether they could carry out a number of daily tasks: carry a plate, hold a glass, hold a pan, turn a key, bolt a door, write, use scissors, use a knife, needle and hammer. Each of these ten tasks were assigned a score, one if they could not perform the task and two if they could, these scores were combined to give a total score for each patient, which is a validated assessment tool.[126]

Statistical analysis

SPSS version 16.0 software was used for statistical analysis (SPSS Inc., Chicago, IL, USA). A Fishers exact test was used to compare the dichotomous variables (activities of daily living, presence of wrist pain, and return to normal use). Paired and unpaired t-tests were used to compare the improvement in the 6-week dorsal angulation, and ulna variance relative to pre-manipulation dorsal angulation and ulna variance, and the effect of case-mix variables upon the improvement in dorsal angulation and ulna variance, grip strength and ROM. A Pearson's correlation coefficient was used to assess the significance of age, and pre-manipulation dorsal angulation and ulna variance upon the 6 week dorsal angulation, and ulna variance with ROM. Multiple linear (stepwise methodology) and logistic (forward conditional methodology) regression analysis were used to identify significant independent predictors of improvement in dorsal angulation and ulnar variance, and risk of malunion. A p-value of ≤0.05 determined statistical significance.

2.6 Predicting the outcome of pelvic fractures in the elderly

Patients with pelvic fractures were identified retrospectively from a prospectively complied trauma database of patients presenting to the study, which covers the same catchment area as described in section 2.4 (Table 2.2). The catchment population increased, relative to that described in section 2.4, for the study time period (2010) and consisted of approximately 665,760, of which 100,562 (15%) are ≥65 years of age (Table 2.1).

Elderly patients, being aged 65 years old or more, sustaining a pelvic fracture were analysed. All patients (n=937) were included in the analysis of for the incidence of pelvic fractures. However, a defined two-year period, 2007 to 2008, was used to describe demographics and outcome of elderly pelvic fractures. A retrospective review of case notes and the hospital patient database was carried out for these

patients; patient domicile, mobility, co-morbidities, mechanism of injury, associated fractures, length of stay (hospital and rehabilitation), and place of discharge were recorded. Six different modes of injury were recorded: simple falls (from standing height), falls from a height or stairs, sport, road traffic accidents (RTA) as a pedestrian or vehicle occupant, assault or direct blows, unknown. A low energy injury was defined as a simple fall from standing height. Mortality for the patients presenting during the two year study period (2007-2008) was obtained from the General Register Office for Scotland.[31]

There were 937 patients aged 65 years or older with pelvic fractures with an average of 62.5 fractures per year. The minimum follow-up was one year (mean 7.2 years, range 1 to 15 years). No patients were lost to survival follow-up. No patients were recalled specifically for this study; all data was obtained from medical records and radiographs.

Fractures were classified using the AO Classification[120] for the two year study period (2007-2008). The radiographs were reviewed by me and an orthopaedic trauma consultant. There were 142 pubic rami fractures (Figure 2.3) and 26 other pelvic fractures. Routine computer tomography (CT) was not undertaken to exclude associated ring fractures of patients sustaining radiographic isolated pubic rami fractures. It is acknowledged that CT assessment may identify that up to 80% of elderly patients also have posterior instability, which has been sub-grouped by Rommens et al.[127] They defined four subgroups of fragility fractures of the pelvis which help to define a management plan. This was not possible in this thesis due to the constraint of increased costs of the CT scan within the National Health Service.

The follow-up regime was dictated by the fracture configuration, and the patient's cognitive function and dependence. No formal clinical follow-up was arranged for pubic rami fractures. Pelvic ring and acetabula fractures received clinical follow-up for 6 months to 1-year post injury.

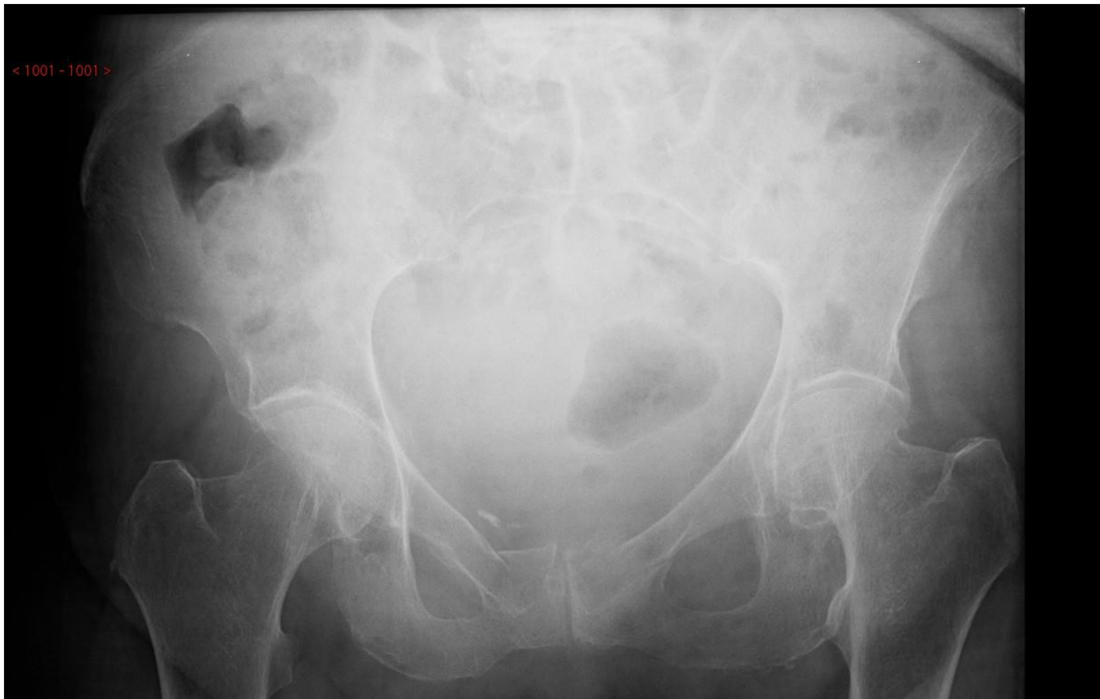

Figure 2.3. Radiograph of a pelvis demonstrating a right superior and inferior pubic rami fractures and a left pubic symphysis fracture (AO classification 61-A2.3)**.**

The SIMD was used to assess socioeconomic deprivation.[109] This methodology assesses deprivation by employment, income, crime, housing, health, education, and access to services. Scotland is divided into 6505 data zones that reflect households of a similar income.[109] The data zones are ranked in order of decreasing deprivation and each data zone is allocated to one of five quintiles based on this rank. The first quintile includes the most deprived quintile and the fifth quintile comprises the least deprived quintile on a national level. Each patient was allocated to a data zone based using their postcode and their deprivation quintile derived from a look-up table.[128] The postcodes for patients resident in a nursing home was taken to be that of their prior residence, which was obtained from their hospital records.

Statistical analysis

SPSS software (version 16.0) for statistical analysis (Chicago, IL) was used. Variables were studied in two groups: (1) case-mix variables included age, gender, comorbidity, history of a previous fracture, pre-fracture residence, pre-fracture mobility, social deprivation, associated fractures, and mechanism of injury; and (2) outcome variables were length of the hospital stay (acute hospital, rehabilitation, and total length), return to pre-fracture domicile, and 1-year unadjusted mortality rates. Spearman's rank correlation coefficient was used to assess the change in incidence of pelvic fractures during the 15-year study period and for age of the patient. A Fisher r-to-z

transformation (FT) was used to compare the correlation coefficient for the incidence of pelvic fractures between male and female gender. Differences in age and number of comorbidities between patients with pubic rami fractures and those with other pelvic fractures were determined using a Students t-test, as this data were normally distributed. Differences in length of stay between patients with pubic rami fractures and those with other pelvic fractures were determined using a Mann-Whitney U test. Differences in gender, residence, mobility, deprivation, associated fractures, injury mechanism, previous fracture, return to domicile, and 1-year mortality between patients with pubic rami fractures and those with other pelvic fractures were determined using a chi square test. Linear (stepwise methodology) and bivariate (forward conditional) regression analysis were used to identify significant independent predictors of outcome (length of stay, return to domicile, and mortality) for patients with pubic rami fractures. Cox regression analysis was used to identify isolated predictors of one-year survival for patients sustaining a pubic rami fracture. No patients were lost to follow-up, and those who died before one-year were censored.

2.7 Predicting the outcome of tibial diaphyseal in the elderly

Between January 1990 and December 1999, 230 elderly patients (≥65 years) with 238 tibial shaft fractures (AO 42) were treated at the study centre (Table 2.2). The catchment population were as described in section 2.4 with the same inconclusion and exclusion criteria for the 2000 period (Table 2.1). Five patients were excluded from the study, as they were resident outside the catchment area. This resulted in 233 fractures in 225 patients being available for study. Data were obtained from a prospectively recorded fracture database within the Orthopaedic Trauma Department and validated using paper and computerised patient records. Missing and additional information was extracted from the latter resources and combined into the original prospective database.

Demographic details were available from the databases. Eight different modes of injury were recorded: none (stress or insufficiency), simple falls (from standing height), falls down slopes or stairs, falls from a height, assault or direct blows, RTA either pedestrian or vehicle occupant, or if the mode of injury was unknown. The Tscherne classification[129] for closed fractures and the Gustilo and Anderson[130, 131] classification for open fractures was used and were recorded prospectively by a trauma orthopaedic consultant. All fractures were classified by the same consultant using the AO classification.[120] The treatment method and complications were

recorded, including deep infection (defined as return to theatre for debridement) and amputation. Union of the fracture was assessed by standard radiological and clinical criteria.[26] Malunion was defined as more than 5° of angular or rotatory malalignment or more than 1 cm of leg-length discrepancy.[132] During the study period all patients underwent peri-operative continued compartment monitoring, and a fasciotomy was performed according to clinical and differential compartment pressures.[133] Information regarding further surgical procedures was also extracted from patient case records.

The demographic and place of domicile details of the patients were used to identify mortality status and date of death if applicable from the General Register Office for Scotland[134] and the National Health Service Central Register.[31]

Statistical analysis

Statistical analysis was performed using Statistical Package for Social Sciences version 17.0 (SPSS Inc., Chicago, IL, USA). Parametric and non-parametric tests were used as appropriate to assess continuous variables for significant differences between groups. A Student's t-test or a one-way analysis of variance were used to compare linear variables between groups, and a Pearson correlation was used to assess the relationship between linear variables. Dichotomous variables were assessed using a Chi square or Fishers exact test if one variable was less than 10. Multivariate regression analysis was used to identify independent predictors of outcome (time to union, non-union, malunion, deep infection, and amputation). Kaplan-Meier methodology was used to analyse mortality, and Cox-regression analysis was use identify independent predictors of survival. SMR matched for age and gender, were calculated using the published expected mortality rates for the study population using data from the General Register Office for Scotland.[31] Subgroup analysis was performed of the mortality rates for both elderly (65 to 79 years old) with super-elderly (≥80 years old) patients. A p-value of ≤0.05 determined statistical significance.

2.8 The epidemiology and outcome of multiple fractures in the elderly

The cohort of patients was identified from the same dataset described in section 2.2 (Table 2.2). All elderly patients (≥65 years) were analysed, recording their gender, age, mode of injury, number of fractures and the fracture type. The patients' postcodes were used to compute their Carstairs scores and social quintiles. The Carstairs score is a z-score based on a number of social factors such as male unemployment, income and car ownership which can be used to define social

deprivation.[135] It is a validated score and has been extensively used in many branches of medicine including orthopaedic trauma.[69] The study population was divided into five quintiles based on social deprivation for subgroup analysis, with 1 being the most affluent and 5 the least affluent. the need for admission to hospital, operative fixation, length [105]of stay, and place of discharge were obtained retrospectively for patients sustaining double fracture combinations. The standardized mortality rate, one year from time of injury, was calculated using data obtained from the General Registrar Office of Scotland.[110]

Patients with multiple fractures were divided into three groups: upper limb multiple fractures only, lower limb multiple fractures only, and combined, involving both the upper and lower limbs. Pelvic fractures were included with lower limb fractures. No data relating to additional injuries were collected nor were injury severity scores collected.

Statistical analysis

SPSS software was used for statistical analysis (Chicago, IL). Parametric and non-parametric tests were used as appropriate to assess continuous variables for significant differences between groups. The Student's t-test, Mann–Whitney U tests, and a one-way ANOVA were used to compare linear variables between groups. Dichotomous variables were assessed using a chi square and Fishers exact test. Standardized mortality rates, matched for age and gender, were calculated using the published expected mortality rates for the study population using data from the General Register Office for Scotland.[12] Subgroup analysis was performed of the mortality rates for both elderly (65 to 79 years old) with very-elderly (≥80 years old) patients. The was to allow a comparison of elderly patients with super-elderly patients. A p-value of ≤0.05 determined statistical significance.

2.9 Ethical approval

The data analysed in this thesis was obtained from established databases held within the Royal Infirmary of Edinburgh. Ethical approval was obtained for the use of such established databases for investigative purposes (Appendix 11).

CHAPTER 3:

THE EPIDEMIOLOGY OF ELDERLY FRACTURES

CHAPTER 3: THE EPIDEMIOLOGY OF ELDERLY FRACTURES

3.1 Aims

The primary aim of this study was to describe the epidemiology of fractures sustained by elderly and super-elderly patients over a one-year period and compare incidence of these fractures with that observed a decade ago for the same patient population. The secondary aims were to compare the fracture risk of patients 65 years old or more to those less than 65 years old, and super-elderly patients to that of elderly patients.

3.2 Chapter Summary

Two prospective fractures databases were used to describe the epidemiology of fractures sustained by elderly and super-elderly patients over a one-year period and compare incidence of these fractures with that observed a decade ago for the same patient population. Each for a period of one year, during 2000 and 2010 for all adult patients presenting to the study centre. Patient demographics, mechanism of injury, anatomical fracture location, whether it was open or closed, and if there was an associated fracture was recorded. Only radiographically diagnosed fractures were included. More than a third of all fractures occurred in elderly patients (n=2331/6996) in 2010, of which half occur in super-elderly patients (n=1177). The risk of sustaining a fracture was significantly increased for the elderly (odds ratio (OR) 2.3) and super-elderly population (OR 2.67). More than 90% of fractures in the elderly were sustained after a fall from standing height. Not only did the absolute number of elderly fractures increase in 2010 (n=2331) compared to the year 2000 (n=1963), but so did the incidence. This was due to a significant increase in the incidence for the elderly (2318 vs 2025/10^5/yr respectively, $p<0.0001$) and for the super-elderly (4045 vs 3733/10^5/yr respectively, $p=0.0003$) fractures. Analysis of specific fractures demonstrated no change in the incidence of proximal femoral or pelvic fractures, but there was an increased incidence observed for distal radial, proximal humeral, and ankle fractures for the elderly and super-elderly population. The number and overall incidence of fractures presenting to medical services is increasing. This increase in incidence was specifically observed for fractures involving the distal radius, proximal humerus, and ankle in the elderly and super-elderly population.

3.3 Results

During 2010 there were 6996 fractures managed at the study centre, of which 2331 (33%) were aged 65 years and 1117 (16%) were aged 80 years or more. The overall fracture incidence was 1238/10^5/year. There were 3633 females and 3363 males with a mean age of 53.2 (15 to 105) years. Fractures involving the distal radius were the most common, with more that 40% occurring in those patients aged 65 years old or greater (Table 3.1). The elderly accounted for 50% or more of proximal femoral, pelvic, femoral diaphyseal, proximal humerus, patella, distal femur, and distal humeral fractures, all of which demonstrated a female predominance (Table 3.1).

Epidemiology of elderly fractures

More than a third of all fractures presenting to the study centre were sustained by elderly patients. Overall the elderly population are more likely to sustain a fracture relative to the population aged between 15 and 64 years of age (odds ratio (OR) 2.3), and fractures of the femur, humerus, pelvis, patella, and distal radius were all at least three times more likely to occur in the elderly age group (Table 3.2). Interestingly, fractures affecting the scapula, proximal tibia, forearm diaphysis, ankle, distal tibia, and clavicle were also more likely to occur in the elderly age group; however, the risk was not as great. In contrast, fractures less likely to occur in the elderly were those involving the foot and hand. The commonest mode of injury for all ages is falls from a standing height and almost 40% of fractures that followed a standing fall occurred in elderly patients (Table 3.3), with 91.2% of all fractures in the elderly occurring after a fall from standing height. The incidence of fractures in elderly males was 1301/10^5/year, and in females was 3055/10^5/year (OR 2.4, $p<0.001$). Despite the observed difference in fracture incidence between elderly males and females, the prevalence of each fracture according to anatomical location is similar (Table 3.4 and 3.5). Approximately 30% of fractures in both males and females involved the proximal femur and 10% of fractures involved the proximal humerus. However, fractures involving the distal radius were less prevalent in males, accounting for 10% of fractures, compared with about 25% in females. The rate of multiple fractures varied with the anatomical site of the fracture, but the overall incidence was approximately 5%. Fractures of the proximal humerus were most commonly associated with a concomitant fracture, occurring in approximately 10% of patients. The rate of open fractures was low but was greater in elderly females and for fractures of the tibia (Tables 3.4 and 3.5).

Table 3.1. Epidemiology of fractures treated in a one-year period. The numbers, prevalence, incidence and gender ratios are shown together with the average ages and percentages of patients ≥ 65 years and ≥ 80 years of age.

All fractures	**n**	**%**	**Incidence** (n/10^5/yr)	**Average age** (yrs)	**≥ 65yr** (%)	**≥ 80yr** (%)	**M/F**
Distal radius/ulna	1221	17.5	235.9	58.4	41.8	18.1	28/72
Metacarpus	781	11.2	150.9	33.6	8.2	3.1	80/20
Proximal femur	753	10.8	145.5	80.7	90.6	63.7	27/73
Ankle	720	10.3	139.1	48.8	23.6	6.0	47/53
Finger phalanges	696	9.9	134.5	41.6	13.6	5.8	60/40
Proximal humerus	478	6.8	92.4	66.3	55.6	23.0	31/69
Metatarsus	465	6.6	89.8	44.6	17.0	5.2	37/63
Proximal forearm	378	5.4	73.0	45.6	17.2	5.8	46/54
Clavicle	257	3.7	49.7	44.5	21.0	9.7	70/30
Toe phalanges	248	3.5	47.9	35.7	3.9	1.0	59/41
Carpus	194	2.8	37.5	38.0	7.7	1.5	64/36
Pelvis	119	1.7	23.0	75.6	74.8	58.8	30/70
Femoral diaphysis	82	1.2	15.8	70.2	67.1	39.0	48/52
Tibial diaphysis	69	1.0	13.3	42.3	8.7	0	71/29
Calcaneus	65	0.9	12.6	41.0	9.2	3.1	74/26
Humeral diaphysis	62	0.9	12.0	59.5	46.8	22.6	47/53
Proximal tibia	59	0.8	11.4	54.5	30.5	11.9	52/48
Distal humerus	56	0.8	10.8	56.4	50.0	25.0	43/57
Forearm diaphysis	55	0.8	10.6	48.0	27.3	16.4	69/31
Patella	49	0.7	9.5	64.8	55.1	28.6	41/59
Scapula	37	0.5	7.1	54.8	32.4	16.2	76/24
Fibula	41	0.5	7.9	46.8	14.6	2.4	46/54
Distal femur	36	0.5	7.0	67.3	52.8	38.9	17/83
Distal tibia	35	0.5	6.8	44.6	22.9	5.7	63/27
Midfoot	28	0.4	5,4	39.4	7.1	0	61/39
Talus	12	0.2	2.3	30.1	0	0	83/17
Total	6996	100.0	1238.2	53.2	34.0	17.3	48/52

Table 3.2. The absolute number of all fractures presenting to the study centre during a one-year period in 2010, and according to age group. The odds ratios for each fracture and significance are given. *chi square test

Fracture	Number			Odds ratio	p-value*
	All	15 to 64yrs	≥65yrs		
Proximal femur	753	70	683	45.36	<0.001
Pelvis	119	30	89	13.71	<0.001
Femoral diaphysis	82	27	55	9.41	<0.001
Proximal humerus	478	211	267	5.86	<0.001
Patella	49	22	27	5.67	<0.001
Distal femur	36	17	19	5.16	<0.001
Distal humerus	56	28	28	4.62	<0.001
Humeral diaphysis	62	33	29	4.06	<0.001
Distal radius/ulna	1221	711	510	3.32	<0.001
Scapula	37	25	12	2.22	0.02
Proximal tibia	59	41	18	2.03	0.01
Forearm diaphysis	55	40	15	1.73	0.07
Ankle	720	550	170	1.43	<0.001
Distal tibia	35	27	8	1.37	0.43
Clavicle	257	203	54	1.23	0.18
Proximal forearm	378	313	65	0.96	0.76
Metatarsus	465	386	79	0.95	0.65
Fibula	41	35	6	0.79	0.60
Finger phalanges	696	602	94	0.72	0.003
Calcaneus	65	59	6	0.47	0.07
Tibial diaphysis	69	63	6	0.44	0.048
Metacarpus	781	717	64	0.41	<0.001
Carpus	194	179	15	0.39	<0.001
Midfoot	28	26	2	0.36	0.02
Toe phalanges	248	238	10	0.19	<0.001
Talus	12	12	0	-	-
Total	6996	4665	2331	2.34	<0.001

Table 3.3. The prevalence and average age according to modes of injury for all fractures presenting to the study centre during a one-year period. and gender ratios are shown. Low height falls include falls downstairs and slopes. Direct blows/assaults include crush injuries.

Mechanism	**Prevalence** (%)	**Average age** (yrs)			**Prevalence** (%)		**M/F**
		All	Males	Females	≥65 yrs	≥80 yrs	
Falls (standing height)	62.5	62.3	54.3	65.7	38.9	20.6	30/70
Falls (stairs/low height)	4.2	51.7	48.2	55.2	27.1	10.8	51/49
Falls (height)	2.3	36.0	37.5	30.0	8.1	2.5	88/12
Direct blow/ assault/ crush	13.6	33.3	31.1	40.1	3.6	1.0	75/25
Sport	11.1	31.3	30.4	35.5	3.0	0.3	82/18
RTA	5.2	42.6	41.7	45.8	10.2	3.0	78/22
Pathological	0.4	67.3	63.5	70.3	60.0	24.0	44/56
Stress/ spontaneous	0.3	49.9	44.5	54.0	21.4	21.4	43/57

Table 3.4. Epidemiology of fractures in males aged ≥65 years presenting to the study centre during a one-year period. The numbers and prevalence of the different fractures are shown as are the prevalence of open fractures and patients with multiple fractures. The two commonest modes of injury for each fracture are shown. db = direct blow

Males ≥65 years	**n**	**Multiple fractures (%)**	**Open (%)**	**Mode of injury**
Proximal femur	180	3.9	0	92.2% falls, 3.9% low fall
Proximal humerus	59	13.6	0	94.9% falls, 1.7% low fall
Distal radius/ulna	54	9.3	0	94.4% falls, 3.7% RTA
Ankle	47	4.3	0	83.0% falls, 6.4% sport
Finger phalanges	35	13.8	3.1	59.4% falls, 18.7% db/assault
Metacarpus	25	41.2	0	72.0% falls, 12.0% sport
Pelvis	20	10.0	0	90.0% falls, 10.0% RTA
Femoral diaphysis	20	5.0	0	80.0% falls, 15.0% pathological
Clavicle	19	10.5	0	63.2% falls, 10.5% RTA
Proximal forearm	15	20.0	0	80.0% falls, 6.6% RTA
Metatarsus	11	18.2	0	63.6% falls, 18.2% db/assault
Humeral diaphysis	9	11.1	0	100% falls
Proximal tibia	8	37.5	12.5	50.0% falls, 12.5% fall height
Distal humerus	7	28.6	0	71.4% falls, 14.3% fall height
Carpus	6	0	0	100% falls
Patella	6	0	0	83.3% falls, 16.6% low fall
Scapula	5	20.0	0	40.0% falls, 20% fall height
Toe phalanges	5	0	0	80.0% db/assault, 20.0% falls
Tibial diaphysis	5	20.0	40.0	60.0% falls, 40.0% RTA
Forearm diaphysis	4	0	0	75.0% falls, 25.0% sport
Fibula	3	0	0	33.3% fall, 33.3% db/assault
Distal femur	3	0	0	100.0% falls
Calcaneus	2	50.0	0	50.0% fall height, 50.0% low fall
Distal tibia	2	0	0	100.0% falls
Midfoot	0	0	0	
Talus	0	0	0	
Total	550	5.7	0.7	83.8% falls, 4.0% RTA

Table 3.5. Epidemiology of fractures in females aged ≥65 years presenting to the study centre during a one-year period (2010). The numbers and prevalence of the different fractures are shown as are the prevalence of open fractures and patients with multiple fractures. The two commonest modes of injury for each fracture are shown.

Females ≥65 years	n	Multiple fractures (%)	Open (%)	Mode of injury
Proximal femur	503	6.2	0	96.8% falls, 1.8% low fall
Distal radius/ulna	456	7.1	1.5	95.6% falls, 2.9% low fall
Proximal humerus	208	9.2	0	93.8% falls, 5.3% low fall
Ankle	123	5.7	2.4	95.1% falls, 2.4% low fall
Pelvis	69	8.7	0	97.1% falls, 2.9% low fall
Metatarsus	68	20.0	0	91.2% falls, 4.4% low fall
Finger phalanges	59	18.0	3.6	72.9% falls, 15.3% db/assault
Proximal forearm	50	16.0	4.0	94.0% falls, 4.0% RTA
Metacarpus	39	17.6	2.6	92.3% falls, 2.4 % low fall
Clavicle	35	5.7	0	91.4% falls, 5.7% RTA
Femoral diaphysis	35	2.9	0	88.6% falls, 5.7% pathological
Distal humerus	21	14.3	0	100.0% falls
Patella	21	0	4.8	95.2% falls, 4.8% db/assault
Humeral diaphysis	20	0	5.0	85.0% falls, 10.0% pathological
Distal femur	16	12.5	6.2	81.2% falls, 12.5% low fall
Forearm diaphysis	11	9.1	0	90.9%falls, 9.1% pathological
Proximal tibia	10	20.0	0	70.0% falls, 20.0% low fall
Carpus	9	11.1	0	88.9% falls, 11.1% db/assault
Scapula	7	14.3	0	100.0% falls
Distal tibia	6	0	0	83.3% falls, 16.6% low fall
Toe phalanges	5	0	0	80.0% falls, 20.0% db/assault
Calcaneus	4	25.0	0	100.0% falls
Fibula	3	63.3	0	66.6% falls, 33.3% RTA
Midfoot	2	0	0	50.0% fall height, 50.0% sport
Tibial diaphysis	1	0	100.0	100.0% falls
Talus	0	0	0	
Total	1781	5.0	1.2	94.3% falls, 2.9% low fall

Epidemiology of super-elderly fractures

More than half of all proximal femur and pelvic fractures, and approximately a quarter of all proximal humeral fractures occur in the super-elderly age group (Table 3.1). The super-elderly group were at a significantly greater risk of sustaining a fracture compared to elderly patients (OR 2.57 $p<0.001$). Fractures involving the pelvis, distal femur, proximal femur, forearm diaphysis and femoral diaphysis were at least three times more common in the super-elderly (≥80 years) group compared to elderly patients, whereas fractures of the hand and foot were less common (Table 3.6). The overall incidence of fractures in the super-elderly was $4045/10^5$/year, which is nearly double that observed for the elderly population which was $2318/10^5$/year. Fractures involving the proximal femur, distal radius, and proximal humerus were observed to have the greatest incidence in the super-elderly population, which were all significantly greater than the elderly population (Table 3.7). This is particularly obvious in proximal femoral fractures where the overall incidence was $145/10^5$/year, which increased to $679/10^5$/year in the elderly population and increased further to $1646/10^5$/year in the super-elderly population. The prevalence of simple fall related fractures in the super-elderly age group was 94.3%, who were significantly more likely to sustain fractures from a fall compared to both the adult population aged between 15 years and 64 years of age (OR 2.4, $p<0.001$) and the elderly population (OR 1.2, $p=0.02$). The incidence of fractures in super-elderly males was $2880/10^5$/year, and in females was $4870/10^5$/year (OR 1.7, $p<0.001$). Despite the observed gender difference in fracture incidence, the prevalence of fractures is similar, for example approximately 40% of fractures involved the proximal femur and 10% involved the proximal humerus (Tables 3.8 and 3.9). However, fractures involving the distal radius only accounted for 7% of fractures in male super-elderly patients compared with 22% of fractures in super-elderly females. The rate of multiple fractures varied according to fracture site for both genders. The overall rate of multiple fractures was 6%, but this varied between fracture types (Tables 3.8 and 3.9). One in ten patients who sustained a proximal humerus or distal radius fracture also had an associated fracture.

Table 3.6. The numbers of elderly fractures presenting to the study centre during a one-year period (2010), stratified according to age group and risk of sustaining each fracture relative to the 65 to 79-year-old group.

Fracture	Age Group (n)			Odds ratio
	≥65	65-79yrs	≥80	
Pelvis	89	19	70	9.07
Distal femur	19	5	14	6.88
Proximal femur	683	204	479	5.85
Forearm diaphysis	15	6	9	3.69
Femoral diaphysis	55	23	32	3.42
Patella	27	13	14	2.65
Distal humerus	28	14	14	2.46
Scapula	12	6	6	2.46
Humeral diaphysis	29	15	14	2.29
Clavicle	54	29	25	2.12
Distal radius/ulna	510	289	221	1.89
Proximal humerus	267	156	111	1.75
Finger phalanges	94	55	39	1.74
Proximal tibia	18	11	7	1.56
Metacarpus	64	40	24	1.47
Proximal forearm	65	43	22	1.26
Calcaneus	6	4	2	1.23
Metatarsus	79	55	24	1.07
Ankle	170	127	43	0.83
Distal tibia	8	6	2	0.82
Carpus	15	12	3	0.61
Fibula	6	5	1	0.49
Toe phalanges	10	9	1	0.27
Talus	0	0	0	-
Midfoot	2	2	0	-
Tibial diaphysis	6	6	0	-
Total	2331	1154	1177	2.57

Table 3.7. The prevalence and incidence of each fracture type for the elderly and the super-elderly groups presenting to the study centre during a one-year period.

Fracture	**≥65 years**			**≥80 years**		
	n	**%**	**Incidence** (n/10^5/yr)	**n**	**%**	**Incidence** (n/10^5/yr)
Ankle	170	7.3	169.0	43	3.7	147.8
Calcaneus	6	0.3	6.0	2	0.2	6.9
Carpus	15	0.6	14.9	3	0.3	10.3
Clavicle	54	2.3	53.7	25	2.1	85.9
Distal femur	19	0.8	18.9	14	1.2	48.1
Distal humerus	28	1.2	27.8	14	1.2	48.1
Distal radius/ulna	510	21.9	507.1	221	18.8	759.6
Distal tibia	8	0.3	8.0	2	0.2	6.9
Femoral diaphysis	55	2.4	54.7	32	2.7	110.0
Fibula	6	0.3	6.0	1	0.1	3.4
Finger phalanges	94	4.0	93.5	39	3.3	134.0
Forearm diaphysis	15	0.6	14.9	9	0.8	30.9
Humeral diaphysis	29	1.2	28.8	14	1.2	48.1
Metacarpus	64	2.7	63.6	24	2.0	82.5
Metatarsus	79	3.4	78.6	24	2.0	82.5
Midfoot	2	0.1	2.0	0	0.0	0.0
Patella	27	1.2	26.8	14	1.2	48.1
Pelvis	89	3.8	88.5	70	5.9	240.6
Proximal femur	683	29.3	679.2	479	40.7	1646.3
Proximal forearm	65	2.8	64.6	22	1.9	75.6
Proximal humerus	267	11.5	265.5	111	9.4	381.5
Proximal tibia	18	0.8	17.9	7	0.6	24.1
Scapula	12	0.5	11.9	6	0.5	20.6
Talus	0	0.0	0.0	0	0.0	0.0
Tibial diaphysis	6	0.3	6.0	0	0.0	0.0
Toe phalanges	10	0.4	9.9	1	0.1	3.4
Total	2331	100.0	2318.0	1177	100.0	4045.2

Table 3.8. Epidemiology of fractures in males aged ≥80 years presenting to the study centre during a one-year period. The numbers and prevalence of the different fractures are shown as are the prevalence of open fractures and patients with multiple fractures. The two commonest modes of injury for each fracture are shown.

Males ≥80 years	n	%	Multiple fractures (%)	Open (%)	Mode of injury
Proximal femur	112	44.4	4.5	0	92.8% falls, 4.5% fall height
Proximal humerus	25	9.9	24.0	0	100% falls
Distal radius/ulna	18	7.1	16.7	0	94.4% falls, 5.6% RTA
Pelvis	13	5.2	0	0	100% falls
Finger phalanges	13	5.2	30.0	0	84.6% falls, 15.4% RTA
Femoral diaphysis	12	4.8	0	0	91.7% falls, 8.3% pathological
Metacarpus	11	4.4	25.0	0	72.7% falls, 18.2% fall height
Ankle	10	4.0	0	0	90% falls, 10% RTA
Clavicle	6	2.4	0	0	83.3% falls, 16.6% low fall
Humeral diaphysis	6	2.4	16.6	0	100% falls
Proximal forearm	5	2.0	40.0	0	100% falls
Distal humerus	4	1.6	25.0	0	50% falls, 25% fall height
Metatarsus	3	1.2	0	0	77.7% falls, 18.2% fall height
Patella	3	1.2	0	0	100% falls
Distal femur	3	1.2	0	0	100% falls
Forearm diaphysis	3	1.2	0	0	66.6% falls, 33.3% sport
Proximal tibia	3	1.2	33.3	0	66.6% falls, 33.3% fall height
Carpus	1	0.4	0	0	100% falls
Toe phalanges	1	0.4	0	0	100% db/ assault
Scapula	0	0	0	0	
Distal tibia	0	0	0	0	
Calcaneus	0	0	0	0	
Fibula	0	0	0	0	
Midfoot	0	0	0	0	
Tibial diaphysis	0	0	0	0	
Talus	0	0	0	0	
Total	252	100.0	5.8	0	90.5% falls, 2.4% low fall

Table 3.9. Epidemiology of fractures in females aged ≥80 years presenting to the study centre during a one-year period. The numbers and prevalence of the different fractures are shown as are the prevalence of open fractures and patients with multiple fractures. The two commonest modes of injury for each fracture are shown.

Females ≥80 years	n	%	Multiple fractures (%)	Open (%)	Mode of injury
Proximal femur	367	39.7	5.4	0	97% falls, 1.9% low fall
Distal radius/ulna	203	21.9	10.5	1.0	98.5% falls, 1.5% low fall
Proximal humerus	86	9.3	12.8	0	96.5% falls, 3.5% low falls
Pelvis	57	6.2	8.8	0	96.5% falls, 3.5% low falls
Ankle	33	3.6	12.1	6.1	93.9% falls, 3% low falls
Finger phalanges	26	2.8	25.0	7.7	88.5% falls, 7.7% db/ assaults
Metatarsus	21	2.3	36.4	0	76.2% falls, 14.3% RTA
Femoral diaphysis	20	2.2	5.0	0	95% falls, 5% low fall
Clavicle	19	2.1	5.3	0	94.7% falls, 5.3% RTA
Proximal forearm	17	1.8	11.8	5.9	100% falls
Metacarpus	13	1.4	36.4	0	92.3% falls, 7.7% db/ assaults
Patella	11	1.2	0	0	100% falls
Distal femur	11	1.2	9.1	0	90.9% falls, 9.1% low falls
Distal humerus	10	1.1	0	0	100% falls
Humeral diaphysis	8	0.9	0	0	87.5% falls, 12.5% pathological
Forearm diaphysis	6	0.6	0	0	100% falls
Scapula	6	0.6	16.6	0	100% falls
Proximal tibia	4	0.4	25.0	0	75% falls, 25% RTA
Carpus	2	0.2	0	0	100% falls
Distal tibia	2	0.2	0	50.0	100% falls
Calcaneus	2	0.2	0	0	100% falls
Fibula	1	0.1	100.0	0	100% falls
Toe phalanges	0	0	0	0	
Midfoot	0	0	0	0	
Tibial diaphysis	0	0	0	0	
Talus	0	0	0	0	
Total	925	100.0	5.4	0.9	96.1% falls, 2.1% low fall

The fracture incidence in 2000 compared to 2010

The overall incidence of all adult fractures during the study period increased from 1091.1/10^5/year in 2000 to 1238.4/10^5/year in 2010 (OR 1.1, p=0.002), with a significant increase in fracture risk associated with females (OR 1.1, p=0.037). This increase was due to a significant surge in elderly and super-elderly fractures, with no change in incidence being observed for those patients aged less than 65 years of age (Table 3.10).

