Morbidity and Mortality Following Pelvic Rami Fractures in an Elderly Newfoundland Population

By

© Christopher B Hamilton MD

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Abstract

Introduction: Pelvic rami fractures in the elderly are associated with significant morbidity and mortality. Despite our rapidly aging population there is a paucity of literature dealing with fractures of the pelvic rami in this age group. The purpose of this study is report mortality rates following these injuries in the Eastern region of Newfoundland. Additionally, we aim to describe and quantify the important resultant morbidity in this vulnerable elderly population .

Methods: A retrospective chart review was performed of all the pelvic fractures in individuals over the age of 60 between 2000 and 2005 in the Eastern Health region of Newfoundland and Labrador. From these patients, only those with the radiographic parameters consistent with low energy pattern pelvic ring injuries were included. Excluded from the study were those with concurrent fractures of the femur. Survival data, comorbidities, injury characteristics, hospital stay, ambulatory status, and place of residence were recorded from the chart. A surrogate control group was formulated from Statistics Canada survival data for use as a survival comparison group.

Results: There were 80 fractures of the pelvis identified in patients over 60 years old from 2000-2005. Of these, 43 met our inclusion/exclusion criteria and were used in our analysis. The one and five year mortalities of these patients were 16.3% (95% CI; 7.80% to 30.3%) and 58.1% (95% CI; 43.3% to 71.6%), respectively. These were both significantly different from the point estimates from our constructed age and gender matched control group from the Statistics Canada data

of 6.58% (one year mortality) and 31.3% (five year mortality). Morbidity was quantified by change in ambulatory status (independent, walker/cane assisted, wheelchair) and change in residential independence (independent, assisted living, nursing home). Post fracture, 36% of patients permanently required increased ambulatory aids and 21% of patients required a permanent increase in everyday level of care.

Conclusion: This study suggests that there may be significantly increased mortality and morbidity following low energy pattern pelvic rami fractures in an elderly population compared to age and gender matched controls. In contrast to previous studies describing these injuries, there is greater homogeneity in this population with respect to age and mechanism of injury. This study generates several important hypotheses for future research and in particular highlights the need for larger prospective studies to identify factors predicting the highest risk for poor outcomes in this population.

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Dedication

This work, many years in the making, is dedicated to those closest to me.

For my parents. Your steadfast support of me to this day has and will continue to be a large part of achieving any goal moving forward. This project would be impossible without this support, and for that I thank you.

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

APC	Anteroposterior Compression
AO	Arbeitsgemeinschaft fur Osteosynthesefragen
BMD	Bone Mineral Density
COPD	Chronic Obstructive Pulmonary Disease
CT	Computed Tomography
DXA	Dual-energy X-ray Absorptiometry
EPV	Events per Predictor Variable
FRAX	Fracture Risk Assessment Tool
HR	Hazard Ratio
HREA	Health Research Ethics Authority
LC	Lateral Compression
MRI	Magnetic Resonance Imaging
MVA	Motor Vehicle Accident
MVPA	Motor Vehicle Pedestrian Accident
NLCHI	Newfoundland and Labrador Centre for Health Information
OTA	Orthopaedic Trauma Association
PMMA	Polymethylmethacrylate
PTH	Parathyroid Hormone

RCT	Randomized Controlled Trial
SI	Sacroiliac
VAS	Visual Analogue Scale
VS	Vertical shear
WHO	World Health Organization

Chapter 1 Introduction

1.1 Low Energy Pelvic Ring Fractures

Fractures about the pelvic ring can be divided into many categories. The energy required to impart the injury is likely the most important dividing factor. The demographics of the patients sustaining pelvic fractures can often predict the level of energy involved. Low energy fracture patterns generally will occur in weaker, osteoporotic bone. They are usually the result of falls from standing height.[1] In contrast, high energy pelvic ring fracture patterns will generally require a fall from significant height or motor vehicle accident (MVA) to impart such an injury. While these two patterns of injury affect the same bones, the injuries are quite different because of the difference in the energy required to cause them. The fracture patterns seen on radiographs vary but the greatest difference is in the damage sustained by surrounding soft tissues. High energy pelvic fractures coincide with significant trauma about the pelvis including vascular and ligamentous disruptions that can often lead to significant hemodynamic instability in the patient.[2] There are also frequent concomitant injuries such as life threatening intraabdominal, intrathoracic, and intracranial injuries when a high energy pelvic fracture occurs.[2]

This hemodynamic instability and associated life threatening injuries are generally not seen in low energy pelvic ring fractures. The overall effect on patient morbidity and mortality is therefore very different. Low energy fractures of the pelvis are frequent isolated injuries.[3] They most commonly occur in elderly patients.[3] Frequently, these patients have significant medical comorbidities prior to their fall.[3] Recovery can, therefore, be somewhat of a challenge despite the relatively minor injury compared to that of high energy pelvic fractures. The presumed decreased physiologic reserve to overcome injury in an elderly patient suggests that low energy pelvic fractures will have a significant effect on morbidity and mortality.

1.2 Aging Population and Osteoporosis

The segment of the population aged 65 and older in Europe is expected to rise from 68 million in 1990 to 133 million in 2050; that number in Asia will grow from 145 million to 894 million.[4] Statistics Canada projects the proportion of the total population aged over 65 in 2030 will be about 23%, from 15.3% in 2013.[5] In Newfoundland and Labrador that increase is expected to be even more dramatic with an increase from 17.1% in 2013 to between 31.6% and 35.9% in 2038.[5]

Coinciding with this increase in age is an increase in osteoporosis. Osteoporosis is defined by the US National Institute of Health as "a disease characterized by low bone mass and micro architectural deterioration of bone tissue, leading to enhanced bone fragility and a consequent increase in fracture risk."[6] To allow the diagnosis of osteoporosis prior to fracture, the World Health Organization (WHO) has operationally defined osteoporosis on the basis of bone mineral density (BMD) measurements. WHO criteria define osteoporosis as BMD of 2.5 standard deviations or more below the mean value of a young healthy woman.[7] Using this definition, the Canadian Multicentre Osteoporosis Study estimated the prevalence of osteoporosis in those over 50 years old to be 21.3% in women and 5.5% in men.[8]

The goal of the operational objective definition of osteoporosis is to predict future fragility fracture. It must be understood, however, that the most significant risk factor for future fracture is previous fracture. Up to forty percent of women who sustain a fragility fracture have had a previous fracture.[9] In the year following a hip fracture, the risk of sustaining another fracture is 5-10%.[10] The lifetime risk of subsequent fracture following a hip fracture is increased 2.5 fold.[10]

As would be anticipated, concurrently with the increasing age of the world's population, the rate of osteoporosis is increasing as well. The likelihood of developing osteoporosis is greatest in North America and Europe; however as the population longevity continues to rise in developing nations, the prevalence of osteoporosis will rise with it.[7] Based on census data in the United States from 2000, the prevalence of osteoporosis at that time was about 10 million Americans, with that number predicted to be greater than 14 million by 2020.[11]

It has been recognized that BMD readings are the best individual value to predict fragility fracture; however, this predictive value can be enhanced significantly with the addition of other biochemical indices and clinical risk factors.[12] With this in mind, the WHO developed the Fracture Risk Assessment Tool (FRAX) using a series of meta-analyses that identified clinical risk factors for osteoporosis.[13–15] The FRAX tool, which has been individualized from country to country based on epidemiological data, uses several factors to predict the ten-year probability of a major osteoporotic fracture. This includes proximal humerus, distal radius, proximal femur and clinical vertebral fractures. The questionnaire assesses clinical factors: age, sex, BMI, previous fracture, parental hip fracture, current smoking, glucocorticoids, rheumatoid arthritis, secondary osteoporosis, and alcohol intake per day (see Appendix 1 – FRAX ® WHO Fracture Risk Assessment Questionnaire).

The purpose of such a risk assessment tool is to provide clinicians with some guidance of when to initiate osteoporosis treatment. It must be recognized when using such a tool that there are limitations and that each patient will need to be assessed individually. The FRAX tool is likely most accurate in predicting hip fractures as the databases used to develop the tool are composed largely of individuals with treated hip fractures. Distal radius and proximal humerus fractures are generally treated as outpatients, which will lead to an underestimation of their incidence in most studies. It is also difficult to elucidate an accurate incidence of acute vertebral fractures as many will not come to medical attention.

In addition to the “major osteoporotic” fractures and hip fractures included in FRAX, several large studies have shown that almost all types of fracture are increased in osteoporotic bone.[16,17] These other fractures that are secondary to osteoporosis can certainly cause significant morbidity, mortality and burden on a health care system. One such group of fractures that can certainly be attributed to osteoporosis are low energy fractures about the pelvic ring. Low energy pelvic fractures will normally not occur in young individuals with healthy bone.

1.3 Pelvic Ring Anatomy

The pelvis serves as a critical structure in the human skeleton. It provides the mechanical link between the between the axial skeleton and the lower extremity. This is of critical importance to the transfer of the weight of the body to the major weight-bearing locomotive structures. The forces involved in sitting, standing and ambulating are all dependent on an intact, stable pelvis. The pelvis is also vital in housing and protecting vital organs and structures that pass through from the genitourinary, neurologic, vascular, and gastrointestinal systems.[18]

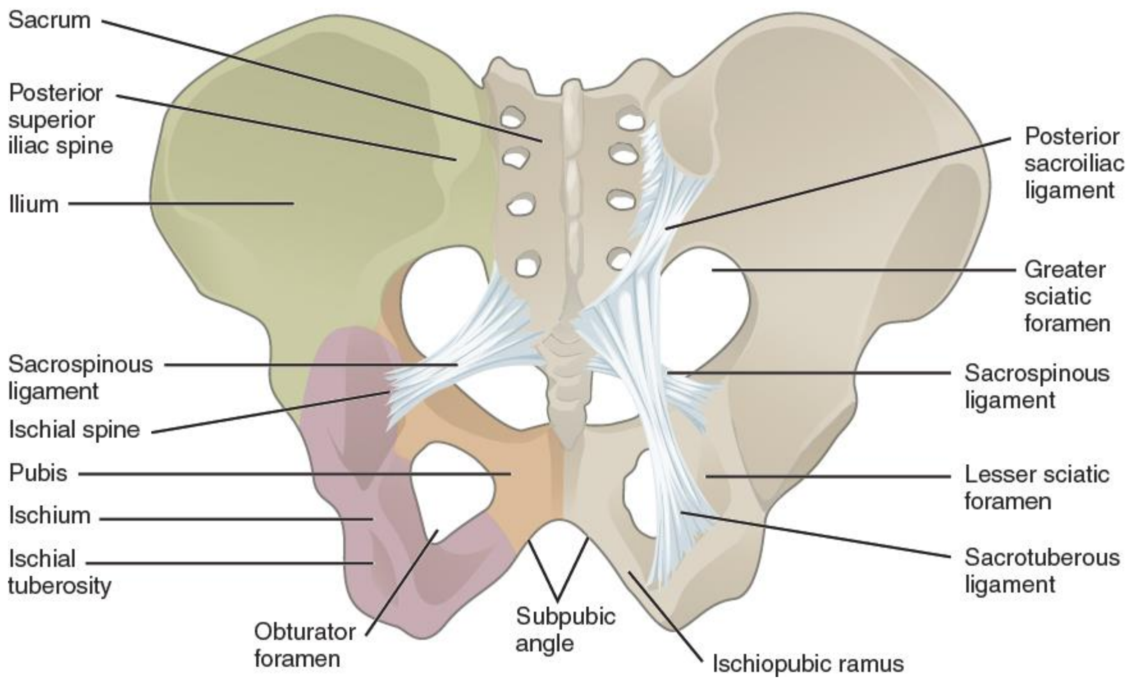


Figure 1-1 Bony and Ligamentous Pelvic Anatomy

The bony pelvis is made up of three interconnected bones: the sacrum and two innominate bones (Figure 1.1). The innominate bones are formed from the fusion of three ossification centers: the ilium, the ischium, and the pubis. In childhood these are seen as three separate bones interconnected at the triradiate cartilage of the acetabulum. At skeletal maturity, they fuse together to form the complete innominate bone. The bony anatomy of the sacrum and innominate bones provides no inherent stability without ligamentous attachments.[19]

The two innominate bones articulate posteriorly with the sacrum at two sacroiliac (SI) joints and anteriorly meet one another at the pubic symphysis. The sacroiliac joint proper is a synovial joint with articular cartilage on the sacral side and fibrocartilage on the iliac side and provides minimal stability.[1918] The bony surfaces of the pubic symphysis are covered in hyaline cartilage and surrounded by a thick band of fibrous tissue.

Stability of the pelvic ring is primarily maintained by a combination of strong ligamentous structures. The strongest of these structures are found in the posterior aspect of the SI joints.[19] This ligamentous complex is formed of short and long posterior SI ligaments (Figure 1.1). The long ligaments run from the lateral aspect of the sacrum to the posterior superior iliac spines and the short ligaments run obliquely from the posterior ridge of the sacrum to the posterior superior and inferior iliac spines. The weaker anterior SI ligaments provide some stability but are disrupted with significantly less force than the posterior ligaments. The fibrous band covering the pubic symphysis is usually thickest anteriorly and superiorly and is reinforced inferiorly by muscular insertions.

There are two other ligamentous complexes within the pelvis that provide significant stability in addition to the previously mentioned periarticular ligaments. Firstly, the sacrotuberous ligament runs from the posterolateral sacrum to the ischial tuberosity (Figure 1.1). This ligament is particularly important in vertical stability of the pelvis.[19] Second is the sacrospinous ligament which runs from the lateral margins of the sacrum and coccyx and inserts onto the ischial spine (Figure 1.1). The sacrospinous ligament is felt to be important in resisting external rotation forces.

Biomechanical studies have sequentially sectioned these various ligaments of the pelvis to determine their contribution to pelvic ring stability. When the symphysis alone was sectioned, it was found that no greater than 2.5 cm of symphyseal diastasis was possible with mechanical loading with the remaining stabilizing structures of the pelvis intact.[20] With the additional sectioning of the anterior SI ligaments and the pelvic floor ligaments, greater than 2.5 cm of symphyseal diastasis was noted. Further sectioning of the posterior SI ligaments leads to the pelvis being grossly unstable in all directions.[19] A biomechanical study examining vertical symphysis displacement with a flexion moment on the hemipelvis concluded that with less than 11 mm the pelvis likely has maintained rotational stability in the flexion-extension plane.[21]

1.4 Pelvic Ring Injury Classifications

The stability of the pelvic ring is dependent on the previously described anatomy. Attempts to devise a classification system to delineate which injury patterns are stable and unstable has led to a multitude of classification systems. One of the most commonly used classification systems currently is the Young and Burgess Classification. The early work for this classification was done by *Pennal et al*. who introduced a system based upon the force and direction of injury.[22] Three categories of pelvic disruption were described: 1) anteroposterior compression (open-book type), 2) lateral compression, and 3) vertical shear. These three radiographic patterns of pelvic disruption were named for the direction of force from which the injury was caused. This system was modified by *Young et al*. to include subsets for anteroposterior compression and lateral compression injuries.[23,24] These subsets were meant to further quantify the forces involved in these injuries, which would aid the treating surgeon in determining stability. *Young et al.* also devised a fourth category of pelvic injuries which was essentially meant for patterns that did not fit into the other three categories and was therefore some combination thereof, the combined mechanical or complex pattern injury (Appendix 2 – Young and Burgess Pelvic Ring Injury Classification).

