Older patients with odontoid process and cervical spine fractures: evaluating clinical risk factors, clinical pathways and treatment to prevent further fracture.

Submitted by Naomi Fuller to the University of Exeter as a thesis for the degree of Masters by Research in Medical Studies in July 2018.

I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

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ABSTRACT

INTRODUCTION

The most common site of cervical spine fracture in the elderly is the odontoid process. These fractures result predominantly from ground level falls. Osteoporosis has been identified as an important predisposing risk factor. This study aimed to evaluate the management of older patients with cervical spine fractures and identify opportunities to reduce fracture rates.

METHODS

A service evaluation was undertaken utilising a retrospective review of electronic hospital records at the Royal Devon and Exeter hospital for patients aged 50 years and over who sustained a cervical spine fracture over a four year period. Patients were identified from CT cervical spine reports positive for fracture.

RESULTS

85 patients ($\bar{x}$ age: 77.2 years, σ ±12.7) were identified. 61.2% sustained fractures from a ground level fall. Prior to cervical spine fracture 41.2% had sustained at least one previous fracture of any bone, 11.8% had a dual-energy X-ray absorptiometry (DXA) scan and 9.4% had bisphosphonate use recorded. One year following cervical spine fracture, a further five people had a DXA and one more person was taking a bisphosphonate. Five people attended the hospital with a fracture within a year of the c-spine fracture, four of which were neck of femur fractures.

Mortality at three months and one year were 11.8% and 20.8% respectively. There was no clearly superior management strategy between surgical or non-surgical management.

There was a high prevalence of cervical spondylosis but no association between severity and any characteristics of the injury.

Projection radiography was carried out before CT in 71.3% of patients. Time spent in A&E was under four hours in 38.2% of visits. Median initial inpatient stay length was

seven nights. Re-admission rate at 30 days was 15.9%. Patients were discharged from an inpatient stay to their usual place of residence in 78.1% of cases.

CONCLUSION

Mortality rates are similar to those published in other studies. Guidelines for initial imaging of cervical spine injuries are not consistently being followed. Fracture prevention is not an integrated part of c-spine fracture care despite their association with osteoporosis in the elderly. Implementation of a Fracture Liaison Service is recommended.

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LIST OF ABBREVIATIONS

A&E – Accident and Emergency
AOJ – Atlanto-odontoid joint
ASA – American Society of Anesthesiologists Physical Status Classification System
BMD – Bone Mineral Density
BMI – Body Mass Index
C1 – First cervical vertebra (atlas)
C2 – Second cervical vertebra (axis)
C3 – Third cervical vertebra
C4 – Fourth cervical vertebra
C5 – Fifth cervical vertebra
C6 – Sixth cervical vertebra
C7 – Seventh cervical vertebra
CCSR – Canadian Cervical Spine Rules
CDM – Clinical Data Management system
CRIS – Computerised Radiology Information System
C-spine – Cervical spine
CT – Computed Tomography
DXA – Dual-energy X-ray Absorptiometry
FLS – Fracture liaison service
FRAX – Fracture Risk Assessment Tool
GP – General Practitioner
HRA – Health Research Authority
IG – Information Governance
ITU – Intensive Therapy Unit
L1 – First lumbar vertebra
L4 – Fourth lumbar vertebra
LCSF – Lower cervical spine fracture – fractures of C3-7
MRI – Magnetic Resonance Imaging
NEXUS – National Emergency X-Radiography Utilization Study

NHFD – National Hip Fracture Database

NHS – National Health Service

NICE – National Institute for Health and Care Excellence

NOF – Neck of femur (usually in reference to neck of femur fracture)

OA – Osteoarthritis

OP – Osteoporosis

PACS – Picture Archiving and Communication System

PAS – Patient Administration System

POC – Package of Care

QCT – Quantitative Computed Tomography

QFracture – Calculator used to work out risk of developing any osteoporotic fracture or hip fracture alone

QUS – Quantitative Ultrasound

RANKL – Receptor Activator of Nuclear factor Kappa B Ligand

RD&E – Royal Devon and Exeter

SCI – Spinal Cord Injury

T12 – Twelfth thoracic vertebra

$t_{Dr\text{-}CT}$ – Time taken for patients to receive a CT scan after the time they were recorded as seeing a doctor

UCSF – Upper cervical spine fracture – fractures of C1 and C2

UK – United Kingdom of Great Britain and Northern Ireland

US – United States of America

WHO – World Health Organization

CHAPTER 1. INTRODUCTION

1.1 MOTIVATION FOR STUDY

Due to increasing life expectancy and falling birth rates, the proportion and size of the elderly population is rapidly increasing and is projected to continue to rise. Between 2005 and 2014 there was an 18.8% increase in the number of people aged over 65 and a 29.3% increase in those over 85. Furthermore, between 2015 and 2035 there is predicted to be a 49.2% rise in numbers of people aged over 65 and a 122.4% increase in over 85s.(1) Older people are more likely to have health conditions and multiple co-morbidities which make care more complex and expensive. Therefore focusing research in improving care in this group of people should be a priority so that provision can be made for a future with a larger elderly population and resources can be used as efficiently as possible.