Table 3.10. The patient numbers and fracture incidences in 2000 and 2010. The odds ratios and p-values are shown

Patients	2000		2010		Odds ratio	p-value*
	n	Incidence (n/10^5/yr)	n	Incidence (n/10^5/yr)		
All	5647	1091.1	6996	1238.4	1.13	0.002
15-64 yrs	4602	1094.7	4665	1004.6	0.92	0.051
≥65 yrs	1960	2025.1	2331	2318.0	1.15	<0.0001
≥80 yrs	930	3733.4	1177	4045.2	1.09	0.0003

*chi square test

Fractures affecting the proximal femur, distal radius, proximal humerus, ankle, and pelvis were among the most common fractures observed in the elderly, whereas fractures of tibial diaphysis are less common (Tables 3.11 and 3.12). The overall incidence of proximal femoral fractures was relatively static and decreased in those patients 90 years and older (Figure 3.1). The overall incidence of distal radial fractures significantly increased from 195/10^5/year in the year 2000 to 236/10^5/year in 2010 (OR 1.2, p=0.048), and the general trend was towards an increase in incidence for all age categories which increased with age (Figure 3.2). The overall incidence of proximal humeral fractures in the year 2000 was 63/10^5/year which increased to 92/10^5/year in 2010 (OR 1.5, p=0.02), but this increase was due to a significantly greater incidence in those patients aged 50 years and older (Figure 3.3). The overall incidence of ankle fractures also increased from 101/10^5/year in 2000 to 139/10^5/year in 2010 (OR 1.4, p=0.02), which was also due to a significant increase in incidence in patients greater than 50 years of age (Figure 3.4). In contrast the overall incidence of pelvic fractures did not increase significantly, with an incidence of 17/10^5/year in 2000 compared to 23/10^5/year in 2010 (OR 1.4, p=0.42). However, there was an increase in the incidence those patients aged 90 years or older (Figure 3.5). Interestingly, the incidence of tibial diaphyseal fractures decreased from 22/10^5/year in 2000 compared to 13/10^5/year in 2010 (OR 0.6, p=0.18), which was due to a significant decrease in of fractures in the super-elderly population (Figure 3.6).

Table 3.11. The incidence of proximal femoral, distal radial and proximal humeral fractures according to age group for 2000 and 2010. The risk of sustaining each of these fractures according to age group in the year 2010 relative to the year 2000 is illustrated.

Age group	Incidence (n/10^5/yr)		Odds ratio	95% CI	p-value
	2000	2010			
Proximal femoral fractures					
15-29	4.5	1.3	0.2	0.02 to 1.7	0.9
30-39	3.0	3.1	1.0	0.2 to 5.0	0.9
40-49	10.6	4.2	0.4	0.1 to 1.1	0.12
50-59	38.5	35.2	0.9	0.6 to 1.5	0.82
60-69	76.9	100.5	1.3	0.9 to 1.8	0.08
70-79	380.0	349.4	0.9	0.8 to 1.1	0.26
80-89	1439.9	1445.3	1.0	0.9 to 1.1	0.9
90+	3353.7	2994.5	0.9	0.8 to 0.9	<0.001
Distal radial fractures					
15-29	144.2	155.8	1.1	0.9 to 1.4	0.49
30-39	85.3	109.9	1.3	0.97 to 1.7	0.07
40-49	76.8	125.5	1.6	1.2 to 2.2	0.0006
50-59	149.8	231.5	1.5	1.3 to 1.9	<0.001
60-69	273.6	339.1	1.2	1.1 to 1.5	0.009
70-79	500.7	430.6	0.9	0.7 to 0.97	0.02
80-89	677.0	788.4	1.2	1.1 to 1.3	0.003
90+	813.0	970.1	1.2	1.1 to 1.3	0.0002
Proximal humeral fractures					
15-29	9.7	5.8	0.6	0.2 to 1.7	0.45
30-39	23.8	21.6	0.9	0.5 to 1.6	0.76
40-49	37.8	47.1	1.2	0.8 to 1.9	0.33
50-59	66.0	93.1	1.4	1.02 to 1.9	0.03
60-69	118.0	169.6	1.4	1.1 to 1.8	0.002
70-79	172.1	225.4	1.3	1.1 to 1.6	0.008
80-89	271.8	398.3	1.5	1.3 to 1.7	<0.001
90+	482.7	442.9	0.9	0.8 to 1.04	0.19

Table 3.12. The incidence of ankle, pelvic and tibial diaphyseal fractures according to age group for 2000 and 2010. The risk of sustaining each of these fractures according to age group in the year 2010 relative to the year 2000 is illustrated.

Age group	**Incidence** (n/10^5/yr)		**Odds ratio**	**95% CI**	**p-value**
	2000	**2010**			
Ankle fractures					
15-29	97.9	113.3	1.2	0.9 to 1.5	0.33
30-39	79.4	92.4	1.2	0.9 to 1.6	0.35
40-49	92.2	118.2	1.3	0.97 to 1.7	0.08
50-59	103.1	159.8	1.6	1.2 to 2.0	0.0005
60-69	144.8	186.8	1.3	1.03 to 1.6	0.02
70-79	105.1	151.0	1.4	1.1 to 1.8	0.005
80-89	138.3	176.6	1.3	1.02 to 1.6	0.02
90+	76.2	147.6	2.0	1.5 to 2.7	<0.001
Pelvic fractures					
15-29	3.0	4.5	1.0	0.5 to 1.7	0.9
30-39	4.0	2.1	0.5	0.1 to 2.7	0.9
40-49	3.5	4.2	1.0	0.3 to 4.0	0.9
50-59	4.1	10.1	2.5	0.8 to 8.0	0.18
60-69	17.9	25.1	1.4	0.8 to 2.5	0.35
70-79	40.2	24.8	0.6	0.4 to 1.03	0.08
80-89	157.3	180.7	1.2	0.9 to 1.4	0.21
90+	228.7	611.6	2.7	2.3 to 3.1	<0.001
Tibial Diaphyseal fractures					
15-29	26.9	14.2	0.5	0.4 to 1.0	0.06
30-39	20.8	15.4	0.7	0.4 to 1.4	0.41
40-49	21.3	15.7	0.8	0.4 to 1.5	0.51
50-59	9.6	8.8	0.9	0.4 to 2.2	0.82
60-69	14.3	12.6	0.9	0.4 to 2.0	0.84
70-79	15.6	11.3	0.7	0.3 to 1.5	0.4
80-89	23.8	0	-		<0.001
90+	101.6	0	-		<0.001

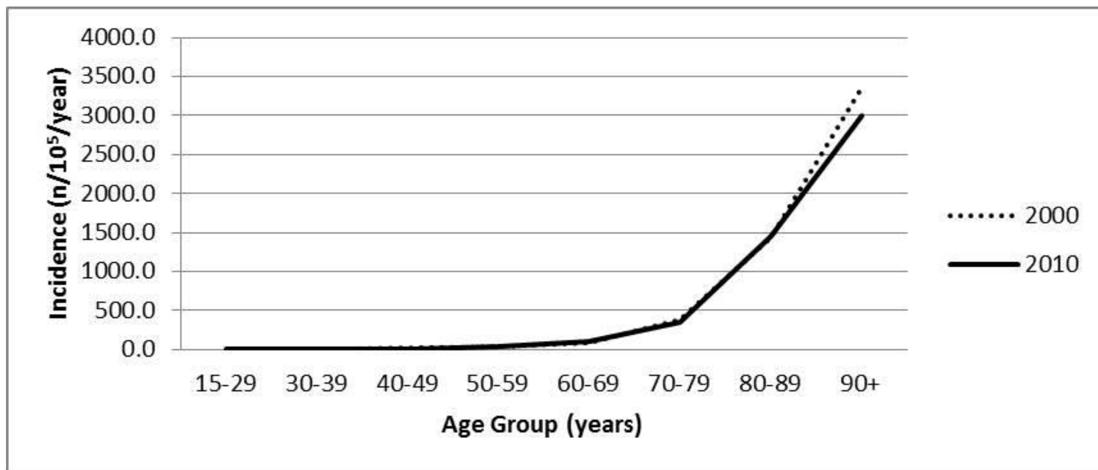

Figure 3.1. Incidence of proximal femoral fractures for the year 2000 and 2010, according to patient age.

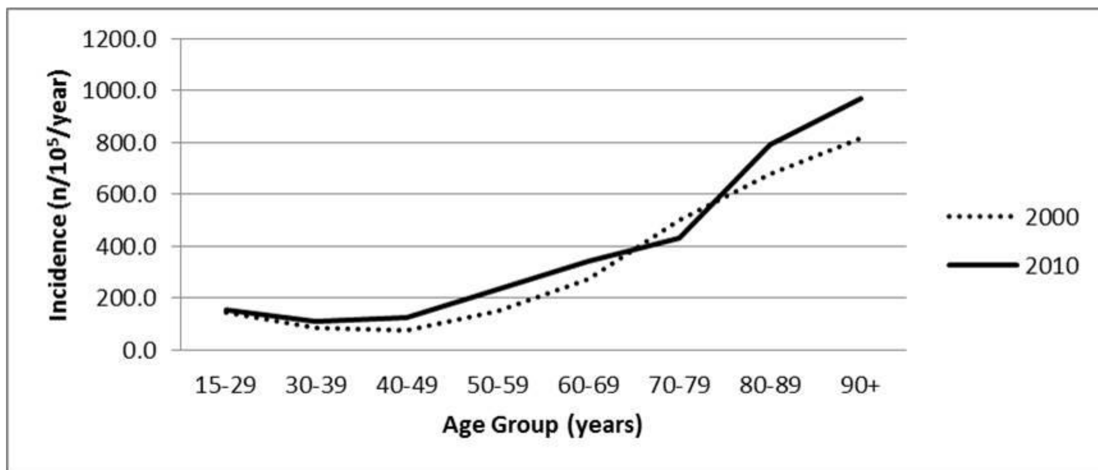

Figure 3.2. Incidence of distal radial fractures for the year 2000 and 2010, according to patient age.

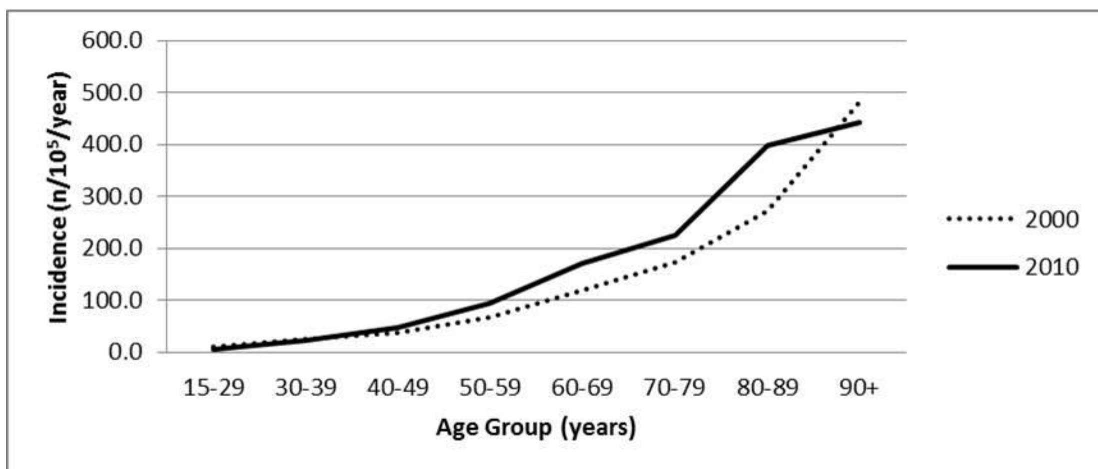

Figure 3.3. Incidence of proximal humeral fractures for the year 2000 and 2010, according to patient age.

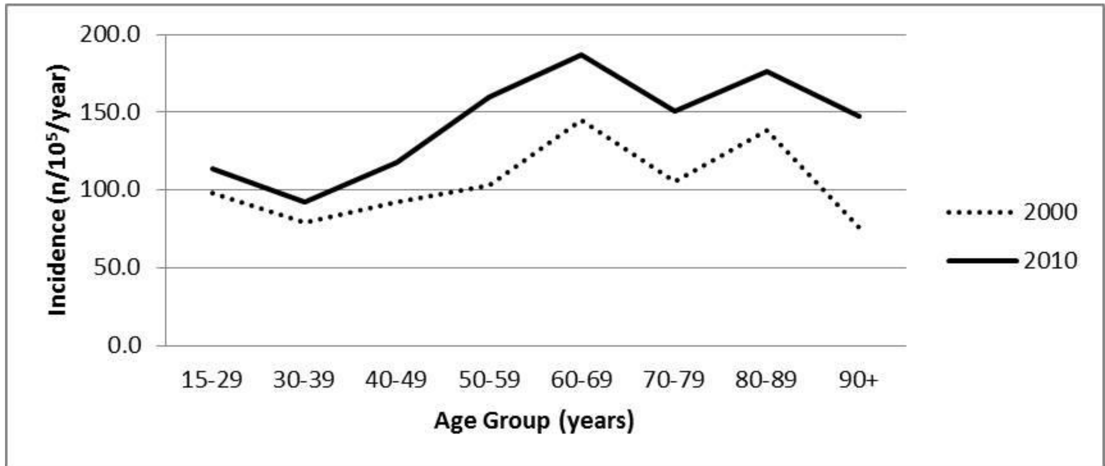

Figure 3.4. Incidence of ankle fractures for the year 2000 and 2010, according to patient age.

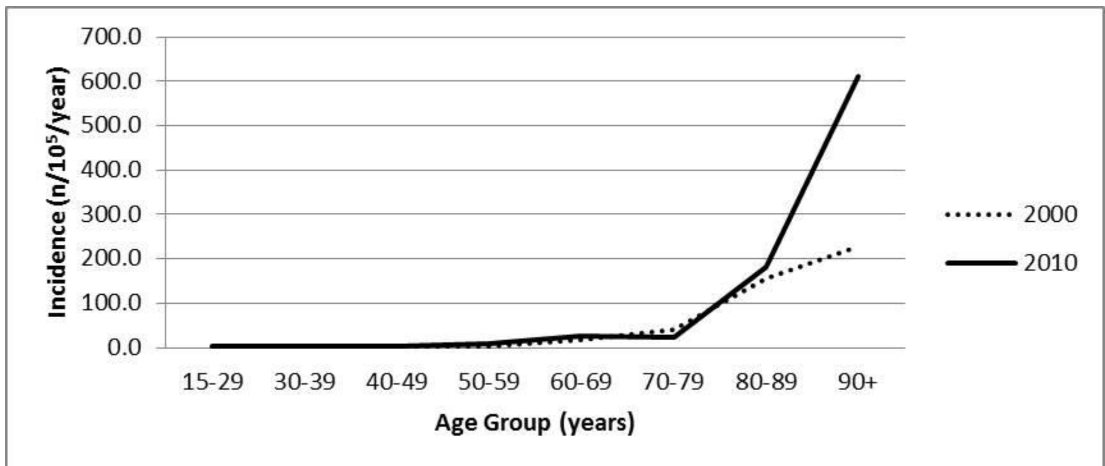

Figure 3.5. Incidence of pelvic fractures for the year 2000 and 2010, according to patient age.

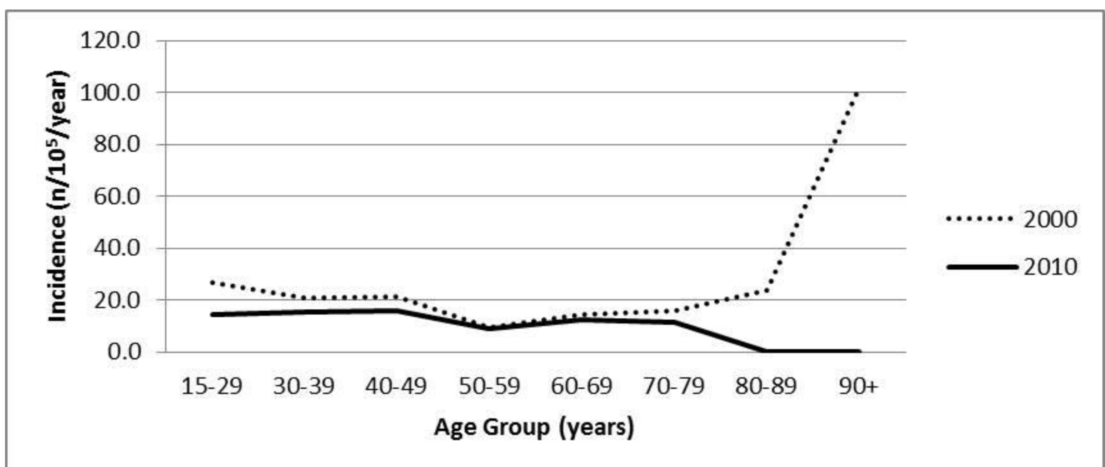

Figure 3.6. Incidence of tibial fractures for the year 2000 and 2010, according to patient age.

3.4 Discussion

This study has demonstrated that more a third of all fractures occur in elderly patients, of which half occur in super-elderly patients. The risk of sustaining a fracture was significantly greater in the elderly population compared to those age 15 to 64 years of age, and this risk increased further for the super-elderly population. Fractures of the proximal femur, distal radius, proximal humerus, and ankle were the most prevalent fractures sustained by both the elderly and super-elderly population, who were more likely to sustain these fractures compared to younger patients. More than 90% of these fractures in the elderly were sustained after a low energy fall from standing height. Elderly and super-elderly females had a significantly increased risk of sustaining a fracture, especially those involving the distal radius, and approximately one in 20 sustained multiple fractures at the time of their injury, which most commonly involved the proximal humerus. Open fractures in the elderly are rare overall but were more prevalent with tibial diaphyseal fractures. Not only did the absolute number of fractures increase in 2010 compared to the year 2000, but so did the incidence which was due to a significant increase in incidence for the elderly and more so in the super-elderly population. However, analysis of specific fractures demonstrated no change in the incidence of proximal femoral or pelvic fractures, but there was an increased incidence observed for distal radial, proximal humeral, and ankle fractures in the elderly and super-elderly. In contrast there was a decrease in the incidence for less common fractures in the elderly such as tibial diaphyseal fractures.

It could be argued that these findings may be specific to the catchment population that was used, however data from Scotland is likely to be representative of the fracture incidence of the Western World with similar hip fracture rates being observed.[136] Figures from both Europe and America affirm the increasing rate of fragility fractures, which may explain the increased incidence of fragility fractures demonstrated for the population studied. In developed and developing countries the incidence of osteoporosis is increasing at a rate faster than would be predicted simply by the increasing longevity of the population.[35] The increasing rate of osteoporosis may be one aspect of the increasing rate of fragility fractures observed in Scotland.

As discussed in section 1.6 the rate of osteoporosis seems to be accelerating and may explain the increasing incidence of fractures observed in elderly population over the last decade for the study groups. This makes elderly fractures one of the most important groups to understand as this growing group of patients will constitute more of the orthopaedic trauma workload of the future.

It is not surprising that more than half of proximal femoral and proximal humeral fractures occur in elderly patients, as these are generally accepted as fragility fractures of the elderly. However, it is interesting to note that more than half of pelvic, distal femoral and

femoral diaphyseal fractures occur in this elderly group. These fractures are not routinely reported as fragility fractures and may not be considered as such by some surgeons. Each of these fractures, except femoral diaphyseal fractures, are associated with an approximate 70/30 female to male ratio, which is likely to be due to the effect of osteoporosis in this elderly population. In contrast, tibial diaphyseal fractures demonstrated a male predominance, and may explain why the incidence of these fractures has not increase as they are associated with higher energy injuries in younger patients.[100]

The definition of what constitutes a fragility fracture lies in the pattern of presentation and relates to age and the low energy mechanism of injury. However, if it is accepted that these fractures are more likely to occur in the elderly population, then more than half of all fractures are fragility fractures. Overall the elderly population were more likely to sustain a fracture relative to the population aged between 15 and 64 years of age. Fractures of the femur, humerus, pelvis, patella, and distal radius were at least three times more likely to occur in the elderly age group whereas fractures involving the foot and hand were less likely. This difference probably relates to the mechanism by which these fractures are sustained. Younger patients were more likely to sustain their fracture by a fall from height, a direct blow, sport, or a RTA which are the typical mechanisms by which foot and hand fractures occur.[86] Hence, it would seem these fractures are less likely, even in the presence of osteoporosis, to occur after a simple fall from standing height in the elderly.

Currently 10 million people in the UK are aged 65 years and older, which is predicted to increase to 16 million in the next 20 years.[137] If the increase in the incidence of elderly fractures, that this study has demonstrated, continues during this same period this would double the number of fragility fractures presenting to orthopaedic trauma services. Even if the incidence rate remains static, by 2030 there will be approximated 108,640 proximal femoral, 81,120 distal radius, and 42,480 proximal humeral fractures presenting to orthopaedic services in the UK alone. This will have considerable repercussions upon trauma services and the management of these frail patients. Furthermore, it is interesting to note that the incidence of distal radial, proximal humeral and ankle fractures is increasing in incidence, whereas the incidence of proximal femoral fractures remained static. This has been observed in other European countries.[138] This study also demonstrated that there was a trend towards a decreasing incidence of tibial diaphyseal fractures, which may suggest that trauma in the Western World is changing from high energy modes of injury, due to increasing health and safety measures[139], that are associated with diaphyseal fractures[140], and towards low energy modes of injury involving the metaphysis due to diminishing bone density with age.

The commonest mode of injury for all ages is falls from a standing height and almost 40% of fractures that followed a standing fall occurred in elderly patients. Falls from a standing

height were more common in females, whereas all other modes of injury were equally distributed between the genders or were male predominant. This may relate to the marked difference in the fracture incidence between males and females in both the elderly and super-elderly populations. As females were significantly more likely to sustain a fracture relative to males, which would imply that elderly females are twice as likely to sustain a fracture after a fall from standing height when compared to males if the rate of falls is assumed to be equal. This predisposition is probably related to deceasing bone mineral density with age, which is more marked in females after the menopause. This hypothesis also explains why fractures involving the distal radius were less prevalent in males, accounting for only 10% of fractures compared with about 25% in females, as they are associated with diminished bone density with aging in females.[141]

Knowledge and understanding of the fracture epidemiology of the super-elderly age group forms an important aspect of what the future may hold for orthopaedic trauma services. The super-elderly population, comprising patients over the age of 80 years, has doubled during the last 25 years and will probably double again in the next 25 years.[142] If this were the case and the incidence remains static at $4045/10^5$/year, which is nearly double that observed for the elderly patients of $2318/10^5$/year, that would result in 2354 fractures being managed at the study centre in 2035. Approximately half of all fragility fractures occur in this super-elderly subgroup despite only accounting for 29% of the elderly population. More than half of all proximal femur and pelvic fractures, and approximately a quarter of all humeral fractures occur in the super-elderly, and also account for 40% of femoral diaphyseal and distal femoral which are traditionally associated with high energy trauma.[140]

The reasons why the incidence of distal radial, proximal humeral and ankle fractures significantly increased whereas proximal femoral and pelvic fractures remained relatively static in the elderly and super-elderly populations between 2000 and 2010 is not clear. Frailer patients are more likely to incur proximal limb girdle fractures due to diminished protective reflexes and hence sustain proximal humeral and femoral fractures.[143, 144] Whereas patients who retain their protective reflexes are more likely to sustain a distal radial fracture, which may reflect a superior physiological status of elderly patients in 2010. Also, the increasing use of bisphosphonates to prevent fragility fractures may have influenced the location of fractures sustained after falls, with atypical fractures being associated with bisphosphonate use.[145]

A limitation of the comparative aspect of this study was that it was not a longitudinal study throughout the decade assessed, as comparing epidemiological data separated by several years does not have compensated for a potential variation in fracture incidence with time to be observed. However, no studies have been published that demonstrate a fluctuating fracture incidence with time. A potential limitation of the method used to collect the data, is

that a hospital's catchment population may not be a reliable denominator for descriptive epidemiological study and some fractures may be missed as they do not present to medical services.[46] However, using a hospital's catchment can also be considered a strength of this study, as the collected data was from a defined catchment population with no other hospital or accident and emergency department serving the area. In addition to rely on a patient's own diagnosis of their fracture can result in an over estimation of one in ten fractures.[146] Furthermore, reliance upon emergency department data alone can also result in a 25% false positive rate[147], and hence the presented study using a radiographically diagnosed fracture and exclusion of all suspected fractures offers an accurate measure of fracture incidence. Also, the figures presented represent those patients presenting to medical services and hence are those for whom predictions of future service provision is required. Despite these weaknesses this is the only study to describe the change in incidence of all fractures over the last decade in the UK, and although it may only offer the epidemiology for a localised area it serves as a marker for the current state of fracture epidemiology in the UK.

3.5 Conclusion

The number and overall incidence of fractures presenting to orthopaedic services is increasing, which is due to the increasing incidence in the growing elderly and super-elderly population. This will result in an increased need for elderly trauma services in the future if the projected increase in this population is correct.

CHAPTER 4:

THE OUTCOME OF SUPER-ELDERLY FRACTURES

CHAPTER 4: THE OUTCOME OF SUPER-ELDERLY FRACTURES

4.1 Aims

The primary aim was to present the epidemiology and outcomes of fractures for this super-elderly (≥80 years) group and compare those patients less than 90 years with those 90 years old or more. The secondary aims were to assess the repercussions of the results for this growing super-elderly population upon future healthcare.

4.2 Chapter Summary

Case-mix and outcome variables for 1310 super-elderly patients sustaining acute fractures were recorded. A cohort of 318 very-elderly (90+ years) patients was compared with a group of 992 elderly (80-89 years) patients. The very-elderly group accounted for only 0.6% of the overall population, but they represent 4.1% of all fractures and 9.3% of all orthopaedic admissions. Patients in the very-elderly cohort were more likely to require hospital admission (OR 1.4), were less likely to return to independent living (OR 3.1), and their total length of hospital stay was significantly longer (increased by 10 days, p=0.01). Thirty-day and 120-day unadjusted mortality was greater in the very-elderly group. The 120-day mortality associated with non-hip lower limb fractures was equal to that of proximal femoral fractures and was significantly increased with delay (>48 hours) to surgery if applicable, for both age groups (p=0.04). This suggests the principle of early surgery and mobilisation of elderly patients with hip fractures should be extended to incorporate other operatively managed lower limb fractures in this vulnerable age group.

4.3 Results

A total of 7,701 fractures were prospectively recorded. Patients aged 80 years or more accounted for 1310 fractures and 976 hospital admissions, 33.7% of all acute orthopaedic trauma admissions (Table 4.1). Excluding hip fractures, all of which were admitted, the very-elderly group were more likely to be admitted to hospital for their injury (OR 2.1, p=0.0001 after adjusting for other case-mix variables). The median age was 93 years (mean 93 ± 2.2 years; range 90-102 years) in the very-elderly group, compared with 84 years (mean 84 ± 3.4 years; range 80-89 years) in the elderly group.

Significant case-mix differences existed between the cohorts (Table 4.2). The very-elderly patients were less likely (OR 3.0. p=0.0001) to live in their own home and were less likely (OR 4.5, p=0.0001) to be independently mobile. No significant difference was observed in relation to the gender distribution of the two groups. Dementia was significantly more common in the very-elderly group (p<0.01).

Table 4.1. Number of fractures and inpatient admissions for both groups. Percentages given are for that age group.

	Age Group (%)	
	Elderly	Very-elderly
Total Number	992	318
Inpatients	717 (71.9)	269 (84.6)
Hip fractures	408 (40.9)	158 (49.7)
Inpatients without hip fractures	309 (31.0)	111 (34.9)

Table 4.2. Case-mix variables for each cohort.

Case-Mix Variables	Age Group	
	Elderly	Very-elderly
Gender		
Male	18.0% (n=179)	18.2% (n=58)
Female	82.0% (n=813)	81.8% (n=260)
Prefracture residence of inpatients		
Own home*	82.6%	68.8%
Residential care*	5.9%	8.6%
Nursing Home*	11.2%	22.3%
Hospital	0.4%	0.4%
Prefracture mobility		
No aids*	49.0%	17.6%
One stick	33.7%	38.5%
Two sticks*	11.1%	14.6%
Zimmer frame*	4.4%	23.9%
Unable to walk*	1.8%	5.4%
Comorbidities		
Nil	6.1%	4.1%
One	23.0%	20.6%
Two	39.5%	40.2%
Three	22.3%	23.7%
Four or more	10.1%	11.4%
Dementia*	5.1%	11.6%

* chi-squared test, p=<0.01

The very-elderly group were more likely to have sustained a proximal femoral (OR 1.4, p=0.01) or a pelvic (OR 1.7, p=0.05) fracture, but less likely to sustain a distal radial (OR 1.8, p=0.003) or finger phalanx (OR 2.0, p=0.07) fracture (Table 4.3).

Table 4.3. Number of fractures for all patients, 80-89-year olds (elderly) and those 90 years or older (very-elderly) with percentages for that group.

Fracture	All Fractures		Elderly		Very-elderly	
	Number	%	Number	%	Number	%
Ankle	732	9.5%	30	3.0%	10	3.1%
Calcaneus	65	0.8%	1	0.1%	0	0
Carpus	219	2.8%	3	0.3%	0	0
Clavicle	325	4.2%	22	2.2%	5	1.6%
Distal Femur	43	0.6%	8	0.8%	6	1.9%
Distal Humerus	61	0.8%	11	1.1%	3	0.9%
Distal Radius*	1264	16.4%	180	18.2%	35	11.1%
Distal Tibia	70	0.9%	2	0.2%	1	0.3%
Distal Ulna	39	0.5%	7	0.7%	1	0.3%
Femoral Diaphysis	114	1.5%	29	2.9%	12	3.8%
Fibula	26	0.3%	1	0.1%	0	0
Finger Phalanx*	781	10.1%	31	3.1%	5	1.6%
Humeral Diaphysis	75	1.0%	8	0.8%	4	1.3%
MC	779	10.1%	13	1.3%	1	0.3%
MT	442	5.7%	15	1.5%	1	0.3%
Midfoot	43	0.6%	1	0.1%	0	0
Patella	65	0.8%	10	1.0%	1	1.3%
Pelvis*	152	2.0%	43	4.3%	23	7.3%
Proximal Femur*	935	12.1%	421	42.5%	160	50.6%
Proximal Humerus	541	7.0%	110	11.0%	34	10.8%
Proximal Radius	287	3.7%	13	1.3%	0	0
Proximal Radius & Ulna	9	0.1%	2	0.2%	1	0.3%
Proximal Tibia	98	1.3%	10	1.0%	6	1.9%
Proximal Ulna	84	1.1%	7	0.7%	5	1.6%
Radius & Ulna	31	0.4%	1	0.1%	0	0
Radial Diaphysis	26	0.3%	1	0.1%	0	0
Scapula	58	0.8%	3	0.3%	1	0.3%
Talus	40	0.5%	0	0	0	0
Tibial Diaphysis	106	1.4%	4	0.4%	1	0.3%
Toe Phalanx	143	1.9%	1	0.1%	0	0
Ulna Diaphysis	48	0.6%	4	0.4%	2	0.6%
Total	7701		992		318	

* chi-squared test, p=<0.01

Table 4.4 illustrates the number of patients in each of the cohorts and the percentage of those undergoing operative management. Patients in the very-elderly cohort sustaining upper limb (proximal humerus and distal radius) and proximal femur fractures were more likely to be managed non-operatively (OR 4.1, p=0.006 and OR 2.4, p=0.03 respectively). Very-elderly patients with more than two co-morbidities were less likely to undergo operative intervention (OR 2.1, p=0.02). Poor cognition increased the likelihood of non-operative management, as patients with dementia were less likely to undergo surgery (OR 4.8, p=0.0007). However, very-elderly patients residing at home were more likely to undergo operative management (OR 3.2, p=0.01), which may reflect an increased functional demand.

Table 4.4. Number patients in each of four cohorts and risk of surgery, comparing the elderly with the very-elderly.

Fracture Group	Elderly		Very-elderly		Risk of Surgery	p-value*
	Number Patients (%)	Receiving Operation (%)	Number Patients (%)	Receiving Operation (%)		
Lower Limb						
Ankle	30 (3.0)	8 (26.7)	10 (3.1)	3 (30.0)	OR 1.1	p=0.6
Distal Femur	8 (0.8)	6 (75.0)	6 (1.9)	5 (83.3)	OR 1.7	p=0.6
Femoral Diaphysis	29 (2.9)	27 (93.1)	12 (3.8)	11 (91.7)	OR 1.2	p=0.7
Proximal Tibia	10 (1.0)	7 (70.0)	6 (1.9)	4 (66.7)	OR 1.2	p=0.7
Total	77	48 (62.3)	34	23 (67.6)	OR 1.3	p=0.4
Upper Limb						
Distal Radius	180 (18.2)	41 (22.8)	35 (11.1)	2 (5.7)	OR 4.0	p=0.04
Proximal Humerus	110 (11.0)	11 (10.0)	34 (10.8)	1 (2.9)	OR 3.4	p=0.2
Total	290	52	69	3	OR 4.1	p=0.006
Pelvis	43 (4.3)	1 (2.3)	23 (7.3)	1 (4.3)	OR 1.9	p=0.6
Proximal Femur	421 (42.5)	409 (97.1)	160 (50.6)	149 (93.1)	OR 2.4	p=0.03

* chi-squared test, p<0.01

Overall the elderly (80 to 89 years) group had a significantly better unadjusted survival rate at 120 days (Table 4.5), which was observed for all four cohorts (Figure 4.1). The 120-day survival for hip fractures and lower limb fractures in both the elderly (80 to 89 years) and very-elderly (>90 years) were not significantly different (83.1% versus 86.7% and 71.5% versus 71.1% respectively p>0.1).

The mean time to theatre significantly differed between the cohorts (excluding the pelvic fracture group as there was only one patient for each age group). The average time to theatre for proximal femur fractures was 1.8 days, lower limb fractures 2.4 days, and for upper limb fractures 4.3 days (p=0.003). Subgroup analysis of 120-day mortality demonstrated that both elderly and very-elderly patients in the lower limb fracture group receiving their operation within 48 hours of admission were more likely to survive (OR 6.3 p=0.008, and OR 10.5, p=0.04 respectively).

Table 4.5. Outcome measures according to age group.