Anteroposterior compression (APC) injuries were divided into types I, II, and III. This pattern of injury is the result of a direct anterior to posterior force. Type I APC injuries show symphyseal diastasis with no significant posterior instability.[23] Previous biomechanical work has suggested that the symphyseal diastasis can be up to 2.5 cm without posterior ligamentous disruption.[20] Therefore an opening of less than 2.5 cm is expected in a Type I APC injury.[23] Type II APC fractures will have further symphyseal diastasis with some anterior SI complex disruption/instability. Again with reference to the previous biomechanical research, with some disruption of the SI joints, greater than 2.5 cm of symphyseal diastasis may be observed.[20,23] This will be dependent on the position of the pelvis at the time of imaging, which is particularly susceptible to inaccuracy when reduction maneuvers have been performed. Therefore, measuring symphyseal diastasis alone is not sufficient to diagnose this injury pattern. Radiographic evidence of anterior SI joint opening is critical to evaluate when assessing for this injury.[23] The Type III APC fracture patterns are somewhat easier to recognize as they have complete disruption of the SI joints both anteriorly and posteriorly. This results in complete hemipelvis separation; however there should be no vertical displacement in a purely APC pattern.

Lateral compression (LC) pelvic fractures are the result of primarily laterally based compressive forces, that will in turn tend to internally rotate the hemipelvis if there are intact posterior structures.[23,24] The pubic rami fractures in LC pelvic fractures are characteristically horizontal and in the coronal plane, as opposed to the rami fractures associated with APC and vertical shear patterns being more vertical. On plain film radiography, this orientation of rami fractures is significantly better appreciated on a pelvic inlet view (patient supine with x-ray tube angled 40 degrees caudad) than a standard AP pelvis.[24] The subsets of LC injuries are differentiated primarily by their posterior pathology. In Type I LC injuries there is often a crush or buckle fracture of the anterior sacrum. This is explained by the hemipelvis internally rotating and hinging through the strong posterior SI ligaments, causing the ilium to compress the anterior sacrum. Type II LC fracture pattern implies some posterior instability of the pelvis. This is most frequently manifests as a “crescent fracture” of the posterior ilium.[2] The crescent fracture is a fracture just lateral to the SI joint on the ipsilateral side of injury that leaves a distinctive posterior iliac wing segment attached to the sacrum. This creates a functional disruption of the posterior pelvis, despite the SI ligaments remaining intact, as they are only now stabilizing the fracture fragment. In Type III LC injury patterns, the severity of the internal rotation of the hemipelvis is so severe that an external rotation force is placed upon the contralateral hemipelvis.[23,24] This is seen on radiographs as diastasis of the contralateral SI joint.[24] This yields what is effectively a contralateral APC injury and has been given the moniker “windswept pelvis”.

Vertical shear (VS) pelvic ring disruptions are typically the result of falls from height, or violent axial loading of an extended hip in a motor vehicle accident (MVA) or motorcycle accident.[2] This is usually appreciated on standard AP radiographs; however cephalad migration of the hemipelvis is best appreciated on a pelvic outlet view (patient supine with x-ray tube angled 40 degrees cephalad).[2,22] With the pelvic inclination being, on average, about 40 degrees off the vertical plain to the remainder of the body, there is generally posterior displacement of the hemipelvis seen in addition to the cephalad migration in VS injuries. This is best appreciated on the pelvic inlet view.[2]

A second commonly used classification system is that put forth by the Orthopaedic Trauma Association (OTA) and the AO (Arbeitsgemeinschaft fur

Osteosynthesefragen).[25] This comprehensive classification system is used primarily as a standardized approach to data collection and reporting but also gives some gauge of stability that can aid in determining prognosis and treatment options.

As per the remainder of the initial long bones classification, each bone is given an alpha-numeric code with the pelvis being denoted as bone 6.[25] The location in the bone is denoted by a second digit with the pelvic ring denoted as 61. Each of the injury patterns described about the pelvic ring will all begin with 61. This system first divides each injury into groups A, B and C indicating stable, partially stable and unstable, respectively. These denotations of stability are primarily with respect to the posterior arch of the pelvis which is located behind the acetabular surface.

Type A or “stable” injuries preserve the posterior complex of the pelvic ring and therefore are felt to never cause instability. The 61-A1 injuries are all felt to be avulsion injuries from sudden muscular pull from the various muscle origins about the pelvis. The 61-A2 injuries are all felt to be the result of a direct blow to the innominate bones of the pelvis. This includes 61-A2.2 which is described as a unilateral fracture of the anterior arch either isolated through the pelvic rami or involving the pubic symphysis. This also includes 61-A2.3, a bifocal fracture of the anterior arch with either bilateral pelvic rami fractures or unilateral rami fractures and symphysis pubis involvement. The type A3 injury is a transverse fracture of the sacrum or coccyx that does not involve the posterior arch support structures.

Type B fractures are meant to represent partially stable pelvic ring injuries. 61-B1 injuries coincide closely with the Young and Burgess APC-II, unilateral, external rotation injury with intact posterior SI ligaments that prevent vertical instability in this rotationally unstable injury pattern. The 61-B2 injuries represent another partially stable, rotationally unstable injury pattern resulting from unilateral internal rotation from lateral compression of the pelvis. This group includes the lateral compression Type I and II of the Young and Burgess Classification system. The 61-B2.1 pattern has an anterior compression fracture of the sacrum and anterior pelvis lesion (rami or symphysis pubis disruption); this coincides with the LC-I of the Young and Burgess system. The B2.2 and B2.3 types represent further instability and LC–II pattern with partial SI joint fracture/subluxation or incomplete posterior iliac fracture, respectively. The Type B3 pattern has bilateral posterior ring injuries with neither side vertically unstable. The combination of bilateral internal and external rotation injuries are represented in multiple subsets of this group. The pelvis floor ligaments must remain intact throughout this group.

The final group of pelvic ring injuries in this classification system are the globally unstable, Type C injuries. This instability is due to complete disruption of the posterior elements that stabilize the axial skeleton to the hemipelvis. A C1 injury is a unilateral complete disruption, a C2 pattern has an additional contralateral incomplete disruption, and a C3 injury has bilateral global instability.

1.5 Classification Challenges and Presence of Posterior Ring Injury

The aforementioned classifications are likely the two most commonly used classification systems; however, there are multiple others with various strengths and weaknesses. While all fracture classification systems have shortcomings, there are some specific characteristics of pelvic ring injuries that make them particularly challenging to classify. Firstly, the posterior elements are difficult to image radiographically, particularly with the plain films upon which most of the classification systems are initially based. Secondly, any imaging done statically is taken long after the point of maximal displacement during the injury and many times following deliberate reduction maneuvers. The heterogeneity, particularly in level of energy, involved in different pelvic ring injuries is grossly underappreciated when static imaging such as plain films or CT are used. This imparts a challenge in determining which injuries are unstable when deciding on management options. Using stress films with fluoroscopy in the operating room is one way to overcome this; the significant cost and patient risk associated with this is prohibitive of this method being routinely widely used.

These challenges in classification and determining stability hold particularly true when dealing with pelvic fractures in an elderly population. Concomitant musculoskeletal disability, medical comorbidities and cognitive decline can often make for an unreliable history as well as physical exam. A reported ground level fall will often not go on to advanced imaging such as CT or MRI in an elderly patient with presumed isolated pelvic rami fractures with inadequately imaged posterior elements on plain films.

A 1977 study by *Gertzbein et al.* examined six consecutive cases of low energy, presumably isolated, pelvic rami fractures with 99m Tc-Methylene Diphosphonate bone scan.[26] They found that in all six cases there was increased uptake at sites in the pelvic ring distant from the rami fracture. All had increased uptake around the ipsilateral sacroiliac joint and four of six had increased uptake around either the ipsilateral or contralateral acetabulum. This increased uptake may have been the result of an occult fracture or ligamentous disruption.

More recent studies with more specific imaging modalities have demonstrated similar phenomena. A study of 50 elderly (mean age 78) patients sustaining low energy pelvic rami fractures found that 95% of patients had a vertical compression fracture of the sacrum on MRI.[27] This sacral fracture was unilateral and ipsilateral to the involved ramus 82% of the time and involved the contralateral sacrum in 8% of patients. Eight percent of patients with unilateral ramus fractures had bilateral sacral involvement. Patient with bilateral ramus fractures had bilateral sacral injury 33% of the time. Clinically, 44 of the 45 patients with sacral fractures complained of sacral pain.

Other studies report variable and significantly lower numbers in associated posterior pelvic injuries. In a prospective study of 19 elderly females with an initial diagnosis of isolated pubic rami fractures in the emergency department, only 6 (32%) were found to have associated sacral fractures on subsequent CT imaging.[28] Another prospective study examining outcomes in osteoporotic fractures about the pelvis found 54% (33 of 61) of patients with pelvic rami fractures to have an associated sacral fracture.[29] This study, however, only used advanced imaging (MRI) on patients who were complaining of low back pain or had lumbosacral tenderness on clinical examination. Of the 37 patients who had undergone MRI, 31 (84%) showed sacral fractures. Deduced from this, either there is a higher rate of sacral fractures missed in those who were not imaged, or clinical symptoms are an accurate predictor of sacral fractures.

Studies examining the incidence of posterior pelvic ring injuries in all pelvic rami fractures can also be useful when examining this injury. It must be understood, however, that this represents a very heterogeneous group of injuries with high and low energy trauma as well as highly variable bone quality, particularly in comparing young trauma patients to the elderly. A 2012 study that examined 177 patients with one or more pubic rami fractures found 96.8% of patients had an injury to the posterior pelvic ring on CT.[30] Patients with an obvious pelvic ring injury on plain films were excluded and the patient ages ranged from 15 to 101 years.[30] Clearly there were geriatric pelvic fractures included in this study but an analysis of this group alone was not published.[30]

Another study that examined patients initially diagnosed with isolated pubic rami fractures using conventional radiography found 53% to have posterior ring injuries on CT.[31] This study used a more homogeneous population with a mean age of 75 (range 53 to 92 years), possibly representing a more osteoporotic patient population.[3130] They also found that both their clinical exam and the radiographic extent of the anterior ring injuries did not assist in predicting those patients with posterior ring injuries.

The heterogeneity of the Young and Burgess LC-1 fracture group is quite evident in a trauma registry study by *Lefaivre et al*.[32] A consecutive series of 100 patients with pelvic fractures classified as LC-1(OTA 61-B2) injuries were identified from a Texas trauma registry. Using CT, they found only 2 (2%) did not have a posterior pelvic ring injury. Mean age of this population was 38 years (range 13-87) and 48% of the sacral injuries were complete, from anterior to posterior cortex. This is quite different from the initially described anterior buckle or crush fracture of the sacral ala in LC-1 patterns described by *Young* and *Burgess*.[23,24] The group in this study is therefore not reflective of low energy osteoporotic fractures.

With studies reporting large proportions of patients with under-reported injuries about the pelvis when there are rami fractures; it may be worth considering more advanced imaging when rami fractures are detected in all patients, including the elderly. Our current routine of primarily using plain films in low energy falls in the elderly, will lead us to underappreciate the severity of some injuries secondary to the aforementioned classification challenges. Improved appreciation of the full extent of an injury may allow us to further offer therapeutic options.

1.6 Incidence of Pelvic Ring Injury in the Elderly

Among pelvic ring injuries, low energy osteoporotic fractures are undoubtedly the most common. A retrospective study in 1981 found the overall incidence of pelvic fractures to be 37 per 100,000 person-years.[33] In further examining this population, they found that this number increases to 220 per 100,000 person-years in men over 85 and an even greater increase in women over 85 years old, 446 per 100,000 person-years. A subsequent study from Sweden recorded an overall pelvic fracture incidence to be 20 per 100,000 person-years.[34] Similarly they found a large increase in elderly patients. Men over 80 were found to have an incidence of 91 per

100,000 person-years and women in this age group, again had a greater increase to 277 per 100,000 person-years.

Kannus et al. report pelvic fracture incidence over 27 years, 1970 to 1997, in Finland.[35] They found a dramatic increase in the rate of pelvic fractures in patients over 60 years of age from 20 per 100,000 person years in 1970 to 92 per 100,000 person years in 1997. The average age of the Finnish patients sustaining these fractures also increased from 74 in 1970 to 80 years old in 1997. This study also predicts that based on the increasing age of the population in Finland, the number of fractures will increase 3-fold, from 913 in 1997 to about 2700 osteoporotic pelvic fractures in 2020.

1.7 Osteoporotic Pelvic Fracture Mortality

Pelvic fractures comprise a large heterogeneous group of injuries. The mortality rates following these injuries are also quite variable. The mortality rate of young adults sustaining high energy pelvic ring disruptions may be expected to differ greatly from elderly osteoporotic pelvic fractures.

Unstable pelvic fractures have a high mortality attributable to both the unstable pelvis and the globally poly-traumatized patient. Mortality rates are reported between 10% and 20% in closed unstable pelvic injuries, with that rate increasing drastically in open pelvic fractures to as high as 50%.[36–42] Mortality rates in geriatric osteoporotic low energy fractures also approaches 10-20% but this is rooted in the physiologic capacity to overcome any injury and not the gross instability of the pelvis or multisystem poly-trauma.

A 1997 study examined all the geriatric pelvic fracture patients that presented to the emergency department over a 7 year period.[43] They reported a mortality rate during their hospital admission of 11%. The majority of these were attributed to exacerbation of underlying cardiovascular disease. *Dechert et al.* reported a mortality rate of 20.4% during the admission following injury as well.[44] Although patients in this study were in the osteoporotic age group, 71% were identified upon trauma team activation from motor vehicle collisions.[44] This is likely an overestimate of mortality relative to the typical low energy fractures of the pelvis in the osteoporotic patient.

In a study of pelvic fractures in a predominantly elderly Scottish population, 20 patients (7%) died in hospital following admission.[1] The investigators also followed these patients after their initial hospital admission to yield a one year mortality rate of 13.3% and a five year mortality rate of 54.4%. While this study used a predominantly elderly population, mean age 74.7 years, they also included those much younger, range 17 to 97 years. This allows for increased heterogeneity in the study and ultimately a decrease in the reliability of the values obtained for an elderly population. A median age was not published, but would likely have provided a better measure of central tendency given the skewed age of the sample. This study used two comparison groups for survival. An age matched cohort (14,838 people, mean age 74.7 years) from the general population in Edinburgh was found to have a statistically improved survival, more marked in the first year (Hazard Ratio (HR) 2.6; 95%CI 1.9-3.5) than at five years (HR 1.8; 95%CI 1.5-2.1). This comparison group, matched using mean age, is unlikely to provide an appropriately matched cohort as the mean is a poor measure of central tendency for this population with such a wide age range of skewed data, which is not normally distributed. A population of patients sustaining hip fractures (mean age 79.9 years) were found to have a worse survival than the pelvic fracture group in the first year (HR 0.5, 95%CI 0.3-0.7), but no statistical difference was seen at five years.