Cervical spine fractures have two peaks in incidence, one in young adults caused by high levels of trauma and a second in the elderly caused mainly by falls. Young adults tend to sustain fractures in the lower cervical spine whereas fractures of the odontoid process are most common in the elderly.(2-5) Fracture site, aetiology and management are very different in young adults and the elderly, despite this no separate guidelines exist for cervical spine fracture care in the elderly. There is evidence to suggest that cervical spine fractures in the elderly, which are frequently sustained following minimal trauma, have an association with osteoporosis (OP).(6) The majority of research into vertebral fractures related to OP has focused on thoracolumbar fractures. Identifying OP related fractures is beneficial to both individual patients and to healthcare service providers because treatment to reduce future fracture risk is proven to be effective at reducing fracture rates, and the associated morbidity and financial costs they would incur.

This study aims to evaluate the care pathway for elderly people with cervical spine fracture to identify areas of good practice and potential for improvement. The information gathered will not only enable refinement of the service at the study centre, but also allow sharing of strategies which have a positive impact on patient care among other centres with similar services.

1.2 SEARCH STRATEGY

The following narrative literature review was produced from searching Pubmed and Trip Medical Database for articles available through the University of Exeter library and OpenAthens for Royal Devon & Exeter (RD&E) NHS Foundation Trust. Search terms included 'elderly', 'c-spine', 'fracture', 'osteoporosis', 'spondylosis' and related terms and excluded terms such as 'paediatric'. Sources also included physical and electronic textbooks available from the University of Exeter library.

1.3 C-SPINE

This section will give an overview of the anatomy of the cervical spine, in health and aging, and of cervical spine fractures, their identification and management. A basic knowledge of the anatomy of the cervical spine is necessary to understand how it can be affected by aging and trauma. In order to evaluate the efficacy of a service dealing with patients with cervical spine fractures it is important to understand who is affected, how their injuries are sustained, and how evidence suggests these patients should be imaged and treated.

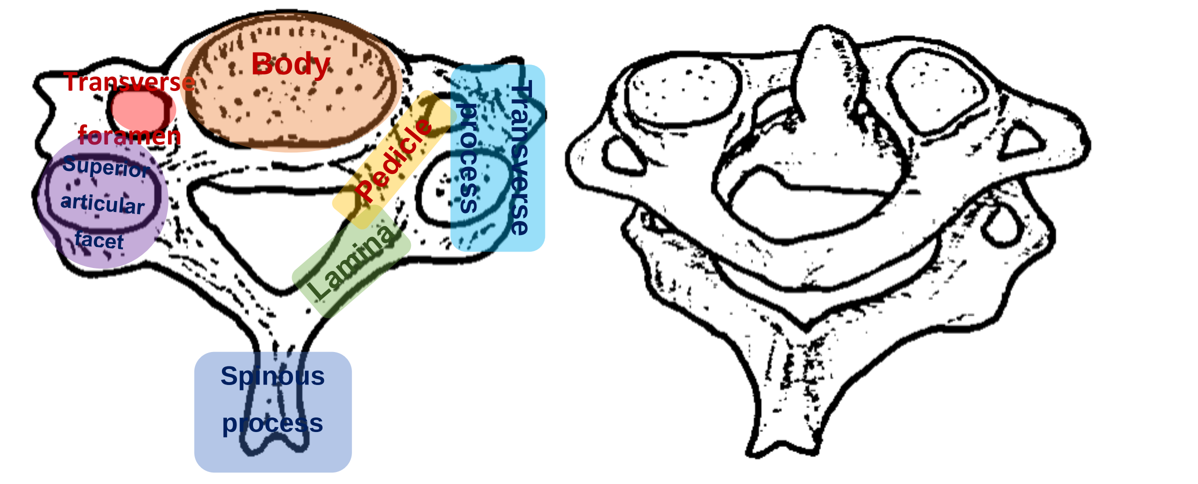
1.3.1 Anatomy

Bones

The adult spine is usually made up of 24 separate vertebrae - seven cervical, 12 thoracic and five lumbar - plus five fused sacral vertebrae and three to five partially fused coccygeal vertebrae. The function of the vertebral column is to provide structure, support and movement to the trunk, as well as protection of the spinal-cord. Other important functions include haematopoiesis and mineral homeostasis. The cervical vertebrae are referred to as C1-7; C1 articulating with the base of the skull down to C7 at the base of the neck.[7-10]