Outcome	Age Group		Odds Ratio	p-value*
	Elderly	Very-elderly		
30-day survival for all inpatients				
Alive	94.6%	91.1%	1.68	0.03
Dead	5.4%	8.9%		
120-day survival for all inpatients				
Alive	85.5%	74.0%	2.09	<0.001
Dead	14.4%	26.0%		
Residence at 120 days if patient lived at home prior to fracture				
Own home	81.3%	58.4%	Reference	
Residential care	9.3%	15.7%	2.36	<0.001
Nursing Home	6.6%	18.9%	4.00	<0.001
Rehabilitation ward	3.0%	6.5%	3.03	<0.001
Hospital	0%	1.1%	-	-

* chi-squared test

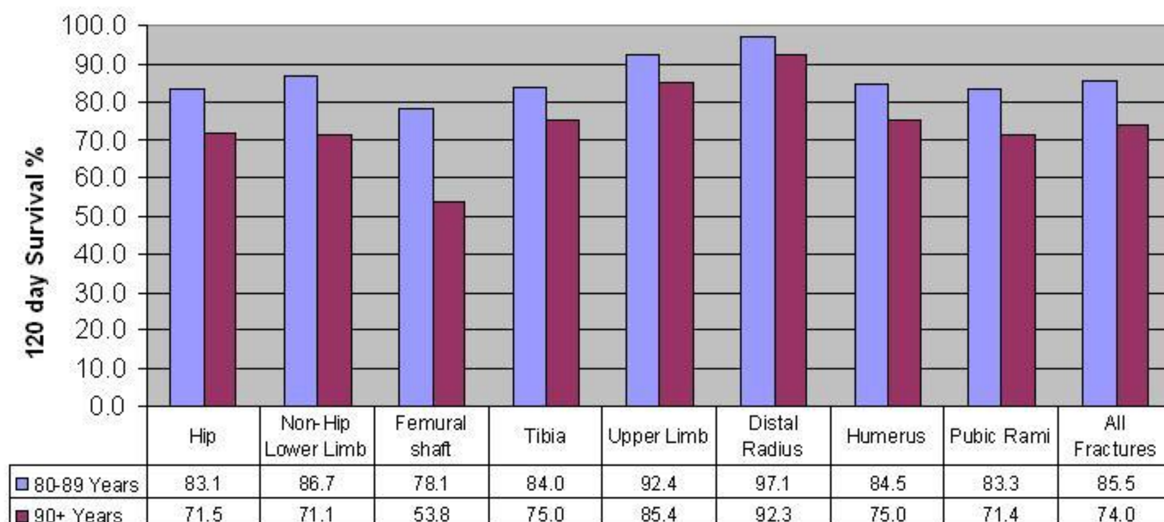

Figure 4.1. Survival for each fracture at 120 days according to age group.

Only 58.4% of the surviving very-elderly patients who had lived independently prior to injury returned to their original address after discharge compared with 81.3% of the patients in the elderly group (OR 3.1, p=0.0001), (Table 4.5). The very-elderly group were also more likely to need transfer to a rehabilitation ward prior to discharge (OR 8.7, p=0.004).

There was a significant difference in the total length of hospital stay (including subsequent rehabilitation and/or acute ward stays) between the groups; median 31.9 days versus 22.1 days; p = 0.01).

4.4 Discussion

This study has described the epidemiology and outcome of fractures for the super-elderly population. They account for more than a third of all acute orthopaedic trauma admissions. The very-elderly group only constitute 0.6% of the overall population, but they represent 4.1% of adult fractures and account for 9.3% of all acute orthopaedic trauma admissions. Data from the General Register Office for Scotland predicts that the number of individuals with an age of ninety years or more will increase two to threefold by the year 2031.[148] This suggests that there will be a significant increase in the orthopaedic trauma workload to manage such frail patients in the future with a resultant burden upon resources.

Increasing age is associated with a higher rate of mortality after hip fracture.[28] This study confirms the increased risk of mortality associated with proximal femur fractures, but also that it extends across all common fractures. When survival outcome was analysed, the very-elderly group was less likely to survive 120 days for all fracture subgroups. There were no significant differences in patient demographics or number of comorbidities between the two groups. This suggests that extreme old age is an isolated variable that is associated with a higher mortality after fracture, irrespective of other case-mix variables.

Several studies have demonstrated that advancing age is associated with increased length of hospital stay after surgery for the treatment of hip fractures.[149,150] The median length of hospital stay was significantly longer for the very-elderly group. Assuming that the cost of stay per day in an acute ward is similar to that of a fractured hip (£433[151]), then this would result in an increased cost of £4,330 per patient. This has important implications for future resource allocation and service provision in the face of an aging population.

Those patients admitted from their own home form an important group. The aim of treatment should be to return the patient to independent living. Only 58.4% of very-elderly patients living independently returned to their original address. Failure to discharge these patients directly home may reflect their worsening and poor mobility when compared to elderly patients (Table 4.2), with their fracture finally initiating the need for increased care. This may also explain why there was an increased length of stay for this group, as there may well have been a delay in organising a safe place of permanent discharge. The cost implications of future care packages after injury were not assessed, but this financial burden is well recognised in hip fracture studies.[7,11]

The very-elderly group were more likely to have sustained a proximal femoral or a pelvic fracture, but less likely to sustain a distal radial fracture. This may be due to decreasing cognition with age, reflected by an increased prevalence of dementia in this group. Frailer patients are more likely to incur proximal limb girdle fractures secondary to diminished protective reflexes[143, 144], and hence sustain pelvic and proximal femoral fractures. Whereas,

patients who retain these protective reflexes sustain distal radial fractures, and this may reflect a better overall physiological status.

The very-elderly group were more likely to be managed non-operatively for upper limb fractures, or if they had more than two comorbidities, or had a diagnosis of dementia. This is probably due to their diminished functional demand with nearly a third of patients residing in care homes, which is supported by the fact that if they were living at home, being more functionally demanding the rate of operative intervention increased.

The study centre works towards National Health Service targets, operating on proximal femoral fractures within 48 hours of admission. This target is derived from evidence that demonstrates a decreased number of post-operative complications and shorter hospital stays when operative intervention occurs early.[152] If this principle was applied to all lower limb fractures requiring surgery in the elderly to aid early rehabilitation the same benefits may be observed. This study has demonstrated a significantly increased mortality risk for super-elderly patients with lower limb fractures who undergo delayed surgery (>48 hours). However, this delay may also be due to optimisation of the most physically unwell patients who may carry an increased mortality risk. This claim would need to be studied independently to confirm that early surgery and mobilisation improves survival for all lower limb fractures.

Due to the complex issues surrounding the inclusive care of these very-elderly patients a multidisciplinary team approach, which has been used for hip fracture patients with improved one year patient survival[153], maybe a potential solution in addressing all the needs of these patients.[154] More effective liaison between: nursing staff, orthopaedic surgeons, physicians, physiotherapists, occupational therapists, social workers, patients and their family may result in earlier physical and functional optimisation, and facilitate a safe early discharge. The acute orthopaedic trauma ward may also be sub optimal to manage such patients who may need an environment that would address all their multifaceted needs.

4.5 Conclusion

This study has demonstrated that the very-elderly patients have a similar number of co-morbidities relative to their elderly counterparts, but they are less likely to be independently mobile or to live in their own home prior to injury. They are more likely to require admission to hospital, have a longer length of stay, and are less likely to return to independent living. The principle of early surgery and mobilisation of elderly patients with hip fractures may be extended to incorporate other operatively managed lower limb fractures to aid early rehabilitation. An increase in the services specific to this expanding super-elderly population will be needed to aid early surgery and a timely discharge in the future.

CHAPTER 5:

PREDICTING THE OUTCOME OF UNDISPLACED FEMORAL NECK FRACTURES IN THE ELDERLY

CHAPTER 5: PREDICTING THE OUTCOME OF UNDISPLACED FEMORAL NECK FRACTURES IN THE ELDERLY

5.1 Aims

The primary aim of this study was to identify predictors of failure of internal fixation and one-year mortality of elderly patients sustaining undisplaced intracapsular hip fractures. The secondary aims were to describe the epidemiology and outcome of elderly patients with undisplaced intracapsular hip fractures according to their socioeconomic status.

5.2 Chapter Summary

During a three-year period, a prospective consecutive series of 162 elderly (≥65 years old) patients that underwent internal fixation for minimally displaced (Garden stage I or II) intracapsular hip fracture were studied. All patients were followed up for a minimum of one year. Each patient's socioeconomic status was assigned using the SIMD.[109] Patient mortality was established using the General Register Office for Scotland. There were 28 failures of fixation during the study period. ASA grade and the presence of posterior tilt ($p<0.0001$) were significant independent predictors of fixation failure using Cox regression analysis. The overall unadjusted mortality rate at one year was 19% (n=30/162). Cox regression analysis also affirmed ASA grade to be the only significant independent predictor of one-year mortality ($p=0.003$). The standardised mortality rate for the cohort was 2.3 ($p<0.001$), which was significantly greater for patients less than 80 years of age ($p=0.004$). Socioeconomic status did not influence the outcome, but the most deprived patients sustain their fracture at a significantly younger age ($p=0.001$). ASA grade and posterior tilt (>10 degrees) of the femoral neck were independent predictors of fixation failure of undisplaced intracapsular hip fractures in elderly patients, and ASA grade was also an independent predictor of mortality.

5.3 Results

The mean age of the patients was 81.8 years (range 65 to 98). The mean age of male patients was 80.8 (range 66 to 96) years, and female patients was 82.1 (range 65 to 98) years ($p=0.37$). The majority of patients were female and had a severe systemic disease according to their ASA grade (Table 5.1). A simple fall from standing height was the cause of the fracture in all except one, who fell from a bicycle. The cohort was relatively affluent according to their socioeconomic status. Garden stage I was the commonest fracture pattern, with Pauwels grade III being a rare configuration (Table 5.1). Posterior tilt was observed in 27 patients (16.7%), and more than 90% of patients were classified as having had adequate screw fixation.

Table 5.1. Case-mix variables for the study cohort (n=162).

Case-mix variables		Cohort (n, %)
Gender	Male	34 (21.0)
	Female	128 (79.0)
ASA grade	I	6 (3.7)
	II	37 (22.8)
	III	86 (53.1)
	IV	33 (20.4)
SIMD quintile	1 (most)	17 (10.5)
	2	33 (20.4)
	3	29 (17.9)
	4	32 (19.7)
	5 (least)	51 (31.5)
Garden stage	I	120 (74.1)
	II	42 (25.9)
Pauwels	I	74 (45.7)
	II	84 (51.9)
	III	4 (2.5)
Posterior tilt	Yes	27 (16.7)
	No	135 (83.3)
Adequate screw position	Yes	148 (91.4)
	No	14 (8.6)

There were 28 failures of fixation during the study period. This resulted in a one-year implant survival rate of 87% (95% CI 81.5 to 92.5), however, this diminished to 81% (95% CI 75.9 to 86.1) and 78% (95% CI 71.9 to 84.1) at two and three years respectively (Figure 5.1). The only significant risk factors of fixation failure after univariate analysis were ASA grade and the presence of posterior tilt (Table 5.2, Figure 5.2 and Figure 5.3). Subgroup analysis was also undertaken according to surgical grade (p=0.13) and surgeon (p=0.56) performing the surgery, neither of which were significant predictors of failure. ASA grade and the presence of posterior tilt remained significant independent predictors of fixation failure, after adjusting for confounding variables (Table 5.3). Post-hoc analysis identified that those patients who had a shorter length of hospital stay were more likely to fail than those patients with a longer length of stay (p=0.003).

Table 5.2. The effect of case-mix variables on the outcome of elderly intracapsular hip fractures.

Case-mix variables		Outcome					
		Fixation Failure			**One-year Mortality**		
		No (n=134)	Yes (n=28)	p value	Alive (n=132)	Deceased (n=30)	p value
Mean Age (years)		81.9	81.3	0.72*	81.6	82.4	0.59*
Gender	Male	29	5	0.66**	28	6	0.88**
(n)	Female	105	23		104	24	
ASA grade	I	3	3	0.03**	6	0	0.02**
(n)	II	28	9		33	4	
	III	72	14		72	14	
	IV	31	2		21	12	
SIMD quintile	1 (most)	12	5	0.40**	14	3	0.32**
(n)	2	26	7		29	4	
	3	23	6		22	7	
	4	28	3		28	3	
	5 (least)	44	7		38	13	
Garden stage	I	99	21	0.9**	97	23	0.72**
(n)	II	35	7		35	7	
Pauwels classification	I	60	14	0.16**	63	11	0.29**
	II	72	12		65	19	
(n)	III	2	2		4	0	
Posterior tilt	Yes	16	11	<0.001**	110	25	0.9**
(n)	No	118	17		22	5	
Adequate screw position (n)	No	10	4	0.24**	11	3	0.77**
	Yes	124	24		121	27	

* unpaired t-test

** chi square test

Table 5.3. Independent risk factors of failure of cannulated screw fixation for undisplaced intracapsular hip fractures in elderly patients using Cox regression analysis.

Risk factor	OR	95% CI)		p-value
		Lower	Upper	
ASA grade				
ASA 1	Reference			
ASA 2	0.49	0.23	1.04	0.09
ASA 3	0.30	0.08	0.92	0.03
ASA 4	0.13	0.02	0.78	0.01
Posterior tilt				
No	Reference			
Yes	4.20	1.94	9.08	<0.0001

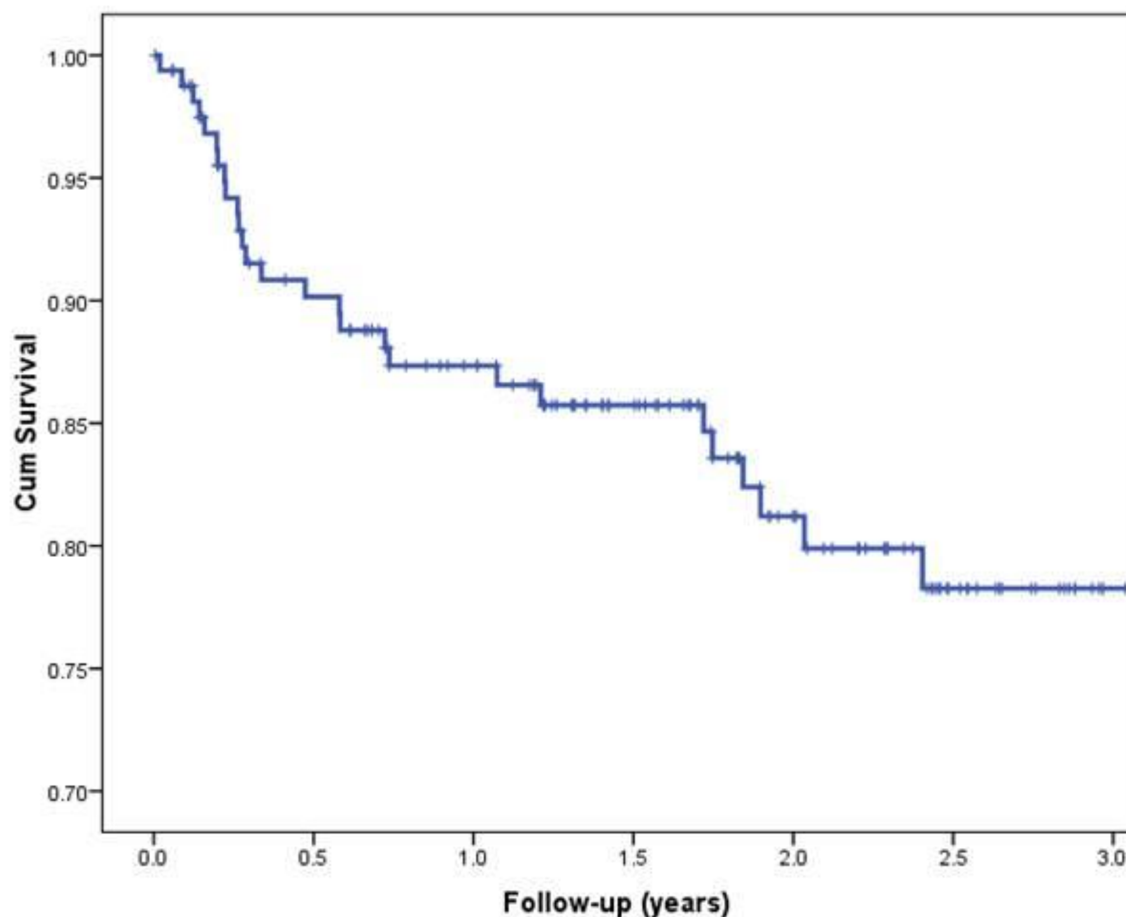

Figure 5.1 Kaplan-Meier survivorship curve for fixation of elderly undisplaced intracapsular hip fractures.

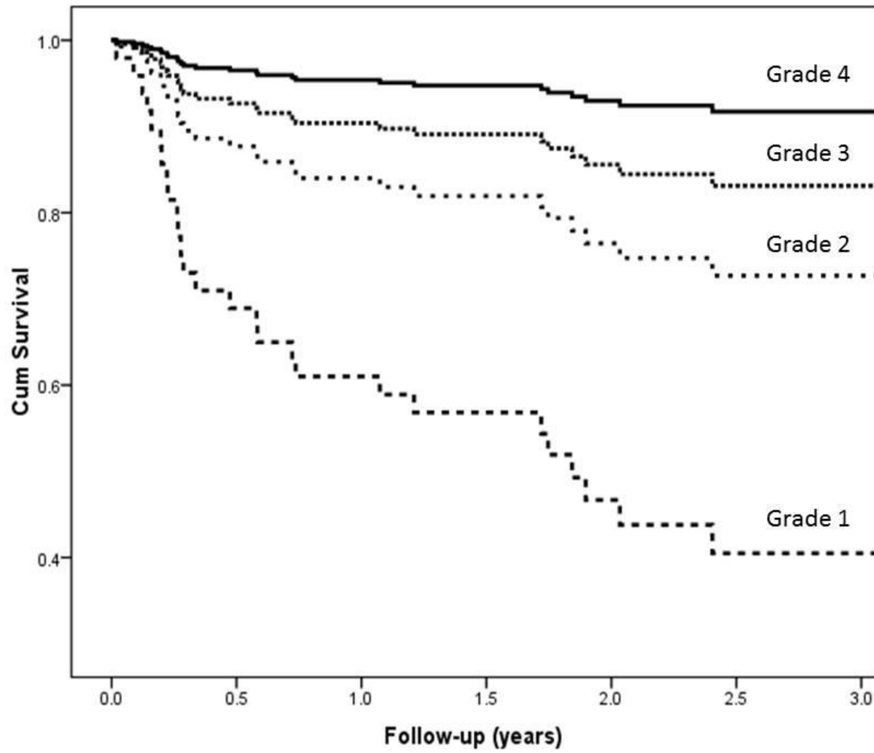

Figure 5.2 Kaplan-Meier survivorship curve for fixation of elderly undisplaced intracapsular hip fractures according to ASA grade.

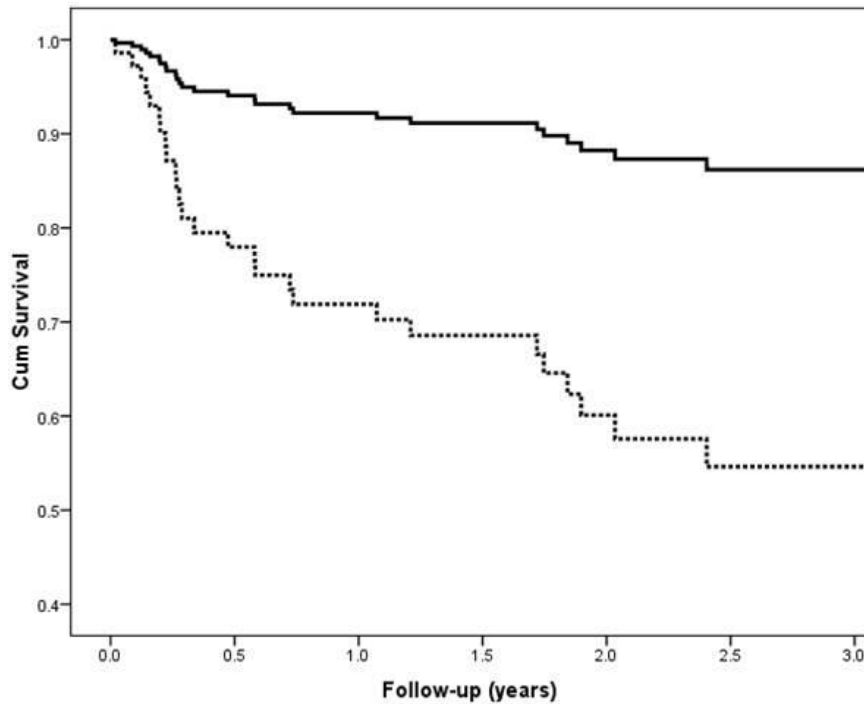

Figure 5.3 Kaplan-Meier survivorship curve for fixation of elderly undisplaced intracapsular hip fractures according to posterior tilt (solid line = no tilt, dashed line = >10 degrees of tilt).

The overall unadjusted mortality rate at one-year was 19% (n=30/162). ASA grade was the only significant risk factor of one-year mortality (Table 5.2) and remained the only significant independent predictor of mortality OR 2.0, 95% CI 1.3 to 3.1, Cox regression p=0.003) after adjusting for case-mix variables. The overall SMR for the cohort was 2.3 (95% CI 1.59 to 3.25, chi square p<0.0001), but this varied according to gender and age (Table 5.4). There was no significant difference between genders (p=0.23), but patients aged 65 to 79 years old had a significantly greater one-year SMR (p=0.004) relative to older patients.

Table 5.4. One-year SMR for elderly patients with intra-capsular hip fractures, according to age and gender.

Group	SMR	95% confidence interval	p-value*
All patients	2.3	1.59 to 3.25	<0.0001
Male	2.0	0.81 to 4.16	0.08
Female	2.4	1.54 to 3.52	<0.0001
65 to 79 years	6.5	3.61 to 10.84	<0.0001
80+ years	1.7	1.02 to 2.66	0.02

* chi square test

The incidence, patient demographics, and fracture patterns were similar across all social quintiles, with no statistical difference (Table 5.5). The mean age, however, was significantly different between social quintiles (p=0.001), with the most deprived patients sustaining their hip fracture some seven years earlier than the least deprived (Figure 5.4). There were no significant differences in outcome according to social status, with similar rates of fixation failure, unadjusted mortality rates, and SMR being observed (Table 5.5).

Table 5.5. Patient demographics, fracture classification and one-year mortality rates according deprivation index.

Demographic	Descriptive	Socioeconomic Deprivation (SIMD)					
		1 (n=17)	2 (n=33)	3 (n=29)	4 (n=31)	5 (n=51)	p-value
Age adjusted incidence	(n/10^5/yr)	36.8	48.3	46.6	46.6	41.6	0.48*
Gender (M/F) (n, % quintile)	Male	5 (36.6)	3 (39.6)	7 (43.2)	4(51.6)	14 (44.3)	0.18*
	Female	12 (63.4)	30 (60.4)	22 (56.8)	22 (48.4)	37 (55.7)	
Mean Age (years: mean, SD)		78.2 (8.8)	80.5 (6.5)	80.2 (5.6)	81.2 (6.8)	85.1 (6.8)	**0.001****
ASA grade (n, % of quintile)	I	2 (11.8)	1 (3.0)	0	1 (3.2)	1 (2.0)	0.08*
	II	5 (29.4)	10 (30.3)	7 (24.1)	5 (16.1)	10 (19.6)	
	III	10 (58.8)	18 (54.5)	11 (37.9)	20 (64.5)	27 (52.9)	
	IV	0	4 (12.1)	11 (37.9)	5 (16.1)	13 (25.5)	
Garden stage (n, % of quintile)	I	14 (82.4)	21 (63.6)	22 (78.6)	23 (74.2)	39 (76.5)	0.62*
	II	3 (17.6)	12 (36.4)	7 (24.1)	8 (25.8)	12 (23.5)	
Pauwels grade (n, % of quintile)	1	9 (52.9)	10 (30.3)	14 (48.3)	16 (51.6)	24 (47.1)	0.42*
	2	8 (47.1)	22 (66.7)	14 (48.3)	13 (41.9)	27 (52.9)	
	3	0	1 (3.0)	1 (3.4)	1 (3.2)	0	
Mortality (n, % of quintile)	Alive	14 (82.3)	29 (87.9)	22 (76.0)	28 (90.3)	38 (74.5)	0.44*
	Deceased	3 (17.7)	4 (12.1)	7 (24.0)	3 (9.7)	13 (25.5)	
SMR		2.3	2.1	3.0	2.2	2.3	0.27*

* chi square test ** ANOVA

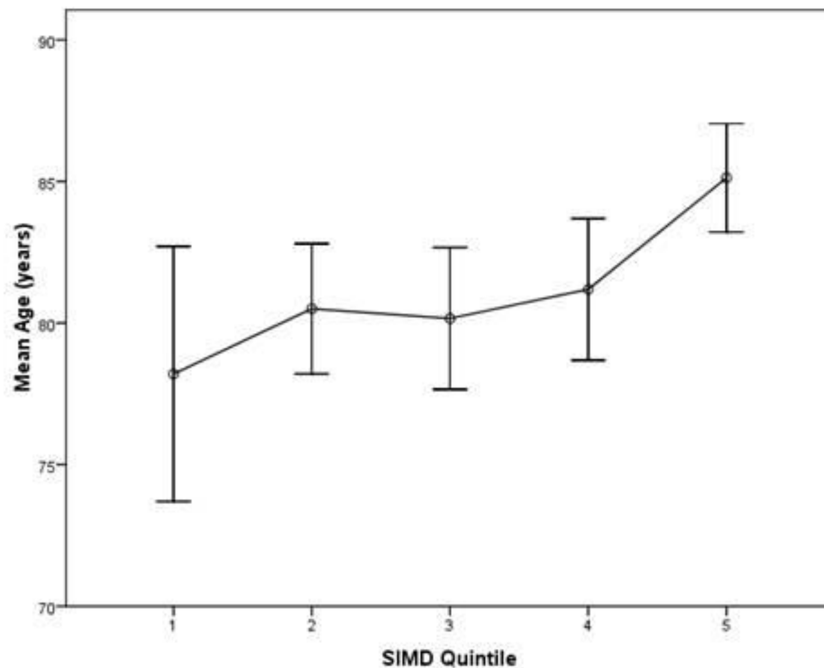

Figure 5.4 Mean age at time of intracapsular hip fracture according to social quintile (95% error bars). SIMD quintile: 1 = most socially deprived and 5 = the least socially deprived

5.4 Discussion

ASA grade and posterior tilt of the femoral neck are independent predictors of fixation failure of minimally displaced intracapsular hip fractures in elderly patients, and ASA grade was also an independent predictor of mortality. Although, social deprivation did not influence the outcome of minimally displaced intra-capsular hip fractures in the elderly, the age at which the most deprived sustained their fracture was significantly younger than the more affluent patients.

A limiting factor of this study was that only patients who re-presented with pain or dissatisfaction and subsequently revised were labelled a failure. It is possible that patients with limited functional demand or died did not re-present and may have gone on to covert failure. Hence, the fixation survival rate observed probably represents the best-case scenario, which may be worse if all patients had endured radiographic assessment. The prospective nature with a relatively large cohort and 100% follow-up from a defined catchment population are the main strengths of the study lending validity to the results. In addition, the effect of bone mineral density upon the failure of the cannulated screws was investigated, however only 46 patients in the study cohort had a dual-energy X-ray absorptiometry scan performed prior to their hip fracture. Analysis of this smaller sub-group demonstrated a trend towards significance for an increased failure rate in those patients with a lower bone mineral density (-1.2 versus -2.3, p=0.09).

The implant survival rate reported of 78% at 3 years is lower than that observed in previous studies. Survival rates of 83%[64] to 100%[155] have been reported, with the largest series in the literature finding an 88% survival.[63] The reason for the lower reported survival rate may relate to the case-mix variables of the study cohort, as only included patients aged 65 years or more and therefore the mean age of reported cohort (82 years) is the oldest reported in the literature.[63] Increasing age has been associated with non-union of femoral neck fractures[63, 156, 157], and hence the lower survival observed may be due to the older age of the study cohort. Age was, however, not demonstrated to be a predictor of implant survival in the elderly cohort, with only ASA grade and posterior tilt being significant predictors. Interestingly a lower ASA grade was associated with a greater rate of fixation failure, this may be the opposite to what is expected, as with increasing morbidity there is a greater rate of non-union for displaced intracapsular hip fractures.[158] It would seem from the study cohort that an increasing level of comorbidity, for minimally displaced intra-capsular fractures in the elderly, is not related to fixation failure. The reason for this discrepancy is not clear, but may relate to the functional demand of the patient, as patients with a lower ASA grade have an earlier return to full weight bearing and independent living.[159] This is supported by the fact that patients with a shorter length of hospital stay, being a marker of independence, was associated with an increased risk of failure of fixation. This early mobilisation may increase the stress upon the fixation and result in failure of the fixation. Hence, it may be prudent to advise such patients to touch weight bear in the first six weeks as would be advised for patients who has the same fixation for a displaced intracapsular hip fracture, but this may not be possible in the elderly cohort.[158]

Posterior tilt (anterior angulation) on the lateral radiograph of the hip was an independent predictor of fixation failure, which has previously identified to be a risk factor by Conn and Parker[63] for minimally displaced intra-capsular hip fractures. The presence of posterior tilt probably relates to comminution of the posterior aspect of the femoral neck. This is associated with an inferior biomechanical construction when using cannulated screws.[160] These patients, with posterior tilt, may benefit from the biomechanical advantage of either four screws or a fixed angle device, such as a sliding hip screw, which could potentially improve their survival rate.[161] Evidence from the Norwegian hip fracture registry demonstrated that patients with a displaced intracapsular hip fractures experienced a greater patient satisfaction, pain relief and functional result when compared to patients who had sustained minimally displaced intra-capsular hip fractures managed with internal fixation.[62] Gjertsen et al[62] hypothesize this difference in outcome may relate to the higher re-operation rate associated with internal fixation (10%) when compared to hemiarthroplasty (3%). This would suggest patients with a high risk of failure of internal fixation, lower ASA grade and posterior tilt on the

lateral radiograph, may be a specific subgroup that would benefit from a hemiarthroplasty. A recent randomised controlled trial (RCT) by Dolatowski et al[162] found no functional advantage of arthroplasty over fixation of nondisplaced intracapsular hip fractures in the elderly but there was a lower rate of re-operation in the arthroplasty group.

The one year unadjusted mortality rate demonstrated of 19% is similar to previous reports[63], which is approximately 10% less than other hip fracture patterns.[66] The patients age and gender have previously been shown to be independent predictors of mortality for hip fracture patients[58, 68], this was not the case for the study cohort. This may be related to the specific subgroup analysed, including only elderly patients with minimally displaced intra-capsular fractures, which are different relative to other hip fracture patterns. The ASA grade was designed to predict peri-operative mortality, which has been shown to be an independent predictor of early mortality for hip fracture patients previously.[58] The study confirmed the predictive effect of the ASA grade into the long-term. Patients with a lower ASA grade, predicting longevity, but with risk factors for failure of internal fixation may benefit from a primary total hip replacement if rational as discussed above in applied.[65]

The author is unaware of any previously published study identifying younger age to be associated with a greater SMR, as this study has illustrated, after a hip fracture. Most studies analysing survival identify increasing age as a predictor of mortality.[58, 66, 68] These studies, however, did not use aged and gender standardise methodology. Patients sustaining an undisplaced intracapsular hip fracture aged 65 to 79 years, with the greatest SMR, may benefit from early ortho-geriatric review and medical optimisation which may improve their survival.[163]

Socially deprived patients sustained their hip fracture at a younger age when compared to more affluent patients, which has been established previously by Quah et al[70]. However, the current study did not find deprivation to influence the incidence, level of comorbidity, or mortality which where demonstrated to differ by Quah et al[70]. In contrast the current study had a 7 year age difference between the most and least deprived, which was greater than that demonstrated by Quah et al[70] (1 year). There was no significant difference in mortality, both unadjusted and SMR, but deprived patients sustained a morbid fracture some 7 years earlier than the least deprived. The reason for this disparity is not clear, but further work should be undertaken to investigate this social discrepancy and aim to improve the outcome the most deprived within society.

5.5. Conclusion

The management of elderly patients with a minimally displaced fractured neck of femur has a high risk of fixation failure, and future RCT are required to compare the outcome of alternative methods of internal fixation and/or arthroplasty for these patients.

CHAPTER 6:

PREDICTING THE OUTCOME OF PROXIMAL HUMERAL FRACTURES IN THE ELDERLY

CHAPTER 6: PREDICTING THE OUTCOME OF PROXIMAL HUMERAL FRACTURES IN THE ELDERLY

6.1 Aims

The primary aim of this study was to describe the epidemiology and predictors of outcome, for mortality and shoulder function at one year, for elderly and super-elderly patients after a proximal humeral fracture. The secondary aim was to identify independent predictors of a poor functional outcome after a proximal humeral in elderly patients.

6.2 Chapter Summary

This study describes the epidemiology and outcome of proximal humeral fractures in the elderly (≥65 years old). The majority of proximal humeral fractures in the elderly were either minimally displaced (44%) or two part fractures (39%) that predominantly occur in females (82%) after a simple fall (95%), who lived independently in their own home (89%), and one in ten sustain a concomitant fracture. The one-year mortality rate was 10%, with the only independent predictor of survival being whether the patient lived in their own home (p=0.025). Multiple factors associated to the patients' social independence significantly influenced the relative Constant score (age and gender adjusted) one year after their fracture. More than a quarter of elderly patients sustaining proximal humeral fractures had a poor functional outcome, with those patients not living in their own home (p=0.04), participating in recreational activities (p=0.01), able to perform their own shopping (p<0.001), or ability to dress themselves (p=0.02) being at an increased risk of a poor outcome which was independent of fracture severity (p=0.001). A poor functional outcome after a proximal humeral fracture is not independently influence by age in the elderly and factors associated with social independence are more predictive of outcome.

6.3 Results

The mean age of the study cohort was 76.9 (SD 7.0, range 65 to 98) years. There were 112 male patients with a mean age of 75.6 (SD 7.0, range 65 to 95) years and 525 female patients with a mean age of 77.2 (SD 7.0, range 65 to 98) years. There were 394 elderly patients and 243 super-elderly patients. The incidence of proximal humeral fractures was $136/10^5$/year in the elderly group and $260/10^5$/year in the super-elderly cohort (OR 1.91, 95% CI 1.56 to 2.36, chi square p<0.001).

The commonest mode of injury was a simple fall from standing height (n=604, 94.8%), with the remainder being due to falls from height (n=15, 2.4%), sport (n=2, 0.3%), RTA (n=10, 1.6%), and direct blows or assaults (n=6, 0.9%). There was no significant difference in the

mechanism of injury according to age group (p=0.11, chi square).

Super-elderly patients were less likely to live in their own home, participate in recreational activities, perform their own shopping, dress themselves independently, to be able to do their own house work, and were more likely to live alone, need home help, and sustain multiple fractures compared to elderly patients (Table 6.1). There was a significantly greater rate of displaced fractures in the super-elderly group (OR 1.51, 95% CI 1.09 to 2.09, chi square p=0.017). Despite this increased rate of displaced fractures with age there was no significant difference in the rate of non-operative management.

Nine patients went on to non-union of their proximal humeral fracture (Table 6.2). Hence, the non-union rate for all fractures was 1.4% (n=9/637) but increased to 2.2% (n=8/359) when analysing displaced fractures only. The rate of non-union was not significantly different according to age, either all fractures (p=0.73) or for displaced fractures (p=0.72).

Sixty-one patients died within one year of their fracture, with a one-year survival rate of 90.4% (95% CI 88.5 to 92.2) (Figure 6.1). The standardised mortality ratio was 2.41 (95% CI 1.99 to 3.78, p<0.001). Univariate analysis identified several risk factors associated with one-year mortality (Table 6.3). Upon entering the case-mix variables into the Cox regression model the only significant predictor of mortality, after adjusting for confounding variables, was whether a patient lived in their own home, with those patients not living in their own home having a greater risk of one year mortality (OR 3.64, 95% CI 1.18 to 11.22, p=0.025).

The mean one-year Constant score for the cohort was 64.2(SD 16.4). Univariate analysis identified several factors that significantly influenced the Constant score at one year (Table 6.4). Multivariable regression analysis confirmed that eight of the 14 factors assessed were independent predictors of the Constant score at one year (Table 6.5).

There were 128 (26.5%) patients that had a poor outcome according to the Constant score (a score of 55 points or less) at one year. Multivariable logistic regression analysis identified five independent predictors of a poor outcome after adjusting for confounding variables (Table 6.6).

Table 6.1 The case-mix variables for the study cohort, and according to age group.