The one year mortality rate reported by *Koval et al.* in a New York population over 55 years old was 9.5%.[45] In a Hong Kong population of pelvic fracture patients over 60 years, a one year mortality rate of 11.7% was reported with 28.5% of these patients dying on their initial admission of causes directly related to their pelvic fracture.[46]

A study of patients admitted to medical and geriatric wards in the UK with closed pelvic fractures reported an inpatient mortality rate of 7.6%.[47] Subsequent follow up yielded a one year mortality rate of 27% in this population.

The admission mortality rate in a population greater than 55 years reported by *O'Brien et al.* was found to be 12.3%.[48] This study, however was in a level I trauma centre with most (68%) sustaining their injuries from a motor vehicle collision as opposed to a ground level fall (11%).

A review combined the mortality rates in the previous six studies and yielded a one year mortality rate of 16.3% in the combined 557 patients.[3] As discussed, there is significant heterogeneity in these study populations, with the primary difference being in the average energy imparted to cause injury; it is unlikely to represent the true parameter in low energy osteoporotic pelvic fractures.

A recent study by *Bible et al.* reported mortality rates at various points throughout the first year following pelvic fracture in a population greater than 60 years old.[49] Their patient population was from a busy level I trauma centre which will inherently lead to higher energy injuries being managed there. They divided all the patients into operative (n=24) and nonoperative (n=46) groups. The nonoperative group was a statistically older population and likely more closely represented low energy pattern osteoporotic fractures. The mortality rate was 6.5% during initial hospital admission, then 8.7%, 13.0% and 15.2% at three, six and twelve months, respectively. When the higher energy, operative fractures were included in the one year mortality rate, it decreased to 12.9%. This higher energy group, therefore, represents a different population of patients than those sustaining low energy osteoporotic fractures.

Part of the challenge in quantifying the effect of pelvic fracture on mortality in an elderly population is in determining the baseline mortality rate of this aged population. A study by *van Dijk et al.* used an age-matched population to determine the effect of a single isolated pubic ramus fracture on mortality.[50] The age matched cohort were patients undergoing surgery for basal cell carcinoma because they represented a population felt to be without increased mortality from their cancer. The one, five and ten year mortality rates were 24.7%, 64.4% and 93.7%, respectively. All three of these were significantly higher statistically than the age matched cohort. This difference, however, was largest in the first five years, which the authors felt was the only period where the fracture and its complications had a significant effect. When the patients were divided by age, only the patient group 60

– 69 years had a significantly different survival rate compared to the controls. Pelvic rami fractures in this relatively younger age group can therefore be thought of as a marker for frailty and poorer overall medical status.

With one year mortality rates ranging from 9.5% to 27% in the preceding studies, the true incidence likely falls somewhere in the middle. This reported variability is likely secondary to the previously discussed heterogeneity in the patient populations studied; in addition to the inconsistency with which it is reported. That is, some studies have only reported the acute inpatient hospital mortality without following the patients out to a year.

1.8 Mobility following osteoporotic pelvic fracture

Mortality is certainly an important parameter when measuring the effect of injury; the short and long term morbidity, however, is also of great consequence. This is particularly true in dealing with an elderly population as small deteriorations in mobility or cognitive ability can determine whether a patient is able to live independently or will require various levels of assisted living or nursing home placement. In addition to the personal, mental, and familial stress imparted in such a situation, there is a significant economic burden on the healthcare system.

In the previously discussed study by *Leung et al.*, 36% of the patients available for follow-up at one year following pelvic fracture in a Hong Kong elderly population had deterioration in their ambulatory status.[46] They also found that 81% of patients did not experience any pubic or groin pain requiring regular analgesia. A study by *Mears and Berry* of osteoporotic pelvic and sacral fractures found that only 15% of patients were able to walk without an ambulatory aid following their injury.[51]

This deterioration in ambulatory status is further delineated in a more recent study examining osteoporotic fractures about the pelvic ring. *Alnaib et al.* found that pre-injury, 52.2% of patients were walking fully independently and this decreased to only 9% on discharge from hospital.[29] The number of patients requiring a frame (walker) increased from 22.4% on admission to 53.7% upon discharge.

A study of an elderly population sustaining pelvic insufficiency fractures in France found that only 58% of the patients who had previously been able to walk independently had returned to this level on discharge.[52] In a follow up one year later only 39% of the overall population were able to stay at the same level of mobility self-sufficiency. They also found that the only factor associated with loss of self-sufficiency was patient age.

In the Scottish study by *Hill et al.* 47% of patients had returned to their previous level of mobility upon discharge.[1] Of the surviving patients at follow up, 60.4% had regained their previous mobility. The breakdown of this level of mobility was 51.1% independent ambulators, 38.8% using walking aids and 10% immobile or wheelchair bound.

A smaller study of pubic rami fractures of patients over 55 years found that 92% of patients available for follow up at 1 year had maintained their pre-fracture ambulatory status.[45] Only 60% of patients initially entering the study were available for 1 year follow up data, however. In the initial patient group 79% were independent community ambulators and 21% were community ambulators requiring assistive devices.

In contrast to mortality, the reporting of mobility outcomes is far more varied. The lack of standardization in this reporting allows for significant difficulty when comparing results between studies. Overall, within this varied data, it is apparent that many patients go on to have difficulty regaining their pre-injury ambulatory potential. Some studies, do however report over half and up to 92% of patients can eventually get to this point.[45] As such, this should continue to be the goal for those caring for these patients.

1.9 Length of stay and discharge destination

Very much related to the mobility of patients before and after injury is the length of time spent treated in hospital and rehab facilities. The goal for all patients with any injury should always be to return them to their previous level of function. The expectation of meeting this goal and the subsequent modified goals will vary from injury to injury and patient to patient. In the elderly population that sustains osteoporotic fractures about the pelvis, the focus of their inpatient experience will be on mobilization, assuming all medical issues have been addressed. The manner in which different regions and health institutions go about striving to achieve this goal is highly variable.[53] This begins with the admitting service to which these patients initially present from the emergency department. This can vary from being admitted to a general surgery trauma service, directly to an orthopaedic surgeon, to a geriatrics or medicine service run primarily by internists or any combination thereof. In some hospitals these patients will remain under this acute service until discharge while others will transfer the patients to a rehabilitation hospital or a dedicated geriatric orthopaedic rehabilitation unit.

Following their hospital or rehab admission, the discharge destination is a critical parameter when measuring the effect of these injuries on patients as well as health care resources. As per mobility, the goal should always be to get patients back to their previous place of residence and independence. There are some challenges in quantifying this in the literature. The level of care given at different nursing homes is often quite variable locally, which can be particularly challenging when comparing the care in different regions around the world. Additionally, many patients who sustain low energy fractures who have been living alone independently would arguably not have passed the activity of daily living benchmarks for patients to get home independently prior to their injury.

In a study by *Breuil et al*. the mean length of stay on an acute ward of a population having sustained osteoporotic pelvic fractures was 13.9 days (range= 3 – 34 days).[54] Upon discharge from this acute bed only 31% returned home, while 3.4% were institutionalized and 65.6% were transferred to a geriatric in-patient centre. A follow up survey done at a variable time following fracture, mean 29 months (range=2-58 months), found that 74.5% of patients had in fact returned home. Over half of the patients (60%) required assistance for at least one activity of daily living at the time of this follow up survey.

In the study by *Dechert et al*. that had a population of elderly (greater than 65 years) pelvic fractures that had been subject to a relatively higher level of trauma, the mean length of stay in hospital was 12.5 days (±13.1 SD).[44] This also included an intensive care unit mean stay of 5.5 days (±10.0 SD), indicating the higher level of trauma of the population in this study and decreasing the applicability to low energy osteoporotic pelvic fractures. Conversely, *Leung et al*. reported a mean length of stay of 20.8 days (±19.7 SD) in an elderly study population documented to have sustained pelvic fractures following low energy falls in 85% of patients.[46]

A study by *Mears et al.* examined a quite elderly population (mean age 85 years) with displaced and non-displaced pelvic ring fractures.[51] Only 110 of the 181 patients were acutely admitted for these injuries. The mean acute hospital length of stay was 5.9 days (±4.2 SD). Upon discharge only 37% returned to their own home, in contrast to the 53% living at home prior to injury. Fifty two percent of patients were in a nursing home post injury; a significant increase from the proportion in a nursing home prior to their injury, 31%. All others in this study were characterized as living in an assisted living facility.

In the ten year follow up study by *van Dijk et al*. that examined pubic rami fractures in patients over 60 years old, 64% of patients were discharged home and

33% to a nursing home.[50] The median length of stay of their acute hospital admission was 10 days. During their long (10 year) follow up period, they noted that 24.2% went on to sustain another fracture, 54% of which were proximal femur fractures. The majority (79%) of these subsequent fractures occurred within the first 2 years following discharge.

The recent study by *Alnaib et al*. described a few factors that contributed to length of stay following osteoporotic pelvic ring injury.[29] Mean length of stay of all patients in their study was 45 days (±35 SD). All patients under 75 years (65 – 74) were discharged under 21 days. Conversely, all patients over 75 had minimum lengths of stay greater than the overall mean, except for the group of patients aged 80-84 years. This illustrates the significant heterogeneity in the patient population that sustain these injuries. Pelvic ring injuries in this study were also divided into isolated pelvic rami fractures and pelvic rami fractures combined with an identified posterior ring injury. The mean length of stay was affected by this as patients having both anterior and posterior ring injuries were admitted for 52.9 days (±37.1 SD), while those with an isolated anterior ring injury only 36.3 days (±30.8 SD). The proportion of patients discharged to their own home was only 53.7%, down significantly from the 89.6% of patients living home prior to admission. Twelve percent were discharged to a nursing home and another 12% were discharged to a community rehabilitation bed. They did not find, however, that there was any significant relationship between the discharge destination and the nature of pelvic ring injury, isolated or combined anterior and posterior.

In the French study by *Taillandier* and colleagues, the mean length of stay was 45 days (±28 SD), with a range of 10 to 130 days.[52] The large variability and longer stays of some were attributed to the need to plan for institutionalization. The patients who were not self-sufficient prior to their injury had a significantly longer admission. Seventy five percent of patients returned to their previous place of residence while 25% were discharged to institutions (18% to nursing home and 7% to extended stay hospitals).

The large UK study of *Hill et al*. that examined pubic rami fractures in a mostly elderly population (mean age 74.7 years, range 17 to 97) yielded a mean length of stay as varied as their patient population, 9.3 days (range 1 to 64 days).[1] The discharge destination in this five year study did not demonstrate a significant proportion of patients requiring nursing homes with only 14% of discharged patients, a slight increase from the 13% admitted from a nursing home. Almost 80% of patients were eventually discharged to their original residence, with 56% of these patients going directly home from the ward and 44% discharged first to an orthopaedic geriatric unit. Age also contributed as only 31% of patients over 80 years were discharged directly home, while 59% of those under 80 years were discharged directly home.

A smaller study of pubic rami fractures in the elderly by *Koval et al*. reported a length of stay mean of 14 days (range 1-69 days).[45] The vast majority of these patients, 95%, were discharged home following this acute admission, about half of which required some additional home supports. The remaining 5% required nursing home placement.

The varying results of the preceding studies are quite indicative of the challenges in describing outcomes in this fracture population. The paucity of evidence with homogeneous patient groups is primarily accountable for this. Patient ages and energy of injury seem to rarely be similar in comparing studies. The other major factor, particularly when describing non-mortality outcomes such as length of stay and discharge destination, is the varying health care systems with varying resources and facilities. Some regions have very efficient orthopaedic geriatric units, which allows for short stays admitted to an acute care bed. Other regions have no rehabilitation beds and patients therefore remain in an acute care bed until they rehabilitate enough to return home or are discharged to a nursing facility. This variability is challenging from a research perspective in analyzing the morbidity associated with these fractures as it leads to significant regional bias.

Despite the wide range of reported mean lengths of stay in the preceding studies (5.9 to 45 days)[29,51,52], it is quite evident that this is an important outcome that can be used as a target measure of improvement. Similarly, the discharge destination, while reported variably (range of patients discharged home 37% to 80%)[1,51], serves as a critical measure of success in treating this patient population.

1.10 Comparison with hip fracture literature

In stark contrast to the predominantly non-operative treatment of low energy pelvic ring injuries, low energy fractures of the proximal femur are treated almost entirely operatively. These hip fractures occur in the same osteoporotic patients, with generally the same low energy fall from standing mechanism but have a vastly different treatment mantra. As such, an understanding of how these groups compare is critical to guiding advances in treatment for pelvic rami fractures to the point with which this has been done in proximal femur fractures already.

The most recent Canadian data show that about 30,000 proximal femur fractures occur every year nationally.[55] This yields an annual age-standardized hip fracture incidence of 74.4 per 100,000 in Canada. The overall and annual incidences of pelvic ring injuries have not been published in Canada; the international rates previously discussed are wide ranging from overall rates of 20 per 100,000 person years to 446 per 100,000 person years in elderly populations.[33–35]

The mortality following hip fracture is generally estimated to be about 10% at one month and nearing 30% at one year, independent of fracture pattern.[56] This is somewhat comparable with pelvic ring injuries, but as discussed above (Section 1.7) the heterogeneity of these pelvic fractures yields a large variability in mortality rates; therefore it is difficult to discern the true rate of low energy pelvic fractures.

Since the original description of fixation for femoral neck fracture by *Smith-Petersen et al.* in 1931, all displaced proximal femur fractures are essentially treated operatively except for those patients with gross medical contraindications.[57] The primary goals and rationale for this are mobility and pain control. Without internal fixation, these patients would remain essentially bedridden until the fracture heals. The complications that coincide with this (e.g. decubitus ulcers, urinary tract infection, pneumonia and venothromboembolic disease), would result in significant mortality in this generally elderly, unwell population.

In contrast, the first line treatment in low energy pelvic ring fractures in this same population is conservative, medical management with pain control and physiotherapy as tolerated. Patients are able to tolerate more mobilization with osteoporotic pelvic rami fracture relative to osteoporotic proximal femur fractures. As previously discussed (Section 1.8), this slightly improved tolerance to mobilization continues to yield significant morbidity as many patients have extended hospital stays following admission and many do not return to their previous level of independence at home.[1,45,52]

Much of the hip fracture post-injury morbidity literature focuses on comparing outcomes of different fracture patterns (femoral neck, pertrochanteric) and the different fixation techniques used (arthroplasty, osteosynthesis, etc.). In studies comparing fixation strategies for femoral neck fractures, arthroplasty versus internal fixation, it was determined that there was no difference in the proportion of patients regaining previous levels of mobility with an overall rate of 46%.[58–61] Also reported is a rate of 15% to 20% of patients that are unable to return to their previous place of residence.[58] Similarly, in a study comparing different internal fixation techniques for femoral neck fractures (Hansson hook-pins versus AO-screws), 80% of patients admitted initially from their own home had returned there by four months, with 10% in a nursing home and 8% having died.[62] This study also reported mobility at one year, with 35% of patients walking with ambulatory aids, 57% walking independently and 7% not walking.