C3-7 are similar in structure to the thoracic and lumbar vertebrae. The typical structure of a vertebra consists of the weight-bearing body anteriorly, and an arch posteriorly enclosing a hole named the vertebral foramen. The spinal cord sits in the vertebral canal; the tunnel formed from the aligned vertebral foramina. Each side of the vertebral arch is made up of a cylindrical "pedicle" which projects posteriorly from the body and a flatter “lamina” which meets its partner to form the posterior aspect of the arch from which the spinous process extends posteriorly. Where the pedicle meets the lamina on each side, a transverse process extends laterally and articular processes sit superiorly and inferiorly. The transverse and spinous processes provide attachments for various muscles. The cervical vertebrae are identifiable from the thoracic and lumbar vertebrae due to an opening in each transverse process called the transverse foramen through which the vertebral arteries (not through C7), vertebral veins and sympathetic nerve fibres pass (see Figure 1). C2-6 are frequently also distinctive due to a bifid spinous process.[7-10]

Figure 1: Superior view of a typical cervical vertebra (left) and C1 on top of C2 (right)



C1, also known as the atlas, and C2, also called the axis, are atypical vertebrae. The atlas is ring shaped and does not have a body or spinous process. It is comprised of a posterior arch, an anterior arch with an articular facet for the dens of C2 and two lateral masses which bear the weight of the cranium. Each lateral mass includes a superior and inferior articular surface, transverse process with transverse foramen and a tubercle for the transverse ligament. The axis most noticeably has a large protuberance extending cranially from the superior part of the body termed the dens, peg or odontoid process. Large superior articular surfaces lie either side of the dens where the pedicles join the body.[7-11]

Joints

The articulations of the cervical spine enable the neck to perform a wide range of complex movements combining flexion, extension, lateral flexion and rotation. The superior articular surfaces of the lateral masses of C1 articulate with the occipital condyles of the base of the skull in a synovial joint; the alanto-occipital joints. This joint allows some flexion, extension and lateral flexion but no rotation. A large degree of rotation is allowed at the joint between the dens of the axis and the articular facet of the atlas which acts as a pivot, held in place by the transverse ligament of the atlas (part of the cruciate ligament of the atlas). The synovial joint between the inferior articular process of one vertebrae and the superior articular process of the vertebrae below is called the facet, zygapophyseal or apophyseal joint. The facet joints, in conjunction with ligaments, help to stabilise the spine and limit the movement possible between vertebrae at the intervertebral fibrocartilaginous joints; between the bodies of two adjacent vertebrae. These fibrocartilaginous joints or “intervertebral discs” lie between all the cervical vertebrae apart from C1 and C2. An endplate – a layer of hyaline cartilage – lines the superior and inferior surface of the vertebral bodies which adheres to the annulus fibrosus – the outer fibrous layer of the IV disc. The annulus fibrosus surrounds the nucleus polposus – the gelatinous centre. The IV discs allow a great deal of mobility due to their resilience to being stretched and compressed. Uncovertebral joints, present from C3 to C7, are articulations between projections, known as the uncinate processes, on the superior lateral aspects of the vertebral bodies and the above vertebral body.[7-10]

Ligaments

The cervical vertebrae are stabilised by a number of ligaments. At the top of the spine, the occiput, atlas and axis are secured by the external and internal craniocervical ligaments. The largest of the interior ligaments is the tectorial membrane which joins the clivus of the skull to the axis body and continues on caudally as the posterior longitudinal ligament which travels posterior to the vertebral bodies until the back of the sacrum. Other interior ligaments include the cruciate ligament, comprised of transverse and longitudinal ligament bands, which holds the dens of C2 in articulation, the apical ligament which attaches the apex of the dens to the anterior margin of the foramen magnum, and several other smaller ligaments. The external ligaments include the anterior and posterior atlanto-occipital membranes and the anterior longitudinal ligament which extends from the base of the skull to the sacrum. The posterior ligamentous complex is important in stabilisation of the vertebral column and is made up of facet joint capsules, the ligamentum flavum, the interspinous ligament and the supraspinous ligament. The ligamentum flavum runs between adjacent laminae of the vertebrae. The interspinous and supraspinous ligaments join the spinous processes. The other large ligament in the neck is the ligamentum nuchae which originates from the external occipital protuberance and attaches to the posterior arch of the atlas and the cervical spinous processes.[12]