Case-mix variables		All patients n=637	Elderly n=394	Super-elderly n=243	OR (95% CI)	p-value*
Gender (n,%)	Male	112 (17.6)	74 (18.8)	38 (15.6)	1.25	0.31
	Female	525 (82.4)	320 (81.2)	205 (84.4)	(0.81 to 1.92)	
Deprivation (n,%)	1 (least)	149 (23.4)	85 (21.6)	64 (26.3)	-	0.06
	2	134 (21.0)	74 (18.8)	60 (24.6)		
	3	104 (16.3)	66 (16.8)	38 (15.6)		
	4	192 (30.1)	126 (32.0)	66 (27.2)		
	5 (most)	52 (8.2)	39 (9.9)	13 (5.3)		
	Unknown	6 (0.9)	4 (1.0)	2 (0.8)		
Live in own home (n,%)	Yes	560 (87.9)	368 (93.4)	192 (79.0)	4.18	**<0.001**
	No	70 (11.0)	22 (5.6)	48 (19.8)	(2.45 to 7.13)	
	Unknown	7 (1.1)	4 (1.0)	3 (1.2)		
Live alone (n,%)	Yes	297 (46.6)	164 (41.6)	133 (54.7)	1.71	**0.002**
	No	329 (51.7)	223 (56.6)	106 (43.6)	(1.23 to 2.36)	
	Unknown	11 (1.7)	7 (1.8)	4 (1.6)		
Employed (n,%)	Yes	24 (3.8)	18 (4.6)	6 (2.5)	1.88	0.26
	No	558 (87.6)	343 (87.1)	215 (88.5)	(0.74 to 4.81)	
	Unknown	55 (8.6)	33 (8.4)	22 (9.1)		
Recreation (n,%)	Yes	323 (50.7)	235 (59.6)	88 (36.2)	2.68	**<0.001**
	No	293 (46.0)	146 (37.1)	147 (60.5)	(1.92 to 3.76)	
	Unknown	21 (3.3)	13 (3.3)	8 (3.3)		
Shopping (n,%)	Yes	466 (73.2)	332 (84.3)	134 (55.1)	4.76	**<0.001**
	No	146 (22.9)	50 (12.7)	96 (39.5)	(3.20 to 7.07)	
	Unknown	25 (3.9)	12 (3.0)	13 (5.3)		
Dressing (n,%)	Yes	576 (90.4)	366 (92.9)	210 (86.4)	2.44	**0.01**
	No	36 (5.7)	15 (3.8)	21 (8.6)	(1.23 to 4.85)	
	Unknown	25 (3.9)	13 (3.3)	12 (4.9)		
Housework (n,%)	Yes	467 (73.3)	333 (84.5)	134 (55.1)	4.87	**<0.001**
	No	142 (22.3)	48 (12.2)	94 (38.7)	(3.25 to 7.27)	
	Unknown	28 (4.5)	13 (3.3)	15 (6.2)		
Home help (n,%)	Yes	138 (21.7)	55 (14.0)	83 (34.2)	3.34	**<0.001**
	No	469 (73.6)	323 (82.0)	146 (60.1)	(2.25 to 4.95)	
	Unknown	30 (4.7)	16 (4.1)	14 (5.8)		
Multiple fractures (n,%)	Yes	76 (11.9)	39 (9.9)	37 (15.2)	1.63	**0.04**
	No	561 (88.1)	355 (90.1)	206 (84.8)	(1.01 to 2.65	
Parts (n,%)	0	278 (43.6)	187 (47.5)	91 (37.4)	-	0.07
	2	250 (39.2)	140 (35.5)	110 (45.3)		
	3	78 (12.2)	48 (12.2)	30 (12.3)		
	4	31 (4.9)	19 (4.8)	12 (4.9)		
Non-operative (n,%)	Yes	587 (92.2)	358 (90.9)	229 (94.2)	1.64	0.12
	No	50 (7.8)	36 (9.1)	14 (5.8)	(0.87 to 3.12)	

*chi square test

Table 6.2 Demographics of the elderly patients that had non-union of their proximal humeral fracture.

Gender	Age	Neer Subgroup
Female	68	Minimally displace
Female	69	3-part
Female	75	2-part surgical neck
Female	75	2-part surgical neck
Female	75	2-part surgical neck
Male	81	4-part
Female	83	2-part surgical neck
Female	83	2-part surgical neck
Female	86	3-part

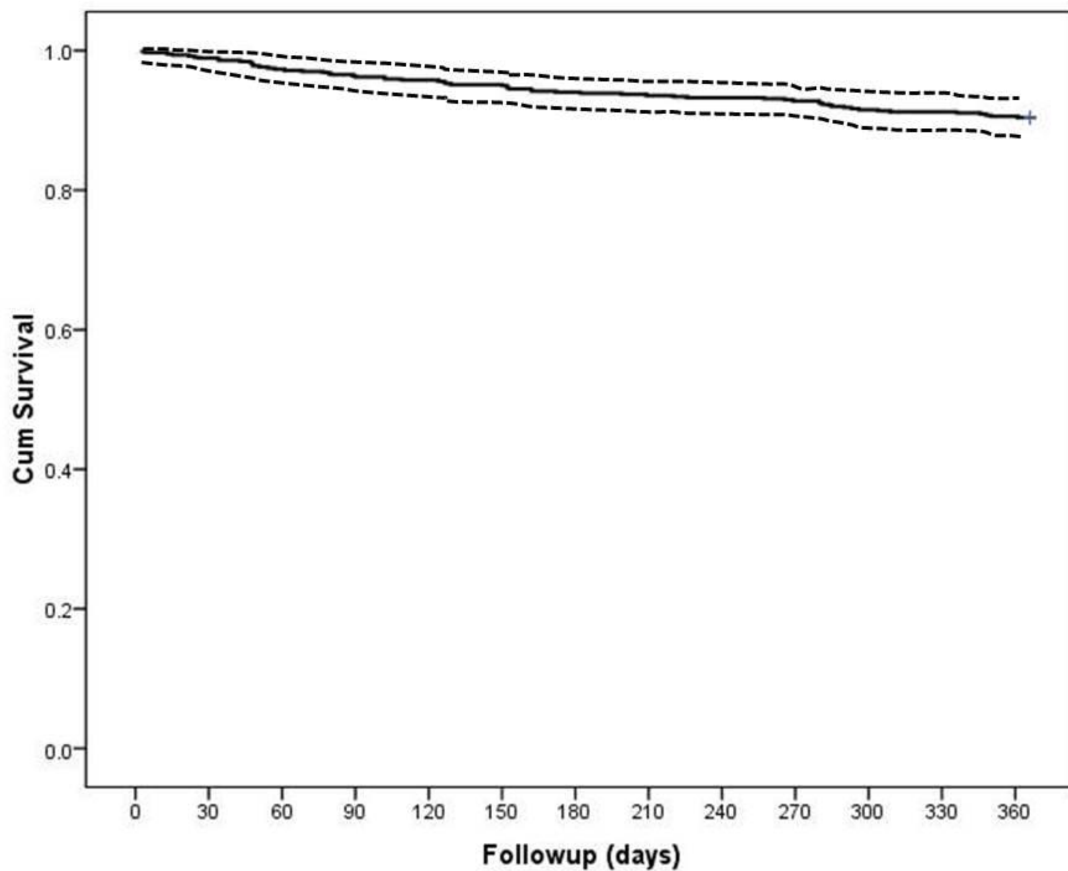

Figure 6.1 Kaplan Meier survivorship curve with 95% CI (dashed lines) for the study cohort illustrating mortality one year after sustaining a proximal humeral fracture.

Table 6.3. The case-mix variables for the study cohort according to their one-year mortality.

Case-mix variables		Alive n=576	Deceased n=61	OR (95% CI)	p-value*
Gender	Male	99 (17.2)	13 (21.3)	0.77	0.65
(n,%)	Female	477 (82.8)	48 (78.7)	(0.40 to 1.47)	
Super-elderly	Yes	201 (34.9)	42 (68.9)	4.12	**<0.001**
(n,%)	No	375 (65.1)	19 (31.1)	(2.34 to 7.28)	
Deprivation	1 (least)	132 (22.9)	17 (27.9)	-	0.41
(n,%)	2	118 (20.5)	16 (26.2)		
	3	96 (16.7)	8 (13.1)		
	4	175 (30.4)	17 (27.9)		
	5 (most)	50 (8.7)	2 (3.3)		
	Unknown	5 (0.9)	1 (1.6)		
Live in own home	Yes	521 (90.5)	39 (63.9)	4.98	**<0.001**
(n,%)	No	51 (8.9)	19 (31.1)	(2.68 to 9.24)	
	Unknown	4 (0.7)	3 (4.9)		
Live alone	Yes	266 (46.2)	31 (50.8)	1.42	0.26
(n,%)	No	304 (52.8)	25 (41.0)	(0.82 to 2.46)	
	Unknown	6 (1.0)	5 (8.2)		
Employed	Yes	24 (4.2)	0	1.10	0.12
(n,%)	No	507 (88.0)	51 (83.6)	(1.07 to 1.13)	
	Unknown	45 (7.8)	10 (16.4)		
Recreation	Yes	313 (54.3)	10 (16.4)	5.38	**<0.001**
(n,%)	No	250 (43.4)	43 (70.5)	(2.65 to 10.93)	
	Unknown	45 (7.8)	10 (16.4)		
Shopping	Yes	450 (78.1)	16 (26.2)	8.21	**<0.001**
(n,%)	No	113 (19.6)	33 (54.1)	(4.37 to 15.45)	
	Unknown	13 (2.3)	12 (19.7)		
Dressing	Yes	538 (93.4)	38 (62.3)	7.08	**<0.001**
(n,%)	No	24 (4.2)	12 (19.7)	(3.29 to 15.24)	
	Unknown	14 (2.4)	11 (18.0)		
Housework	Yes	451 (78.3)	16 (26.2)	8.53	**<0.001**
(n,%)	No	109 (18.9)	33 (54.1)	(4.53 to 16.07)	
	Unknown	16 (2.8)	12 (19.7)		
Home help	Yes	115 (20.0)	23 (37.7)	0.32	**<0.001**
(n,%)	No	441 (76.6)	28 (45.9)	(0.18 to 0.57)	
	Unknown	20 (3.5)	10 (16.4)		
Multiple fractures	Yes	65 (11.3)	11 (18.0)	0.58	0.12
(n,%)	No	511 (88.7)	50 (82.0)	(0.29 to 1.17)	
Parts	0	260 (45.1)	18 (29.5)		**0.009**
(n,%)	2	214 (37.2)	36 (59.0)		
	3	74 (12.8)	4 (6.6)		
	4	28 (4.9)	3 (4.9)		
Non-operative	Yes	528 (91.7)	59 (96.7)	0.37	0.16
(n,%)	No	48 (8.3)	2 (3.3)	(0.09 to 1.57)	

*chi square test

Table 6.4. Constant score according to patient case-mix variables.

Case-mix variables		n	Constant Score (Mean, SD)	Difference (95% CI)	p-value*
Gender	Male	69	67.4 (18.4)	3.6 (-0.5 to 7.9)	0.09
	Female	414	63.7 (16.0)		
Super-elderly	Yes	156	59.2 (16.5)	7.4 (4.3 to 10.5)	**<0.001**
	No	327	66.6 (15.8)		
Deprivation	1 (least)	112	64.2 (17.5)	-	0.80**
(n,%)	2	98	63.2 (16.5)		
	3	87	64.6 (16.3)		
	4	140	65.4 (16.2)		
	5 (most)	41	62.3 (16.4)		
Live in own home	Yes	442	65.6 (15.7)	18.0 (10.1 to 21.0)	**<0.001**
(n,%)	No	41	49.6 (16.5)		
Live alone	Yes	226	63.8 (16.1)	0.81 (-2.1 to 3.8)	0.59
(n,%)	No	256	64.7 (16.7)		
Employed	Yes	19	70.8 (12.0)	6.7 (-0.8 to 14.1)	0.08
(n,%)	No	427	64.2 (16.3)		
Recreation	Yes	290	67.9 (14.6)	9.3 (6.4 to 12.1)	**<0.001**
(n,%)	No	191	58.7 (17.2)		
Shopping	Yes	397	66.6 (15.5)	13.4 (9.7 to 17.1)	**<0.001**
(n,%)	No	83	53.2 (16.0)		
Dressing	Yes	461	65.2 (15.8)	23.2 (15.8 to 30.8)	**<0.001**
(n,%)	No	18	41.9 (15.8)		
Housework	Yes	399	66.5 (15.7)	13.2 (9.4 to 16.9)	**<0.001**
(n,%)	No	80	53.3 (15.6)		
Home help	Yes	86	57.5 (15.8)	8.4 (4.7 to 12.2)	**<0.001**
(n,%)	No	388	65.9 (16.0)		
Multiple fractures	Yes	51	58.1 (19.4)	6.9 (2.2 to 11.6)	**<0.001**
(n,%)	No	432	65.0 (15.8)		
Parts	0	211	68.8 (14.2)	-	**<0.001****
(n,%)	2	183	61.6 (17.0)		
	3	67	61.1 (17.0)		
	4	22	52.6 (17.2)		
Non-operative	Yes	448	65.2 (15.7)	12.6 (71 to 18.2)	**<0.001**
(n,%)	No	35	52.5 (19.9)		

* t-test unless otherwise stated, **ANOVA

Table 6.5. Predictors of the Constant score at one year after sustaining a proximal humeral fracture on linear multivariable regression analysis using "enter" methodology.

Predictors in the model (R^2=0.31)		**B**	**95% Confidence Intervals**		**p-value**
			Lower	Upper	
Gender	Male	Reference			
	Female	-8.67	-1.17	-4.92	**0.01**
Age group	Elderly	Reference			
	Super-elderly	-6.58	-0.40	-3.49	**0.03**
Deprivation	Quintile 1	Reference			
	Each quintile	-1.31	0.71	-0.30	0.56
Live in own home	Yes	Reference			
	No	-17.98	-5.72	-11.85	**<0.0001**
Live alone	Yes	Reference			
	No	-3.26	2.40	-0.43	0.77
Employed	Yes	Reference			
	No	-12.23	0.75	-5.74	0.08
Recreation	Yes	Reference			
	No	-7.99	-2.32	-5.15	**<0.0001**
Shopping	Yes	Reference			
	No	-8.66	2.85	-2.90	0.32
Dressing	Yes	Reference			
	No	-25.31	-7.63	-16.47	**<0.0001**
Housework	Yes	Reference			
	No	-5.36	6.66	0.65	0.83
Home help	Yes	Reference			
	No	0.80	8.96	4.88	**0.02**
Multiple fractures	Yes	Reference			
	No	-0.69	8.28	3.79	0.09
Parts	Minimal	Reference			
	Each part	-3.44	-1.31	-2.37	**<0.0001**
Non-operative	Yes	Reference			
	No	-14.23	-3.80	-9.01	**0.001**

Table 6.6. Independent case-mix variables associated with a poor outcome one year after sustaining a proximal humeral fracture using multivariable logistic regression analysis and "forward Wald" methodology.

Predictors in the model (R^2=0.19)		**OR**	**95% Confidence Intervals**		**p-value**
			Lower	Upper	
Live in own home	Yes	Reference			0.04
	No	2.62	1.04	6.57	
Recreation	Yes	Reference			0.01
	No	1.85	1.15	2.98	
Shopping	Yes	Reference			0.02
	No	2.22	1.1	4.29	
Dressing	Yes	Reference			0.02
	No	6.93	1.33	36.10	
Parts	Minimal	Reference			0.001
	Each part	1.37	1.14	1.65	
(Constant)		0.002	-	-	<0.0001

6.4 Discussion

This study has demonstrated that the majority of proximal humeral fractures in the elderly are either minimally displaced or two-part fractures that predominantly occur in females after a simple fall who live independently in their own home and one in ten sustain a concomitant fracture. The incidence of proximal humeral fractures was significantly greater for super-elderly patients, who were less likely to live independently in their own home and more likely to sustain a displaced fracture and a concomitant facture. The one-year mortality rate was 10%, with the only independent predictor of survival being whether the patient lived in their own home. Multiple factors that related to the patient's social independence influenced the relative Constant score, which was independent of fracture severity and management. More than a quarter of elderly patients sustaining proximal humeral fractures have a poor functional outcome.

More than 60% of all proximal humeral fractures occur in the elderly[86], despite this there is a paucity of studies reporting the epidemiology and outcome of these fractures in the elderly.[57] The reported study demonstrated that proximal humeral fractures in the elderly occur at a greater rate in female patients compared to prior epidemiological studies.[26, 71] An original aspect of this study was the description of the multiple factors relating to each patients level of social independence, which revealed that 88% of elderly patients live independently in their own home, which is similar to all adults sustaining a proximal humeral fracture.[164] However,

the super-elderly patients were significantly less likely to live in their own home and were less independent, which is probably reflective of the increasing frailty with aging.[56, 57] The rate of associated fractures (12%) is similar to that described in the literature previously[57], but it is interesting to note that this rate is significantly greater in the super-elderly in whom the overall incidence of proximal humeral is increasing.[165] In addition the fracture severity was also demonstrated to increase with age, with a greater rate of displaced fractures (56%) compared to the described in the general adult population[164], and more specifically in super-elderly patients compared to elderly patients. This probably relates to decreasing bone density with increasing age, which has been shown to correlate with increasing severity of distal radial fractures.[166]

The 10% one year mortality rate and 2.4 SMR reported in this study is consistent with prior studies reporting mortality in elderly patients.[7,167] Shortt and Robinson[167] identified that older age, male gender, and use of walking aids predicted mortality after proximal humeral fractures. Gender and age (elderly versus super-elderly) were not identified as independent predictors of one-year mortality in the reported elderly cohort. This may be due to the age of the reported cohorts, with Shortt and Robinson[167] analysing patients aged 40 years and older compared the older elderly group reported in the current study. However, both studies identified factors associated with social independence to be predictive of patient mortality, Shortt and Robinson[167] identifying the use of walking aids and this study finding patients no longer living in their own home to have an increased mortality risk. Hence, it would seem reasonable if operative intervention was to be considered that the independence of the elderly patient, according to domicile and morbidity, should be considered to ensure those patients with greatest likelihood to survive enjoy the benefits of their intervention.

A recent systematic review of the outcome of proximal humeral fractures concluded that non-operative management is supported for minimally displaced and two part fractures.[80] However, the studies included in this review only demonstrated a “fair” outcome overall and no predictors of outcome were identified. In the current study of elderly fractures using the Constant score, adjusting for age, gender, fracture severity, and management, factors associated with social independence where demonstrated to influence outcome. Furthermore, it is interesting that these factors were the only predictors of a poor outcome, which was not influenced by age. These influencing social factors should be described in future studies reporting the outcome of proximal humeral fractures, in conjunction with an age and gender matched outcome measure, to enable a fair comparison and conclusion to be made.

The choice as to whether operative management of a proximal humeral fracture is undertaken is influenced by multiple factors, with few absolute indications.[78] Some authors[78] have suggested that age is a relative contra-indication to surgery, but it would seem from the

reported study of elderly patients that markers of social independence are of greater significance in regard to outcome. A recent review of operative fixation of proximal humeral fractures demonstrated marked heterogeneity between studies; with the mean age ranging from 42 to 78 years old.[168] Overall the mean age of the patients undergoing fixation were younger than the average age of patients sustaining proximal humeral fractures, which may suggest that there is an inclusion bias reserving such an intervention for younger patients. There have been two RCT comparing the outcome of the fixation of three part fractures[169] and hemiarthroplasty for four part proximal humeral fractures[169] with non-operative management in elderly patients (≥55 years). No statistical difference in any of the outcome measures assessed were demonstrated between fixation with non-operative management for three part fractures, and in addition there was a 33% re-operation rate.[169] In contrast patients receiving a hemiarthroplasty for their four part proximal humeral fracture had a significantly greater generic health score (Euro Qol™) at 2 years compared to non-operative management. This may however represent a type I error as there was no difference in the joint specific Constant score or the Disabilities of Arm Shoulder and Hand (DASH) score, there was a 11% re-operation rate.[169] The failure to demonstrate a difference in the Constant score between operative and non-operative interventions in these studies may have been influenced by the case-mix variables of the cohorts, although both RCT only included patients from “independent living conditions”. However, most patients with proximal humeral fractures live in their own home, as demonstrated by this study, and factors that have greater affect upon a patient’s outcome such as the ability perform recreational activities and to shop independently may have influenced their findings. These factors should be considered when enrolling patients into clinical trials and contemplating operative intervention.

The retrospective nature of this study is a limitation, and although no patient was lost to follow from survival analysis 93 (15%) patients did not have functional assessment available at one year. However, the prospectively compiled database used for this study was relatively complete, with few data points missing (Table 6.1). In addition, although 15% of patients had no functional assessment performed the presented series of elderly patients represents the largest reported cohort of non-operatively managed patients. It could also be argued that the length of follow-up at one year largest is relatively short, but previous authors have demonstrated no further improvement after this time point for elderly patients.[169]

6.5 Conclusion

This study has demonstrated age does not result in a poor outcome, either mortality or function, of proximal humeral fractures in the elderly. Factors associated with social independence, such as living in their own home, pursuing recreational activities, and being able to shop for themselves, were more influential upon outcome. These factors should be taken into account when considering which patients may benefit from orthopaedic interventions, and future RCT should include these in their recruitment criteria, to ensure they do not influence the outcome and conclusion of their study.

CHAPTER 7:

PREDICTING THE OUTCOME OF DISTAL RADIAL FRACTURES IN THE SUPER-ELDERLY

CHAPTER 7: PREDICTING THE OUTCOME OF DISTAL RADIAL FRACTURES IN THE SUPER-ELDERLY

7.1 Aims

The original question was to assess whether it was possible to identify those patients at risk of malunion of their distal radial fracture, however this evolved into whether a malunion in a super-elderly patient influences functional outcome. To address these two questions two separate studies were carried out using the same patient cohort.

7.1.1 Predictors of malunion

The primary aim of this study was to identify predictors of malunion and degree of improvement in the fracture position offered by closed manipulation of displaced distal radial fractures in the super-elderly. The secondary aim was to describe the epidemiology of super-elderly patients with displaced distal radial fractures.

7.1.2 Does distal radial malunion influence functional outcome?

The primary aim of this study was to compare the functional outcome, both subjective and objective, of super-elderly patients with and without malunion after a distal radial fracture. The secondary aim was to assess whether the final radiographic assessment of the distal radius correlated to ROM and or function.

7.2 Chapter Summary

Two hundred and twenty-eight displaced distal radial fractures in super-elderly patients were retrospectively identified from a prospective database of 4024 distal radial fractures. The inclusion criterion was a patient that underwent closed manipulation as their primary intervention. The majority of patients (n=196, 86%) were defined as having a malunion. A pre-manipulation dorsal angulation of greater 25 degrees (p=0.047) and an ulnar variance of 6mm or more (p=0.02) significantly increased the risk of malunion. The pre-manipulation dorsal angulation was a significant independent predictor of the degree of improvement in the final dorsal angulation (p<0.001) and ulnar variance (p=0.01). Fifty-one super-elderly patients living independently with displaced fractures had additional functional data recorded. No significant difference was observed in activities of daily living (p=0.28), wrist pain (p=0.14), whether the wrist had returned to its normal level function (p=0.25), grip strength (p=0.31), or ROM (p=0.41) between the malunion group (n=17) and the non-malunion group (n=34). An increasing degree of dorsal angulation correlated with diminished ROM (r=0.3, p=0.038), compared to the contra-lateral wrist, but did not correlate with activities of daily living (r=0.25,

p=0.10). Patients with a high risk of malunion or poor improvement in the fracture position can be identified pre-manipulation and these patients may benefit from primary surgical intervention. However, malunion of the distal radius does not seem to influence the functional outcome of independent super-elderly patients. This questions whether surgical intervention in this low demand population should be undertaken.

7.3 Results

7.3.1 Predictors of malunion

The majority of patients were female and were independent (Table 7.1). The mean age of males was 83.2 (range 80 to 88) years and females was 83.7 (range 80 to 98) years (p=0.58). Thirty-seven (16%) of patients sustained an associated fracture during the same injury, of which the commonest mode was a simple fall from standing height (Table 7.1). Dorsal comminution was observed in most patients, and only one patient sustained a partial articular fracture (Table 7.1). The mean pre-manipulation dorsal angulation was 25.2 degrees (10 to 56 degrees, SD 14.9) and radial shortening was 2.9mm (-4 to 16 degrees, SD 3.1).

Table 7.1. Case-mix variables for the study cohort.

Case-mix variables		**n= (%)**
Gender	Male	15 (6.6)
	Female	213 (93.4)
Dominant limb	Yes	93 (40.8)
	No	135 (59.2)
Independent	Yes	126 (55.3)
	No	102 (44.7)
Injury mechanism	Simple fall	224 (98.2)
	Fall from height	1 (0.4)
	RTA	2 (0.9)
	Assault	1 (0.9)
Associated fracture	Yes	37 (16.2)
	No	191 (83.8)
AO Classification	A	123 (53.9)
	B	1 (0.4)
	C	104 (45.6)
Dorsal comminution	Yes	212 (93.0)
	No	16 (7.0)

An adequate reduction of the distal radial fracture was achieved in 87 patients (38%). Overall there was a significant improvement in the position of the fracture, in both the degree of dorsal angulation and ulnar variance (Table 7.2). The position of the fracture 6 weeks post injury had deteriorated, resulting in 196 (86%) patients being defined has having a malunion (Table 7.2).

Table 7.2. Dorsal angulation and ulnar variance pre- and post-manipulation, and the statistical significance of improvement relative pre-manipulation measurement.

Time Point		**Dorsal Angulation in degrees (SD)**	**p-value***	**Ulnar variance in mm (SD)**	**p-value***
Pre-manipulation		25.2 (10.1)	-	2.9 (3.1)	-
One week	Absolute	1.2 (9.4)	<0.001	0.9 (2.6)	<0.001
	Improvement	24.0		2.0	
6 weeks	Absolute	11.9 (14.5)	<0.001	4.3 (3.0)	<0.001
	Improvement	13.3		-1.4	

* paired t-test

There was a significant correlation between pre-manipulation dorsal angulation (r=0.24, Pearson correlation p<0.001) and ulnar variance (r=0.54, Pearson correlation p<0.001) with that measured at 6 weeks post injury (Figures 7.1 and 7.2). Using these correlations on average a mean dorsal angulation of greater 25 degrees, or an ulnar variance of 6mm or more would result in a malunion at 6 weeks (Figures 7.1 and 7.2). Using these values as predictors, a dorsal angulation of greater 25 degrees (odds ratio (OR) 2.3, chi square p=0.047) and an ulnar variance of 6mm or more (OR 1.2, chi square p=0.02) both significantly increased the risk of malunion. These two risk factors were additive (OR 2.7, chi square p=0.014), and combining these two predictors alone would result in a test that is 52% sensitive and 72% specific for predicting malunion. This test was a significant independent predictor of malunion when adjusting for other confounding variables (R^2=0.05, OR 2.72, bivariate regression analysis p=0.017). No other variables were significant and were not included within the model.

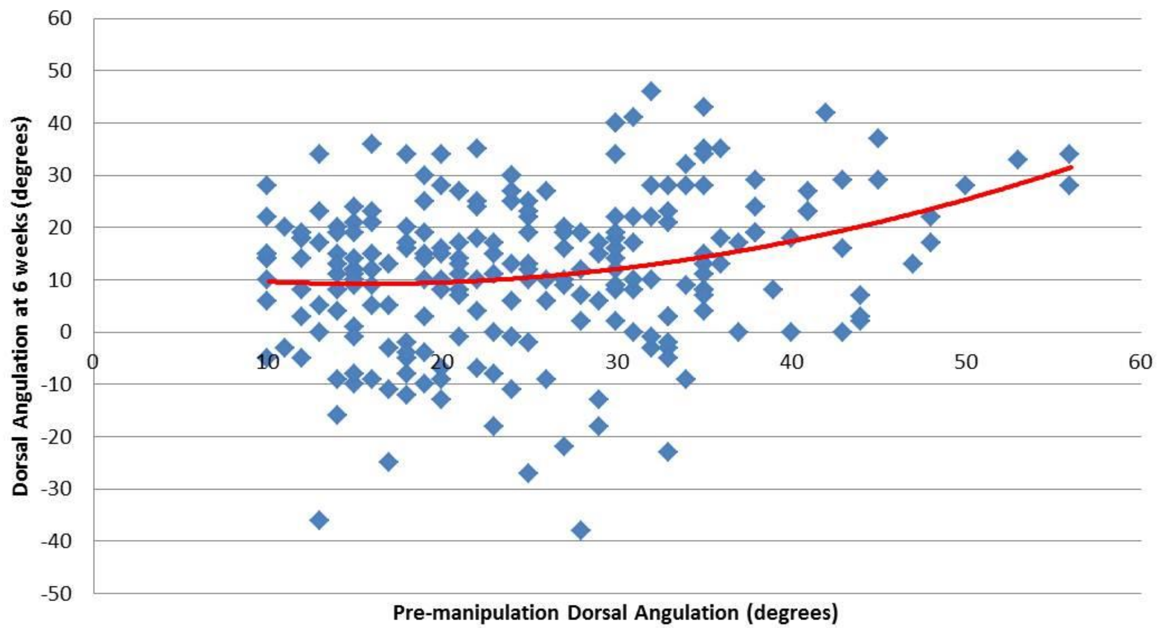

Figure 7.1. Correlation between pre-manipulation dorsal angulation and dorsal angulation at 6 weeks.

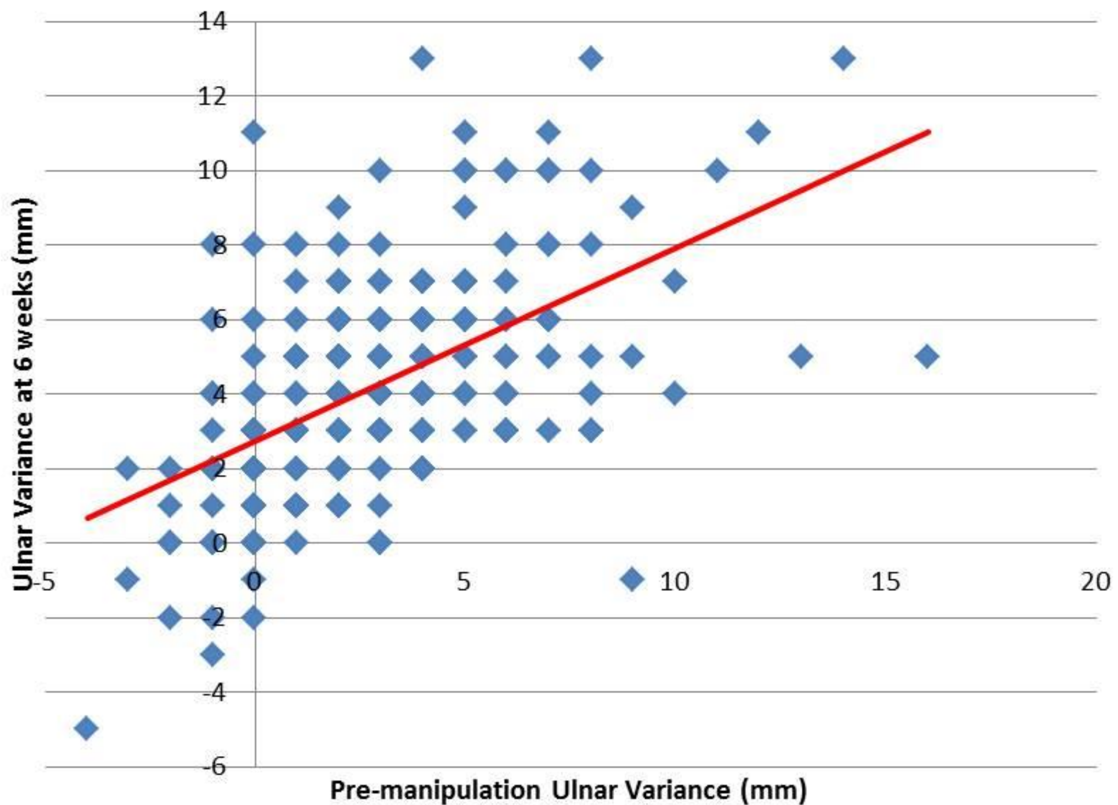

Figure 7.2. Correlation between pre-manipulation ulnar variance and ulnar variance at 6 weeks.

Dorsal comminution, the pre-manipulation dorsal angulation, and ulnar variance were significant predictors of the degree of improvement in the 6-week dorsal angulation and ulnar variance (Tables 7.3 and 7.4). Pre-manipulation dorsal angulation was the only significant isolated predictor, after adjusting for other confounding variables, of improvement in the degree of dorsal angulation at 6 weeks (Table 7.5). Pre-manipulation dorsal angulation and ulnar variance, and dorsal comminution were all significant isolated predictors, after adjusting for other confounding variables, of improvement in the ulnar variance at 6 weeks (Table 7.5).

Table 7.3. Predictors of improvement in dorsal angulation at 6 weeks.

Case-mix variables		**Improvement in Dorsal Angulation (degrees)**	**r=**	**p-value**
Gender	Male	13.7	-	0.92*
	Female	13.3	-	
Age		-	0.05	0.46†
Independent	Yes	14.2	-	0.35*
	No	12.3	-	
Dorsal comminution	Yes	13.4	-	0.7*
	No	11.9	-	
AO Classification	A	14.0	-	0.15**
	B	16.0	-	
	C	12.8	-	
Pre-manipulation	Dorsal angulation	-	0.43	<0.001†
	Ulnar variance	-	0.15	0.021†

* unpaired t-test

** ANOVA

† Pearson correlation

Table 7.4. Predictors of improvement in ulna variance at 6 weeks.

Case-mix variables		**Improvement in Ulnar Variance (mm)**	**r=**	**p-value**
Gender	Male	1.7	-	0.51*
	Female	2.1	-	
Age		-	0.05	0.47†
Independent	Yes	1.9	-	0.24*
	No	2.3	-	
Dorsal comminution	Yes	2.2	-	0.001*
	No	0.1	-	
AO Classification	A	2.0	-	0.7**
	B	4.0	-	
	C	2.2	-	
Pre-manipulation	Dorsal angulation	-	0.34	<0.001†
	Ulnar variance	-	0.70	<0.001†

* unpaired t-test

** ANOVA

† Pearson correlation

Table 7.5. Significant predictors of improvement in dorsal angulation and ulna variance at 6 weeks.

Outcome variable	**Risk factor**	**B**	**95% confidence interval**	**p-value***
		(degrees)		
Improvement in dorsal angulation ($R^2 = 0.20$)	Pre-manipulation dorsal angulation	0.66	0.47 to 0.84	< 0.001
		(mm)		
Improvement in ulnar variance ($R^2 = 0.31$)	Pre-manipulation dorsal angulation	0.03	0.01 to 0.06	0.01
	Pre-manipulation ulnar variance	0.53	0.46 to 0.61	<0.001
	Dorsal comminution	1.43	0.52 to 2.34	0.002

*Linear regression analysis

7.3.2 Does distal radial malunion influence functional outcome?

In the super elderly group, twenty-seven patients (52.9%) sustained a fracture of the right wrist and 24 patients (47.1%) sustained a fracture of the left wrist. The predominant mechanism was a fall from standing height (n=48, 94.1%), and three patients (5.9%) fell downstairs. Forty-three patients (84.3%) were independent, with eight needing help to carry out their shopping. Table 7.6 illustrates the distribution according to the OTA and Frykman classifications. Forty-two patients (82.4%) had dorsal comminution. The normal dorsal angle and ulna variance, of the uninjured side, was -8.3 degrees (SD 9.9 degrees) and +1.2mm (SD 1.7mm) respectively. The mean dorsal angulation was 16.1 degrees (0 to 44 degrees, SD 14.9) and radial shortening was 2.2mm (-3 to 10 degrees, SD 2.6) for the injured side.

Table 7.6. OTA class and Frykmann class distribution for the 51 patients.

AO Classification	Frequency (%)
A2	3 (5.9)
A3	25 (49.0)
B3	4 (7.8)
C2	16 (31.4)
C3	3 (5.9)
Total	51 (100.0)

Frykman Classification	Frequency (%)
1	9 (17.6)
2	3 (5.9)
3	3 (5.9)
4	1 (2.0)
5	9 (17.6)
6	7 (13.7)
7	4 (7.8)
8	12 (23.5)
Unknown	3 (5.9)

Thirty-five patients (68.6%) underwent manipulation within the emergency room setting, prior to application of a dorsal plaster slab. The pre- and post-manipulation radiographic measurements are shown in table 7.7. However, 16 of these 35 (45.7%) lost their satisfactory position and underwent surgery. The final radiographic measurements for the 19 who did not undergo surgery are included in table 7.7, which demonstrated a significant improvement in fracture position. Two (10.5%) of the 19 patients who underwent manipulation only, without a later surgical intervention, went on to malunion.