A study of pertrochanteric hip fractures found that at four months, 55% of patients lived in their own homes, 19% in nursing homes, and 25% remained in an institution.[63] Relative to their pre-injury residential status, 80% of patients returned to their previous residence. Mobility was reported in this study at 4 months with 33% of patients able to walk independently, 55% requiring aids and 12% unable to ambulate. This reflected a 65% proportion of patients that were able to return to pre-injury ambulatory status, a value replicated in another similar study.[64]

A study of pertrochanteric fractures by *Janzing et al.* compares hip screw devices and reports mobility and residential status at one year.[65] They found 45% of patients walked without aids at one year, 42% required aids and 13% were unable to ambulate. This represented 36% of the patients able to ambulate independently prior to their injury having a deterioration in their ambulatory status. They also reported residential status at one year: 52% of patients were independent at home, 32% were required to live with family or in an “old people’s home”, and 16% of patients were in a nursing home/hospital.

While there exists a much greater breadth of literature examining outcomes following low energy fractures of the proximal femur, the heterogeneity with which these outcomes are reported decreases the clinical utility of the data. A systematic review by *Butler et al*. examined 74 randomized controlled trials and found 30 different functional measures for femoral neck fractures and 24 measures for pertrochanteric fractures.[66] This 2011 systematic review concluded ultimately that factors relating to functional status and quality of life measures cannot be addressed with the existing geriatric hip fracture literature. As these outcomes are poorly reported in pelvic rami fractures as well, the comparison of current literature in these areas will not yield meaningful results.

Mortality following proximal femur fractures has been fairly consistently been reported to be 20% to 30% at one year.[56] These values fall within the range of the far less studied mortality rates reported for pelvic rami fractures of 10% to 30%.[1,45]

1.11 Treatment of Osteoporotic Pelvic Ring Fractures

In contrast to most high energy unstable pelvic fractures, low energy osteoporotic fractures about the pelvic ring are generally treated non-operatively. This is somewhat predicated on the previously discussed soft tissue injuries represented by the osseous injury visible on plain films. In high energy pelvic ring injury, the significant ligamentous disruption that occurs concurrently with the osseous injury will frequently yield a grossly unstable pelvic ring, requiring operative stabilization. The osseous injury in low energy fractures in the elderly is usually secondary to osteoporosis, therefore not representative of significant ligamentous disruption as the bone has failed largely independently. These fractures are then thought of as inherently stable with intact ligaments and the treatment algorithm follows accordingly. The mainstay of treatment is pain control and mobilization with physical therapy as tolerated.

In addition to this treatment strategy, several other treatment modalities have been suggested in the literature. These range from medical treatment to minimally invasive procedures to full surgical fixation. Unfortunately to this point, there exists a paucity of evidence to recommend any such modalities routinely.

An Austrian study by *Peichl et al*. used recombinant parathyroid hormone (PTH) in the treatment osteoporotic pelvic fractures.[67] This study randomly assigned patients to a treatment group with daily subcutaneous injections of 100 micrograms of PTH 1-84 and compared them to a non-placebo control group. The population was all female with unilateral pelvic fracture, DXA confirmed osteoporosis (T-score <-2.5), and age greater than 70 years. All patients were treated with calcium and vitamin D for the entirety of the two year study period and had not been managed with other osteoporosis treatments for six months. Using CT scans every four weeks, bridging callus across the fracture site was considered bony union. With this definition, the median time to union in the treatment group was 7.8 weeks versus 12.6 weeks in the control group. The primary end point of union at 8 weeks was achieved in 100% of patients in the treatment group and only 9.1% in the control group. The clinical outcomes were also significantly improved in the treatment group. In terms of pain, the time zero to week 8 visual analog score

(VAS) improved from 7.6 to 3.2 in the treatment group, while the control group VAS score decreased from 7.7 to 6.5. Additionally they performed a standardized "Timed Up and Go" test at 8 weeks in both groups with the treatment group performing significantly better with a mean time of 22.9 seconds compared to the mean 54.3 seconds in the control. All statistics measured in this study showed a very clear benefit to parathyroid hormone treatment. This was a small study with 21 patients in the treatment group and 44 in a non-placebo control group. The systemic effects of such drug treatment would be the primary long term concern, particularly with respect to calcium homeostasis. Such laboratory values were monitored monthly in this study without any adverse events or abnormality. Further long term, larger, blinded, prospectively randomized studies are required to further validate the efficacy of this treatment modality.

Another non-surgical treatment suggested for these fractures is ramoplasty. This more invasive treatment modality is done using radiographic imaging to guide the injection of polymethylmethacrylate (PMMA) into the ramus fracture site. This technique is currently well established in the treatment of vertebral compression fractures.[68] It is associated with a significant decrease in pain and improved mobility in this vertebral compression fracture group. This technique was reported by *Beall et al*. on two patients with superior ramus fractures.[69] One patient presented with an acute fall and was doing poorly with conservative treatment as her ambulation was quite limited by pain. It was felt operative fixation was not appropriate for this patient; therefore it was decided to try the percutaneous injection of PMMA. The patient did quite well with a decrease in VAS from 9 to 3 immediately following the procedure and was discharged the following day. The second patient in the study was found to have chronic bilateral sacral insufficiency fractures with a superior ramus fracture. With pain having been ongoing for a year it was decided to try the percutaneous injection of PMMA. Similar improvement in VAS were seen, from 7 to 2, immediately following the procedure. There are few other reports of this technique for rami fractures seen the literature, therefore there is certainly room for larger higher quality studies surrounding this technique. With more research, this may be a reasonable local modality for treatment that does not require a general anaesthetic and can yield very prompt pain relief.

A more invasive technique that remains short of open reduction and internal fixation is closed reduction and percutaneous fixation. Most of the small amount of literature on this technique is in the fixation of high energy, unstable fracture patterns. The initial study describing percutaneous fixation of superior rami fractures by *Rout et al.* in 1995 used retrograde intramedullary screws in 26 patients with unstable pelvic ring injuries.[70] In this study, the reduction was achieved closed in 15 patients and required formal open reduction in the remaining 9 patients. Their results were mostly positive with all fractures going on to heal. One patient had a misdirected screw placed and another patient experienced late symptomatic screw disengagement at a 6 week follow up. This patient was said to be elderly with osteoporotic bone and she required removal of the screw and replacement with a longer screw; this then went on to heal. A 2008 study by *Starr et al.* had a much larger cohort of patients with unstable pelvic fracture undergo screw fixation of superior rami fractures.[71] In this study, 145 superior ramus fractures were fixed with percutaneous screws; 89 using retrograde screw placement and 56 using antegrade placement. All reductions were achieved without a formal open exposure; 113 (78%) were reduced closed and 32 (22%) required percutaneous reduction techniques. A total of 12 fractures were found to have lost their reduction in follow up imaging. This represented 15% of the remaining patients not lost to follow up. Six of the nine patients over 60 years old went on to fixation failure. This is in contrast to the 6 out of 73 fixation failures seen in patients younger than 60 years. The injuries in this study were all high energy and unstable, which represents a very different injury pattern, as previously discussed. The stress on the fixation in the ramus will be significantly greater in an unstable pelvic ring injury. The hardware failure in the presumed osteoporotic/osteopenic bone is, however, somewhat concerning. Further research into the use of this nature of fixation in low energy superior ramus fractures is certainly required prior to its widespread adoption.

Given there are some concerns with purchase of a single screw in osteoporotic bone, there may be a role for formal open reduction and internal fixation in some patients. There is little published on the operative treatment of this injury population. A recent study of osteoporotic pelvic ring fractures used a failure of a trial of conservative management as an indication to proceed with operative fixation.[72] This was defined as persistent and/or increasing pain causing immobility after 4 weeks. Five of the 132 patients in this study required operative fixation, with all five requiring percutaneous iliosacral screws and two requiring open reduction with plate and screw osteosynthesis. Significant pain relief was achieved in all five patients, allowing immediate immobilization. The remainder of the literature published on this injury makes no mention of any consideration of operative intervention due to the "stability" of the fracture pattern.

1.12 Rationale and Purpose of Current Study

The expenditures on healthcare as a proportion of the GDP have remained stable and actually decreased slightly in the past few years in Canada since its all-time high of 11.9% in 2010.[73,74] The world's population, however, is aging (as discussed in section 1.2). With this, there will be a large proportion of the population entering the geriatric age bracket which will come with an increase in all of the associated geriatric health problems. The research focus to prepare for this must involve improving patient outcomes in these geriatric health issues; additionally, we must concurrently focus on the short and long term costs associated with the treatments of these conditions and aim for improved economic efficiency.

Osteoporosis is one such health condition whose prevalence increases with age. Osteoporosis and its sequelae are a source of morbidity and mortality that will have a major impact on healthcare and its costs in the coming years. Optimizing outcomes following osteoporotic related fractures will not only improve mortality and the quality of life of these patients, it will also minimize the amount of care required following these injuries. This includes physician follow-up, as well as multidisciplinary care from nurses, therapists, and everyday caregivers required until patients are independent. Therefore if there is an increased up front cost spent on the treatment of these patients with the goal to earlier independence, the long term costs may decrease significantly.

Determining this optimal treatment has thus far been elusive in current literature dealing with patients who have sustained osteoporotic fractures of the pelvic ring. This often at risk population of patients has been underrepresented in the literature. The current standard of treatment is largely pain control and mobilization as tolerated. As described in the previous section (1.11), there are multiple other modalities that have had varying success in small studies in the treatment of these injuries. These range of from medical hormonal treatments to minimally invasive procedures to full open surgical fixation. As this population increases, determining more effective treatments will become increasingly important. This will require larger trials of the previously described and perhaps other treatment modalities that have yet to be thought of.

The step prior to experimenting with new solutions involves the process of fully delineating a problem. The study of low energy pelvic ring fractures is a problem that has been largely overlooked in both the osteoporosis and pelvic fracture literature. As previously discussed, the pelvic fracture literature is vastly weighted toward the management of high energy pelvic injuries. Similarly, the orthopaedic osteoporosis literature focus is geared significantly more toward other injuries (proximal femur, distal radius, proximal humerus) than the pelvic fracture.

The purpose of the current study is to elucidate the morbidity and mortality following low energy pattern fractures about the pelvic ring in patients greater than sixty years old in eastern Newfoundland. The primary outcome will be mortality following these pelvic ring injuries. Secondarily, we wish to quantify other outcomes following these injuries, particularly mobility, residential status and length of acute hospital admission.

For our primary outcome, we hypothesize that the mortality of our elderly rami fracture population will be greater than that of the uninjured public. Additionally, we believe the value will be equivocal with mortality described in the literature for proximal femur fractures in the elderly. Furthermore, we hypothesize that our secondary outcomes will demonstrate a dramatic decrease in mobility, increases in level of care and extended hospital stays following injury.

Chapter 2 Methods

2.1 Study Design

A retrospective cohort study design was used to investigate our desired outcomes. A retrospective medical record review study design was chosen for the following reasons. Firstly, there is no existing ongoing prospective database available for this patient population. Secondly, with a primary outcome of mortality, any prospectively collected data would need to be collected over a long period of time for a complete data set. Finally, the retrospective design allows for cost efficient data collection.

2.2 Ethics Approval

The research proposal for this study was submitted to the Health Research Ethics Authority (HREA) and approved by the Research Proposals Approval Committee of Eastern Health on September 13, 2011 (HREA Reference # 11.307) (Appendix 3). To allow further data collection this approval was renewed on July 20, 2012 (Appendix 4).

2.3 Patient Identification

The patient database of the Newfoundland and Labrador Centre for Health Information (NLCHI) was used to identify all patients over sixty years of age that had sustained any injury about the pelvis from 2000-2005 in the Eastern Health region. Multiple diagnostic codes were used in the initial query of this database to attain the maximum number of patients with pelvic fractures to then apply our specific x-ray criteria. The terms coded and used in the NLCHI database query were: fracture of ilium, fracture of acetabulum, fracture of pubis, multiple fractures of lumbar spine and pelvis and fracture of other and unspecified parts of lumbar spine and pelvis.

This database query was run in September, 2011 at NLCHI by their data analysts. This yielded a report listing all patients that have been coded as having the aforementioned injuries between January 1, 2000 and December 31, 2005.

The NLCHI database is made up of data coded by Health Information Management coders. These Health Information Management coder must have successful completion of a recognized/approved two-year program in Health Records Administration or Health Information Management. All data coded is from inpatient data of patients admitted to an Eastern Health facility.

2.4 Inclusion and Exclusion Criteria

Following the identification of patients over sixty that had sustained all manner of pelvic injury over the study period, each individual patient's paper and electronic health records were used to extract additional information. Firstly, the list of each patient's injuries were extracted from the charts by examining the emergency physician notes and the admitting consultation service's history and physical. Patients were excluded if there was a fracture of any part of the femur or remainder of lower extremity, or if there was a fracture of the pelvis requiring surgical fixation. Examination of operative reports, combined with radiology reports and the admitting services history and physical notes allowed all of these injuries to have been detected.

Next, the remaining patient's radiographs were examined to fully delineate the features to allow classification of their pelvic injury. This was carried out by a single orthopedic surgery resident (Primary Investigator) for all patients. All patients had available plain film radiographs. Features were then confirmed by a radiologist report. These features were then used to classify the pattern of injury and were subsequently included in the study if they fit into one of the two following described patterns: 1.) Isolated pelvic rami fractures having either a unilateral fracture of the anterior arch (OTA 61-A2.2) or bilateral fractures of the anterior arch (OTA 61-A2.3). 2.) Young and Burgess lateral compression type I pelvic fracture (OTA 61-B2.1); an anterior compression fracture of the sacrum with ipsilateral or contralateral anterior pelvic ring lesion (fracture of rami or disruption through pubic symphysis).

2.5 Data Extraction

With our patient population identified, we proceeded to extract further data from paper and electronic medical records. This data was manually extracted, by the primary investigator, from each patient's medical record via discharge summaries, clinic visit letters, death records, inpatient progress notes and assessments by physicians, nurses, physiotherapists, occupational therapists and social workers.

Firstly demographic and injury data were extracted including patients gender, age at time of injury, and the date and mechanism of injury. Next, the injury was further characterized by recording the radiographic description of the pelvic fracture (left or right, superior or inferior, or combination) as well as any associated extrapelvic injuries. Each patients length of stay in both an acute care hospital and rehab hospital were determined. The date of death of every patient that died within five years of their injury was recorded. Next, the ambulatory status (independent, cane, walker, wheelchair) and residential status (house, assisted living, or nursing home) were extracted from the each patient's chart for both pre and post injury.