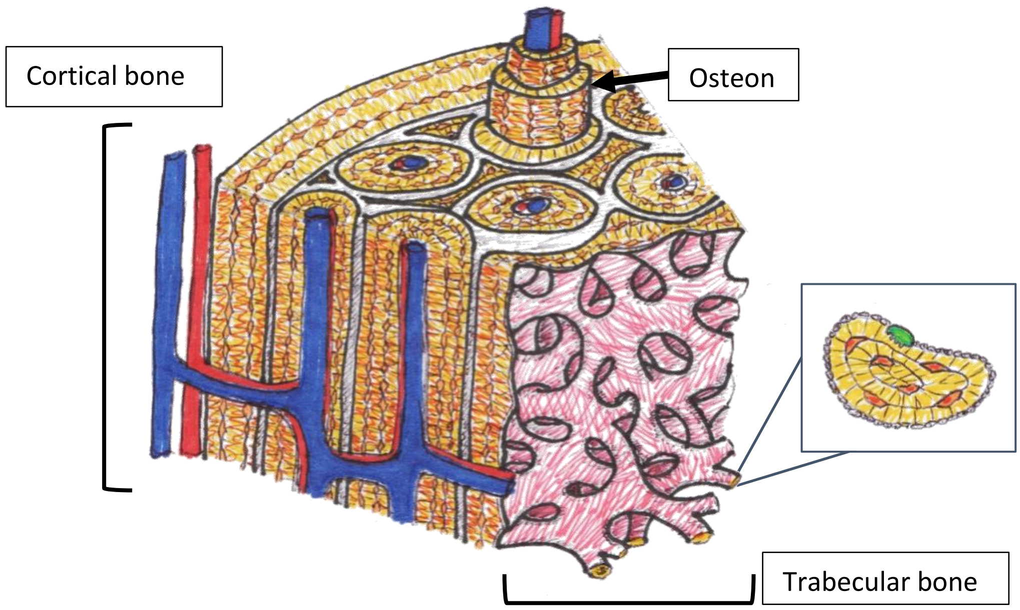
Bone structure

Like most bones in the human body, vertebrae are made up of trabecular bone tissue surround by cortical bone tissue. Cortical bone tissue is very strong, contains few spaces and is made up of tube-like units called osteons (see Figure 2). Each osteon is made up of a central canal, containing blood vessels, lymphatics, and nerves, surrounded by concentric rings of mineralised extracellular matrix termed concentric lamellae. The extracellular matrix is made up of an organic and an inorganic component. Collagen fibres, primarily type I collagen, make up the majority of the organic component, along with proteoglycans, matrix proteins, cytokines and growth factors. Collagen fibres are arranged in a triple helix and provide tensile strength. The inorganic component is comprised of calcium phosphate and hydroxyapatite crystals which provide compressive strength. The concentric lamellae are formed by osteoblasts which secrete collagen and other organic components and initiate mineralisation until they become trapped and mature into osteocytes. Osteocytes sit in small spaces called lacunae between the concentric lamellae and are responsible for maintaining metabolism of the bone. Tiny extracellular fluid-filled channels, called canaliculi, radiate out in all directions from the lacunae. The alignment of osteons in cortical bone is affected by physical stresses on the bone and can change over time in response to differing stresses.[9, 13, 14]

Trabecular bone tissue does not contain osteons, instead it is arranged in trabeculae. These are similar to osteons in that they consist of concentric lamellae, lacunae containing osteocytes and canaliculi. However they are less regular and contain no central canal. There are large spaces between trabeculae filled with red marrow. Red marrow contains mesenchymal stem cells which are important for making and repairing skeletal tissues and hematopoietic stem cells which give rise to all types of blood cells. Red marrow also contains numerous small blood vessels which serve the osteocytes. The trabeculae precisely organised to provide strength along lines of stress despite appearing unorganised.[9, 13]

Bone remodelling is a normal physiological process which happens throughout adult life. The process of remodelling begins with recruitment and differentiation of osteoclasts which attach to the bone, dissolve mineral and fragment collagen creating erosion pits. Osteoblasts then lay down an organic matrix mainly composed of collagen fibres. Primary mineralization then occurs; calcium and phosphate ions are incorporated into the collagen matrix. Secondary mineralization, addition and maturation of hydroxyapatite crystals, continues during quiescence (the resting phase).[13]

Figure 2: Cortical bone structure, with osteons, and trabecular bone structure[9]