Of the remaining 16 patients two underwent surgery, without any prior manipulation and 14 patients did not undergo manipulation or any surgical interventions.

Table 7.7. Radiological evaluation of patients undergoing manipulation and surgical intervention.

Intervention	Time Point	Dorsal Angulation (SD)	p-value[†]	Ulna Variance (SD)	p-value[†]
Manipulation n=35	Original	23.0 degrees (11.4)	-	-2.5mm (2.4)	-
	Post-manipulation	0.2 degrees (9.7)	<0.0001	0.9mm (1.7)	<0.0001
	Final*	6.8 degrees (14.5)	<0.0001	3.4mm (2.8)	<0.0001
Surgery n=18**	Original	21.2 degrees (13.1)	-	-2.3mm (2.1)	-
	Post-surgery	6.6 degrees (6.0)	<0.0001	2.8mm (2.6)	<0.0001
	Final	12.9 degrees (11.7)	<0.0001	1.8mm (2.4)	<0.0001

*19 patients only, as 16 of the 35 went onto have surgery, † paired t-test

** This includes the 16 patients that had surgery after manipulation and two that had initial surgical management

Eighteen (31%) patients underwent surgery of which: 7 had open reduction internal fixation, 10 had an external fixator, and one patient had manipulation with insertion of Kirschner wires. The pre- and post-operative, and final radiographic measurements are shown in table 7.7. Four (22.2%) patients suffered minor pin tract infections, which resolved after oral antibiotics. Eight of the 18 (44.4%) had a malunion.

Seventeen (33.3%) patients had a malunion. The outcomes of the independent patients with and without malunion are compared in table 7.8, with a mean follow-up of 15 (6 to 20) months. No statistically significant difference was observed in activities of daily living, wrist pain, whether the wrist had returned to its normal level of function, grip strength or ROM. Figure 7.3 illustrates no significant difference in the total loss in ROM for those patients with and without malunion (p=0.41). Only one (12.5%) of the eight dependent patients suffered a malunion (OR 0.24, p=0.24). If the dependent group was also included in the outcome analysis, the only statistically significant difference was observed for the ability to lift a pan of water (OR 4.9, p=0.03).

The final dorsal angle correlated significantly (r=0.3, p=0.038) with the observed diminished global ROM at the wrist (Figure 7.4). This correlation was not observed with radial shortening in isolation (r=0.1, p=0.46). In addition, there was no correlation between activities of daily living and dorsal angulation (r=0.25, p=0.10) or diminished ROM (r=0.01, p=0.95).

Table 7.8. Comparison of subjective and objective outcome variables for independent patients with and without malunion.

Outcome variable		Malunion		Odds Ratio or 95% CI	p-value
		Yes n=16	No n=27		
Activities of daily living					
Able to:	Plate	80.0%	96.0%	2.3	0.14†
	Glass	100%	100%	-	-
	Pan	66.7%	91.7%	4.6	0.10†
	Key	100%	100%	-	-
	Bolt	100%	100%	-	-
	Write	93.8%	100%	2.8	0.37†
	Scissors	100%	100%	-	-
	Knife	100%	96.2%	1.6	0.62†
	Needle	86.7%	91.3%	1.2	1.0†
	Hammer	93.8%	96.2%	1.4	1.0†
Total ADL Score		19.0	19.3	-0.9 to 0.28	0.28††
Wrist pain		18.8%	3.7%	6.0	0.14†
Normal use		43.8%	59.2%	1.5	0.25†
Grip strength*		-2.0	-4.1	-2.0 to 6.1	0.31††
ROM* (degrees)					
	Pronation	-5.8	-0.6	-15.3 to 14.6	0.15††
	Supination	-5.1	-2.5	-11.6 to 6.4	0.56††
	Flexion	-20.7	-9.5	-21.4 to 0.34	0.85††
	Extension	0.0	-3.1	-6.7 to 13.1	0.52††
	Radial deviation	-2.5	0.0	-9.3 to 4.3	0.47††
	Ulna deviation	-3.3	-7.9	-4.0 to 13.3	0.93††
	Global	36.8	22.5	-15.0 to 43.5	0.41††

*Difference compared with opposite (normal) wrist

† Fishers exact test

†† unpaired t-test

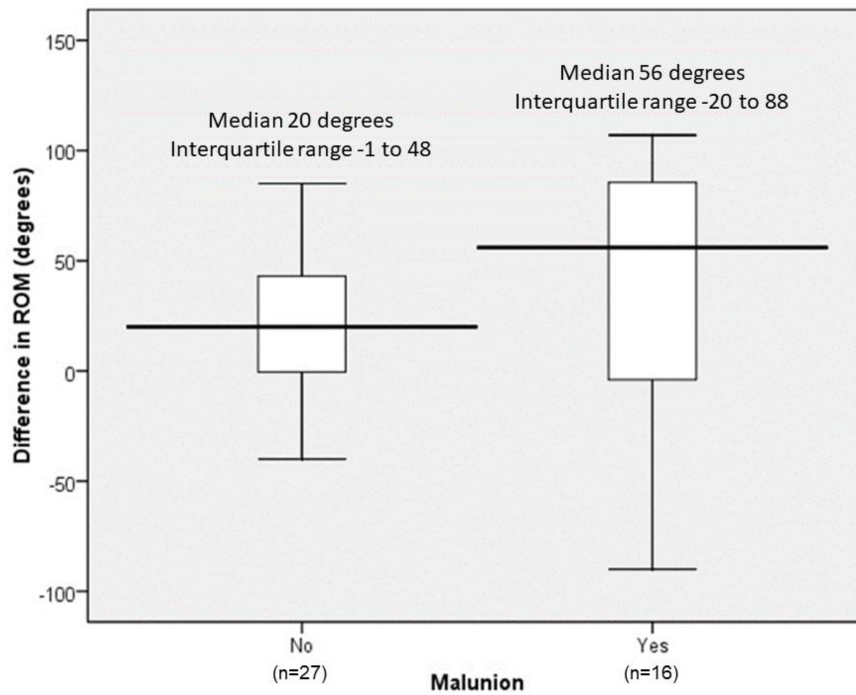

Figure 7.3. A boxplot illustrating the loss in ROM by the interquartile range for patients with and without malunion. The horizontal black line represents the median value.

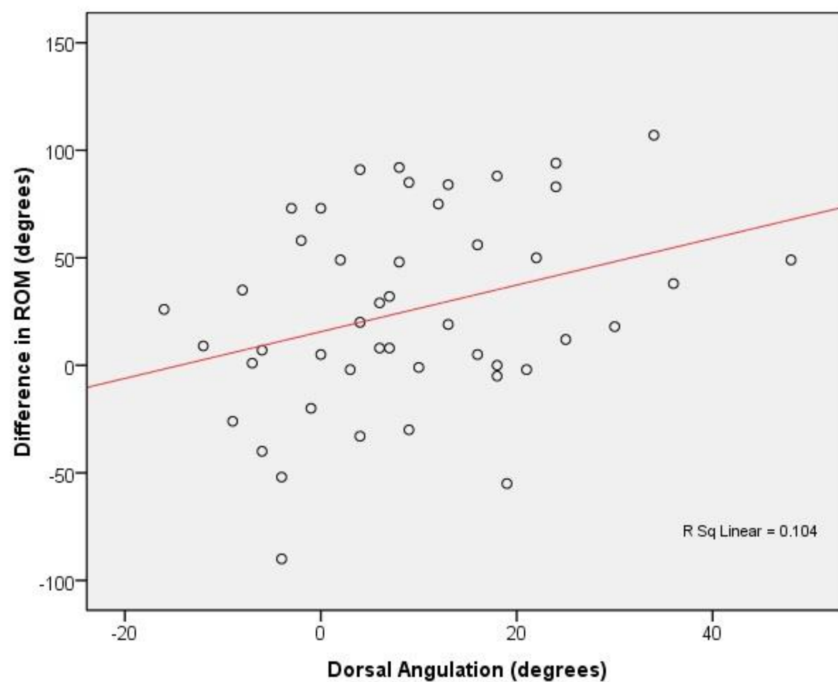

Figure 7.4. A scatter graph with a line of best fit showing the correlation between dorsal angle diminished global ROM for the wrist at final follow-up.

7.4 Chapter Discussion

7.4.1. Predicting malunion

The majority of displaced distal radial fractures in super-elderly patients occur in females, after a simple fall, of which approximately half are functionally independent. Closed manipulation of the distal radial fracture achieved an adequate reduction in a third of patients, and the majority of patients had an improvement of their fracture position. The degree of dorsal angulation, ulna variance and dorsal comminution were independent predictors of improvement in the position of the fracture, however, most patients (86%) went onto a malunion. Those patients with a dorsal angulation of greater than 25 degrees and an ulna variance of more than 6mm at the time of their injury were at the greatest risk of malunion.

Approximately 30% of distal radial fractures occur in men and 70% are due to falls from standing height.[86] The prevalence of super-elderly male patients sustaining displaced distal radial fractures is less, accounting for only 6%, and 98% are due to falls from standing. This probably relates to the increased fragility of the super-elderly population, with a greater prevalence of osteoporosis in female patients[166], resulting in more low energy fractures in women. The incidence of distal radial fractures increases with age, with a peak of $1107/10^5$/year in super-elderly women.[170] If the predicted rise in the population is correct this will result in 44 thousand (population estimate 6 million[59] with an approximate incidence of $730/10^5$/year[86]) distal radial fractures in super-elderly patients presenting to orthopaedic trauma services per year in the UK by the year 2030. Assuming 40% will have displaced fractures, as demonstrated, this would mean 18 thousand super-elderly patients may undergo manipulation. This will have major repercussions upon the orthopaedic trauma workload, hence efficient and appropriate management of these fragility fractures will be of paramount importance in optimising the care of these patients.

A unique aspect of this study was to define specific cut off values for dorsal angulation and ulnar variants as independent predictors of malunion of distal radius fractures in the super-elderly. Previous studies identifying risk factors for malunion found dorsal comminution to be an independent predictor of malunion.[88, 171] This study also demonstrated that the combination of dorsal angulation of greater than 25 degrees and/or ulnar variance of greater than 6mm resulted in the greatest risk of malunion in the super-elderly patients. The clinical relevance of this is not clear in this low demand group.[84] There is a body of evidence which demonstrates that the functional outcome of distal radial fractures correlates with the end anatomic result.[82, 83, 85] These studies are, however, heterogeneous including patients with a wide age range and include both extra and intra-articular fracture patterns. Studies focusing on elderly patients and those with low functional demand have shown that malunion does not correlate with an inferior outcome.[84] More recently Grewal and MacDermid[89] demonstrated that for independent

elderly patients with displaced extra articular distal radius fractures, malunion did not result in a diminished functional outcome.

If a malunion does not affect functional outcome, then the question could be asked whether it is worth manipulating displaced distal radius fractures in super-elderly patients? Beumer and McQueen[92] suggested that for functionally active elderly patients it would be reasonable to assume that functional outcome does correlate with reduction of the fracture, as demonstrated for younger patients. Therefore, manipulation of the fracture with improvement in the position, despite being defined as a malunion, may result in an improved outcome. Kelly et al[172] demonstrated that elderly patients with more than 30 degrees of dorsal angulation and 5mm of ulnar variance resulted in a poorer outcome. Using prediction models for improvement in dorsal angulation and ulnar variance for super-elderly patients it would be mathematically possible to calculate the improvement potentially offered by manipulation of displaced fractures, for example:

Improvement in dorsal angulation (DA) = (pre-manipulation DA x 0.655) – 3.174 (constant)

Improvement in ulna variance (UV) = (pre-manipulation UV x 0.534) + (pre-manipulation DA x 0.032) + 1.433 if dorsal comminution – 1.617 (constant)

This would enable a patients final position to be calculated, identifying those patients who would achieve or fail to achieve the radiographic criteria defined by Kelly et al[172]. Independent super-elderly patients who are predicted to fail to achieve these radiographic criteria may benefit from primary surgical intervention, to avoid a wasted intervention and delay in definitive management.

7.4.2 Does distal radial malunion influence functional outcome?

Malunion of the distal radius does not influence the functional outcome of independent super-elderly patients. More than two thirds of patients were deemed to require manipulation of their distal radial fracture, of which half went onto have surgery due to loss of reduction. A third of all patients underwent surgical intervention, which was associated with complications. Despite manipulation and surgical intervention more than a quarter of patients still went on to malunion. The degree of malunion did correlate with a reduced ROM, but neither the degree of malunion nor the associated diminished ROM influenced the functional outcome of the super-elderly patients.

Colles[173] some 200 years ago on describing his fracture stated that *"one consolation only remains, that the limb at some remote period again enjoy perfect freedom in all its motions, and be completely exempt from pain: the deformity, however, will remain undiminished through life."* This statement may not have been fully supported by the results

of the study, with an observed diminished ROM, and some residual pain and dysfunction after a distal radial fracture. However, the super-elderly cohort may not have the full freedom of motion, but this does not seem to impair the functional use of the limb. If this was Colles' intention then the super-elderly group supports his statement as it would seem that malunion, the persistent deformity he describes, does not hinder activities of daily living in this low functional demand group.

The correlation between malunion and functional outcome in elderly patients has been described; with no association being demonstrated for low demand patients with malunion union after a distal radial fracture and functional outcome.[90-92] Beumer and McQueen[92]questioned whether attempted reduction of displaced distal radial fractures should be attempted in very elderly, frail, dependant, or demented patient after finding that the majority (53/60) lost reduction and went on to malunion. Young and Rayan[91] and Chang et al[90] illustrated that malunion did not correlate with poor functional outcome. However, these studies only included elderly patients, being 60 years or more, with low physical demands. More recently Grewal and MacDermid[89] included all patients, with no exclusions according to physical demands, and found no difference in the outcome of extra-articular fractures of the distal radius after malunion in patients greater than 65 years old. They did however demonstrate an increased risk of a poor functional outcome, defined as DASH score greater than 20, with a malunion regardless of age, but this risk diminished with advancing age. However, the DASH score is not validated for patients at the extremes of age[174], and to state that a DASH score of 20 points or more is a poor outcome for very elderly patients is difficult to support as this score may be normal for them. In fact one study found the mean DASH score to be 22 points for a group of patients with a mean age of 78 years after sustaining a distal radial fracture.[175] This supports the finding for the super-elderly population, with malunion having no influence upon functional outcome.

If the predicted increase of the super-elderly population is correct, then they will form an increasing percentage of the orthopaedic trauma workload. This will have associated cost implications for both the management of their fracture and the need for increased social support. The management of distal radial fractures, being the most prevalent fracture of the super-elderly[45], will form the greatest proportion of the emergency room and orthopaedic trauma workload. If the results of the study are acknowledged, super-elderly patients with a displaced distal radial fracture could be managed conservatively, without the need to reduce their fracture or to intervene surgically. These patients would not have to suffer the further discomfort of manipulation of their fracture or surgical measures with associated risks, and still achieve a satisfactory functional outcome. This would also have cost saving implications, avoiding the need for primary reduction within the emergency room and the costs of surgery

and reduce the number of clinic appointments and radiographs performed. This management protocol would benefit the super-elderly population, who would therefore endure fewer medical consultations and interventions, but achieve an adequate functional outcome.

If a conservative protocol was followed for all distal radial fractures in the super-elderly group, a potential risk would be the development of a symptomatic malunion in some patients. A distal radial osteotomy is indicated in fit patients with symptomatic malunion interfering with function irrespective of age.[176-179] Patients generally achieve a good functional outcome, but the rate of metalwork removal is high from 25% to 54% when plates are used to stabilise the osteotomy.[176-179] However, more recently the use of a non-bridging external fixator has been described to stabilise the osteotomy, offering a minimally invasive technique and good functional results without the subsequent need to remove the metalwork.[180] This technique could be offered to those super-elderly patients who develop a symptomatic malunion, if conservative methods fail.

There are several limitations to this study. The major limitation is the retrospective nature of this study and the small cohort analysed. It should be acknowledged that the functional assessment cohort may not be representative of the typical super-elderly cohort with only 37% having a malunion whereas a rate of malunion expected of this age group from section 7.3.1 would higher at 86%. However, the prospective data capture was of high quality, with only a single data point being absent (ROM of opposite wrist) for a single patient. In addition, this is the only case series reporting the outcome for super-elderly (≥80years) patients in the current literature. Both extra- and intra-articular fractures were included which may have skewed the results. However, on post hoc analysis no statistical difference was observed between extra- (AO/OTA type A) and intra-(AO/OTA type B and C) articular fractures for rate of malunion, ROM, or functional outcome. A prospective RCT comparing conservative versus interventional (manipulation or surgery) management would need to be performed to confirm the results before the proposed treatment protocol could be confidently recommended. Such a RCT should be powered to a validated and accepted patient reported outcome measure that is either joint or limb specific.

7.5 Conclusion

Super-elderly patients with a displaced distal radial fracture managed with closed manipulation alone is likely result in a malunion for the majority of patients. The position of the fracture will however be improved by closed manipulation. However, the limited functional demand of the super-elderly population should be acknowledged before they are offered reduction of their distal radial fracture. Malunion of the distal radius, despite efforts to restore normal anatomical alignment, often occurs, but there would seem to be no functional deficit of malunion for independent super-elderly patients according to the small group assessed in this study. This questions whether a surgical intervention should be offered after a displaced distal radial fracture in this population and suggests that they should be managed conservatively with the option of radial osteotomy in the small numbers of patients whose malunion becomes symptomatic. This would have major repercussions in the management of super-elderly patients with distal radial fractures, potentially avoiding the risks associated with fracture manipulation and surgical intervention but achieving the same functional outcome. This should be assessed in future RCT's.

CHAPTER 8:

PREDICTING THE OUTCOME OF PELVIC FRACTURES IN THE ELDERLY

CHAPTER 8: PREDICTING THE OUTCOME OF PELVIC FRACTURES IN THE ELDERLY

8.1 Aims

The primary aim of this study was to determine the incidence of elderly pelvic fractures over the last decade and describe the epidemiology and outcome of patients with pubic rami fractures and compare these to those patients sustaining all other pelvic fractures. The secondary aims were to identify independent predictors of length of stay, return to domicile, and one-year mortality for patients with pubic rami fractures.

8.2 Chapter Summary

There were 937 elderly patients (≥65 years) with pelvic fractures presenting to the study centre over a 15-year period. The incidence increased from 7.9 per 100,000 to 13.1 per 100,000. The majority were fragility fractures of the pubic rami (84%). Patients sustaining a pubic rami fracture were older, more likely to be female, less deprived, and have sustained an isolated injury by a low-energy mechanism. Patients sustaining a pubic rami fracture were less likely to return to their original place of domicile. Pre-injury independence and mobility, socioeconomic status, associated fractures, energy of injury, and male gender were independent predictors of length of stay, return to original place of domicile, and one-year mortality. The incidence of elderly pelvic fractures increased, and fractures of the pubic ramus have different patient demographics compared to other pelvic fractures. Patient demographics could be used to predict length of stay, return to domicile, and one-year mortality after a pubic rami fracture.

8.3 Results

The number of fractures per year nearly doubled ($p < 0.001$) during the study period, from 38 patients in 1996 to 72 patients in 2010, which resulted in an increase ($p < 0.001$) in the overall incidence from 7.9 (95% CI 4.5 to 11.2) per 100,000 to 13.1 (95% CI 10.9 to 16.4) per 100,000. The proportion of the elderly population also increased from 95,876 to 100.562 during the study period.[31] The age specific incidence during the study period increased ($p < 0.001$) from 39.6 (95% CI 31.8 to 48.1) to 71.6 (95% CI 58.4 to 81.0), which was greater for females ($p=0.03$) (Figure 8.1). Increasing age correlated ($p < 0.001$) with an increase in the aged matched incidence of pelvic fractures (Figure 8.2).

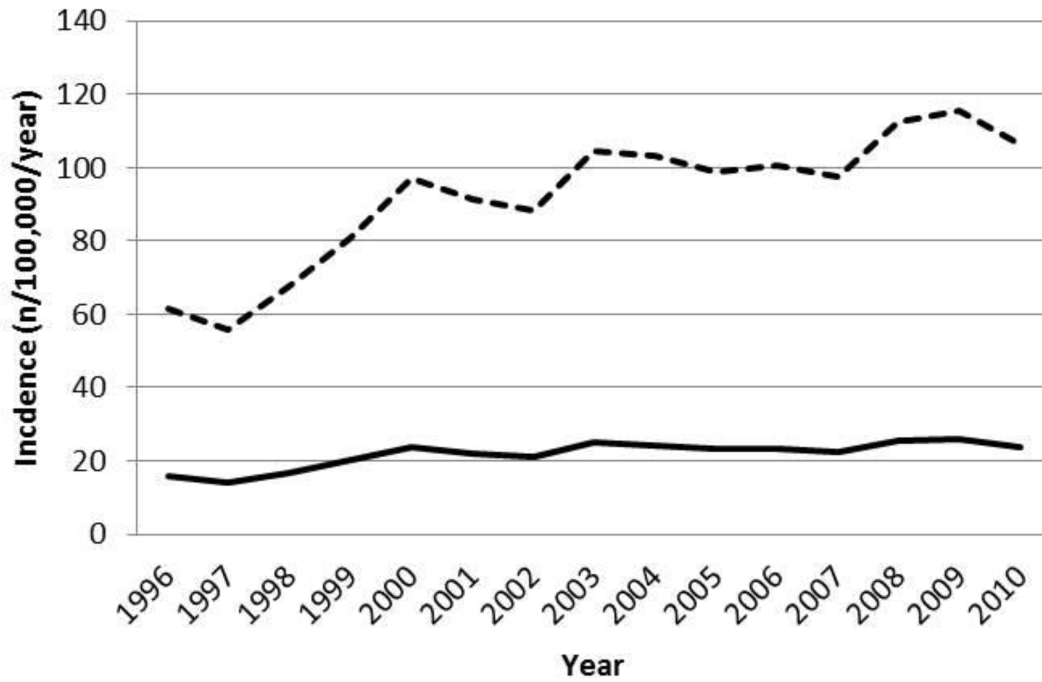

Figure 8.1 Age and gender (dash line = female, solid line = male) adjusted incidence of elderly pelvic fractures during the study period.

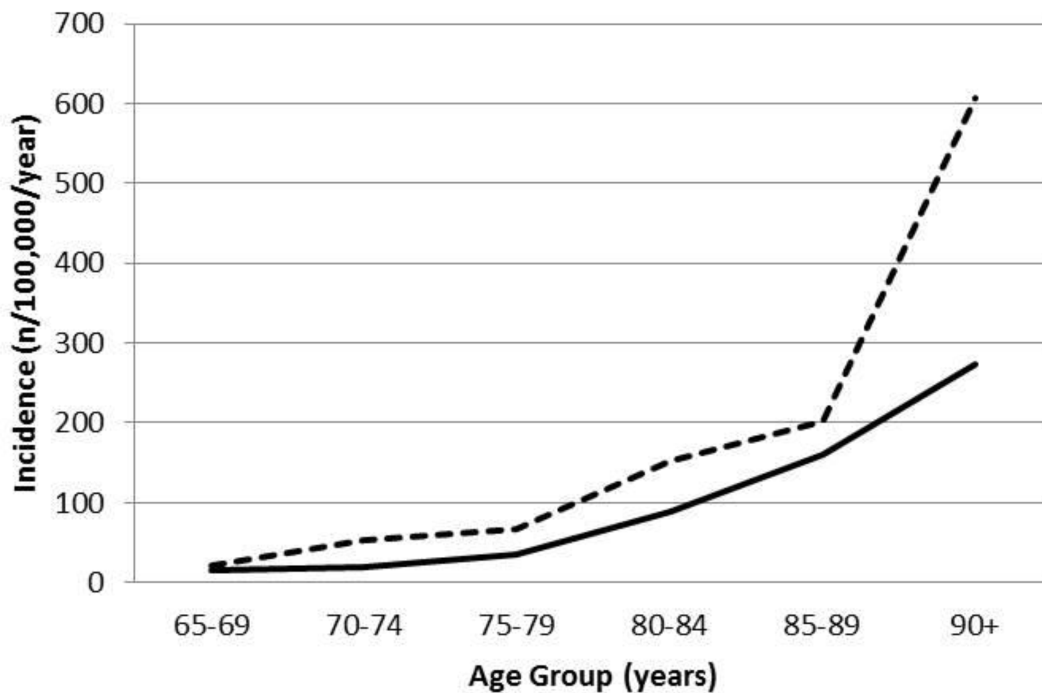

Figure 8.2 Distribution curve according to age and gender (dash line = female, solid = male) for all for all patients with a pubic rami fracture.

There were 142 pubic rami, 16 acetabula, 4 pelvic ring, three iliac wing, and three sacral fractures (Table 8.1) during the 2-year period analysed. There were significant differences in the case-mix variables (Table 8.2) between patients sustaining a pubic rami fracture and those sustaining all other pelvic fractures. Patients sustaining pubic rami fractures were older (95% CI 2.3 to 9.0 years) and more likely to be female (95% CI odds ratio 9.2 to 16.0), less deprived (95% CI odds ratio 0.9 to 16.1), sustain an isolated fracture (95% CI odds ratio 9.0 to 28.5), and incur their fracture by a low-energy mechanism (95% CI odds ratio 17.0 to 31.7) (Table 8.2). No difference was observed in the number of comorbidities, place of residence, mobility, or history of a previous fracture between patients with a pubic rami fracture compared to other pelvic fractures (Table 8.2).

Length of stay was longer in the other pelvic fracture group, which was the result of a longer acute hospital stay (Table 8.3). Patients sustaining a pubic rami fracture were less likely to return to their place of domicile than the other pelvic fracture group (Table 8.3). Lengths of stay were shorter for those patients residing in a nursing home, or were independently mobile, or had sustained a pubic rami fracture in isolation with no associated fracture(s) (Table 8.4). Patients who were independently mobile or were less socially deprived were more likely to return to their original domicile (Table 8.4). High-energy mechanism of injury, older age, and male gender (Figure 8.3) were independently predictors of one-year survival (Table 8.4).

Table 8.1. Demographics, classification, and management of all pelvic fractures except those of the pubic rami (61-A2.2). *Acetabula fractures were kept touch weight bearing for 6 to 8 weeks before progression to full weight bearing as the patient's cognition allowed. All ring fractures were stable and weight bearing as pain allow was commenced immediately.

Gender	Age	Pelvic Fracture	Mechanism	AO Classification	Management*
M	68	Wing	Fall from height	61-A2.1	Conservative
M	69	Acetabulum	Fall downstairs	62-A3.1	Conservative
M	70	Sacral	Fall from height	61-A3.2	Conservative
M	70	Acetabulum	Simple fall	62-A3.3	Conservative
M	71	Acetabulum	Simple fall	62-C2.3	Conservative
M	73	Acetabulum	Fall downstairs	62-A3.1	Conservative
F	73	Acetabulum	Simple fall	62-A3.1	Conservative
M	75	Acetabulum	Simple fall	62-A3.3	Conservative
M	77	Acetabulum	Simple fall	62-C2.3	Conservative
M	77	Acetabulum	Slip on ice	62-A1.1	Conservative
M	77	Acetabulum	Simple fall	62-B1.1	Conservative
F	78	Sacrum	Simple fall	61-A3.2	Conservative
M	79	Acetabulum	Simple fall	62-B1.1	Conservative
F	79	Sacrum	Fall downstairs	61-A3.2	Conservative
F	80	Wing	Simple fall	61-A2.1	Conservative
M	82	Acetabulum	Simple Fall	62-B2.1	Conservative
F	82	Ring	RTA	61-B1.1	Conservative
M	83	Acetabulum	Simple Fall	62-B2.1	Conservative
F	84	Wing	Simple fall	61-A2.1	Conservative
F	85	Ring	Fall downstairs	61-B1.1	Conservative
M	85	Ring	RTA	61-B2.1	Conservative
M	86	Acetabulum	Ice	62-A1.1	Conservative
M	86	Acetabulum	Simple fall	62-B1.1	Conservative
M	87	Ring	RTA	61-B2.1	Conservative
F	88	Acetabulum	Simple fall	62-A3.1	Conservative
M	93	Acetabulum	Simple fall	62-B1.1	Conservative

Table 8.2. Case-mix differences between patients sustaining a pubic rami fracture and those sustaining all other pelvic fractures. Low energy mechanism was defined as a simple fall from standing height.

Case-mix Variables		Pubic Ramus	All Other Pelvic Fractures	Odds Ratio	p-value
Age		84.1 (SD 7.7)	79.1 (SD 7.3)		0.03*
Gender (M/F)		14/86	69/31	13.7	0.0001†
Co-Morbidity		3.6 (SD 1.8)	3.5 (SD 2.0)		0.40*
Residence	Independent	113	18	1.7	0.36†
	Dependant	29	8		
Mobility	Independent	38	8	1.5	0.50†
	Stick(s)	62	8		
	Frame	42	10		
Deprivation Quintile	1 (most)	12	2	8.0	0.09†
	2	18	8		
	3	20	6		
	4	28	4		
	5 (least)	64	6		
Associated Fractures	1	120	16	18.2	0.0001†
	2	20	6		
	3	2	0		
	4	0	4		
Mechanism	Low Energy	134	14	25.2	0.0001†
	High Energy	8	12		
Prior Fracture	Yes	56	10	2.1	0.35†
	No	80	16		

* t-test, † = chi square test

Table 8.3. Comparison of outcome between patients sustaining a pubic rami fracture and those sustaining all other pelvic fractures. * = Mann Whitney † = chi square test

Outcome		Pubic Ramus	All Other Pelvic Fractures	Odds Ratio	p-value
Acute Hospital Stay		16.5 (SD 11.9)	23.3 (SD 31.3)	-	0.0001*
Rehabilitation Stay		19.9 (SD 23.5)	20.1 (SD 25.7)	-	0.44*
Total Length of Stay		36.4 (SD 25.7)	43.4 (SD 44.1)	-	0.0001*
Return Place Residence	Yes	120	26	8.0	0.02†
	No	22	0		
One-year Mortality Rate	Dead	32	10	2.8	0.09†
	Alive	110	16		

Table 8.4. Significant independent predictors of outcome for pubic rami fractures.

Outcome	Risk Factor	Exp(B)	95% CI	p- value*
Length of stay (R^2 = 0.20)	Nursing Home	-30.79	-43.08 to 18.5	<0.0001
	Independent mobility	12.64	7.73 to 17.56	<0.0001
	Associated fracture(s)	9.00	0.10 to 17.91	0.048
Discharge to domicile (R^2 = 0.31)	Independent mobility	0.48	0.25 to 0.93	0.03
	Deprivation quintile	1.42	1.02 to 1.98	0.04
One-year mortality (R^2 = 0.32)	Mechanism energy	0.04	0.004 to 0.44	0.008
	Age	1.17	1.08 to 1.27	<0.0001
	Gender	5.22	1.65 to 16.58	0.005

*Regression analysis

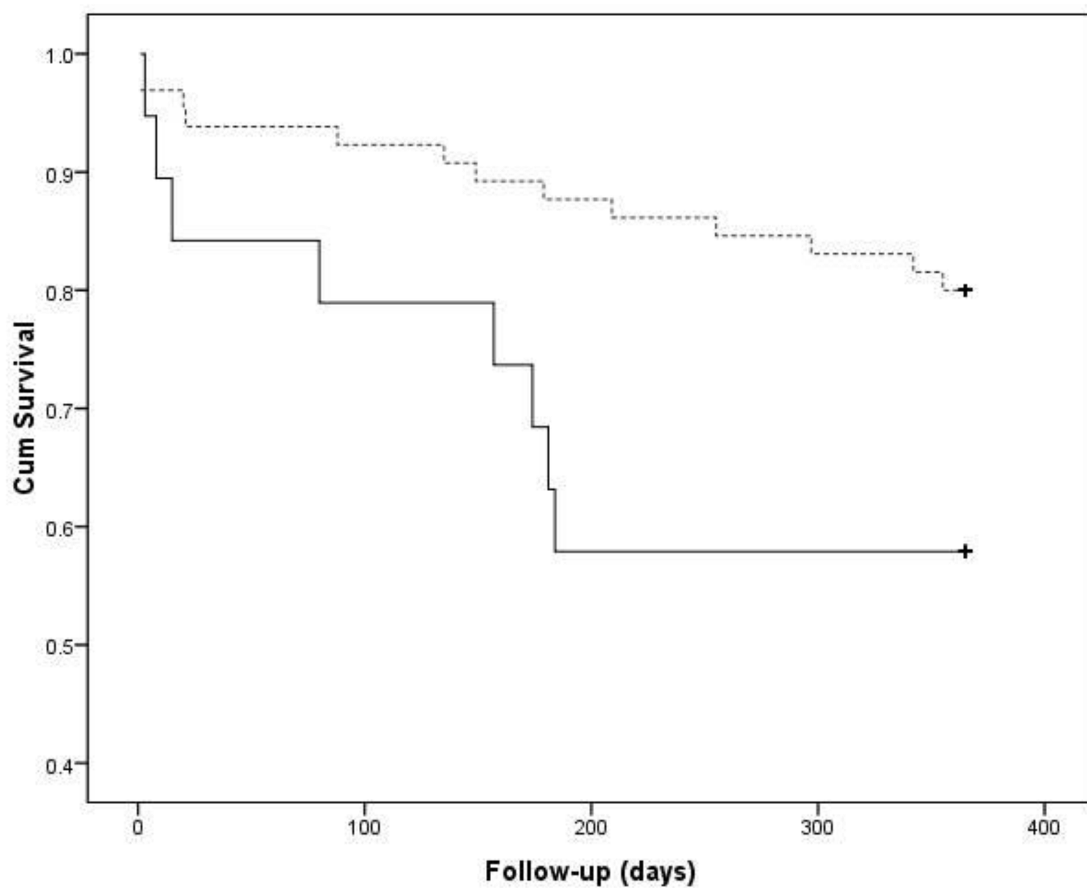

Figure 8.3 Survival of patients with a pubic rami fracture; male gender (solid line) as an isolated risk factor was associated with an increased (p=0.002) mortality at one year.

8.4 Chapter Discussion

Pelvic fractures are common in the elderly[86], however, there is modest literature documenting the change in incidence with time, demographics of different pelvic fractures, and the patient predictors of length of stay, return to domicile, and one-year mortality of these fractures. This study has demonstrated: (1) the incidence of elderly pelvic fractures is increasing, (2) the epidemiology and outcome of patients with pubic rami fractures is different from those sustaining other pelvic fractures, and (3) patient demographics predict length of stay, return to domicile, and one-year mortality.

The retrospective nature of the study is a limitation. The electronic trauma patient database used for this study was prospectively compiled, recording patient demographics and fracture location. The study centre is also the only hospital receiving fractures for the study population, and this was the case for the entire study period, which allowed for a reliable evaluation of the incidence of these fractures. The two-year period used to compare the demographics, length of stay, return to domicile, and one-year mortality of patients with a pubic rami fracture to all other pelvic fractures, was also retrieved retrospectively. All of this data were recorded prospectively on the hospitals electronic patient database and no patient was lost to follow-up. Classification of the type of pelvic fragility fracture was not possible as CT scans were not routinely performed at the study centre and further sub-group classification may have demonstrated differences in the outcomes.[127]

Data from the Office for National Statistics predicts that 23% of the population by 2034 will be aged 65 years or older.[6] This study has demonstrated the incidence of pelvic fractures increased and if the future growth predictions are correct the number of elderly pelvic fractures will likely continue to escalate. This will not only have an impact on the orthopaedic trauma workload, to manage such frail patients who generally do not need surgery, there will also be an additional burden on resources with a prolonged length of stay and need for future social care. The reason(s) for this increased incidence is not clear and may related to increased longevity of increasing frail population.

The demographic differences between the pubic rami and all other pelvic fractures may relate to the mechanism of injury. The other pelvic fracture group were more likely to incur their injury by a high-energy mechanism, which is associated with multiple fractures and are more likely to occur in younger males.[99] This may explain the observed male predominance in the other pelvic fracture group, who were some 5 years younger than the pubic rami fracture group and were more likely to sustain associated fractures.