Pre-morbid medical conditions were then extracted from each patients record. Any patient with a history of documented myocardial infarction, presence of coronary artery disease on a cardiac angiogram, or history of coronary artery bypass grafting surgery was considered to have ischemic heart disease. Any previously documented stroke or transient ischemic attack was recorded as a patient having cerebrovascular disease. Those with a history of hypertension prior to injury were noted. Patients with any diabetic admitting medications were said to be diabetics. The presence of chronic obstructive pulmonary disease (COPD) and dementia were noted in the admitting history and physical. Patients known to have a history of hemodialysis prior to injury were recorded as having end stage chronic kidney disease.

2.6 Data Analysis

The primary outcome of mortality following osteoporotic pelvic ring fractures was represented by the calculation of one and five year mortality rates. The date of death was available on all patients determined to have died in the 5 years following their injury. This date was taken in reference to the time of injury to determine the overall one and five year mortality rates. The 95% confidence intervals were then calculated using the adjusted Wald Method and used for comparison.

Using the methodology in a study by *Finkelstein et al.*, age and gender matched yearly survival rates were developed from Statistics Canada Life Tables.[5,75] Using census data, the Statistics Canada Life Tables publish the probability of a person dying at age X before reaching X+1, q(x). These are published in gender specific tables for the overall Canadian population, as well as for each province. The male and female life tables for Newfoundland and Labrador for 2009 to 2011 were used in our study. Using the age and gender of each patient in our study, an age and gender matched individual survival probability was calculated for each of the five years following their injury. This was done by first by referencing the Statistics Canada Life Tables for the q(x) value for a patients age and gender. This value was then converted into a 1 year survival rate by the following equation.

$$1 \text{ year survival} = e^{-(q(x))}$$

To then calculate the survival rates for the subsequent four years, a cumulative death rate (CDR) was calculated. This was done by adding a patients gender specific q(x) value for the year of their injury to the q(x) values for the years subsequent, to yield 2, 3, 4, and 5 year CDR's for each patient.

For example, the 3 year CDR for a patient who was injured at age 70 would be calculated by adding the q(x) values for ages 70, 71, and 72.

Each CDR was converted into an individual survival rate for each year by the following equation.

$$\textit{Individual survival} = e^{-(CDR)}$$

The predicted individual survival rates for each patient were calculated for each of the five years following injury. The mean of the individual expected survival rates was calculated for our entire patient sample population for these years. These age, gender and province matched survival rates for the general population are then compared to our study population on a survival curve.

All confidence intervals for rates were calculated using the Adjusted Wald Method. Rates were compared using Pearson Chi-squared test. Statistical significance was a p-value less than 0.05. Calculations done using SPSS version 20.0 (SPSS, Inc, Chicago, IL).

Chapter 3 Results

3.1 Patient population

Using the NLCHI database, 80 patients over 60 years old with fractures about the pelvis were identified over a five year period (2000-2005) at Eastern Health. Following application of the inclusion and exclusion criteria (Section 2.4), 43 patients remained. The demographic and pre-injury data (Table 3.1) reveal an elderly (mean age 79 years), predominantly female (74%) population with most patients living at home (74%) and able to ambulate independently without aid (74%) prior to their injury.

Table 3-1 Pre-injury Demographics and Morbidity of Patients Over 60 Years Old That Have Sustained a Pelvic Rami Fracture

Variable	**Number of Patients (%)**
Total Study Population	43
Gender Male	11 (25.6)
Mean age at time of injury ± SD (Median)	79.4 years ± 9.2 (80.0)
Patients independently ambulatory pre-injury	32 (74.4)
Patients requiring cane or walker pre injury	11 (25.6)
Patients living in own house pre-injury	32 (74.4)
Patients in assisted living facility pre-injury	10 (23.3)
Patients living in nursing home pre-injury	1 (2.3)

3.2 Patient Injury and Admission

The injury and hospital admission data (Table 3.2) demonstrates mostly low energy, ground level falls (86%). Documentation of the mechanism of injury was complete and present in all charts. Most patients sustained fractures of multiple rami (mean 1.95) and many sustained other associated extra-pelvic fractures (35%) from their injury. These associated injuries were predominantly upper extremity fractures (67%), with the remainder being fractures of the axial skeleton. There were 3 fractures of the distal radius and 5 of the proximal humerus. The axial skeleton fractures consisted of 1 lumbar compression fracture and 4 patients having sustained rib fractures.

The admission data reveals a significant length of stay following these injuries with a mean of over three weeks (25 days) in an acute care hospital bed and greater than five weeks (38 days) total when also accounting for their rehab hospital admission. The standard deviation for both means is quite large, however, due in large part to the range of total admission lengths (3 to 201 days). The median admission lengths of 17 days for acute care and 30 days for total hospital admission may be a more representative measure of central tendency given this range.

Table 3-2 Injury and Hospital Admission Details Following Pelvic Rami Fractures in an Elderly Newfoundland Population

Variable	**Number of Patients (%)**
Ground Level Fall	37 (86.0%)
Fall Down 3-5 Steps	2 (4.7%)
Fall from height or MVA	4 (9.3%)
Bilateral Rami Fractures	5 (11.6%)
Patients sustaining other fractures	15 (34.9%)
Mean number of rami fractured	1.95 rami
Mean Length of Stay in Hospital ± SD	24.6 days ± 27.4
Mean Length of Stay of Combined Acute Care Hospital and Rehab Hospital ± SD	38.1 days ± 38.0

3.3 Injury Mortality

The primary outcome of this study, mortality, is calculated at one and five years post-injury (Table 3.3). We found the one year mortality following an osteoporotic fracture of the pelvic ring to be 16.3% [95% CI, 7.8% to 30.3%] with a five year mortality of 58.1% [95% CI, 43.3% to 71.6%].

Table 3-3 Mortality of Elderly Patients Following Pelvic Rami Fracture

	n	**Rate %**	**95% CI**
One year mortality	7	16.3	7.8% - 30.3%
Five year mortality	25	58.1%	43.3% - 71.6%

The mortality rates for an age, gender and province matched cohort of the general population was generated using the Statistics Canada Life Tables and the calculations in Section 2.6 (Table 3.4). These rates were plotted on a survival curve of the study population (Figure 3.1). The one and five year mortality rates generated from the general population were 6.58% and 31.3%, respectively.

Table 3-4 Mortality of Cohort Matched for Age and Gender of Study Population Generated from Statistics Canada Survival Tables for Newfoundland and Labrador

Years	Mortality Rate
1	6.58%
2	12.9%
3	19.1%
4	25.3%
5	31.3%

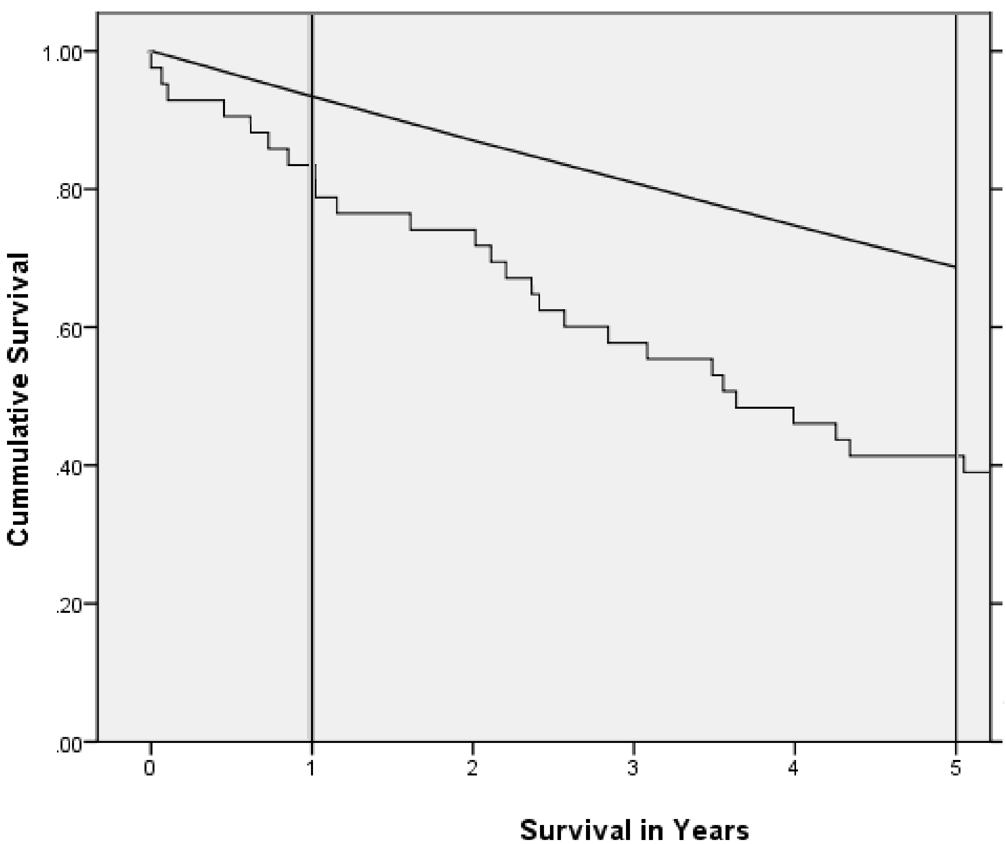


Figure 3-1 Survival Curve of Study Population (Lower) Compared to Age and Gender Matched Survival Curve for Newfoundland and Labrador Population (Upper)

3.4 Ambulatory Status and Residence

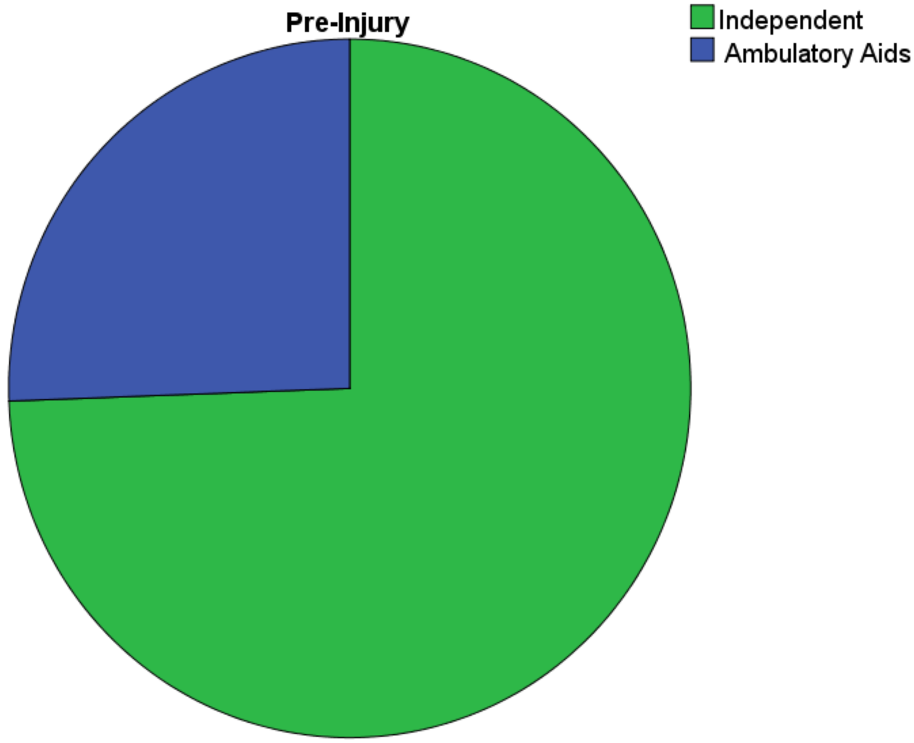
The post injury ambulation status and residency information (Table 3.5) demonstrates a deterioration in many of these patients. The proportion of independently ambulatory patients of those that survived, decreased by a quarter (25.7%) relative to the pre-injury population (Figure 3.2). This worsening of ambulatory status is further reflected in the number of patients requiring increased ambulatory aid on follow up of 35.9% (Table 3.6). There were a large number of patients that were eventually able to return to their own homes (72%)(Figure 3.3).

The four in-hospital deaths were admitted from either assisted living homes (1) or nursing homes (3). All four of these patients were ambulatory using a cane or walker prior to their injury.

Table 3-5 Pre and Post Pelvic Fracture Ambulation and Residency Status in an Elderly Newfoundland Population

	Pre-Injury, n (%) n=43	**Post-Injury, n (%)* n=39**	**Change in proportion (p-value)**
Patients independently ambulatory	32 (74.4)	19 (48.7)	-25.7% (0.017)
Patients requiring cane or walker	11 (25.6)	18 (46.2)	+20.6% (0.052)
Patients immobile/ wheelchair bound	0	2 (5.1)	+5.1% (0.133)
Patients living in own house	32 (74.4)	28 (71.8)	-2.6% (0.789)
Patients in assisted living facility	10 (23.3)	7 (17.9)	-5.4% (0.554)
Patients living in nursing home	1 (2.3)	4 (10.2)	+7.9% (0.134)

*Percentage of patients discharged from hospital, not including four in-hospital deaths



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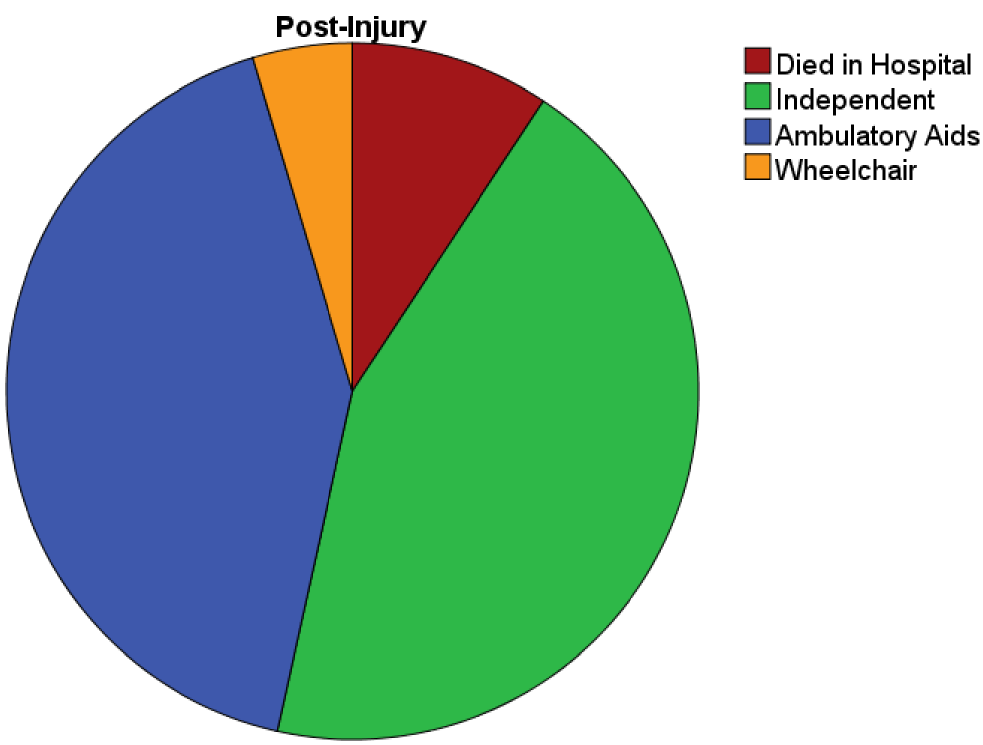
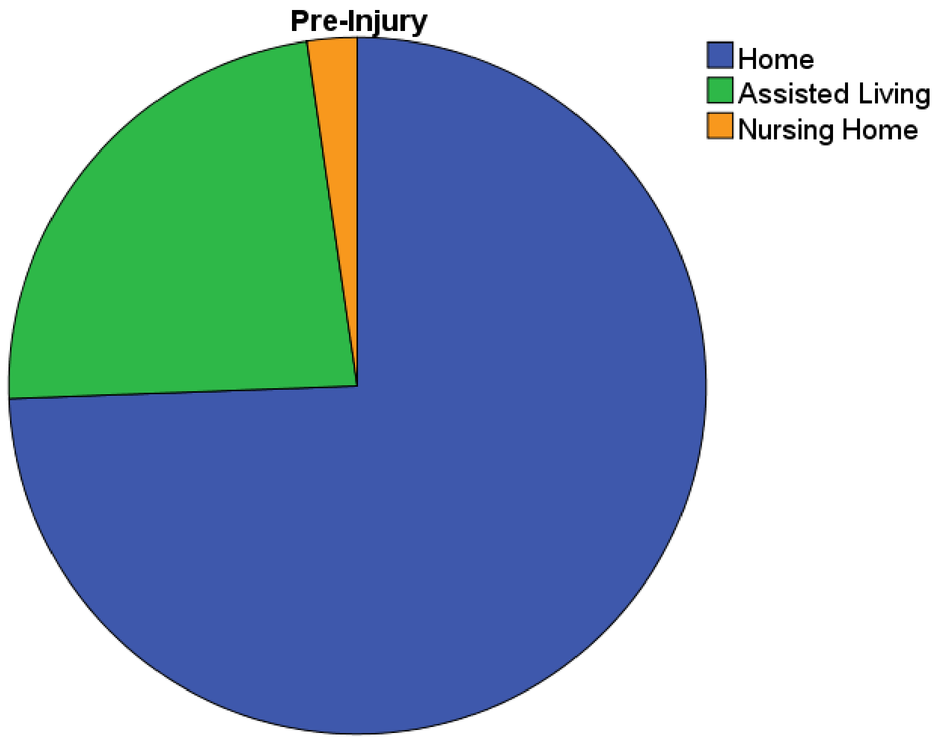


Figure 3-2 Pre and Post Pelvic Fracture Ambulatory Status in Elderly Population



Figure

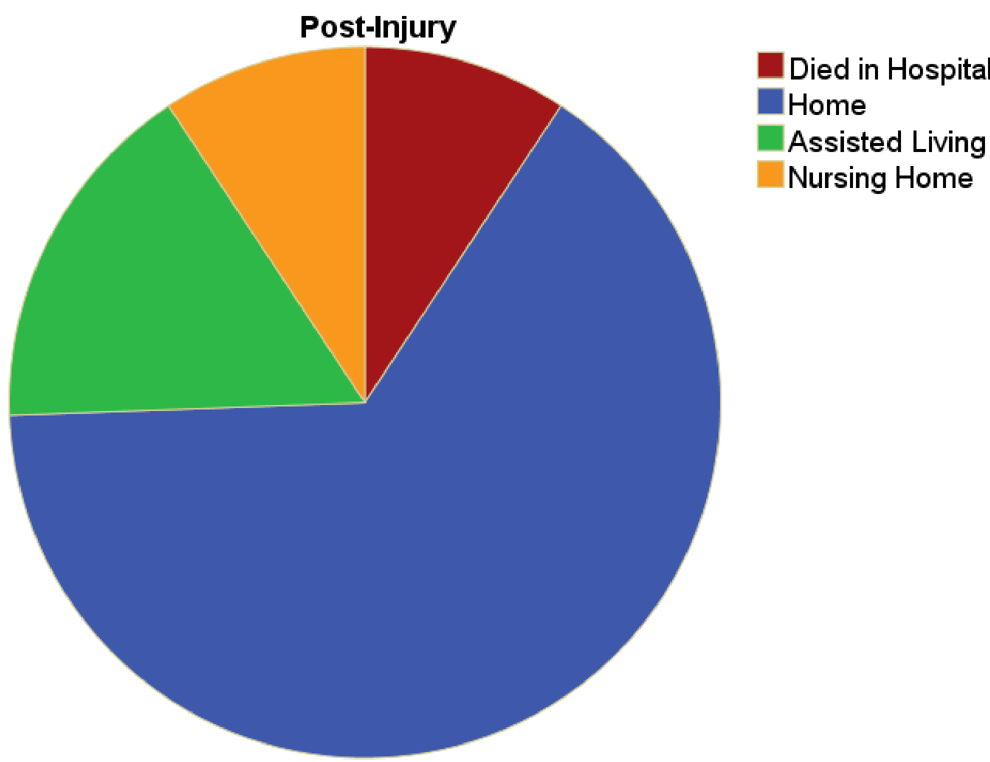


Figure 3-3 Pre and Post Pelvic Fracture Residency Status in Elderly Population

Table 3-6 Change in Ambulation and Residency Status Following Pelvic Fracture in an Elderly Newfoundland Population

	n	**% of discharged patients**	**95% CI**
Patients requiring increased ambulatory aid	14	35.9	22.7 - 51.6
Patients with increased level of care needs	8	20.5	10.5 - 35.8

3.5 Comorbidities

The qualitative presence of medical comorbidities (Table 3.7) demonstrates that the majority of patients have documented hypertension (54%). Unexpectedly, an even greater proportion of patients have documented ischemic heart disease (63%).

Table 3-7 Pre-Injury Medical Comorbidities

Comorbidity	Number of patients, n (%)	95% CI
Hypertension	23 (53.5%)	38.9% - 67.5%
Ischemic Heart Disease	27 (62.8%)	47.8% - 75.7%
Cerebrovascular Disease	7 (16%)	7.80% - 30.3%
Diabetes Mellitus	7 (16.3%)	7.80% - 30.3%
Chronic Obstructive Pulmonary Disease	12 (27.9%)	16.6% - 42.8%
Chronic Kidney Disease	4 (9.3%)	3.12% - 22.2%
Dementia	7 (16.3%)	7.80% - 30.3%

Chapter 4 Discussion

4.1 Background and Rationale

The world's population is aging. In the next 30 years the population over 65 is expected to almost double in Europe and increase over 6-fold in Asia .[4] Concurrently with this increase in age will be a dramatic increase in health issues relating to frailty and the elderly. When people age, there are multiple health problems that arise and worsen over time as the body slows and each of its essential systems slows with it. One system that is overlooked by many is the musculoskeletal system, more specifically, bone health. There is a large and growing field in medicine examining osteoporosis and its prevention. Management of its sequelae from an orthopedic surgical perspective is grossly lacking. Joint problems, such as arthritis, often receive attention from physicians and researchers because there is ongoing pain and morbidity that patients present with and wish to have treated. Poor bone health, however, does not result in crippling pain for many affected. In fact, most of those with poor bone health are largely asymptomatic until an event. This event may be a high energy trauma, a low energy fall or a spontaneous insufficiency fracture. Regardless, the concept of bone health is frequently not considered until the occurrence of an event that results in a significant amount of pain, morbidity and in some cases death.

The focus of this study was to further characterize and improve our understanding of one such event that is largely under-represented in the literature. The limited available studies suggest that pelvic fractures in elderly populations occur with rates ranging from 91 to 446 per 100,000 person years.[33–35] With an aging population, the overall incidence of these fractures will increase concurrently. This expected increase further emphasizes the importance of fully understanding these injuries with the ultimate goal to better treat and even prevent their occurrence.

The minimal literature available on osteoporotic fractures of the pelvis is further limited by the heterogeneity of the patient populations in the studies involved. These osteoporotic pattern fractures are frequently included in many studies of much higher energy injuries of the pelvic ring. This high energy fracture pattern about the pelvis is a completely different injury, as discussed previously (Section 1.1), despite the fractures being present in the same bones. The objective of this study was to establish prognosis data in a relatively homogeneous population of patients with pelvic injuries arising largely from ground level falls.

4.2 Study Design

A retrospective study design was used to characterize prognosis following the occurrence of osteoporotic pattern pelvic fractures. This design was chosen for a couple of reasons. Firstly, there is no existing ongoing prospective database of this patient population. Secondly, data acquisition is significantly more time and cost efficient in a retrospective study, particularly so in our study examining five year outcomes.

Inherent in the use of a retrospectively designed study are some advantages as well as limitations. The primary methodologic advantage to such a retrospective studies is generalizability. Without interventions or additional patient care visits, a retrospective study allows data to be interpreted with the current real-life patient experience. This is important in a study examining prognosis as it allows examination of the current standard of care being provided to a patient population.

A prospective cohort design would have provided a study of a higher level of evidence on the methodological study hierarchy. This study design allows data collection and follow-up to be more closely monitored with the ability to ensure the data set is complete and as accurate as possible. Such a study in examining prognosis following pelvic fracture would be most effective with the inclusion of a non-fracture, matched control group. This would prove to be quite costly and largely impractical, particularly in selecting a matched control group that is not wrought with selection bias. Additionally, prospectively collected data in a study of prognosis without an intervention, effectively a natural history study, can allow for study bias from additional visits and closer physician scrutiny.

A prospective randomized controlled trial (RCT) would provide the study design of highest methodological quality, but this design is best served for the examination of an intervention. As patients cannot be randomized to injury, this design is challenging to apply to a study examining prognosis with the current standard of care without the introduction of a treatment modality. Additionally, RCTs often have strict inclusion/exclusion criteria to generate a homogeneous population to accurately assess an intervention while minimizing bias. The external validity of such a study may suffer as a result of this homogeneity.

There are also significant limitations to a retrospective chart review. The increased generalizability of a retrospective chart review is generally at the cost of decreased internal validity. This represents the ability of a study to determine if the outcomes were secondary to the measured event (pelvic fracture), or were the result of other unmeasured variables.

The inherent sampling bias in this retrospective chart review of disease prognosis must also be recognized. Our patient selection of only inpatient presentations at Eastern Health, the most urban area of Newfoundland and Labrador, may paint a misleading picture of disease severity if there are a number of patients who never present in such a way. This may be the case in those who present in more rural settings or in those in whom the pain is not as severe and do not seek medical attention. The effect of these patients is unmeasurable in our study and therefore assumed to be negligible; however this may not be the case.

In the current study and others like it, the heterogeneity in the health of the patient population will greatly contribute to decreased internal validity. A well matched control group may have helped limit some of the effects of baseline health heterogeneity in this primarily female, elderly population. Additionally, the lack of standardization in treatment protocol for these patients will further increase the study's heterogeneity.

We chose to use available data on the mortality rate of the general population from Statistics Canada as a surrogate control group to draw comparisons. This allowed for a comparison group matched for region, age and gender, however not for comorbid conditions. The number and severity of comorbid conditions will have a drastic effect on mortality; therefore this average general population data will have limitations as an accurate control group.

Retrospective data is also at a disadvantage in terms of potential accuracy. The collected data is only as accurate as the data that was initially logged. The data in our study was collected from multiple sources, including physician letters, discharge summaries, multidisciplinary personnel reports, etc. While there was certainly an effort to find data previously recorded in multiple locations, this was not always the case. Particularly in assessing for comorbidities, using information from a previous documentation of medical history will be less reliable than obtaining first-hand information from the patient and objective up to date tests. As such, the accuracy of the collected data is likely lower than data collected prospectively by an experienced research team for the purposes of a particular study.

4.3 Population Demographics and Injury Characteristics

The demographics of our study population are consistent with previous work on pelvic fractures in the elderly. The mean age of 79.4 years is well within reported average ages in the previously discussed studies, which range from 74.7 to 87.5 years of age.[1,29,44–47,50–52,54] Similarly, our female predominant population (74.4%)

is certainly comparable to most studies which report female proportions ranging from 76.2% to 91.2%. The study by *Dechert et al.* reported a significantly lower female proportion of 57.3% of their study population, however this study likely had patients having sustained a higher energy injuries as patients were enrolled only after a trauma team activation code in a level 1 trauma centre. This would steer the population away from the predominantly female osteoporotic population towards the male predominant trauma population.[76]

A further defining characteristic when dealing with this study population is ambulatory status. Objectively, this is most simply defined by the qualitative use of ambulatory aids prior to their injury as determined by the allied health staff. The use of other measures, such as “Timed Up and Go” testing would allow for a more detailed definition of ambulatory status, however this is not possible to define prior to injury. In our population 74% of patients were independently ambulatory without aids prior to their injury. This rate was closely mirrored by *Koval et al*. who found 79% of patients to have been independently ambulatory prior to injury.[45] This was also quite similar to the French and Scottish studies of pelvic rami fractures, where 68% and 69% of patients walked independently upon admission, respectively.[1,52] Contrasting this is the 52-55% of patients felt to be independent community ambulators prior to injury in two other similar studies of elderly pelvic fractures.[29,46] Further contrasting again is the study by *Mears and Berry* where the pre-injury independently ambulatory population represented only 38%.[51] This variation in reported pre-injury ambulatory rates is not surprising given the variation previously discussed when analyzing this study population. The proportion of pre-injury independent ambulators likely indirectly represents a measure of the frailty in each of the study populations.

The proportion of patients living in their own home prior to injury is also going to be a characteristic marker which will aid in determining the frailty of a population. In our patient sample, 74% of patients were living in their own home prior to admission, with the remaining 26% living in an assisted care or nursing facility. Similar percentages were reported by *Hill et al*. with 79% of patients having been admitted from their own homes.[1] Other studies reported much higher rates of 89% to 100% of patients living at home prior to their injury.[29,45,52] Much lower rates are also reported, with 53-59% of patients living home prior to injury in two other studies.[47,51] The Hong Kong study of elderly patients with pelvic fractures uses alternate descriptions of residency status, choosing instead to describe 72% of their patients to have been independent in activities of daily living.[46] With only 15% of patients living alone and 70% living with family, describing those capable of potentially living by themselves is used to account for cultural differences in eastern Asia.