The average length of stay on an acute trauma ward for an elderly patient with a hip fracture is 23 days[151], which is the same as elderly patients sustaining pelvic fractures other than those of the pubic rami for the reported cohort. The average length of the hospital stay

of an elderly patient with a pubic rami fracture was 17 days, which is longer than previous reports of 9 to 14 days.[94, 95] Assuming that the cost of acute in-patient care is similar to that of a patient with a hip fracture[151], the overall cost of stay would be £8,000 for elderly patients sustaining a pubic rami fracture and £10,800 for all other pelvic fractures.

Koval et al[94] demonstrated that three or more comorbidities increased length of stay, and Hill et al[95] found younger age to be a predictor of discharge to original domicile. The current study demonstrated that place of residence, level of mobility, and socioeconomic status are independent predictors of length of stay and place of discharge for patients sustaining a pubic rami fracture after adjusting for confounding variables. These predictors could be used to identify patients who may have a longer than average stay or may require an increased care package on discharge. Identifying these patients early in their admission and addressing social issues could potentially decrease length of stay and the secondary financial burden.

The one-year mortality rate for the pubic rami group (22%) was greater than previous studies have observed.[94, 95] This could be attributable to the fact that patients younger than 65 years of age were excluded, as they may have an improved one-year survival rate. Also, the current study included all patients, whereas some authors have excluded non-ambulatory and institutionalized patients or those with associated injuries.[94, 97, 99] The majority of other pelvic fractures sustained fractures of the acetabulum (62%), which have been associated with a poorer survival rate.[181] This may explain why there was a greater one-year mortality rate for the other pelvic fracture group.

The male survival rate at one year was approximately 50% when adjusting for age and mechanism of injury, which are other independent predictors of mortality. These risk factors could be used to identify those elderly patients with the poorest prognosis who may benefit from the services of a geriatrician to medically optimise their comorbidity.[182] Also, early physiotherapy and assessment by an occupational therapist may also improve survival. Alternatively, in frail patients, a palliative care approach may be preferred to facilitate end-of-life management.[183]

Krappinger et al[99] and Beall et al[184] suggested that "ramoplasty", percutaneous injection of polymethylmethacrylate into acute pubic rami fractures, may relieve pain and facilitate early mobilization, but this is not wide spread practice nor is there any level one evidence to support this management intervention. The acetabula fractures in the current study were managed conservatively, all returned to their original domicile, despite some patients having gross displacement of their fracture and eventual malunion (Figure 8.4). The risk of surgery in these frail patients may outweigh the benefits, and those who become symptomatic could benefit from a total hip replacement at a later date.[185]

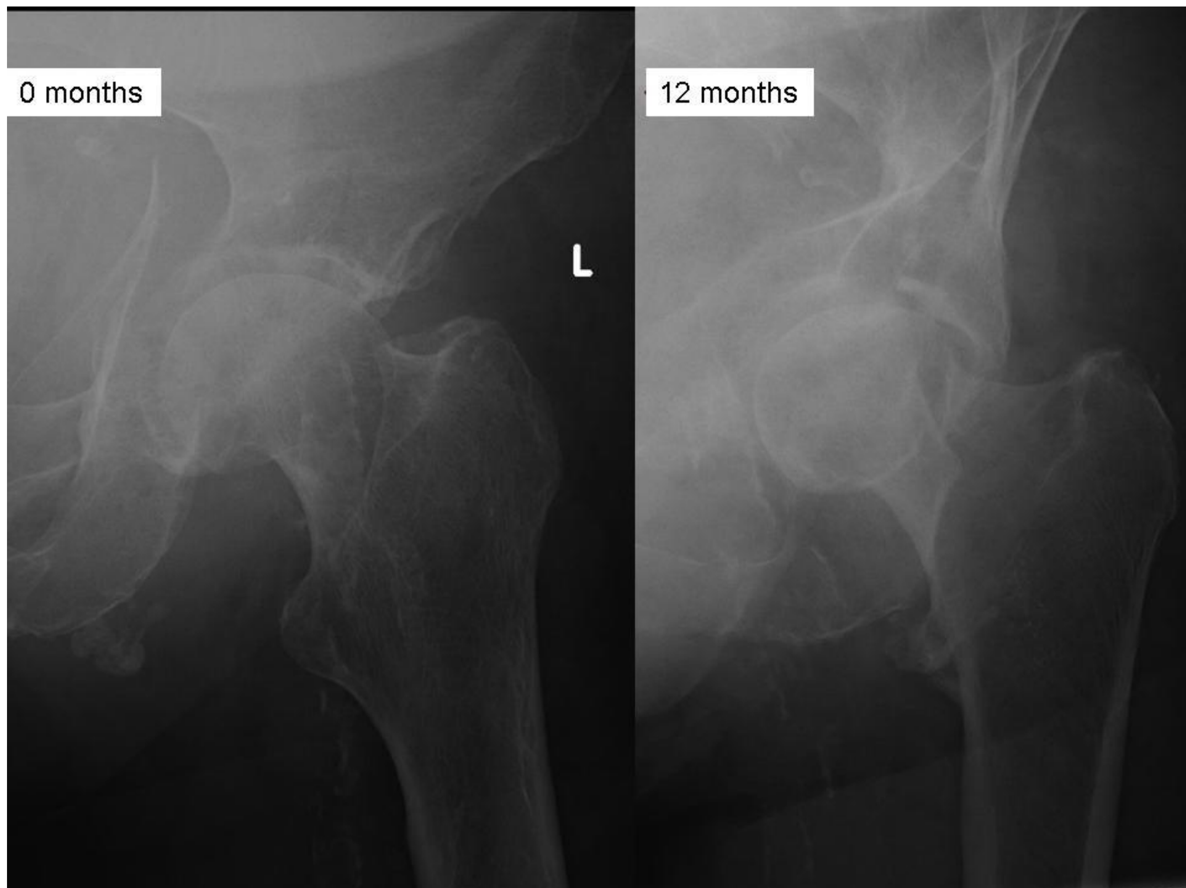

Figure 8.4 Radiographs of a patient with a transverse acetabulum fracture at time of injury (anterior-posterior), and at 12 months post injury (obturator oblique).

8.5 Conclusion

Elderly patients with pelvic fractures have multiple comorbidities and a prolonged costly length of stay on acute trauma wards, where they receive minimal orthopaedic intervention. Future research regarding the potential surgical interventions, such as ramoplasty, may result in an improved survival rate for these morbid fractures.

CHAPTER 9:

PREDICTING THE OUTCOME OF TIBIAL DIAPHYSEAL IN THE ELDERLY

CHAPTER 9: PREDICTING THE OUTCOME OF TIBIAL DIAPHYSEAL IN THE ELDERLY

9.1 Aims

The primary aim of this study was to describe the epidemiology and outcome of tibial diaphyseal fractures in the elderly, being defined as those 65 years old or more. The secondary aims were to identify predictors of outcome and to compare the outcome of elderly patients with super-elderly patients.

9.2 Chapter Summary

Two hundred and thirty-three fractures were prospectively complied in 225 elderly (≥65 years) patients over a ten-year period. Demographic and descriptive data was acquired from a prospective trauma database. Mortality status was obtained from the General Register Office database.[31] Elderly tibial diaphyseal fractures predominantly occurred in females (73%) after a fall (61%). The incidence of these fractures during the study period decreased, nearly halving in number. The 120 day and one-year unadjusted mortality rate was 17% and 27% respectively and was significantly greater for those patients with an open fracture ($p<0.001$). The overall standardised mortality ratio (SMR) was significantly increased (SMR 4.4 $p<0.0001$), relative to the population at risk, and was greatest for elderly female patients (SMR 8.1 $p<0.0001$). These frailer patients had more severe injuries with an increased rate of open fractures (30%) and suffered a greater non-union rate (10%). Tibial diaphyseal fractures in the elderly are more common in females after a fall, which are more likely to be open, and are associated with a high prevalence of non-union and mortality.

9.3 Results

There were 61 males and 164 females with an average age of 77.9 years (range 65 to 99 years). Males were significantly younger (75.0 versus 79.0 years, $p=0.001$). The modes of injury are demonstrated in Figure 9.1. The majority of fractures resulted from falls (64% in total, 40% from standing height) and RTA (31%). Females were more likely to sustain their fracture after a low energy simple fall (OR 1.7, CS $p=0.04$). The incidence of elderly tibial fractures decreased during the study period ($r=-0.77$, PC $p=0.01$), from 27/100,000 in 1990 to 14/100,000 in 1999 (Figure 9.2).

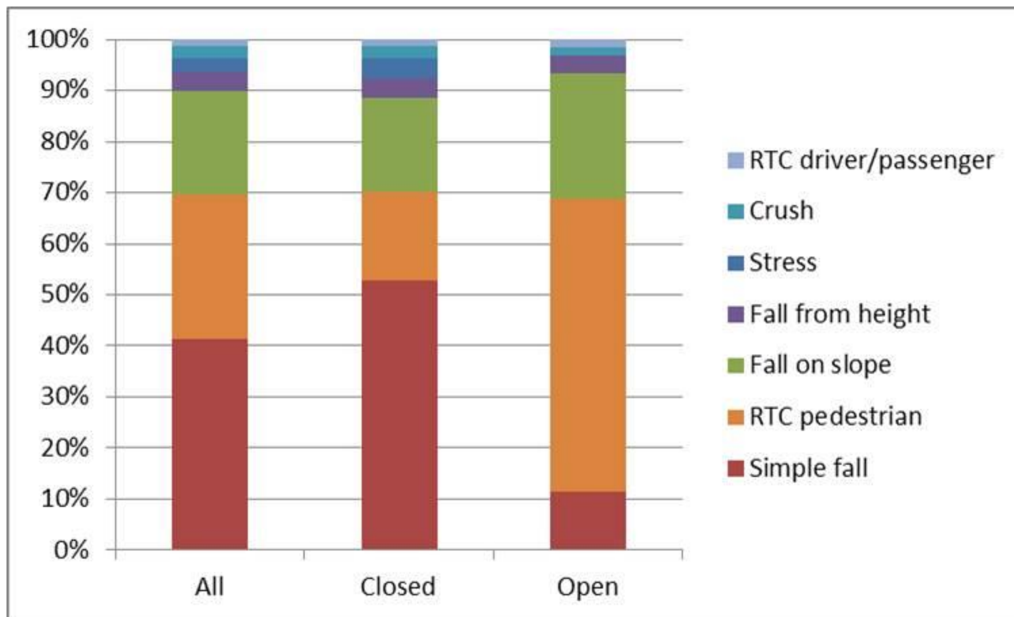

Figure 9.1 Modes of injury for all elderly tibial fractures, and for those patients with a closed or open fracture.

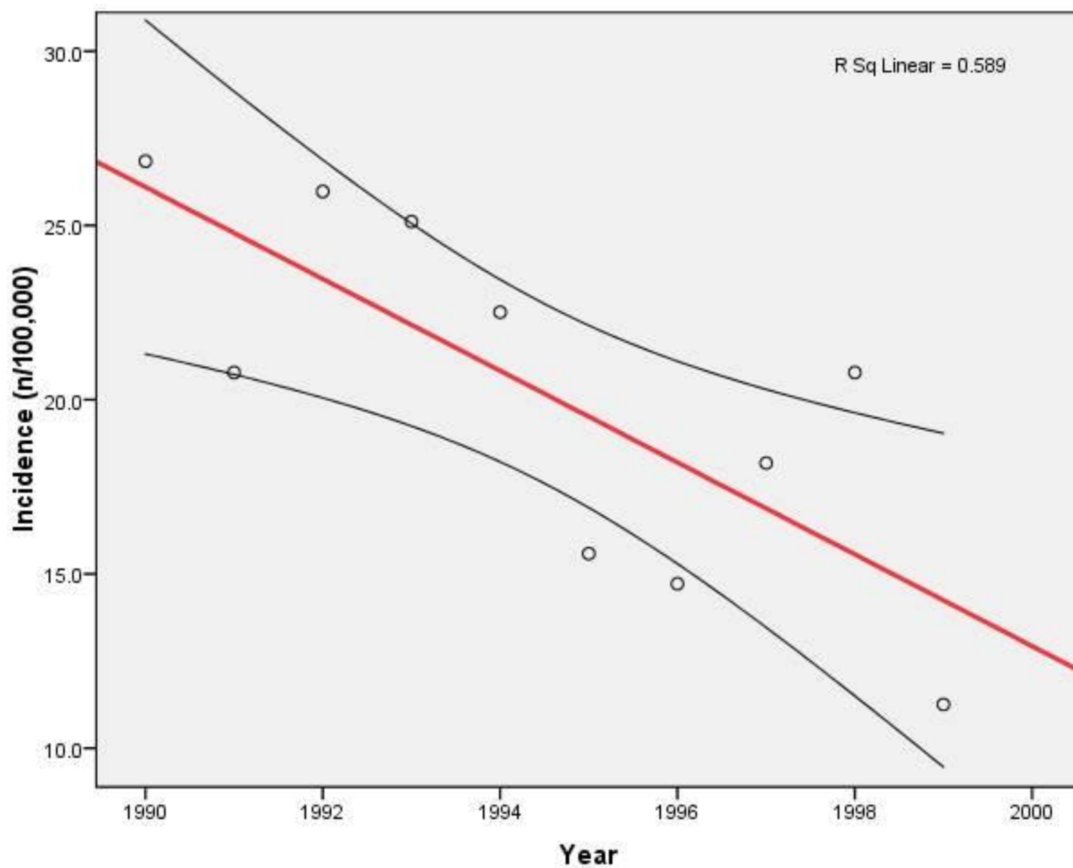

Figure 9.2. Incidence of elderly tibial fractures, within the elderly population during the study period

There was a total of 164 (70%) closed fractures and 69 (30%) open fractures. There was a trend towards less severe soft tissue damage, according to the Tscherne classification, for closed fractures in the elderly patients (Table 9.1). However, there was a greater rate of grade three open fractures in the elderly cohort relative to the population at risk, although most of these were grade A (Table 9.2). Two of these 69 open fractures required primary amputation due to the injury severity and physical frailty, and eight patients died within 3 days of their injury and did not have definitive closure/coverage of their open fracture. Only 5 of the remaining 59 patients required the intervention of a plastic surgeon, with four having a split skin graft and one patient undergoing a muscle flap. There was variation for the mode of injury according to whether the tibial fracture was closed or open (Figure 9.1). An open fracture was more likely to occur after an RTA relative to a fall (OR 6.7, $p<0.0001$). Super-elderly patients were more likely to be of female gender and to have sustained their fracture after a fall, but all other variables were similar (Table 9.3).

Table 9.1. The distribution of the soft-tissue trauma according to the Tscherne classification for closed tibial diaphyseal fractures for both the elderly (n=164) and the general population.[100]

Tscherne type	Incidence in the elderly (%)	Incidence for all age groups (%)
0	24	17
1	53	54
2	15	24
3	2	6
Unclassified	6	-

Table 9.2. The distribution of open tibial diaphyseal fractures according to the Gustilo Anderson classification for both the elderly (n=69) and the general population.[100]

Gustilo type		Incidence in the elderly (%)	Incidence for all age groups (%)
I		16	21
II		13	19
III		71	60
Sub-group	IIIa	59	27
	IIIb	37	60
	IIIc	4	8

Table 9.3. Comparison of patient demographics, fracture severity, and management between elderly and super-elderly patients.

Factor	Elderly	Super-elderly	p-value*
	n=139	n=94	
Gender (m:f)	35:65	15:85	<0.0001
Mechanism			
Falls	61%	68%	0.044
RTA	33 %	29%	
Insufficiency	3%	2%	
Direct Blow	3%	1%	
AO Classification			
A	53%	52%	0.9
B	25%	25%	
C	22%	23%	
Open Fracture	32%	26%	0.17
Tscherne type			
0	19%	31%	0.22
1	54%	51%	
2	19%	10%	
3	1%	3%	
Gustilo type			
I	16%	17%	0.79
II	11%	17%	
III	73%	67%	
Management			
Intra-medullary nail	59%	46%	0.18
External fixation	6%	3%	
Cast only	19%	30%	
Mixed	11%	15%	

* chi square test

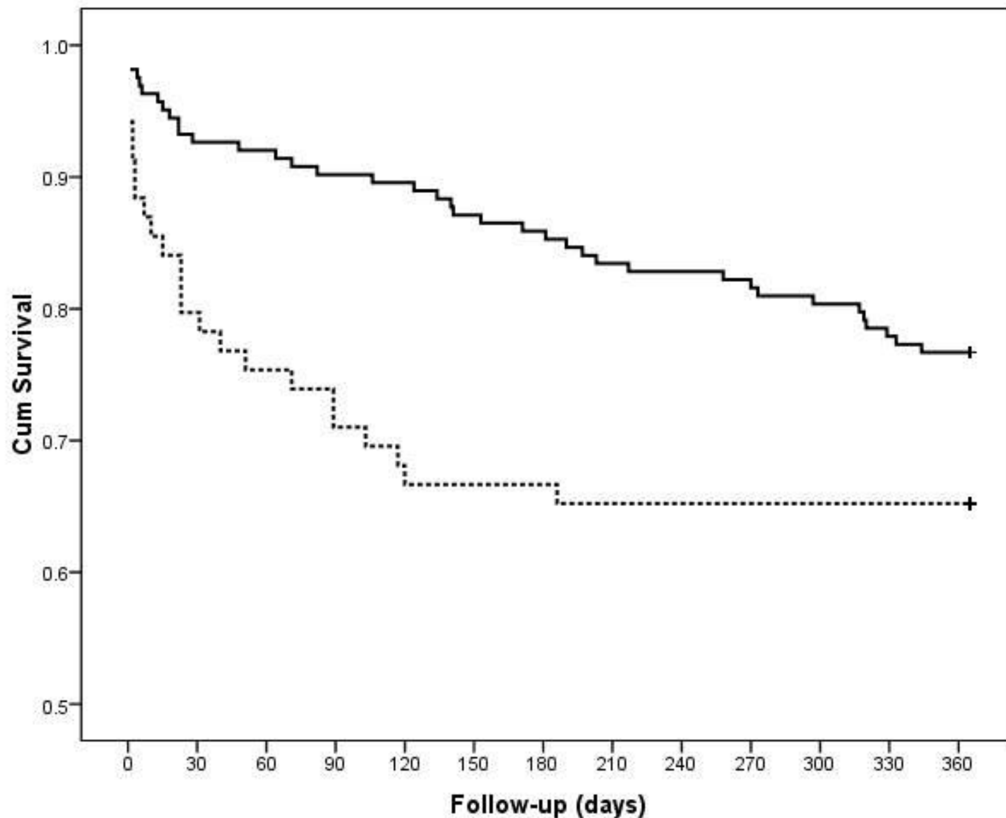

Figure 9.3 Kaplan-Meier patient survivorship curve for patients with closed (solid line) and open (dashed line) tibial fractures up to one-year post injury.

Four patients (2%) died before operative intervention could be undertaken. Reamed intramedullary nailing was the most commonly used fixation method, being used for definitive fixation in 128 (55%) fractures. Conservative management with cast alone was used for 57 (25%) fracture, only two patients were managed with a patella bearing cast primarily, and the remainder were managed in an above knee cast and then conversion to a patella bearing cast at 4 to 8 weeks depending on clinical and radiographic signs of union. Forty-four (19%) fractures were definitively managed with an external fixator. The remaining 3 patients had primary below knee amputations, due to the extent of their initial injury(s) and general frailty.

The outcome measures (time to union, non-union, malunion, infection, amputation, and mortality) varied according to patient demographics, fracture severity, and management (Table 9.4). The non-union rate was almost 10%, which increased for those fractures sustained as a result of a RTA (OR 3.3, p=0.04) or due to an insufficiency/stress fracture (OR 8.5, p=0.05). Time to union was prolonged with increasing Tscherne grade (p=0.03). Insufficiency/stress fractures had a prolonged time to union with a 33% non-union rate. There was a significant amputation rate for all open fractures compared to closed fractures (OR 3.8,

$p<0.0001$). The predictors of outcome that were significant or had a trend towards significance ($p \leq 0.1$) on univariate analysis were entered into regression analysis model. Interestingly, after adjusting for confounding variables, only a few factors remained significant upon regression analysis for each outcome (Table 9.5).

Acute compartment syndrome occurred in 6 patients (3%) of which one patient had bilateral tibial fractures and were both complicated by acute compartment syndrome. This was diagnosed on clinical signs and symptoms, and compartment measurements. All had four compartment fasciotomies performed. None of these patients died within a year of their injury. Three fasciotomies (3/7, 43%) were complicated by deep infection and one had skin necrosis.

No patient was lost to follow-up one year after their fracture. The overall mortality rate at 120 days was 17% (95% CI 16% to 18%), and at one year was 27% (95% CI 26% to 28%). Predictors of survival on univariate analysis are shown in table IV. Upon entering these predictors into Cox-regression analysis only super-elderly patients (OR 4.18 $p<0.0001$, OR 3.0 $p<0.0001$) and those with an open fracture (OR 4.12 $p=0.006$, OR 2.1 $p=0.006$) were at an increased risk death at 120 days and one year (respectively). However, when adjusting for age within the regression model there was no significant difference in the 120-day ($p=0.12$) or one-year ($p=0.22$) mortality rates between elderly and super-elderly age groups. The effect of an open fracture remained significant ($p<0.001$) and although persistent at one year, had a maximal effect upon the 120-day mortality (Figure 9.3). The overall one-year SMR was significantly greater than the general population (Table 9.6). Super-elderly patients, despite a greater unadjusted one-year mortality rate, had a lower SMR relative to elderly patients (OR 1.7, $p=0.2$). Subgroup analysis of the elderly patients demonstrated that female patients had a significantly greater SMR of 8.09 ($p<0.001$), in contrast elderly male patients who did not have a statistically significantly increased SMR ($p=0.16$). One patient was lost to long term follow-up, she moved to live with her daughter out with the catchment population. Patient survival continued to decline with time from their fracture (Figure 9.4). Two thirds of the cohort were deceased after eight years from their fracture, and less than 10% were alive at 18 years (Table 9.7).

Table 9.4. Outcomes according to patient demographics, fracture severity, and management on univariate analysis.

Descriptive Criteria	Nº fractures	Mean time to union (wks)	Non-union (%)	Mal-union (%)	Deep infection (%)	Amputation (%)	120 day mortality (%)	1 year mortality (%)
All	233	20.8	10	17	7	3	17	26.6
Group								
Elderly	139	27.5	12	17	9	4	9	17.2
Super-elderly	94	18.2	6	17	3	3	30	40.4
p-value	-	0.003	0.15	0.56	0.04	0.56	<0.0001	<0.0001
Gender								
Male	63	24.4	9	15	13	3	12.7	20.6
Female	170	19.4	10	18	5	3	18.8	28.8
p-value	-	0.1	0.5	0.4	0.047	0.6	0.18	0.14
Mode of Injury								
Falls	143	18.3	6	17	5	2	12	23
RTA	71	28.7	16	18	12	6	28	32
Insufficiency	6	28	33	17	0	0	0	17
Direct Blow	5	14	0	0	0	0	0	20
Unknown	8	No Data	50	50	20	13	38	50
p-value	-	<0.0001	0.12	0.45	0.07	0.046	0.015	0.6
AO Classification								
A	63	20.5	2	14	4	2	16	20
B	51	28.5	17	30	17	7	23	23
C	89	35.0	12	22	35	8	11	22
p-value	-	0.008	0.12	0.31	0.013	0.17	0.45	0.80
Fracture type								
Closed	164	18.8	6	17	3	0	10	23
Open	69	27.1	21	18	17	13	33	35
p-value	-	<0.0001	0.012	0.53	0.001	<0.0001	<0.0001	0.045
Tscherne type								
0	40	169	3	24	0	0	8	25
1	87	17.8	7	11	4	0	12	25
2	25	25.8	9	21	4	0	4	8
3	3	No Data	0	0	0	0	33	67
p-value	-	0.003	0.13	0.9	0.9	-	0.22	0.81
Gustilo type								
I	11	25	25	13	11	0	27	27
II	9	25.8	0	14	11	11	22	22
III	49	28.4	25	21	19	14	37	39
p-value	-	0.36	0.76	0.57	0.49	0.19	0.43	0.35
- IIIA	29	26.8	13	19	16	10	35	40
- IIIB	18	33.3	50	25	27	11	39	39
- IIIC	2	Amputated			0	100	50	50
Management								
IM nail	123	21.9	7	5	5	2	16	22
External fixation	30	26.8	14	30	12	0	20	17
Cast only	50	15.6	0	20	0	0	12	36
Mixed	11	No Data	78	33	40	0	9	18
p-value	-	<0.0001	0.001	0.13	0.21	0.0001	0.085	0.004

Table 9.5. Significant predictors of outcome identified upon multivariate regression analysis.

Outcome	R^2 value	Predictor	OR	p-value
Time to union*	0.17	Super-elderly	N/A	0.05
Non-union**	0.24	Open fracture	5.8	0.005
		Non-nail fixation	2.5	0.0001
Malunion**	0.18	Non-nail fixation	7.5	0.001
Infection**	0.24	AO class	1.3	0.035
		Open fracture	6.0	0.031
Amputation**	0.48	Implant	0.2	0.005

*Linear regression analysis **Bivariate regression analysis N/A not applicable

Table 9.6. SMR for all elderly patients and for each group according to gender.

Group	Gender	SMR	95% CI	p-value*
All	Male	3.33	1.69-5.94	<0.001
(≥65 years)	Female	4.45	3.33-5.84	<0.001
	All	4.20	3.24-5.4	<0.001
Elderly	Male	2.24	0.64-4.82	0.16
(65 to 79 years)	Female	8.09	5.12-13.3	<0.001
	All	6.39	3.34-7.89	<0.001
Super-elderly	Male	3.59	2.48-4.69	<0.001
(≥80 years)	Female	3.43	1.21-6.24	0.005
	All	3.62	2.47-5.0	<0.001

*chi square test

Table 9.7. Life table for patient survival after a tibial diaphyseal fracture (n=224).

Years since fracture	Number at start	Withdrawn	Number at risk	Died	Annual mortality rate (%)	Cumulative survival
0 to 1	224	0	224	58	25.9	74.1
1 to 2	166	0	166	18	10.8	66.1
2 to 3	148	0	148	10	6.8	61.6
3 to 4	138	0	138	11	8.0	56.7
4 to 5	127	0	127	12	9.4	51.3
5 to 6	115	0	115	14	12.2	45.1
6 to 7	101	0	101	11	10.9	40.2
7 to 8	90	0	90	11	12.2	35.3
8 to 9	79	0	79	7	8.9	32.1
9 to 10	72	0	72	7	9.7	29.0
10 to 11	65	0	65	5	7.7	26.8
11 to 12	60	0	60	4	6.7	25.0
12 to 13	56	0	56	9	16.1	21.0
13 to 14	47	2	46	2	4.3	20.1
14 to 15	43	4	41	6	14.6	17.1
15 to 16	33	3	31.5	5	15.9	14.4
16 to 17	25	3	23.5	2	8.5	13.2
17 to 18	20	2	19	2	10.5	11.8
18 to 19	16	2	15	3	20.0	9.4
19 to 20	11	3	9.5	1	10.5	8.4

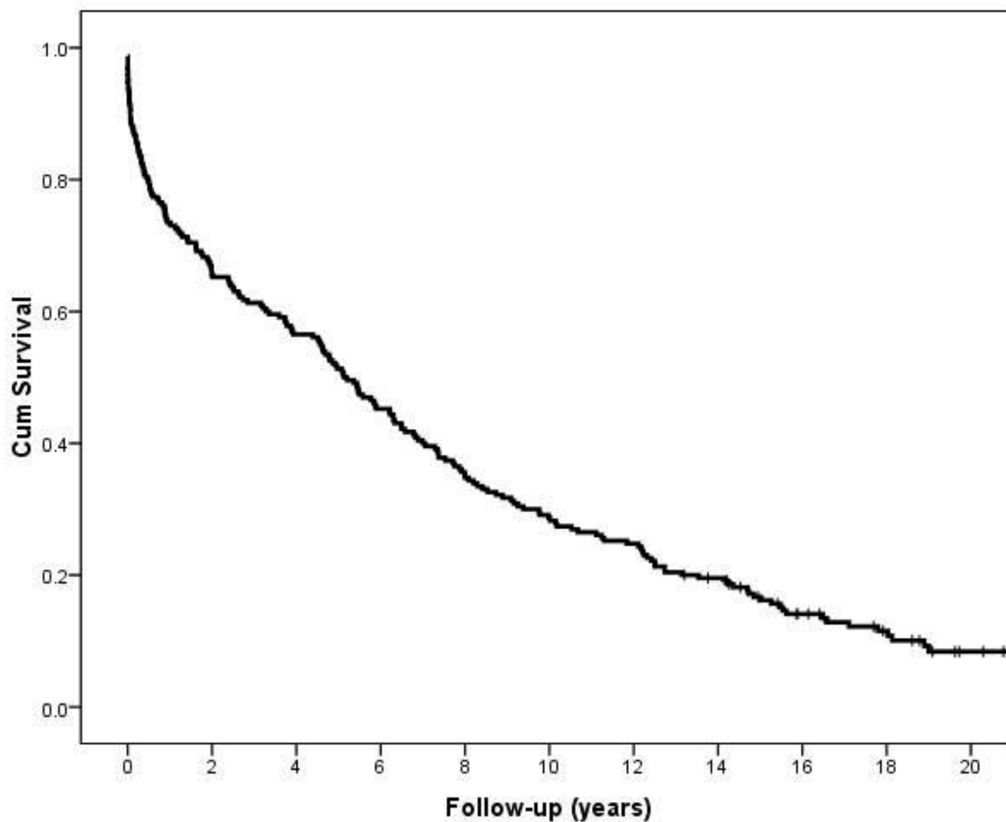

Figure 9.4 Kaplan-Meier patient survivorship curve up to twenty years post tibial fracture for elderly patients (n=224).

9.4 Chapter Discussion

Elderly tibial diaphyseal fractures predominantly occur in females after a low energy fall. The incidence of these fractures however decreased during the study period, nearly halving in number. Overall elderly patients had a greater rate of open fractures (30%). The overall complication rate was also relatively high. The non-union rate was nearly 10%, with a malunion rate of 17%. Seven percent of patients suffered a deep infection and 3% required an amputation. The 120 day and one-year unadjusted mortality rate was 17% and 27% respectively and was significantly greater for those patients with an open fracture. The overall SMR was significantly increased, relative to the population at risk, and was greatest for elderly female patients. Patient survival into the long term was poor, with 73% of patients being deceased ten years after their fracture.

The incidence of elderly tibial diaphyseal fractures declined during the study period. This decreasing incidence has also been demonstrated for tibial fractures of all ages. A recent epidemiological study performed during 2008, from the study unit using the same study population, revealed that the incidence of tibial diaphyseal fractures was greater in the elderly population: 14 per 100,000 for patients less than 65 years and 18 per 100,000 for patients 65 years or more.[86] The observed incidence for these elderly fractures is similar to that observed towards the end of the current study period, suggesting the rate has remained the same over the last decade. Due to the increasing elderly population and presumed static incidence rate the absolute numbers managed by orthopaedic surgeons will hence increase. This in combination with a decreasing incidence of tibial diaphyseal fractures in younger patients will probably result in elderly patients forming an increasing part of the trauma workload. The decrease in incidence may relate to improved safety, such as road safety, that have resulted in a lower rate of high energy tibial diaphyseal fractures. Knowledge of the patient demographics and outcome will hence be important to manage these frail patients optimally.

The epidemiology of elderly tibial diaphyseal fractures is significantly different when compared to patients of all ages sustaining tibial fractures. In the general population there is a 60:40 male to female ratio, however, in the elderly this ratio is reversed to 27:73. The ratio significantly increased with age, as the male to female ratio in the super-elderly group was 15:85. Singer et al[186] demonstrated a similar gender distribution for all fractures in patients 60 years or older, finding that females were twice as likely to suffer a fracture than males. They also demonstrated three peaks of fracture distribution, the first in young males with the other two occurring in elderly patients of both genders. More recently Cox et al[104], reviewed 54 elderly tibial diaphyseal fractures and also found a similar gender distribution, with a 30:70 male to female ratio.

The mechanism by which the elderly patients sustain their tibial fractures is different to that of younger patients. Two thirds of younger patients sustain their fracture after a RTA or from a sporting injury[100], whereas the opposite is true for the elderly with two thirds sustaining their fracture after a fall. This probably reflects the osteopenic and osteoporotic status of this elderly group, with increasing fragility with age, which is supported by the significantly increased rate of simple fall related fractures observed in the super-elderly group. Due to increasing road safety and longevity of patients, the tibial diaphyseal fracture may become a fragility fracture of the future, which is supported by the increasing mean age of patients sustaining these fractures.

Age has been shown to be important in terms of its association with injury severity, as elderly patients are more inclined to suffer an open fracture after a relatively minor injury.[100] This study has also demonstrated a higher proportion of open fractures compared to the overall population, with a rate of 30% for open fractures in the elderly compared to 24% in the overall population. This study also established that these fractures were more likely to occur as a result of minor trauma, with falls being responsible for 61% of all elderly tibial fractures and 35% of open fractures. In the elderly population, whose bone and soft tissues are becoming increasingly fragile[187], an increased injury severity for less severe modes of injury might be expected. This is supported by the distribution of Gustilo grades in the elderly population which showed a trend towards a more severe injury compared to the general population.

The 10% non-union rate of elderly tibial fractures is greater than that expected relative to the general population.[188] Chatziyiannakis et al[189] demonstrated that open fractures, with increasing soft tissue injury and fracture comminution, and soft tissue stripping during surgery may increase the rate of nonunion. The current study has confirmed the independent effect of an open fracture, which significantly increases the risk of nonunion in the elderly. A recent study of grade III open elderly tibial fractures highlighted that these injuries are associated with a higher complication and mortality rate with low rate of return to mobility and place of residence.[190] In addition, it was demonstrated that fracture fixation with an intramedullary nail significantly reduced the non-union rate after adjusting for other confounding variables. Hence, the increased rate of non-union in the elderly study cohort may be explained by the greater rate of open fractures and increased rate of fixation by methods other than an intramedullary nail. There are however, other patient factors which may have contributed to this increased non-union rate which are intrinsically more prevalent within the elderly population, for example patient medications (nonsteroidal anti-inflammatory drugs and steroids), hypothyroidism, diabetes, and vascular insufficiency, which have all been associated with nonunion.[191] Interestingly the rate of nonunion was independent of age, and in actual fact the super-elderly group had a significantly shorter time to radiographic union, and was independent of other

confounding variables. This may reflect a superior physiological status of the super-elderly, which is supported by their own longevity.

Cox et al[104] published the only other study to examine both closed and open elderly tibial diaphyseal fractures comparing the mortality of these injuries, finding no difference between the 6 month mortality rates. They demonstrated a lower mortality rate compared to elderly patients in the current study, finding an 8% and 11% mortality rate at 6 months for closed and open fractures, respectively. Although, mortality rate at 6 months for closed fractures of 13% for the current study was similar to their 8%, the mortality associated with an open fracture in the study group was significantly different with a 33% mortality rate at 6 months. The reason for this difference may reflect a type II statistical error due to their small cohort (n=54), which Cox et al[104] acknowledge in their discussion. In addition, their study centre is a tertiary referral unit for trauma and did not exclude patients' resident out with their own catchment area. This may have skewed the results, with the most unwell or frail patients not being referred, and hence the improved survivorship of their open elderly fractures.