Our study population reported 34.9% of patients having sustained a concomitant fracture at the time of their injury. This is a characteristic less often reported in prior literature. Fractures in other anatomical sites are reported to have occurred simultaneously with pelvic rami fractures by two other studies in 18.3-23.4% of patients.[1,46] Similarly, the associated fractures in these studies were primarily of the of distal radius, proximal humerus and axial skeleton (rib and stable compression fractures of the spine). These fracture locations are commonly associated with osteoporosis. In many circumstances, particularly in dealing with the high energy polytraumatized patient, the absolute number of injuries contributes to the injury severity score, which directly correlates to the energy involved in the injury and to absolute mortality.[77] In this patient population, with most patients sustaining only a ground level fall, an associated fracture is more likely to represent further frailty than increased injury energy. Slowed reaction time in progressive frailty will inhibit the self-protective response to limit injury. Additionally, osteoporosis progression with worsening frailty will increase the risk of multiple fractures with a fall.[78]

There has been some research into concomitant fractures in the hip fracture literature. A study by *Buecking et al*. in 2012 found their hip fracture population had a concomitant fracture rate of 5%.[79] Most frequently fractured were the proximal humerus and distal radius. These patients exhibited no significant difference in their in-hospital mortality, hospitalization length, or incidence of complications when compared to patients with hip fractures only. Three previous studies found similarly low incidences of concomitant fracture in the hip fracture population (2.7-4.7%).[80–82] These studies, however, were only of concomitant upper extremity fractures; only one of these studies, by *Mulhall et al*, demonstrated any statistically significant difference in the clinical outcomes of these patients.

4.4 Primary Outcome: Mortality

Mortality associated with fracture is a frequently used measure in orthopedic literature. The reality that a fracture is rarely directly responsible for a patients cause of death is simply an understood concept in this literature. In high energy injuries, the polytraumatized patient has often sustained orthopedic injuries such as a femur fracture or unstable pelvis. We frequently report mortality rates following these injuries. While these injuries can contribute to the death of a patient with potential massive blood loss, the cause of death is more frequently from injury to other vital organs. Mortality is measured in orthopedic literature with the goal of determining if improvements in orthopedic management can decrease their detrimental effect on the body's other systems. A 1989 study by *Bone et al.* examined the detrimental effects of early versus late stabilization of femur fractures in a polytraumatized patient.[83] They measured the incidence of pulmonary complications and found that patients treated more quickly with stabilization of their femur had less pulmonary complications.

Mortality in individuals with osteoporotic fractures occurs for quite different reasons than in high energy injuries but is equally important to study. The mortality associated with osteoporotic fractures, particularly of the lower extremity, is generally secondary to the coincidental immobility. Immobility and bedrest leads to complications such as significant muscle atrophy and wasting, thromboembolic disease, and chest and urine infections that can result in death in the at risk population that sustains these injuries. In addition to directly causing immobility and its complications, osteoporotic fractures can also be looked upon as a marker of multisystem failure. That is, patients that have sustained an osteoporotic fracture often have coinciding end stage dementia or renal, hepatic, cardiac or pulmonary disease. The osteoporotic fracture may simply be seen as a marker to identify those in the population at risk for increased mortality secondary to multi system failure. This concept is very challenging to prove scientifically and represents a significant void in the literature. A recent study by *Wong et al.* demonstrated that a patient sustaining a fall from less than 0.5 metres, was more likely to die of causes unrelated to their injury than those sustaining a fall from greater than 0.5 metres or other higher energy blunt trauma.

There was significant mortality of the study population over the course of this study of low energy pattern pelvic ring fractures. This was not surprising given the average age at time of injury of those in the study was 79.4 years and patients were followed for 5 years following this. According to Statistics Canada, the one year probability of death of a 79 year old female (our study population was 74% female) in Newfoundland and Labrador is 3.9%.[84] When added to the death rate for the next 4 years, the cumulative death rate of this 79 year old female is 24.6% over 5 years.

The one year mortality rate in our study was 16.3% (95% CI; 7.80% to 30.3%). The calculated age and sex matched one year mortality rate for our sample using Statistics Canada data for Newfoundland and Labrador from 2009 to 2011 was 6.6%.[75,84]. This dramatic difference in mortality is graphically depicted in the survival curve (Figure 3.1). The one year mortality rates in the current literature for pelvic fractures in the elderly range from 9.5% to 27% .[1,45–47,3,49,50] These rates closely mirror and include the 95% confidence interval for mortality rate in our study. As discussed in Section 1.7, these studies represent a significantly heterogeneous group, both in the patient population treated and the manner in which they are managed. One of these studies, a 2010 review by *Krappinger et al*., combined 557 patients from 6 different studies to yield a mean one year mortality rate 16.3%.[3] While this value does replicate the one year mortality rate in the current study, the heterogeneity of the patients included in their calculated value does not suggest increased accuracy of the mortality rate determined in our study.

The five year mortality rate of our patient population was 58.1% (95% CI; 43.3% to 71.6%). The calculated expected five year mortality rate for the gender and age matched population calculated from the Statistics Canada Life Tables is 31.3% . The five year mortality is less frequently reported in the literature but two studies have reported rates of 54.4% and 64.4%.[1,50] The Scottish study by *Hill et al.* that reported a five year mortality of 54.4% appears to represent a relatively similar patient population with a mean age 74.7 years. They do, however, have an age range of 17 to 97 years old and 13% of their fractures were the result of MVA's with 55% of these involving pedestrians. The inclusion of these younger patients adds a significant amount of heterogeneity to the patient sample in this study as the baseline mortality rate of a 97 year old will differ drastically from that of a 17 year old. Similarly, the difference in global injury will decrease the accuracy of outcomes in studies using patients having sustained an MVPA (motor vehicle pedestrian accident) alongside patients after a ground level fall.

The use of Statistics Canada Life Tables to yield an age and gender matched comparison group can only be done with the inherit understanding of its limitations. The values provided by Statistics Canada are assumed to provide accurate data of the overall mortality in Canada and in the province of Newfoundland and Labrador. The published probability of dying within the next year, q(x), used for our estimation calculation, has an associated margin of error published for each value as well. Unfortunately this margin of error was not possible to be brought forward through our calculated estimate of survival. Therefore, use of these point estimates of mortality rates for a matched general population must be done so with caution.

Understanding this, using the overall population as a comparison group provides useful information and perspective when dealing with the mortality in a population with a high baseline mortality. It must be considered, however, that this control group of the overall population at baseline is likely to have less comorbidities on average than that of the study population. Our analysis of comorbidities, however, largely contradicts this, allowing comparisons to be made cautiously with the general population.

A 2012 study of hypertension in Canada using primarily ICD diagnostic coding, reported prevalences of 43.3% in patients aged 60 to 64 and 74.6% in those greater than 85 years.[85] The mean age of our sample was 79.4 years with a hypertension prevalence of 53.5% (95%CI; 38.9% - 67.5%). Given these values, the prevalence of hypertension in the sample of our population is comparable and trending to be lower as the prevalence in the general population for a group including our mean age (75 to 79) was reported as 69.5%.

The prevalence of diabetes in our sample population of 16.3% (95% CI 7.80% to 30.3%) was also found not statistically different than the Canadian prevalence reported by the Public Health Agency of Canada.[86] This report of 2008/09 data has a diabetes prevalence estimate of 16.6% in those aged 60 to 64 and 21% in those >85 years. Additionally, while there is no reported age stratified data for each province in this document, the age standardized prevalences reported between provinces is highest in Newfoundland and Labrador. Therefore, the prevalence reported for the age block including our mean age (70-79) of 25.5% is likely an underestimate for the province.

The rate of COPD reported in our study was 27.9% (95%CI; 16.6% to 42.8%). A 2014 study of Canadian data reported a COPD prevalence of 22.1% (95%CI; 19.9% to 24.7%) in those aged 60 to 69 years and 37% (95%CI; 30.2% to 43.9%) in those 70 to 79 years.[87] There is admitted variability in prevalence estimates for COPD, as acknowledged in their study. They found there to be a two to six times greater prevalence when comparing measured airflow values to self-reported diagnosis. Our patients' diagnoses of COPD were extracted primarily from physician reports and therefore our prevalence is likely an underestimate as many patients are un- or underdiagnosed. Despite these limitations, there is no statistically significant difference detected between the prevalence of COPD in our study relative to the Canadian general population estimates.

The use of the Statistics Canada Life Tables to formulate a comparison group for mortality must be done understanding the limits of this exercise. Despite there being no statistical difference in some of the aforementioned comorbidities, the populations are likely quite different. Some of this lack of statistical difference can be attributed to quite wide 95% confidence intervals in our study secondary to the study's small sample size. There are likely multiple confounding factors if the comparison is meant to only measure the effect of the pelvic fracture. The ideal control group to measure the effect on mortality of the pelvic fracture event alone, outside of a prospective study randomizing patients to pelvic fracture, would involve a group with improved control of the confounding variables. Such a group would require a population matched for comorbidities in addition to gender and age. Independently controlling for comorbidities perfectly is near impossible and further may lead to selection bias. Alternatively, the use of a comparison group with a similar comorbidity profile may have been that of osteoporotic hip fractures. This population, however, is dramatically affected by their injury and therefore its use as a comparison group would provide little insight relative to patients in an "at risk" population who have not sustained an injury.

Hip fracture mortality rates are reported with similar variability in the literature. One-year mortality rates range from 12% to 37%.[88–90] These values are certainly within the same vicinity and within the 95% confidence interval (7.80% to 30.3%) of those reported by our study and others for low energy pattern pelvic ring fractures. All hip fractures are typically treated operatively, as previously discussed (Section 1.10). The mortality rates reported are primarily comprised of operatively treated hip fractures with little literature on what happens to the non-operative patient.

What then, do we take away from this? The goals of surgery in the hip fracture population are pain control and mobilization. This improved mobilization has the most significant impact on mortality. Perhaps then, should we be considering operative fixation in the previously considered non-operative low energy pattern pelvic ring injury? Could improving mobilization yield an ultimate improvement in mortality? Is there a subset of patients whose survival may improve with surgery?

4.5 Secondary Outcomes: Morbidity

There remain ongoing challenges in the documentation of morbidity associated with a traumatic event. Morbidity is particularly important to measure in an osteoporotic elderly population as post traumatic deteriorations in mobility and independence can result in dramatic burdens on associated stakeholders.

The vast majority (74.4%) of our study patients were independently ambulatory without aids prior to injury. There was a statistically significant decrease in independently ambulatory patients to 48.7% following their injury (p=0.017), with 46.2% of patients then requiring a cane or walker. This represented a decrease in ambulatory status in 35.9% (95%CI; 22.7% to 51.6%) of patients following their injury. This value is consistent with this infrequently reported measurement in two previous studies of osteoporotic pelvic rami fractures of 29.6% to 36%.[1,46] Contrasting this is a small study, with follow up of only 60%, of patients in a slightly younger population (>55 years) that found 92% of their patients to have maintained their pre-injury ambulatory status.[45] While their study seemingly represents a somewhat different patient population with many patients treated as outpatients, the pre-injury independent ambulators without aid were reported at 79%, with 21% requiring aids; this is similar to our study values for these rates of 74.4% and 25.6%, respectively.

The level of care required by elderly patients following a traumatic event is also critical in determining the burden of injury. Interestingly, in our study, there was no statistically significant change in level of care required following injury. The patients living in the their own home decreased only slightly from 74.4% to 71.8% ($p=0.554$). The number of patients living in a nursing home increased from 1 to 4 ($p=0.134$). It is possible that with an increased sample size, the power of the study would have allowed a difference to have been detected. *Breuil et al.* reported 74.5% of patients returning to their own homes following this injury.[54] In their study only 31% of patients went home on discharge, with the majority (65.6%) being transferred to a geriatric in-patient centre. This is not the care model used in Newfoundland and Labrador, thereby explaining our increased acute hospital stay of 24.6 days to the 13.9 days in this French study.

The remainder of the studies examining residence level of care following injury report quite varied values for proportions of patients returning to their homes, from 37% to 95%.[1,29,45,50–52] This variation is related to multiple factors. The studies' follow up periods are different, with some reporting the discharge location directly from the acute care ward as the final residence; others report an additional follow up visit or phone call up to five years later. Another factor of critical importance in developing the optimal care model for these patients is the varying geographic locations, and subsequently the varying care models experienced by these patients. These studies from France, America, Holland, and the UK describe discharging patients to geriatric inpatient units, orthopaedic geriatric units, community rehabilitation units and extended stay hospitals. All of these post-acute care units exist very minimally or not at all in the Eastern Health region of Newfoundland and Labrador, from which our sample population was drawn.

4.6 Study Limitations

4.6.1 Design

There are inherent limitations in the retrospective, observational design of the present study. As previously discussed, it is impossible to design a randomized controlled trial to determine the effect of pelvic rami fractures on mortality in the elderly. An improvement on the study design could have involved the use of an appropriately matched control group. The selection of such a control group will however introduce the additional challenge of minimizing associated selection biases. Selecting a control group matched for age and gender would provide the most simplistic approach. Without consideration of comorbidities, this population may likely be considerably more healthy than our population with highly osteoporotic fractures. One highly studied group with likely similar comorbidities is the proximal femur fracture population. Unfortunately, the use of this group for comparison will be ineffective in relating pelvic fractures to the general population and thereby contribute little to elucidating the effect of the injury on mortality. The Dutch study of osteoporotic pelvic fractures by *van Dijk et al.* used an age and gender matched comparison group of patients that presented to the hospital for skin cancers that were presumed not to affect survival.[50] This control group is not matched for any comorbid conditions and therefore is unlikely to represent a group of similar health as those presenting with osteoporotic fractures. These low energy pelvic fractures are more likely to present in those with greater overall frailty than those presenting for excision of skin lesions electively. This is not discussed in the paper.

We emulated a control group of the general population using the Statistics Canada Life Tables for Newfoundland and Labrador to yield a survival curve for comparison. As mentioned, the number and severity of comorbidities in the general population is presumed lower than those found in patients with osteoporotic pelvic rami fractures, thereby adding selection bias with this group. Our qualitative measures for the presence of comorbid disease, however, have shown our rates of chronic disease may not be as different as what was initially assumed (Section 4.5).

Additionally, as we are only given death rates in the Statistics Canada Life Tables, without absolute values this is statistically difficult to compare to our study group. Therefore, having a large appropriately matched control group would have contributed to the statistical validity by allowing us to perform independent sample testing of the survival data. This would be optimally done using survival plots for each group and subsequent analysis with log rank testing.

A retrospective chart review study also lends itself to inherent dependency on previously collected data. This data is only as reliable as the person who captured it. Great effort was made to double check all data from the chart in multiple sources, however this was not always the case. This would have been a benefit to prospectively collected data. All factors could have been assessed by investigators associated with the study, ensuring the reliability of the data, as well as being able to collect additional information that was not available in the patient chart.

4.6.2 Sample Size/ Number of Events

The sample size of our population is arguably the most significant limitation of this study. Firstly, it resulted in decreased accuracy in our estimates of mortality. This is evidenced by wide 95% confidence intervals for both one and five year mortality.