The unadjusted mortality rate was 17% at 120 days and 27% at one year for elderly tibial fractures, with age and fracture status being closed or open predicting mortality. These unadjusted rates are similar to the 18%[58] 120 day and 29%[192] one year mortality rates observed after a fractured neck of femur. The unadjusted rate peaks at 33% for elderly patients with open tibial diaphyseal fractures at 120 days post injury. In addition the 73% 10 year mortality rate illustrated is greater than that observed for fracture hip patients [193], despite a similar mean age. This study supports the suggestion made in Chapter 4 that all lowered limb elder fracture, requiring surgery, should be performed within 48-hour of admission, with specific relevance to tibial diaphyseal fractures in the elderly. As the mortality rate similar to that of a hip fracture, as their outcome may also be enhanced from the fast-track care that now benefits hip fracture patients.[194]

The SMR observed for the elderly tibial fractures is greater than that observed after an isolated hip fracture. The SMR for a hip fracture in the elderly is 3.4[57], whereas the SMR observed for elderly tibial diaphyseal fractures was 4.2, which increases to 8.1 in elderly females. This excess adjusted mortality associated with elderly tibial fractures, confirms that they should receive the same priority as those patients with a hip fracture in an effort to improve their morbidity and mortality.[195] A multidisciplinary team approach has been shown to improve the outcome of older patients with hip fractures.[182] Hence, some authors advocate the involvement of an orthogeriatrician in the management of patients with a hip fracture, being responsible for ensuring appropriate medical treatments are undertaken and liaison with the patient and family for those with a poor prognosis. A recent study demonstrated advance care planning in geriatric inpatients improved the end of life care, and lowered family anxiety.[196] Palliative care is acknowledged to be beneficial for people with advanced non-malignant as

well as malignant disease[197], which has led some authors to suggest a palliative approach to be recognised for frailer patients after a fractured hip.[183] This would facilitate planning for physical, social, psychological and spiritual needs and end of life care, which may result in better care planning.

9.5 Conclusion

The epidemiology of tibial diaphyseal fractures is changing, with a greater proportion occurring in elderly females after a low energy fall. These frailer patients have more severe injuries, with an increased rate of open fractures, and suffer a greater non-union rate. The mortality associated with these fractures is equal to that of a hip fracture and therefore these patients should receive the same level of care and prioritisation.

CHAPTER 10:

THE EPIDEMIOLOGY AND OUTCOME OF MULTIPLE FRACTURES IN THE ELDERLY

CHAPTER 10: THE EPIDEMIOLOGY AND OUTCOME OF MULTIPLE FRACTURES IN THE ELDERLY

10.1 Aims

The primary aim of this chapter was to describe the prevalence of multiple fractures in the elderly, the mechanisms of injury, common patterns of occurrence, the effect of socio-economic status, and the associated SMR. The secondary aims were to evaluate the rate of admission, operative intervention, return to domicile and length of stay for different fracture patterns.

10.2 Chapter Summary

There were 2335 patients aged at least 65 years of age presenting to the study centre over the one-year period. One hundred and nineteen (5.1%) patients presented with multiple fractures. Distal radial ($p<0.0001$), proximal humeral ($p<0.0001$) and pelvic (4.9, $p<0.0001$) fractures were associated with an increased risk of sustaining associated fractures. Only 4.5% of patients after a simple fall sustained multiple fractures, but due to the frequency of falls in the elderly this mechanism resulted in 80.7% of all multiple fractures. The majority of patients required admission (>80%), despite a large proportion not needing surgical fixation (42%), and more than half needed an increased level of care before discharge (54%). The standardised mortality rate at one year was significantly greater after sustaining multiple fractures which included fractures of the pelvis, proximal humerus or proximal femur ($p<0.001$). This mortality risk increased further if patients were less than 80 years of aged, indicating multiple fractures after low energy trauma is a marker of mortality.

10.3 Results

During the study period 2335 patients, aged at least 65 years of age, presented with 2465 fractures. One hundred and nineteen (5.1%) patients presented with multiple fractures. Of these 109 (91.6%) presented with two fractures, 9 (7.6%) presented with three fractures and one (0.8%) patient presented with four fractures. The gender ratio was 22/78 male/female and the average age was 78.7 years. Females were significantly older than males (79.4 years vs 76.5 years respectively, $p=0.003$). A comparison of the demographic characteristics of elderly patients presenting with single and multiple fractures is shown in Table I. Distal radial, proximal humeral and pelvic fractures were associated with an increased risk of sustaining associated fractures (Table 10.1).

Table 10.1. The demographic characteristics of elderly patients who present with single or multiple fractures from all modes of injury. The prevalence and risk of sustaining one of the commonest six fractures are shown.

		Single fractures	Multiple fractures	Odds ratio	p-value
Patients (%)		2216 (94.9)	119 (5.1)	-	-
Average age (yrs)					
	All	78.9	78.7	-	0.78†
	Male	77.7	76.5	-	0.61†
	Female	79.2	79.4	-	0.54†
Male/Female		23/77	22/78	1.0	0.9*
Fracture prevalence (%)					
	Proximal femur	30.6	32.8	1.1	0.34*
	Distal radius	21.1	37.0	2.2	<0.0001*
	Proximal humerus	9.9	35.3	5.1	<0.0001*
	Ankle	6.7	9.2	1.4	0.19*
	Finger phalanx	3.8	7.6	2.1	0.05*
	Pelvis	3.1	12.6	4.9	<0.0001*

† Mann Whitney, * chi square test

Figure 10.1 illustrates the incidence of the multiple fractures for the five social quintiles, which demonstrates a significant increase in the incidence of multiple fractures in the 5th quintile (OR 2.5, 95% CI 1.8 to 3.9, p=0.001). A similar pattern was observed for single fractures, with an increased incidence in quintile 5, and was not significantly different on comparison with the multiple fracture patients (p=0.6).

Table 10.2 demonstrates the modes of injury resulting in multiple fractures. The highest prevalence was observed for RTA and falls from a height, but in the elderly population these modes of injury were uncommon. Although only 4.5% of patients had multiple fractures after a simple fall, because of the frequency of falls in the elderly population this mechanism results in 80.7% of all multiple fractures. Female gender was a risk factor for multiple fractures after a simple fall when compared to other modes of injury, and in addition combined upper and lower limb fractures, and proximal femoral fractures were more likely to occur after a simple fall (Table 10.3).

Table 10.2. The numbers and percentages of multiple fractures caused by different modes of injury. The average ages and gender ratios are also shown.

Mode of Injury	Patients (n)	Multiple fractures	%	Average age (yr)	Male/ Female (%)
Simple fall	2111	96	4.5	79.0	16/84
Fall from height	11	3	27.3	72.0	67/33
Fall downstairs	80	10	12.5	77.0	30/70
Motor vehicle accident	22	8	36.4	80.2	75/25
Direct blow/assault	45	2	4.4	77.5	0/100
Sport	17	0	---	---	---
Spontaneous	24	0	---	---	---
Others	25	0	---	---	---
Total	2335	119	5.1	78.7	22/78

Table 10.3. A comparison of the demographic characteristics of double fractures caused by a fall with those caused by other modes of injury.

	Falls	Other modes of injury	Odds ratio	p-value
Number of patients	90	19	-	-
Fractures	180	38	-	-
Average age (yrs)	79.1	77.9	-	0.4†
Male/ Female (%)	16/84	42/58	3.8	0.03*
Fracture combinations				
Upper limb fractures (%)	32.2	47.4	1.8	0.29*
Lower limb fractures (%)	12.2	31.6	3.4	0.04*
Combined fractures (%)	55.5	21.0	4.6	0.007*
Fracture types				
Proximal femur (%)	21.7	5.3	5.0	0.01*
Distal radius (%)	21.1	18.4	1.0	0.59*
Proximal humerus (%)	18.8	10.5	2.0	0.16*
Pelvis (%)	8.9	10.5	1.2	0.47*

† Mann Whitney, * Fishers exact test

Table 10.4. The epidemiology of the fractures that occurred most commonly in the fall-related double fracture combinations.

Fracture	Number (%)	Average age (yrs)	Male/ Female (%)
Proximal femur	39 (21.7)	81.4	21/79
Distal radius	38 (21.1)	77.6	13/87
Proximal humerus	34 (18.8)	79.7	15/85
Pelvis	11 (6.1)	88.4	9/91

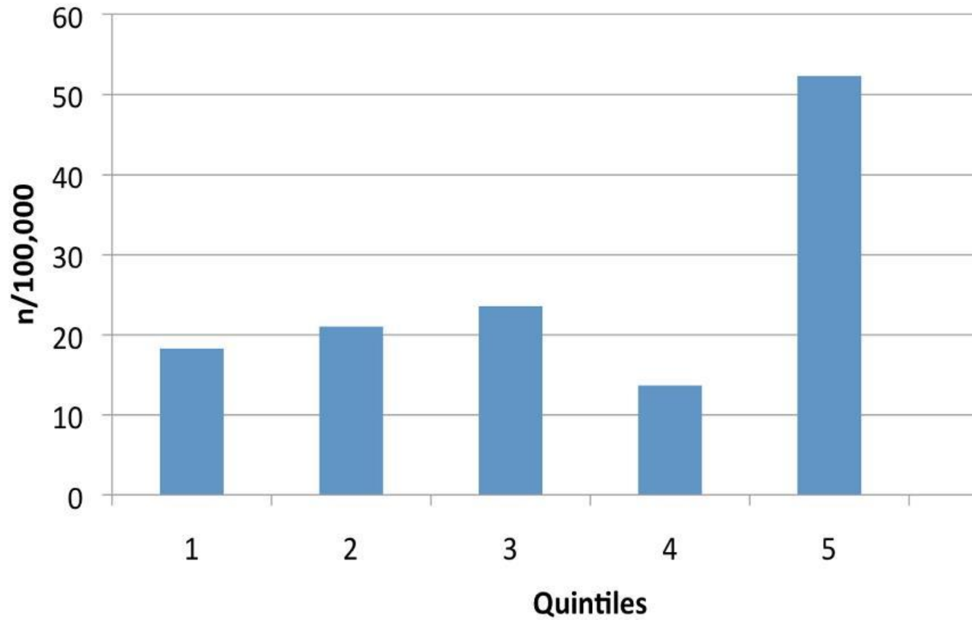

Figure 10.1 A histogram showing the relationship between social deprivation (1 = least deprived and 5 = most deprived) and the incidence of fractures

Table 10.5. The double fracture combinations according to fracture combination group. The numbers, percentages, average age and gender ratio of each combination are shown.

Fracture combinations	Number (%)	Average age (yrs)	*Male/* Female (%)
Upper limb			
Distal radius/ distal radius	8 (27.6)	74.7	25/25
Distal radius/ proximal humerus	4 (13.8)	79.5	0/100
Distal radius/finger phalanx	3 (10.3)	74.6	0/100
Distal radius/ proximal radius	2 (6.9)	73.0	50/50
Proximal humerus/ scapula	2 (6.9)	80.5	0/100
Proximal humerus/ finger phalanx	2 (6.9)	74.5	0/100
All combinations	29 (100)	75.1	17/83
Lower limb			
Ankle/ metatarsal	3 (27.3)	75.3	0/100
Pelvis/ proximal femur	3 (27.3)	92.3	0/100
All combinations	11 (100)	83.4	18/82
Combine			
Proximal femur/ proximal humerus	17 (34.0)	80.9	18/82
Proximal femur/ distal radius	11 (22.0)	80.1	18/82
Pelvis/ proximal humerus	4 (8.0)	87.5	25/75
Pelvis/ distal radius	3 (6.0)	85.0	0/100
Distal radius/ patella	2 (4.0)	76.5	0/100
Distal radius/ metatarsal	2 (4.0)	74.5	0/100
Patella/ proximal forearm	2 (4.0)	74.5	0/100
All combinations	50 (100)	80.5	14/86

Simple Falls

The commonest fractures to be involved in fall-related double fractures were those of the proximal femur, distal radius, proximal humerus and pelvis (Table 10.4). Ninety patients (93.7%) sustained double fractures after a simple fall.

There were 29 patients (32%) in the upper limb group, presenting with 14 different fracture combinations, but only those occurring at least twice are shown in Table 10.5. Patients with upper limb fracture combinations were significantly younger than those in the lower limb and combined fracture groups (p=0.0003). Altogether the distal radius was involved in 19 (65.5%) fracture combinations, and the proximal humerus in 11 (37.9%). Only three (10.3%) upper limb fracture combinations did not contain distal radial or proximal humeral fractures.

Eleven (12.2%) patients had lower limb fracture combinations, but only two occurred more than once (Table 10.5). A further five fracture combinations occurred only once and a proximal femoral fracture occurred in five (45.4%), and the ankle was involved in four (36.4%).

Fifty (55.5%) patients had combined upper and lower limb fractures of which proximal femoral fractures with proximal humeral or distal radial fractures were most common (Table 10.5). Altogether there were 16 different combinations, but only 7 occurred more than once during the year. The proximal femur was involved in 34 (68%) of the fracture combinations.

The rate of admission was greater than 80% for all groups (Table 10.6). This high admission rate was not entirely due to the need for operative fixation of the fracture, with only 24% of upper limb combinations undergoing surgery in contrast to 80% of upper and lower limb combinations (p=0.002). Nine patients (10%) with double fractures underwent operative fixation of both fractures. The length of stay was significantly less for the upper limb fracture group (Table 10.6). However, there was no difference in length of stay (p=0.47) or rate of discharge to original domicile (p=0.72) for patients that underwent surgical fixation with those who did not. The rate of return to original place of domicile was low, with less than 50% of the combined upper and lower limb fracture group and 20% of the lower limb fracture group returning to their original home (Table 10.6).

A review of the six patients after a simple fall who presented with three fractures shows that their average age was 77.3 years and the gender ratio was 17/83. Three patients had an upper limb and three had combined fracture combinations. The fracture distribution showed no consistency.

Table 10.6. Rate of admission, operative intervention, fixation of both fractures, length of stay, and rate of discharge to original domicile (for those patients admitted to hospital) for each double fracture group.

Outcome	Upper limb	Lower limb	Combined	p-value
Admission (%)	24/29 (82.8)	11/11 (100)	46/50 (92.0)	0.14*
Operative intervention (%)	7/29 (24.1)	5/11 (45.5)	40/50 (80.0)	<0.001*
Both fractures fixed (%)	2/29 (6.9)	1/11 (9.1)	6/50 (12.0)	0.75*
Length of stay (days)	8.3	32.8	29.3	0.002†
Return to original place of domicile (%)	21/24 (87.5)	2/11 (18.2)	21/46 (45.6)	<0.001*

* chi square test, † ANOVA

RTA

Twenty-two patients presented with fractures as a result of a RTA but only 8 (36.4%) had multiple fractures (Table 10.2). Seven (87.5%) had double fractures and one 75-year-old male presented with four fractures of his ankle, hindfoot and midfoot. The average age of the patients with double fractures was 81 years and the gender ratio was 71/29 male/female. Six (85.7%) of the patients were pedestrians. There were 2 patients (28.6%) with upper limb fractures combinations, 4 (57.1%) with lower limb combinations, and only 1 patient (4.3%) with combined fractures. Four (57.1%) patients presented with either proximal tibial or a tibial diaphyseal fracture.

Fall downstairs

Ten of eighty patients (12.5%) sustained multiple fractures after a fall downstairs (Table 10.2). Seven patients (70%) presented with double fractures and three (30%) had three fractures. Analysis of the patients with double fractures showed that three (42.9%) presented with an upper limb fracture combination and the remaining four (57.1%) had a combined upper and lower limb fracture combinations.

Mortality

The standardised mortality ratio (SMR) at one year was significantly greater after sustaining both single and multiple fractures involving the pelvis, proximal femur, and proximal humerus (Table 10.7). However, the mortality rate was only significantly increased, relative to patients sustaining single fractures, for pelvic fractures (p=0.04) and proximal humeral fractures (p=0.008). Subgroup analysis demonstrated a lower SMR for very-elderly patients after sustaining multiple fractures and a greater SMR for elderly patients (Table 10.7). Proximal femoral fractures in this younger elderly subgroup (65yrs to 79yrs) were at a significantly

increase mortality risk compared to a fractured proximal femur in isolation (p=0.03). In addition, proximal femoral fractures sustained in combination with a proximal humeral fracture was associated with a statistically significant increased mortality risk at one year relative to isolated proximal femoral fractures (47.1%, OR 1.8, p=0.05). In contrast the mortality of a proximal femoral fracture was reduced if associated with a distal radial fracture (18.2%, OR 1.6, p=0.28).

Table 10.7. The one-year standardized mortality ratios and p-values for single and multiple fractures of the ankle, distal radius, pubic rami, proximal femur and proximal humerus.

Fractures	Single Fracture (95% CI)	p-value*	Multiple Fractures (95% CI)					
			All ages	p-value*	<80yrs	p-value*	≥80yrs	p-value*
Ankle	1.85 (1.03-3.10)	0.02	1.95 (0.34-6.61)	0.32	2.66 (0.33-6.61)	0.31	No deaths	-
Distal radius	0.75 (0.50-1.08)	0.13	1.43 (0.64-4.82)	0.15	2.18 (0.33-6.61)	0.31	1.07 (0.16-3.30)	1.0
Pelvis	2.28 (1.35-3.63)	<0.001	10.50 (2.43-13.05)	<0.001	11.64 (5.38-19.22)	0.03	3.45 (1.27-9.65)	0.003
Proximal femur	3.41 (2.99-3.87)	<0.001	4.66 (2.66-7.64)	<0.001	8.39 (1.83-11.08)	<0.001	3.53 (1.46-5.51)	<0.001
Proximal humerus	2.06 (1.47-2.80)	<0.001	4.95 (2.66-7.64)	<0.001	6.64 (1.83-11.08)	<0.001	4.34 (2.19-8.25)	<0.001

* chi square test

10.4 Chapter Discussion

This study has demonstrated that the majority of multiple fractures in the elderly occur after low energy trauma and are predominantly of a female gender. The distal radius, proximal humerus, and pelvic fractures were associated with an increased risk of sustaining multiple fractures. The commonest multiple fracture group was that of combined fractures involving the upper and lower limbs. The majority of elderly patients sustaining multiple fractures required admission, despite a large proportion not needing surgical fixation (42%), and more than half needed an increased level of care before discharge (54%). There was a significantly increased

SMR associated with multiple fractures that included a proximal humeral, pelvic, or proximal femoral fracture. However, this increased mortality risk diminished with increasing age, with very elderly patients having a lower risk. Combined fractures of the proximal humerus and femur were associated with the highest mortality risk at one year.

The incidence of fractures in the elderly population is increasing, and most occur as the result of low energy falls, usually in their place of domicile.[86, 198] It has been estimated that about one-third of adults, aged 65 years or more who live at home will fall each year, which increases to two-thirds for adults who live in residential homes.[199] Approximately 10% of falls result in a serious injury[200] and a recent Swedish study has suggested that 7% of falls in the elderly result in fracture.[201] It is likely that the incidence of fall-related fractures will increase in the future resulting in considerable expense for all healthcare systems. The Center for Disease Control and Protection in the USA has suggested that the cost of falls in 2020 may reach $54.9 billion.[202]

Most surgeons may believe that multiple fractures are the result of high-energy injuries and this is frequently the case in younger patients. High-energy modes of injury were associated with the highest incidence of multiple fractures in the elderly. However, these modes of injury are uncommon in the elderly and the majority of multiple fractures actually occur after low energy trauma (88.1%).

There was no significant difference in the average age or gender ratios in elderly patients who present with single or multiple fractures. Patients who had multiple fractures were more likely to present with a distal radial, proximal humeral or pelvic fracture. There was no consistency in the distribution of fractures in the patients who presented with three or four fractures, or for fractures that had been sustained by high-energy modes of injury. This is probably due to the relative infrequency of these fractures. However, double fracture combinations that occur as a result of a fall demonstrated definite fracture patterns.

The commonest fractures to be involved in fall-related double fracture combinations (78/90, 86.7%) were those of the proximal femur, proximal humerus and distal radius. Patients who presented with upper limb fracture combinations were significantly younger than those in the other groups, with the majority of patients sustaining a distal radial fracture (n=19, 65.5%). However, the highest frequency of double fractures following a fall was observed in patients with combined upper and lower limb fractures. The combination of a proximal femoral fracture with either a proximal humeral or distal radial fracture accounted for 28 (31.1%) of all fall-related double fracture combinations with a mean age of 82.2 years. These patterns probably reflect the natural epidemiological history of fragility fractures, as the mean age of isolated distal radial, proximal humeral, and proximal femoral fractures is 56 years, 65 years, and 81 years old respectively.[26] Hence, fragility fractures of the upper limb occur at a younger age, which may explain the observed age difference between the upper limb multiple fracture group

and the lower limb and combined fracture groups.

There was a significant difference between the double fractures caused by low-energy and high-energy modes of injury. Despite a similar mean age high-energy trauma was significantly more common in males, with a higher prevalence of combined upper limb fractures, and they were less likely to sustain a proximal femoral fracture. This suggests that the patients who sustain double fractures, especially those of the lower limb, following a low-energy injury may be frailer than those who present with high-energy related double fractures, regardless of similar mean ages.

The frailty of patients who present with double fractures is affirmed by the associated increased standardized mortality rate at one year. This is supported on subgroup analysis; as elderly patients, relative to very-elderly patients, were demonstrated to have an increased mortality risk which may reflect the frailty of this younger age group after sustaining low energy multiple fractures. The mortality risk was significantly increased for multiple fractures that included pelvic or proximal humeral fractures in all elderly patients, or proximal femoral fractures in those aged 65 to 79 years old, relative to factures sustained in isolation. Patients sustaining these multiple fracture combinations should be identified, and both the medical and surgical management should be prioritized in an effort to improve their outcome.

One-year mortality was 47.1% (8/17) for the most common double fracture combination of a proximal femoral and proximal humeral fracture. However, in contrast the combination of a proximal femoral fracture and a distal radial fracture was associated with a decreased mortality of 18.2% (2/11), although this did not reach statistical significance. Allum et al[144] studied age-dependent balance correction and arm movements for falls in different age groups, and showed that compensatory movements to facilitate protection from falls were less effective with increasing age. Frailer patients were more likely to incur proximal limb girdle fractures due to diminished protective reflexes and hence sustain proximal humeral and femoral fractures.[143, 144] Whereas patients who retain their protective reflexes are more likely to sustain a distal radial fracture, which may reflect a superior physiological status. This may account for the observed improved survival rate of proximal femoral fractures associated with distal radial fracture.

There is evidence that demonstrates an increased incidence of fractures in socially deprived patients after falls[203], from this it could be hypothesize that there is an association with multiple fractures and deprivation. There was, however, no difference in the observed fracture incidence according to deprivation between single and multiple fractures for elderly population examined in the current study.

10.5 Conclusion

There will be financial repercussions associated with the manage and ongoing care for these frail elderly patients sustaining multiple fractures, with high admission rates, prolonged length of stay, and the increased level of care needed upon discharge. A large proportion of these patients underwent conservative management needing only rehabilitation. Hence, these frail patients with an increased mortality risk may benefit from early identification and medical optimization, to facilitate rehabilitation and to provide for their potentially increased care needs, in an effort to improve their outcome and shorten their admission stay.

CHAPTER 11:

SUMMATION OF WORK AND FUTURE DIRECTION

CHAPTER 11: SUMMATION OF WORK AND FUTURE DIRECTIONS

11.1 Summation

The number and overall incidence of fractures presenting to orthopaedic services is increasing, which is due to the increasing incidence in the growing elderly and super-elderly population. This will result in an increased need for elderly trauma services in the future if the projected increase in this population is correct. Very-elderly patients have a similar number of co-morbidities relative to their elderly counterparts, but they are less likely to be independently mobile or to live in their own home prior to injury. They are more likely to require admission to hospital, have a longer length of stay, and are less likely to return to independent living. The principle of early surgery and mobilisation of elderly patients with hip fractures may be extended to incorporate other operatively managed lower limb fractures to aid early rehabilitation. An increase in the services specific to this expanding super-elderly population will be needed to aid early surgery and a timely discharge in the future.

The management of elderly patients with a minimally displaced fractured neck of femur with a high risk of fixation failure is difficult, and future work is required to assess whether these patients would benefit from arthroplasty over fixation. This thesis has demonstrated that patients with a posterior tilt of more than 10 degrees are at risk of fixation failure and therefore may benefit from arthroplasty over fixation.

Age is not a predictor of poor outcome, either mortality or function, of proximal humeral fractures in the elderly. Factors associated with social independence, such as living in their own home, pursuing recreational activities, and being able to shop for themselves, were more influential upon outcome. These factors should be taken into account when considering which patients may benefit from orthopaedic interventions.

Super-elderly patients with a displaced distal radial fracture managed with closed manipulation alone will result in a malunion for the majority of patients. The position of the fracture will however be improved by closed manipulation. However, the limited functional demand of the super-elderly population needs to be acknowledged before they are offered reduction of their distal radial fracture. Malunion of the distal radius, despite efforts to restore normal anatomical alignment, often occurs, but there would seem to be no functional deficit if it does occur for independent super-elderly patients. This questions whether a surgical intervention should be offered after a displaced distal radial fracture in this population and suggests that they should manage conservatively with the option of radial osteotomy in the small numbers of patients whose malunion becomes symptomatic.

Elderly patients with pelvic fractures have multiple comorbidities and a prolonged costly length of stay on acute trauma wards, where they receive minimal orthopaedic intervention. Future research regarding the potential surgical interventions, such as

ramoplasty, may result in an improved survival rate for these morbid fractures.

The epidemiology of tibial diaphyseal fractures is changing, with a greater proportion occurring in elderly females after a low energy fall. These frailer patients have more severe injuries, with an increased rate of open fractures, and suffer a greater non-union rate. The mortality associated with these fractures is equal to that of a hip fracture and therefore these patients should receive the same level of care and prioritisation.

It seems likely that, with increasing longevity, multiple fractures secondary to low-energy injuries will become more prevalent and form a greater proportion of the trauma workload in the future. There will be financial repercussions associated with the manage and ongoing care for these frail elderly patients sustaining multiple fractures, with high admission rates, prolonged length of stay, and the increased level of care needed upon discharge. A large proportion of these patients underwent conservative management needing only rehabilitation. Hence, these frail patients with an increased mortality risk may benefit from early identification and medical optimization, to facilitate rehabilitation and to provide for their potentially increased care needs, in an effort to improve their outcome and shorten their admission stay.

11.2 Limitations

Specific limitations relating to each of the study chapters have been discussed within each subsection. Here limitations relevant to all of the chapters are discussed. Table 2.2 highlights the differing time periods that each of the trauma databases used was collected over. These relate back to 1998 for the distal radial and proximal humeral databases. The patient population will have likely changed over the intervening years and may not be fully representative of a modern trauma patient. The super-elderly patient of 30 years ago will likely be different from that presenting today, for example with a distal radial fracture, and may have different expectations of their outcome. Other associated injuries were not routinely collected and did not allow a trauma score, such as the injury severity score[105], to be calculated. This may have helped clarify the influence of the polytraumatised elderly patient on outcome in the context of their associated fracture. The observations and assessments recorded throughout this thesis were generally reliant on one observer which varied according to the data collected (Table 2.2). For example, the classification and fracture angle measurement of the distal radial fractures were reliant on one observer (Professor McQueen) and no inter/intra observer variation was assessed or accounted for. This was the same for all of the fracture classifications for all of the study chapters. In addition, no validated patient reported outcome measure was used to assess the outcome of any of the fractures and this should be the focus of future research in view of the potentially increasing functional demands of the modern elderly population.

11.3 Future directions

This body of work only represents a small amount of the work needed to help understand the fracture epidemiology and outcome of elderly and super-elderly patients. They represent a growing proportion of the population and even if the incidence remains the same the overall numbers presenting to healthcare services will increase with subsequent financial consequences. Future work should continue to assess the incidence of fractures in the elderly and super-elderly to assess whether the incidence is changing which can then be used to direct financial services to prepare for the potential increase in demand of fragility fracture trauma services. Optimisation of hip fracture care continues to improve patient care, but how to manage such fractures such as the distal radius in the super-elderly remain controversial. Whether manipulation or surgical fixation should be contemplated should be assessed in the form of a RCT, to assess if the is any functional benefit. This would certainly be cost saving and avoid surgical complications for super-elderly patients if the results of this thesis are affirmed.

The mortality rate for some of the fractures, such as the pubic rami and tibial diaphysis have SMR similar to hip fractures and the unadjusted mortality rate is greater than for some malignant diseases.[204] A palliative care approach is therefore appropriate for patients with advanced non-malignant as well as malignant disease.[197] Thus a fragility fracture in a frail super-elderly person may reasonably trigger a palliative care approach: anticipating and planning for physical, social, psychological and spiritual needs and end of life care.[183] Active supportive care following their fracture is useful to help patients live and die well. It is currently good practice for a hip fracture in a frail, older person to trigger an orthogeriatric review to prevent and treat medical complications.[205] Some authors have suggested that for such patients, the orthopaedic surgeons, orthogeriatricians, patient and family should be involved in discussions about anticipatory care to optimise the quality of life, and in due course, death.[183] These care plans could then be reviewed and taken forward by family physicians, nurses and social carers in the community. A fracture, especially those of the lower limb and pelvis, in the frail super-elderly patient may be act as a stimulus to consider holistic planning and care typical of a palliative care approach. Specialist palliative care in people with lung cancer has been shown to be associated with improved quality of life and even longevity.[206] It may also be beneficial if clinicians adopt a palliative care approach in selected super-elderly patients with fractures.

References

1. **Pratt HJ** Gray Agendas: Interest Groups and Public Pensions in Canada, Britain and the United States. Michigan: University of Michigan Press, Ann Arbor, 1994.

2. **Rosenberg M, Everitt J** Planning for aging populations: inside or outside the walls. *Progress in Planning* 2001;56:119-68.

3. **Clement ND, Court-Brown CM** Four-score years and ten: The fracture epidemiology of the super-elderly [abstract]. *Injury Extra* 2009;40:235.

4. **Bennett KM, Scarborough JE, Vaslef S** Outcome and health care resource utilization in Super-Elderly trauma patients. *J Surg Research* 2010;163:127-31.

5. United Nations. 2019 Revision of World Population Prospects. https://population.un.org/wpp/ (lasted accessed 10th January 2020).

6. Office of National Satistics. http://www.dft.gov.uk/pgr/statistics (lasted accessed 10th January 2020).

7. **He W, Sengupta M, Velkoff VA, DeBarros KA** 65+ in the United States: 2005. In: 2005:1-254.

8. **Dini E, Goldring S** Estimating the changing population of the 'oldest old'. *Popul Trends* 2008:8-16.

9. **Kannus P, Sievanen H, Palvanen M, Jarvinen T, Parkkari J** Prevention of falls and consequent injuries in elderly people. *Lancet* 2005;366:1885-93.

10. **Stevens JA, Corso PS, Finkelstein EA, Miller TR** The costs of fatal and non-fatal falls among older adults. *Inj Prev* 2006;12:290-5.

11. **Johansson B** Fall injuries among elderly persons living at home. *Scand J Caring Sci* 1998;12:67-72.

12. **Johnell O, Kanis JA** An estimate of the worldwide prevalence and disability associated with osteoporotic fractures. *Osteoporos Int* 2006;17:1726-33.

13. **Kannus P, Niemi S, Parkkari J, Palvanen M, Vuori I, Jarvinen M** Nationwide decline in incidence of hip fracture. *J Bone Miner Res* 2006;21:1836-8.

14. **Piirtola M, Hartikainen S, Akkanen J, Isoaho R, Ryynanen O-P, Kivela S-L** Injurious fall needing medical care in older population. *Suomen Laakarilehti* 2001;57:4903-7.

15. **Nurmi I, Narinen A, Luthje P, Tanninen S** Cost analysis of hip fracture treatment among the elderly for the public health services: a 1-year prospective study in 106 consecutive patients. *Arch Orthop Trauma Surg* 2003;123:551-4.

16. **Borgstrom F, Zethraeus N, Johnell O, Lidgren L, Ponzer S, Svensson O, Abdon P, Ornstein E, Lunsjo K, Thorngren KG, Sernbo I, Rehnberg C, Jonsson B** Costs and quality of life associated with osteoporosis-related fractures in Sweden. *Osteoporos Int* 2006;17:637-50.

17. **Nikitovic M, Wodchis WP, Krahn MD, Cadarette SM** Direct health-care costs

attributed to hip fractures among seniors: a matched cohort study. *Osteoporos Int* 2012.

18. **Piirtola M, Sintonen H, Akkanen J, Isoaho R, Ryynanen O-P, Kivela S-L** The cost of acute care of fall injuries in older population. *Suomen Laakarilehti* 2002;57:4841-8.

19. **Bliuc D, Nguyen ND, Milch VE, Nguyen TV, Eisman JA, Center JR** Mortality risk associated with low-trauma osteoporotic fracture and subsequent fracture in men and women. *JAMA* 2009;301:513-21.

20. **Willig R, Keinanen-Kiukaaniemi S, Jalovaara P** Mortality and quality of life after trochanteric hip fracture. *Public Health* 2001;115:323-7.

21. **Gillespie WJ** Extracts from "clinical evidence": hip fracture. *BMJ* 2001;322:968-75.

22. **Karinkanta S, Piirtola M, Sievanen H, Uusi-Rasi K, Kannus P** Physical therapy approaches to reduce fall and fracture risk among older adults. *Nat Rev Endocrinol* 2010;6:396-407.

23. **Hopewell S, Copsey B, Nicolson P, Adedire B, Boniface G, Lamb S** Multifactorial interventions for preventing falls in older people living in the community: a systematic review and meta-analysis of 41 trials and almost 20 000 participants. *Br J Sports Med* 2019.

24. **Kannus P, Uusi-Rasi K, Palvanen M, Parkkari J** Non-pharmacological means to prevent fractures among older adults. *Ann Med* 2005;37:303-10.

25. **Campbell AJ, Borrie MJ, Spears GF** Risk factors for falls in a community-based prospective study of people 70 years and older. *J Gerontol* 1989;44:M112-M117.

26. **Court-Brown CM, Caesar B** Epidemiology of adult fractures: A review. *Injury* 2006;37:691-7.

27. **Court-Brown CM, Clement N** Four score years and ten: an analysis of the epidemiology of fractures in the very elderly. *Injury* 2009;40:1111-4.

28. **Holt G, Macdonald D, Fraser M, Reece AT** The outcome after hip surgery for fracture of the hip in patients aged over 95 years. *J Bone Joint Surg Br* 2006;88:1060-4.

29. **Holt G, Smith R, Duncan K, Hutchison JD, Gregori A** Outcome after surgery for the treatment of hip fracture in the extremely elderly. *J Bone Joint Surg Am* 2008;90:1899-905.

30. Census 2001 population data. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/ageing/articles/livinglongerhowourpopulationischangingandwhyitmatters/2018-08-13. (lasted accessed 10th January 2020).

31. National Records of Scotland. Statistics and Data. www.nrscotland.gov.uk/statistics-and-data. (lasted accessed 10th January 2020).

32. **Fox Ray N, Chan JK, Thamer M** Medical expenditures for the treatment of osteoporotic fractures in the United States in 1995: report from the National Osteoporosis Foundation. In: 12 ed, 1997:24-35.

33. **Johnell O** The socioeconomic burden of fractures: today and in the 21st century. In: 103 ed, 1997:20S-6S.

34. Consensus development conference: prophylaxis and treatment of osteoporosis. *Am J Med* 1991;90:107-10.

35. **Kohrt WM, Bloomfield SA, Little KD, Nelson ME, Yingling VR** American College of Sports Medicine Position Stand: physical activity and bone health. *Med Sci Sports Exerc* 2004;36:1985-96.

36. **Vestergaard P, Rejnmark L, Mosekilde L** Osteoporosis is markedly underdiagnosed: a nationwide study from Denmark. *Osteoporos Int* 2005;16:134-41.

37. **Diaz CM, Garcia JJ, Carrasco JL, Honorato J, Perez CR, Rapado A, Alvarez SC** Prevalence of osteoporosis assessed by densitometry in the Spanish female population. *Med Clin (Barc)* 2001;116:86-8.

38. **Sambrook PN, Seeman E, Phillips SR, Ebeling PR** Preventing osteoporosis: outcomes of the Australian Fracture Prevention Summit. *Med J Aust* 2002;176 Suppl:S1-16.

39. **Nguyen TV, Eisman JA, Kelly PJ, Sambrook PN** Risk factors for osteoporotic fractures in elderly men. *Am J Epidemiol* 1996;144:255-63.

40. **Shatrugna V, Kulkarni B, Kumar PA, Rani KU, Balakrishna N** Bone status of Indian women from a low-income group and its relationship to the nutritional status. *Osteoporos Int* 2005;16:1827-35.

41. **Iki M, Kagamimori S, Kagawa Y, Matsuzaki T, Yoneshima H, Marumo F** Bone mineral density of the spine, hip and distal forearm in representative samples of the Japanese female population: Japanese Population-Based Osteoporosis (JPOS) Study. *Osteoporos Int* 2001;12:529-37.

42. **Donaldson LJ, Cook A, Thomson RG** Incidence of fractures in a geographically defined population. *J Epidemiol Community Health* 1990;44:241-5.

43. **Knowelden J, BUHR AJ, DUNBAR O** INCIDENCE OF FRACTURES IN PERSONS OVER 35 YEARS OF AGE. A REPORT TO THE M.R.C. WORKING PARTY ON FRACTURES IN THE ELDERLY. *Br J Prev Soc Med* 1964;18:130-41.

44. **van Staa TP, Dennison EM, Leufkens HG, Cooper C** Epidemiology of fractures in England and Wales. *Bone* 2001;29:517-22.

45. **Jones S, Johansen A, Brennan J, Butler J, Lyons RA** The effect of socioeconomic deprivation on fracture incidence in the United Kingdom. *Osteoporos Int* 2004;15:520-4.

46. **Donaldson LJ, Reckless IP, Scholes S, Mindell JS, Shelton NJ** The epidemiology of fractures in England. *J Epidemiol Community Health* 2008;62:174-80.

47. **White SM, Griffiths R** Projected incidence of proximal femoral fracture in England: a

report from the NHS Hip Fracture Anaesthesia Network (HIPFAN). *Injury* 2011;42:1230-3.

48. **Cooper C, Cole ZA, Holroyd CR, Earl SC, Harvey NC, Dennison EM, Melton LJ, Cummings SR, Kanis JA** Secular trends in the incidence of hip and other osteoporotic fractures. *Osteoporos Int* 2011;22:1277-88.

49. **Kannus P, Palvanen M, Niemi S, Parkkari J, Jarvinen M** Epidemiology of osteoporotic pelvic fractures in elderly people in Finland: sharp increase in 1970-1997 and alarming projections for the new millennium. *Osteoporos Int* 2000;11:443-8.

50. **Melton LJ, III, Amadio PC, Crowson CS, O'fallon WM** Long-term trends in the incidence of distal forearm fractures. *Osteoporos Int* 1998;8:341-8.

51. **Kannus P, Parkkari J, Niemi S, Palvanen M** Epidemiology of osteoporotic ankle fractures in elderly persons in Finland. *Ann Intern Med* 1996;125:975-8.

52. **Kannus P, Palvanen M, Niemi S, Parkkari J, Jarvinen M, Vuori I** Osteoporotic fractures of the proximal humerus in elderly Finnish persons: sharp increase in 1970-1998 and alarming projections for the new millennium. *Acta Orthop Scand* 2000;71:465-70.

53. **Brogren E, Petranek M, Atroshi I** Incidence and characteristics of distal radius fractures in a southern Swedish region. *BMC Musculoskelet Disord* 2007;8:48.

54. **Thur CK, Edgren G, Jansson KA, Wretenberg P** Epidemiology of adult ankle fractures in Sweden between 1987 and 2004: a population-based study of 91,410 Swedish inpatients. *Acta Orthop* 2012;83:276-81.

55. **Parkkari J, Kannus P, Niemi S, Pasanen M, Jarvinen M, Luthje P, Vuori I** Secular trends in osteoporotic pelvic fractures in Finland: number and incidence of fractures in 1970-1991 and prediction for the future. *Calcif Tissue Int* 1996;59:79-83.

56. **Clement ND, Aitken SA, Duckworth AD, McQueen MM, Court-Brown CM** The outcome of fractures in very elderly patients. *J Bone Joint Surg Br* 2011;93-B:806-10.

57. **Clement ND, Aitken S, Duckworth AD, McQueen MM, Court-Brown CM** Multiple fractures in the elderly. *J Bone Joint Surg Br* 2012;94:231-6.

58. **Holt G, Smith R, Duncan K, Finlayson DF, Gregori A** Early mortality after surgical fixation of hip fractures in the elderly: an analysis of data from the scottish hip fracture audit. *J Bone Joint Surg Br* 2008;90:1357-63.

59. **Parliament UK**. http://www.parliament.uk/documents/commons/lib/research/key_issues/Key%20Issues%20The%20ageing%20population2007.pdf (lasted accessed 10th January 2020).

60. **Baker PN, Salar O, Ollivere BJ, Forward DP, Weerasuriya N, Moppett IK, Moran CG** Evolution of the hip fracture population: time to consider the future? A retrospective observational analysis. *BMJ Open* 2014;4:e004405.

61. **Gjertsen JE, Engesaeter LB, Furnes O, Havelin LI, Steindal K, Vinje T, Fevang JM** The Norwegian Hip Fracture Register: experiences after the first 2 years and 15,576 reported operations. *Acta Orthop* 2008;79:583-93.

62. **Gjertsen JE, Fevang JM, Matre K, Vinje T, Engesaeter LB** Clinical outcome after undisplaced femoral neck fractures. *Acta Orthop* 2011;82:268-74.

63. **Conn KS, Parker MJ** Undisplaced intracapsular hip fractures: results of internal fixation in 375 patients. *Clin Orthop Relat Res* 2004:249-54.

64. **Lagerby M, Asplund S, Ringqvist I** Cannulated screws for fixation of femoral neck fractures. No difference between Uppsala screws and Richards screws in a randomized prospective study of 268 cases. *Acta Orthop Scand* 1998;69:387-91.

65. **Keating JF, Grant A, Masson M, Scott NW, Forbes JF** Randomized comparison of reduction and fixation, bipolar hemiarthroplasty, and total hip arthroplasty. Treatment of displaced intracapsular hip fractures in healthy older patients. *J Bone Joint Surg Am* 2006;88:249-60.

66. **Wiles MD, Moran CG, Sahota O, Moppett IK** Nottingham Hip Fracture Score as a predictor of one year mortality in patients undergoing surgical repair of fractured neck of femur. *Br J Anaesth* 2011;106:501-4.

67. **Avery PP, Baker RP, Walton MJ, Rooker JC, Squires B, Gargan MF, Bannister GC** Total hip replacement and hemiarthroplasty in mobile, independent patients with a displaced intracapsular fracture of the femoral neck: a seven- to ten-year follow-up report of a prospective randomised controlled trial. *J Bone Joint Surg Br* 2011;93:1045-8.

68. **Stewart NA, Chantrey J, Blankley SJ, Boulton C, Moran CG** Predictors of 5 year survival following hip fracture. *Injury* 2011;42:1253-6.

69. **Clement ND, Muzammil A, MacDonald D, Howie CR, Biant LC** Socioeconomic status affects the early outcome of total hip replacement. *J Bone Joint Surg Br* 2011;93B:464-9.

70. **Quah C, Boulton C, Moran C** The influence of socioeconomic status on the incidence, outcome and mortality of fractures of the hip. *J Bone Joint Surg Br* 2011;93:801-5.

71. **Palvanen M, Kannus P, Niemi S, Parkkari J** Update in the epidemiology of proximal humeral fractures. *Clin Orthop Relat Res* 2006;442:87-92.

72. **Kim SH, Szabo RM, Marder RA** Epidemiology of humerus fractures in the United States: Nationwide emergency department sample, 2008. *Arthritis Care Res (Hoboken)* 2011.

73. Office for National Statistics. http://www.ons.gov.uk/ons/rel/npp/national-population-projections/2010-based-projections/index.html (lasted accessed 10th January 2020).

74. **Clement ND, McQueen MM, Court-Brown CM** Social deprivation influences the epidemiology and outcome of proximal humeral fractures in adults for a defined urban population of Scotland. *Eur J Orthop Surg Traumatol* 2013.

75. **Neer CS** Displaced proximal humeral fractures. I. Classification and evaluation. *J Bone Joint Surg Am* 1970;52:1077-89.

76. **Neer CS** Displaced proximal humeral fractures. II. Treatment of three-part and four-part displacement. *J Bone Joint Surg Am* 1970;52:1090-103.

77. **Robinson CM, Amin AK, Godley KC, Murray IR, White TO** Modern perspectives of open reduction and plate fixation of proximal humerus fractures. *J Orthop Trauma* 2011;25:618-29.

78. **Murray IR, Amin AK, White TO, Robinson CM** Proximal humeral fractures: current concepts in classification, treatment and outcomes. *J Bone Joint Surg Br* 2011;93:1-11.

79. **Robinson CM, Longino D, Murray IR, Duckworth AD** Proximal humerus fractures with valgus deformity of the humeral head: the spectrum of injury, clinical assessment and treatment. *J Shoulder Elbow Surg* 2010;19:1105-14.

80. **Iyengar JJ, Ho J, Feeley BT** Evaluation and management of proximal humerus fractures. *Phys Sportsmed* 2011;39:52-61.

81. **Rangan A, Handoll H, Brealey S, Jefferson L, Keding A, Martin BC, Goodchild L, Chuang LH, Hewitt C, Torgerson D** Surgical vs nonsurgical treatment of adults with displaced fractures of the proximal humerus: the PROFHER randomized clinical trial. *JAMA* 2015;313:1037-47.

82. **McQueen M, Caspers J** Colles fracture: does the anatomical result affect the final function? *J Bone Joint Surg Br* 1988;70:649-51.

83. **Cooney WP** Management of Colles' fractures. *J Hand Surg Br* 1989;14:137-9.

84. **Diaz-Garcia RJ, Oda T, Shauver MJ, Chung KC** A systematic review of outcomes and complications of treating unstable distal radius fractures in the elderly. *J Hand Surg Am* 2011;36:824-35.

85. **McQueen MM** Redisplaced unstable fractures of the distal radius. A randomised, prospective study of bridging versus non-bridging external fixation. *J Bone Joint Surg Br* 1998;80:665-9.

86. **Court-Brown CM, Aitken SA, Forward D, O'Toole RV** The epidemiology of fractures. In: Bucholz RW, Heckman JD, Court-Brown CM, Tornetta P, eds. *Rockwood and greens fractures in adults*, 7 ed. Philadelphia: Lippincott, WIliams & Wilkins, 2010:53-77.

87. **Chen NC, Jupiter JB** Management of distal radial fractures. *J Bone Joint Surg Am* 2007;89:2051-62.

88. **Mackenney PJ, McQueen MM, Elton R** Prediction of instability in distal radial fractures. *J Bone Joint Surg Am* 2006;88:1944-51.

89. **Grewal R, MacDermid JC** The risk of adverse outcomes in extra-articular distal radius fractures is increased with malalignment in patients of all ages but mitigated in older patients. *J Hand Surg Am* 2007;32:962-70.

90. **Chang HC, Tay SC, Chan BK, Low CO** Conservative treatment of redisplaced Colles'

fractures in elderly patients older than 60 years old - anatomical and functional outcome. *Hand Surg* 2001;6:137-44.

91. **Young BT, Rayan GM** Outcome following nonoperative treatment of displaced distal radius fractures in low-demand patients older than 60 years. *J Hand Surg Am* 2000;25:19-28.

92. **Beumer A, McQueen MM** Fractures of the distal radius in low-demand elderly patients: closed reduction of no value in 53 of 60 wrists. *Acta Orthop Scand* 2003;74:98-100.

93. **Melton LJ, III, Sampson JM, Morrey BF, Ilstrup DM** Epidemiologic features of pelvic fractures. *Clin Orthop Relat Res* 1981:43-7.

94. **Koval KJ, Aharonoff GB, Schwartz MC, Alpert S, Cohen G, McShinawy A, Zuckerman JD** Pubic rami fracture: a benign pelvic injury? *J Orthop Trauma* 1997;11:7-9.

95. **Hill RM, Robinson CM, Keating JF** Fractures of the pubic rami. Epidemiology and five-year survival. *J Bone Joint Surg Br* 2001;83:1141-4.

96. **Breuil V, Roux CH, Testa J, Albert C, Chassang M, Brocq O, Euller-Ziegler L** Outcome of osteoporotic pelvic fractures: an underestimated severity. Survey of 60 cases. *Joint Bone Spine* 2008;75:585-8.

97. **van Dijk WA, Poeze M, van Helden SH, Brink PR, Verbruggen JP** Ten-year mortality among hospitalised patients with fractures of the pubic rami. *Injury* 2010;41:411-4.

98. **Morris RO, Sonibare A, Green DJ, Masud T** Closed pelvic fractures: characteristics and outcomes in older patients admitted to medical and geriatric wards. *Postgrad Med J* 2000;76:646-50.

99. **Krappinger D, Struve P, Schmid R, Kroesslhuber J, Blauth M** Fractures of the pubic rami: a retrospective review of 534 cases. *Arch Orthop Trauma Surg* 2009;129:1685-90.

100. **Court-Brown CM, McBirnie J** The epidemiology of tibial fractures. *J Bone Joint Surg Br* 1995;77:417-21.

101. **Bengner U, Ekbom T, Johnell O, Nilsson BE** Incidence of femoral and tibial shaft fractures. Epidemiology 1950-1983 in Malmo, Sweden. *Acta Orthop Scand* 1990;61:251-4.

102. **Emami A, Mjoberg B, Ragnarsson B, Larsson S** Changing epidemiology of tibial shaft fractures. 513 cases compared between 1971-1975 and 1986-1990. *Acta Orthop Scand* 1996;67:557-61.

103. **Ritchie AJ, Small JO, Hart NB, Mollan RA** Type III tibial fractures in the elderly: results of 23 fractures in 20 patients. *Injury* 1991;22:267-70.

104. **Cox G, Jones S, Nikolaou VS, Kontakis G, Giannoudis PV** Elderly tibial shaft fractures: Open fractures are not associated with increased mortality rates. *Injury* 2010;41:620-3.

105. **Boyd CR, Tolson MA, Copes WS** Evaluating trauma care: the TRISS method. Trauma Score and the Injury Severity Score. *J Trauma* 1987;27:370-8.

106. **Sammy I, Lecky F, Sutton A, Leaviss J, O'Cathain A** Factors affecting mortality in older trauma patients-A systematic review and meta-analysis. *Injury* 2016;47:1170-83.

107. National Services Scotland (NHS). Scottish Hip Fracture Audit report 2005. http://www.shfa.scot.nhs.uk/AnnualReport/SHFA_Report_2005.pdf (lasted accessed 10th January 2020).

108. **Garden RS** Low-angle fixation in fractures of the femoral neck. *J Bone Joint Surg Br* 1961;43:647-63.

109. The Scottish Government Scottish Index of Multiple Deprivation 2009: General Report. https://www.gov.scot/publications/scottish-index-multiple-deprivation-2009-general-report/. The Scottish Government, 2009. (lasted accessed 10th January 2020).

110. **Pauwels F** Der Schenkelhalsbruch: Ein mechaniisched problem. Stuttgart: Ferdinand Enke Verlag, 1935.

111. **Garden RS** Malreduction and avascular necrosis in subcapital fractures of the femur. *J Bone Joint Surg Br* 1971;53:183-97.

112. Scottish Intercollegiate Guidelines Network. Management of hip fracture in older people SIGN 111. http://www.sign.ac.uk (lasted accessed 10th January 2020).

113. **Carstairs V, Morris R** Deprivation and Health in Scotland. Aberdeen: Aberdeen University Press, 1991.

114. Information services division Scotland. Deprivation. 2010. http://showcc.nhsscotland.com/isd//3211.html (lasted accessed 10th January 2020).

115. **Constant CR, Murley AH** A clinical method of functional assessment of the shoulder. *Clin Orthop Relat Res* 1987:160-4.

116. **Bjorkenheim JM, Pajarinen J, Savolainen V** Internal fixation of proximal humeral fractures with a locking compression plate: a retrospective evaluation of 72 patients followed for a minimum of 1 year. *Acta Orthop Scand* 2004;75:741-5.

117. **Siwach R, Singh R, Rohilla RK, Kadian VS, Sangwan SS, Dhanda M** Internal fixation of proximal humeral fractures with locking proximal humeral plate (LPHP) in elderly patients with osteoporosis. *J Orthop Traumatol* 2008;9:149-53.

118. **Mattyasovszky SG, Burkhart KJ, Ahlers C, Proschek D, Dietz SO, Becker I, Muller-Haberstock S, Muller LP, Rommens PM** Isolated fractures of the greater tuberosity of the proximal humerus: a long-term retrospective study of 30 patients. *Acta Orthop* 2011;82:714-20.

119. **Kaplan EL, Meier P** Nonparametric estimation from incomplete observation. *J Am Statist Assn* 1958;53:457-81.

120. **Marsh JL, Slongo TF, Agel J, Broderick JS, Creevey W, DeCoster TA, Prokuski L, Sirkin MS, Ziran B, Henley B, Audige L** Fracture and dislocation classification compendium - 2007: Orthopaedic Trauma Association classification, database and outcomes committee. *J Orthop Trauma* 2007;21:S1-133.

121. **Rothstein JM, Miller PJ, Roettger RF** Goniometric reliability in a clinical setting. Elbow and knee measurements. *Phys Ther* 1983;63:1611-5.

122. **Gajdosik RL, Bohannon RW** Clinical measurement of range of motion. Review of goniometry emphasizing reliability and validity. *Phys Ther* 1987;67:1867-72.

123. **BECHTOL CO** Grip test; the use of a dynamometer with adjustable handle spacings. *J Bone Joint Surg Am* 1954;36-A:820-4.

124. **KIRKPATRICK JE** Evaluation of grip loss. *Calif Med* 1956;85:314-20.

125. **KIRKPATRICK JE** Evaluation of grip loos; a factor of permanent partial disability in California. *Ind Med Surg* 1957;26:285-9.

126. **Wakefield AE, McQueen MM** The role of physiotherapy and clinical predictors of outcome after fracture of the distal radius. *J Bone Joint Surg Br* 2000;82:972-6.

127. **Rommens PM, Wagner D, Hofmann A** Do We Need a Separate Classification for Fragility Fractures of the Pelvis? *J Orthop Trauma* 2019;33 Suppl 2:S55-S60.

128. **The Scottish Government** SIMD Postcode to Datazone Lookup Table. In: Vol. 2010 ed. Edinburgh: The Scottish Government, 2009.

129. **Tscherne H, Oestern HJ** A new classification of soft-tissue damage in open and closed fractures (author's transl). *Unfallheilkunde* 1982;85:111-5.

130. **Gustilo RB, Anderson JT** Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. *J Bone Joint Surg Am* 1976;58:453-8.

131. **Gustilo RB, Mendoza RM, Williams DN** Problems in the management of type III (severe) open fractures: a new classification of type III open fractures. *J Trauma* 1984;24:742-6.

132. **Court-Brown CM, Will E, Christie J, McQueen MM** Reamed or unreamed nailing for closed tibial fractures. A prospective study in Tscherne C1 fractures. *J Bone Joint Surg Br* 1996;78:580-3.

133. **McQueen MM, Court-Brown CM** Compartment monitoring in tibial fractures. The pressure threshold for decompression. *J Bone Joint Surg Br* 1996;78:99-104.

134. General Register Office for Scotland. http://www.gro-scotland.gov.uk (lasted accessed 10th January 2020).

135. **Carstairs V** Deprivation indices: their interpretation and use in relation to health. *J Epidemiol Community Health* 1995;49 Suppl 2:S3-S8.

136. **Kanis JA, Oden A, McCloskey EV, Johansson H, Wahl DA, Cooper C** A systematic

review of hip fracture incidence and probability of fracture worldwide. *Osteoporos Int* 2012;23:2239-56.

137. www.parliament.uk The ageing population http://www.parliament.uk/business/publications/research/key-issues-for-the-new-parliament/value-for-money-in-public-services/the-ageing-population/. (lasted accessed 10th January 2020).

138. **Kannus P, Niemi S, Parkkari J, Sievanen H** Continuously declining incidence of hip fracture in Finland: Analysis of nationwide database in 1970-2016. *Arch Gerontol Geriatr* 2018;77:64-7.

139. **Wilson C, Willis C, Hendrikz JK, Le BR, Bellamy N** Speed cameras for the prevention of road traffic injuries and deaths. *Cochrane Database Syst Rev* 2010:CD004607.

140. **Arneson TJ, Melton LJ, III, Lewallen DG, O'fallon WM** Epidemiology of diaphyseal and distal femoral fractures in Rochester, Minnesota, 1965-1984. *Clin Orthop Relat Res* 1988:188-94.

141. **Diamantopoulos AP, Rohde G, Johnsrud I, Skoie IM, Hochberg M, Haugeberg G** The epidemiology of low- and high-energy distal radius fracture in middle-aged and elderly men and women in Southern Norway. *PLoS One* 2012;7:e43367.

142. **Wise J** Number of "oldest old" has doubled in the past 25 years. *BMJ* 2010;340:c3057.

143. **Rankin JK, Woollacott MH, Shumway-Cook A** Cognitive influence on postural stability: a neuromuscular analysis in young and older adults. In: 55 ed, 2000:M112-M119.

144. **Allum JHJ, Carpenter MG, Honegger F** Age-dependant variations in the directional sensitivity of balance corrections and compensatory arm movements in man. In: 542 ed, 2002:643-63.

145. **LeBlanc ES, Rosales AG, Genant HK, Dell RM, Friess DM, Boardman DL, Santora AC, Bauer DC, de Papp AE, Black DM, Orwoll ES** Radiological criteria for atypical features of femur fractures: what we can learn when applied in a clinical study setting. *Osteoporos Int* 2019;30:1287-95.

146. **Nevitt MC, Cummings SR, Browner WS, Seeley DG, Cauley JA, Vogt TM, Black DM** The accuracy of self-report of fractures in elderly women: evidence from a prospective study. *Am J Epidemiol* 1992;135:490-9.

147. **Aitken SA, Rodrigues MA, Duckworth AD, Clement ND, McQueen MM, Court-Brown CM** Determining the incidence of adult fractures: how accurate are emergency department data? *Epidemiology Research International* 2012:ID 837928-7 pages.

148. General Register Office for Scotland. http://www.gro-scotland.gov.uk/press/news2007/rise-projected-for-scotlands-population.html (lasted accessed 10th January 2020).

149. **Jensen JS, Bagger J** Long-term social prognosis after hip fractures. *Acta Orthop Scand* 1982;53:97-101.

150. **Jette AM, Harris BA, Cleary PD, Campion EW** Functional recovery after hip fracture. *Arch Phys Med Rehabil* 1987;68:735-40.

151. **Lawrence TM, White CT, Wenn R, Moran CG** The current hospital costs of treating hip fractures. *Injury* 2005;36:88-91.

152. **Chilov MN, Cameron ID, March LM** Evidence-based guidelines for fixing broken hips: an update. *Med J Aust* 2003;179:489-93.

153. **Adams AL, Schiff MA, Koepsell TD, Rivara FP, Leroux BG, Becker TM, Hedges JR** Physician consultation, multidisciplinary care, and 1-year mortality in Medicare recipients hospitalized with hip and lower extremity injuries. *J Am Geriatr Soc* 2010;58:1835-42.

154. **Handoll HH, Cameron ID, Mak JC, Finnegan TP** Multidisciplinary rehabilitation for older people with hip fractures. *Cochrane Database Syst Rev* 2009:CD007125.

155. **Cserhati P, Kazar G, Manninger J, Fekete K, Frenyo S** Non-operative or operative treatment for undisplaced femoral neck fractures: a comparative study of 122 non-operative and 125 operatively treated cases. *Injury* 1996;27:583-8.

156. **Barnes R, Brown JT, Garden RS, Nicoll EA** Subcapital fractures of the femur. A prospective review. *J Bone Joint Surg Br* 1976;58:2-24.

157. **Chiu FY, Lo WH, Yu CT, Chen TH, Chen CM, Huang CK** Percutaneous pinning in undisplaced subcapital femoral neck fractures. *Injury* 1996;27:53-5.

158. **Duckworth AD, Bennet SJ, Aderinto J, Keating JF** Fixation of intracapsular fractures of the femoral neck in young patients: risk factors for failure. *J Bone Joint Surg Br* 2011;93:811-6.

159. **Parker MJ, Palmer CR** Prediction of rehabilitation after hip fracture. *Age Ageing* 1995;24:96-8.

160. **Deneka DA, Simonian PT, Stankewich CJ, Eckert D, Chapman JR, Tencer AF** Biomechanical comparison of internal fixation techniques for the treatment of unstable basicervical femoral neck fractures. *J Orthop Trauma* 1997;11:337-43.

161. **Kauffman JI, Simon JA, Kummer FJ, Pearlman CJ, Zuckerman JD, Koval KJ** Internal fixation of femoral neck fractures with posterior comminution: a biomechanical study. *J Orthop Trauma* 1999;13:155-9.

162. **Dolatowski FC, Frihagen F, Bartels S, Opland V, Saltyte BJ, Talsnes O, Hoelsbrekken SE, Utvag SE** Screw Fixation Versus Hemiarthroplasty for Nondisplaced Femoral Neck Fractures in Elderly Patients: A Multicenter Randomized Controlled Trial. *J Bone Joint Surg Am* 2019;101:136-44.

163. **Kammerlander C, Roth T, Friedman SM, Suhm N, Luger TJ, Kammerlander-Knauer U, Krappinger D, Blauth M** Ortho-geriatric service--a literature review comparing different models. *Osteoporos Int* 2010;21:S637-S646.

164. **Court-Brown CM, Garg A, McQueen MM** The epidemiology of proximal humeral fractures. *Acta Orthop Scand* 2001;72:365-71.

165. **Kannus P, Palvanen M, Niemi S, Sievanen H, Parkkari J** Rate of proximal humeral fractures in older Finnish women between 1970 and 2007. *Bone* 2009;44:656-9.

166. **Clayton RA, Gaston MS, Ralston SH, Court-Brown CM, McQueen MM** Association between decreased bone mineral density and severity of distal radial fractures. *J Bone Joint Surg Am* 2009;91:613-9.

167. **Shortt NL, Robinson CM** Mortality after low-energy fractures in patients aged at least 45 years old. In: 19 ed, 2005:396-403.

168. **Clement ND** Can we decipher indications and outcomes of the PHILOS plate for fractures of the proximal humerus? *Int Orthop* 2013;37:1199-200.

169. **Olerud P, Ahrengart L, Ponzer S, Saving J, Tidermark J** Hemiarthroplasty versus nonoperative treatment of displaced 4-part proximal humeral fractures in elderly patients: a randomized controlled trial. *J Shoulder Elbow Surg* 2011;20:1025-33.

170. **Flinkkila T, Sirnio K, Hippi M, Hartonen S, Ruuhela R, Ohtonen P, Hyvonen P, Leppilahti J** Epidemiology and seasonal variation of distal radius fractures in Oulu, Finland. *Osteoporos Int* 2011;22:2307-12.

171. **Jenkins NH** The unstable Colles' fracture. *J Hand Surg Br* 1989;14:149-54.

172. **Kelly AJ, Warwick D, Crichlow TP, Bannister GC** Is manipulation of moderately displaced Colles' fracture worthwhile? A prospective randomized trial. *Injury* 1997;28:283-7.

173. **Colles A** On the fracture of the carpal extremity of the radius. *The Edinburgh Medical and Surgical Journal* 1814;10:182-6.

174. **Germann G, Wind G, Harth A** [The DASH(Disability of Arm-Shoulder-Hand) Questionnaire--a new instrument for evaluating upper extremity treatment outcome]. *Handchir Mikrochir Plast Chir* 1999;31:149-52.

175. **Amorosa LF, Vitale MA, Brown S, Kaufmann RA** A functional outcomes survey of elderly patients who sustained distal radius fractures. *Hand (N Y)* 2011;6:260-7.

176. **Hove LM, Molster AO** Surgery for posttraumatic wrist deformity. Radial osteotomy and/or ulnar shortening in 16 Colles' fractures. *Acta Orthop Scand* 1994;65:434-8.

177. **Jupiter JB, Ring D** A comparison of early and late reconstruction of malunited fractures of the distal end of the radius. *J Bone Joint Surg Am* 1996;78:739-48.

178. **Prommersberger KJ, van SJ, Lanz UB** Outcome after corrective osteotomy for malunited fractures of the distal end of the radius. *J Hand Surg Br* 2002;27:55-60.

179. **von CA, Nagy L, Arbab D, Dumont CE** Corrective osteotomies in malunions of the distal radius: do we get what we planned? *Clin Orthop Relat Res* 2006;450:179-85.

180. **McQueen MM, Wakefield A** Distal radial osteotomy for malunion using non-bridging external fixation: good results in 23 patients. *Acta Orthop* 2008;79:390-5.

181. **Steinitz D, Guy P, Passariello A** All superior pubic rami fractures are not created equal. *Can J Surg* 2004;47:422-5.

182. **Leung AH, Lam TP, Cheung WH, Chan T, Sze PC, Lau T, Leung KS** An orthogeriatric collaborative intervention program for fragility fractures: a retrospective cohort study. *J Trauma* 2011;71:1390-4.

183. **Murray IR, Biant LC, Clement ND, Murray SC** Should a hip fracture in a frail older person be a trigger for assessment of palliative care needs? *BMJ Support Palliat Care* 2011;1:3-4.

184. **Beall DP, D'souza SL, Costello RF** Percutaneous augmentation of the superior pubic ramus with polymethylmethacrylate: treatment of acute and chronic insufficiency fractures. *Skeletal Radiol* 2007;36:979-83.

185. **Sermon A, Broos P, Vanderschot P** Total hip replacement for acetabular fractures. Results in121 patients operated between 1983 and 2003. *Injury* 2008;39:914-21.

186. **Singer BR, McLauchlan GJ, Robinson CM, Christie J** Epidemiology of fractures in 15,000 adults: the influence of age and gender. *J Bone Joint Surg Br* 1998;80:243-8.

187. **Cook JL, Dzubow LM** Aging of the skin: implications for cutaneous surgery. *Arch Dermatol* 1997;133:1273-7.

188. **Oni OO, Hui A, Gregg PJ** The healing of closed tibial shaft fractures. The natural history of union with closed treatment. *J Bone Joint Surg Br* 1988;70:787-90.

189. **Chatziyiannakis AA, Verettas DA, Raptis VK, Charpantitis ST** Nonunion of tibial fractures treated with external fixation. Contributing factors studied in 71 fractures. *Acta Orthop Scand Suppl* 1997;275:77-9.

190. **Steele J, Pedersen JB, Jay S, Lohn J, Nielsen D, Vesely M, Trompeter A** Gustilo-Anderson type III tibial fractures have poor functional outcomes in patients over 75 years. *J Clin Orthop Trauma* 2020;11:S71-S75.

191. **Gaston MS, Simpson AH** Inhibition of fracture healing. *J Bone Joint Surg Br* 2007;89:1553-60.

192. **Wiles MD, Moran CG, Sahota O, Moppett IK** Nottingham Hip Fracture Score as a predictor of one year mortality in patients undergoing surgical repair of fractured neck of femur. *Br J Anaesth* 2011;106:501-4.

193. **von FM, Besjakov J, Akesson K** Long-term survival and fracture risk after hip fracture: a 22-year follow-up in women. *J Bone Miner Res* 2008;23:1832-41.

194. **Larsson G, Holgers KM** Fast-track care for patients with suspected hip fracture. *Injury* 2011;42:1257-61.

195. **Rogers FB, Shackford SR, Keller MS** Early fixation reduces morbidity and mortality in elderly patients with hip fractures from low-impact falls. *J Trauma*

1995;39:261-5.

196. **Detering KM, Hancock AD, Reade MC, Silvester W** The impact of advance care planning on end of life care in elderly patients: randomised controlled trial. *BMJ* 2010;340:c1345.

197. **Murray SA, Sheikh A** Palliative Care Beyond Cancer: Care for all at the end of life. *BMJ* 2008;336:958-9.

198. **Kannus P, Parkkari J, Koskinen S, Niemi S, Palvanen M, Jarvinen M, Vuori I** Fall-induced injuries and deaths among older adults. *JAMA* 1999;281:1895-9.

199. **Masud T, Morris RO** Epidemiology of falls. *Age Ageing* 2001;30 Suppl 4:3-7.

200. **Tinetti ME, Speechley M, Ginter SF** Risk factors for falls among elderly persons living in the community. *N Engl J Med* 1988;319:1701-7.

201. **Von Heideken P, Gustafson Y, Kallin K, Jensen J, Lundin-Olsson L** Falls in the very old people: The population based Umea study in Sweden. In: 49 ed, 2009:390-6.

202. Centre of Disease Control and Prevention. Cost of falls among older adults. http//www.cdc.gov.homeandrecreationalsafety/falls/fallscost. (lasted accessed 10th January 2020).

203. **Court-Brown CM, Aitken SA, Ralston SH, McQueen MM** The relationship of fall-related fractures to social deprivation. *Osteoporos Int* 2011;22:1211-8.

204. **Kannegaard PN, van der Mark S, Eiken P, Abrahamsen B** Excess mortality in men compared with women following a hip fracture. National analysis of comedications, comorbidity and survival. *Age Ageing* 2010;39:203-9.

205. **Adunsky A, Lerner-Geva L, Blumstein T, Boyko V, Mizrahi E, Arad M** Improved survival of hip fracture patients treated within a comprehensive geriatric hip fracture unit, compared with standard of care treatment. *J Am Med Dir Assoc* 2011;12:439-44.

206. **Temel JS, Greer JA, Muzikansky A, Gallagher ER, Admane S, Jackson VA, Dahlin CM, Blinderman CD, Jacobsen J, Pirl WF, Billings JA, Lynch TJ** Early palliative care for patients with metastatic non-small-cell lung cancer. *N Engl J Med* 2010;363:733-42.

Appendix 1

The changing epidemiology of fall-related fractures in adults

Court-Brown CM, Clement ND, Duckworth AD, Biant LC, McQueen MM

Injury. 2017 Apr;48(4):819-824. doi: 10.1016/j.injury.2017.02.021.

Appendix 2

Manipulation of displaced distal radial fractures in the superelderly: prediction of malunion and the degree of radiographic improvement.

Clement ND, Duckworth AD, Court-Brown CM, McQueen MM.

Adv Orthop. 2014;2014:785473. doi: 10.1155/2014/785473.

Appendix 3

The outcome of proximal humeral fractures in the elderly: predictors of mortality and function.

Clement ND, Duckworth AD, McQueen MM, Court-Brown CM.

Bone Joint J. 2014 Jul;96-B(7):970-7. doi: 10.1302/0301-620X.96B7.32894.

Appendix 4

Distal radial fractures in the superelderly: does malunion affect functional outcome?

Clement ND, Duckworth AD, Court-Brown CM, McQueen MM.

ISRN Orthop. 2014 Mar 4;2014:189803. doi: 10.1155/2014/189803.

Appendix 5

Elderly pelvic fractures: the incidence is increasing and patient demographics can be used to predict the outcome.

Clement ND, Court-Brown CM.

Eur J Orthop Surg Traumatol. 2014 Dec;24(8):1431-7. doi: 10.1007/s00590-014-1439-7.

Appendix 6

The spectrum of fractures in the elderly.

Court-Brown CM, Clement ND, Duckworth AD, Aitken S, Biant LC, McQueen MM.

Bone Joint J. 2014 Mar;96-B(3):366-72. doi: 10.1302/0301-620X.96B3.33316.

Appendix 7

The outcome of tibial diaphyseal fractures in the elderly.

Clement ND, Beauchamp NJ, Duckworth AD, McQueen MM, Court-Brown CM.

Bone Joint J. 2013 Sep;95-B(9):1255-62. doi: 10.1302/0301-620X.95B9.31112.

Appendix 8

Undisplaced intracapsular hip fractures in the elderly: predicting fixation failure and mortality. A prospective study of 162 patients.

Clement ND, Green K, Murray N, Duckworth AD, McQueen MM, Court-Brown CM.

J Orthop Sci. 2013 Jul;18(4):578-85. doi: 10.1007/s00776-013-0400-7.

Appendix 9

Multiple fractures in the elderly.

Clement ND, Aitken S, Duckworth AD, McQueen MM, Court-Brown CM.

J Bone Joint Surg Br. 2012 Feb;94(2):231-6. doi: 10.1302/0301-620X.94B2.27381.

Appendix 10

The outcome of fractures in very elderly patients.

Clement ND, Aitken SA, Duckworth AD, McQueen MM, Court-Brown CM.

J Bone Joint Surg Br. 2011 Jun;93(6):806-10. doi: 10.1302/0301-620X.93B6.25596.

Appendix 11

Ethical approval for use of existing trauma databases used in this thesis.