Additionally, the sample size and number of mortality events measured restricted our ability to perform multivariate analysis. This is a study of prognosis following an injury in which there is currently little to no treatment, effectively rendering it a natural history study. Such a study can also be effective in determining factors that may be predictive of prognosis, prognostic factors. The most effective way to do this in our study with a binary outcome of survival, would have been through the use of logistic regression. This would have allowed for the simultaneous consideration of the effects of multiple measured variables on our outcome of survival. Unfortunately, our sample size and subsequent number of events measured did not allow for this to be validly performed. The rule of thumb for logistic regression has been a minimum of 10 events per predictor variable (EPV) tested. This is based on simulation studies that showed increasing bias, variability, and unreliable confidence interval coverage with less than 10 EPV.[91–94] A subsequent study by *Vittinghoff and McCulloch* challenged this rule of 10 EPV belief with a large simulation study and found that this rule may be relaxed down to 5-9 EPV with only a minor degree of extra caution.[95] Unfortunately, with only 7 events in our primary outcome of one year mortality, we were unable to perform a robust multiple logistic regression that would have contributed to this study. Logistic regression has been used in three of the previous studies of pelvic rami fractures in the elderly with relatively minimal findings. In the UK study by *Hill et al.*, logistic regression was used to determine prognostic factors and only age and the presence of dementia were found to be predictive of mortality.[1] The study by *Leung et al*. in Hong Kong examined many similar factors to predict survival and found none to be significant..[46] *Taillandier et al.* found age to be significantly associated with a loss of self-sufficiency in their osteoporotic pelvic fracture population.[52]

The sample size was largely dictated by the size of the health region examined and the availability of accurate data from earlier than 2001. Patients were identified by the NLCHI (Newfoundland and Labrador Centre for Health Information) database. This database only has coded information of patients that had been admitted. Any patient that may have been treated as an outpatient with a pelvic ramus fracture either in the emergency department or in the community by their family doctor would not have been captured by this database. This is believed to have been a relatively rare occurrence but it is possible there were some cases missed. The cases that may have been missed would possibly have represented a healthier population with decreased comorbidities and would likely have improved survival, our primary outcome. It is felt that this likely represents a very small proportion of the elderly pelvic fracture population, however, it is impossible to ascertain this for sure given the currently available data.

The sample size of our population was also limited by the parameters we selected to measure. To obtain complete five year mortality data, only data from patients having had their injury at least 5 years prior to data collection in 2012 were included. Without reliably available imaging prior to 2001, only patients who sustained their pelvic fracture after 2001 were included in the study. This left a sample window of 2001 to 2006, from which all patients were identified.

4.6.3 Population Heterogeneity

As discussed, all studies involving pelvic fractures have some element of heterogeneity. This is in both patient factors and injury factors. Our goal was to select a patient population to which we could draw some general conclusions by decreasing this heterogeneity as much as possible. By using a population greater than 60 years old, the heterogeneity was decreased but was certainly not eliminated. The two patients at the extremes of our age range were 61 and 100 years old. There is little doubt the predicted mortality outcome will be quite different in these two patients, which is evidenced by the yearly mortality rates [q(x)] reported in the Statistics Canada Life Tables for ages 61 and 100 years old of 1.0% and 35.8% (probability of dying in the next year). The bone quality in these two patients is less measurable but the likelihood of the same energy causing the same fracture pattern is unrealistic. The injuries in these two patients may have a occurred via a ground level fall, but without being present for the injury to measure the force of the fall, it can be assumed they were quite different. The injury pattern is challenging to completely control for. Some patients fractured only one pelvic ramus, while others fractured all four rami and had additional extra-pelvic fractures. In dealing with traumatized patients there will always be some element of heterogeneity as no two injuries are ever absolutely the same. The degree to which this was limited in the current study is significantly greater than most of the previous studies in the literature on this topic, where wider variabilities in age were compared and low energy injuries were analyzed together with those with much higher energy.

4.6.4 Local Data

The advantages and limitations of locally collected data must also be appreciated in assessing the findings of this study. Using a patient population that has not been examined before in the sparse elderly pelvic fracture literature certainly does provide some novel data to this area of research. To our knowledge, there are no other studies published of elderly pelvic fracture patients in Canada. The variation in mortality rates across Canadian provinces, as seen in the Statistics Canada Life

Tables,[84] further stresses the importance of local data. The genetics, lifestyle, and environmental differences as well as the access to healthcare seen across provinces may have a dramatic effect on our primary outcome of mortality. The use of this population will then increase local applicability but decrease the global generalizability of the study.

Chapter 5 Conclusion

5.1 Pertinent Findings

The purpose of this study was to further elucidate the prognosis of low energy pattern pelvic rami fractures in an elderly population. This is important because this injury in this patient population is quite underrepresented in current literature and is due to significantly increase in incidence as the population ages. The mortality rate of 16% in the first year is quite significant for what many would consider a "benign" injury.[45] These fractures have often been thought of in this manner because they classically have been an injury effectively left untreated. The significance of this injury is further exemplified by the five year mortality of 58%. While sometimes difficult to conceptualize extended mortality in an elderly population, using Statistics Canada Life Tables for the general population, the age and gender matched standard five year mortality for our study sample was about half of this, 31%.

In addition to mortality, we documented significant morbidity following these injuries in those that survived. Only 59% of patients that were independently ambulatory prior to injury were able to walk again without a cane or walker. Surprisingly, 88% of patients who lived in their own home prior to injury were able to return.

5.2 Clinical Significance

The findings of a retrospective prognosis study are difficult to translate directly to clinical practice. The small sample size further decreased the accuracy of our findings, translating to wide confidence intervals in our morbidity and mortality estimates. The mortality and morbidity estimates documented should increase the awareness of this at risk injury population. Unfortunately, without having examined treatment modalities, no specific recommendations on treatment can be made based on this research.

The homogeneity of the population used is quite novel in the minimal literature of this injury, that as previously discussed is quite heterogeneous. Additionally, the use of local data increases the value of this study within the region.

5.3 Research Significance and Future Direction

The true value of this study is in its role in documenting an underrepresented health issue that will only increase in quantity, and thereby its importance, in the coming years. The retrospective design and small sample size limit the practical usefulness of this study to being primarily hypothesis generating. Low energy pelvic fractures in an osteoporotic population are currently an injury for which we do not have adequate treatment. Given the underrepresentation in current literature and the increasing importance of this fracture population, there are plenty of avenues for potential future studies.

Firstly, further epidemiological studies with larger populations across different populations will help us to further document this injury. Retrospective studies of the current standard of care treatment regime in these patients will continue to be useful at present time. A larger study with a greater sample size and subsequently a greater number of death events would allow the use of multiple logistic regression. Using logistic regression may help identify prognostic factors that help generate targets for future therapies. Additionally, it may help us predict areas that will likely require increased attention and resources in the future, such as geriatric orthopedic care.

Concurrent with this, economic analyses of better epidemiological data will allow us to measure the current financial burden of this health issue. There is no literature to our knowledge of the economic impact of pelvic ring injuries in an elderly population. This will provide us with the information necessary for efficient allocation of health care resources; including adequate funding for future research into mediating the burden of disease. Local data in studying the economics of these injuries will be particularly useful to healthcare decision makers as healthcare costs continue to become an increasingly larger portion of the GDP.

Following appropriate documentation of the problem, the next step will be determining the areas to target to improve upon care. This can be grossly divided up into three target areas: prevention, acute treatment, and long term treatment.

Preventing pelvic rami fractures in an elderly population will involve improving the overall management of osteoporosis and decreasing the risk of falls. These are both fairly significant current areas of research; this study will simply serve to re-emphasize their importance and provide the basis for larger studies to be able to identify predictors for such an injury to occur. A recent umbrella review of multiple meta-analyses on preventing falls in community-dwelling adults concluded that there was high-quality evidence that exercise can significantly reduce falls.[96] The same group published an umbrella review of meta-analyses on preventing falls in long term care residents and concluded the evidence for exercise in this population was not convincing at present.[97] Similarly there was mixed evidence in both groups for the effectiveness of Vitamin D in preventing falls.[96,97] In the long term care group both hip protectors and routine medication reviews were not found to decrease falls.[97] These studies also found evidence of benefit in using individualized multifactorial interventions.[96,97]

As discussed in Section 1.2, osteoporosis is a large area of ongoing research. The use of bisphosphonates in recent years seems to have had an effect on this disease. It is impossible to specifically say, however, that bisphosphonates have had a direct impact on the incidence of pelvic fractures in this population as the literature does not exist examining this. Bisphosphonate use, as well as bone mineral densities, would be important osteoporosis related factors to measure in a study powered to assess their utility as predictors of rami fractures.

Acute treatment of these osteoporotic pelvic fractures is an area of significant paucity in current literature. As discussed in Section 1.11, current treatment of low energy pelvic fractures is largely pain management and physical therapy as tolerated. There are multiple suggested surgical treatment options in the literature that have amounted to little more than some small case series at present. These range from full open operative interventions, to percutaneous hardware insertion, to percutaneous injection of polymethylmethacrylate.[69–71] Medical treatment with recombinant parathyroid hormone has also been used with some success but requires significantly more research.[67] Concurrent with improving long term outcomes with improved acute treatment, investigations need to be directed at optimizing the rehabilitation phase. This may include altering any aspect of a multidisciplinary care model focused on orthopedic geriatric rehabilitation.

The aging population will inevitably result in an increase in the incidence of osteoporosis related events in the years to come. The prognosis and treatment of pelvic ring fractures in this population are not well understood. This study was designed to further our knowledge of prognosis following these injuries. It is primarily hypothesis generating, but does provide some valuable insights into the consequences of pelvic rami fractures in an elderly population in Newfoundland and Labrador.

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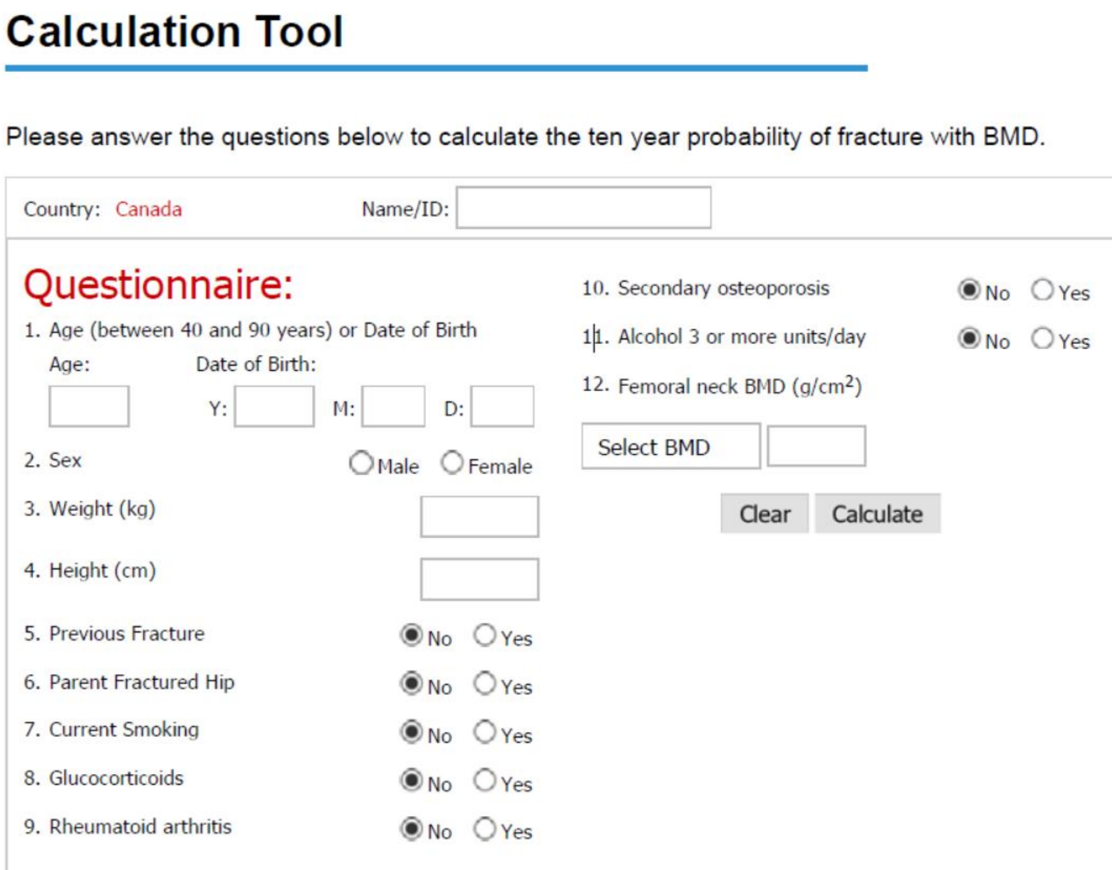
Appendix 1: FRAX ® WHO Fracture Risk Assessment Questionnaire



Calculation Tool

Please answer the questions below to calculate the ten year probability of fracture with BMD.

Country: Canada Name/ID:

Questionnaire:

1. Age (between 40 and 90 years) or Date of Birth
   Age: Date of Birth: Y: M: D:
2. Sex ◯ Male ◯ Female
3. Weight (kg)
4. Height (cm)
5. Previous Fracture ◉ No ◯ Yes
6. Parent Fractured Hip ◉ No ◯ Yes
7. Current Smoking ◉ No ◯ Yes
8. Glucocorticoids ◉ No ◯ Yes
9. Rheumatoid arthritis ◉ No ◯ Yes
10. Secondary osteoporosis ◉ No ◯ Yes
11. Alcohol 3 or more units/day ◉ No ◯ Yes
12. Femoral neck BMD (g/cm^2)

Select BMD

Clear Calculate

Appendix 2: Young and Burgess Pelvic Fracture Classification[2]

Fracture Type	*Common Characteristic*	*Differentiating Characteristic*
Lateral compression 1	Transverse pubic rami fracture	Sacral compression on side of impact
Lateral compression 2	Transverse pubic rami fracture	Crescent (iliac wing) fracture
Lateral compression 3	Transverse pubic rami fracture	Contralateral open-book (anteroposterior compression) injury
Anterior-posterior compression 1	Symphyseal diastasis (1–2 cm)	Slight widening of symphysis and/or sacroiliac (SI) joint, stretched but intact anterior and posterior SI joint ligaments
Anteroposterior compression 2	Symphyseal diastasis or vertical pubic rami fracture	Widened SI joint, disrupted anterior SI ligaments with intact posterior SI ligaments
Anteroposterior compression 3	Symphyseal diastasis or vertical pubic rami fracture	Complete hemipelvis separation but no vertical displacement, anterior and posterior SI joint ligaments ruptured
Vertical shear	Symphyseal diastasis or vertical pubic rami fracture	Vertical hemipelvis displacement, usually through SI joint, occasionally through iliac wing or sacrum
Combined mechanism	Vertical or transverse pubic rami fractures	Combination of patterns: lateral compression with vertical shear or lateral compression with anteroposterior compression