1.3.2 Aging

Aging causes a number of effects on bone tissue. Through infancy, childhood, and adolescence bones increase in thickness and length but after this bones still undergo a process of replacing old bone tissue with new throughout life known as remodelling. Remodelling involves bone resorption by osteoclasts, specialised cells which release enzymes and acids to breakdown protein and mineral components of bone, and bone deposition by osteoblasts. Several factors affect normal bone metabolism/remodelling in adults. These include dietary intake of minerals, particularly calcium and phosphorus, and vitamins including vitamins A, C, D, K and B12. Levels of a number of hormones, notably sex hormones, and weight bearing exercise also affect bone remodelling and consequently bone strength. As a result of the normal aging process levels of sex hormones drop, most dramatically in post-menopausal women, causing the rate of bone deposition by osteoblasts to become outweighed by bone resorption by osteoclasts leading to loss of bone mass (this will be discussed further in the section on osteoporosis). Bone tissue also becomes more brittle in old age due to a decreased rate of collagen synthesis and therefore more susceptible to fracture.(7, 9, 13)

Articular surfaces also undergo age-related changes. The layer of cartilage lining the joints degenerates and depletes and bony growths can occur in reaction to the decreased protective cushioning.(15) It has been suggested that IV discs can show some degenerative changes even from as early as the teenage years, and by the age of 70 around 60% of discs could be classified as severely degenerated.(16) The nucleus polposus becomes less gel-like and more fibrotic with increasing age and the annulus fibrosus decreases in elasticity and strength. Degenerate IV discs have a lower water content, lose height and fluid more readily when compressed and as a result cause inappropriate stress to other structures.(16)

1.3.3 Fracture Epidemiology

The incidence of cervical spine fractures is unclear from the literature as a large proportion of studies looking at the epidemiology of spinal injuries concentrate on spinal cord injuries, rather than on fractures of the vertebrae, or group together spinal column injuries such as fracture, subluxation, dislocation and ligamentous injury. The annual incidence of cervical spine fracture can be estimated from one Canadian and one Norwegian study to be around 12 per 100 000 of the population.(2, 17, 18) The incidence of spinal column injuries in adults, including c-spine fracture, tends to show a bimodal age distribution with the first peak in young adults, predominantly in males, and a second smaller peak in the elderly.(2, 3, 19) Road traffic accidents and falls are reported to be the most common causes of spinal fractures, with the proportion of fall-associated fractures increasing with age.(4, 5) One Finnish study reports a rise in incidence of fall induced cervical spine injuries in over 50 year olds over the period of 1970 to 2004, that exceeds any change in population demographics, and predicts further increase in the future.(20) The lower cervical spine (C5-7) is the most common site of cervical spine fracture in younger adults whereas the odontoid process of the axis is the most common site in the elderly population.[5, 11, 18, 21-23]

1.3.4 Risk factors for c-spine fracture in the elderly

Decreased bone mineral density (BMD) has been identified as the most important predisposing factor for odontoid fractures in the elderly in a recent study.[6] The same study concluded that there was no association with reduced BMD in cervical spine fractures at other sites. Several other studies and case reports acknowledge a relationship between OP and odontoid fractures but fail to quantify the level of risk it poses or demonstrate a difference in OP rates in patients with c-spine fractures and age- and sex-matched controls.[24-28] Several studies have observed that elderly patients more readily sustain cervical fractures at lower velocity mechanism of injury, such as fall from a standing height or lower, whereas younger patients require higher energy trauma.[21] This would suggest that these fractures could be defined as fragility fractures which are often attributed to OP.

Degenerative changes of the cervical vertebrae have also been hypothesised to increase risk of cervical spinal fracture in elderly patients in several studies. One study concluded that patients with odontoid fractures were 7.7 times more likely to have a subchondral cyst present in the odontoid process, and 4.6 times more likely to have retro-dens synovitis than patients without a fracture, after adjusting for age and gender.[29] However the precise nature of the association between these changes and odontoid fractures was not defined so a causal relationship cannot be assumed. It also failed to explore the aetiology of the synovitis in these patients. Another small study suggests there is a significantly increased prevalence of loss of joint space in the atlanto-odontoid joint (AOJ) in patients with Type II odontoid fracture, compared with those with no Type II odontoid fracture.[25] Disproportionate osteoarthritic degeneration between the atlanto-odontoid and lateral atlantoaxial joints has been identified as being more prevalent in older people with a Type II odontoid fracture than other axis fractures.[26] It has also been postulated that degenerative changes of the spine reduce mobility in the lower cervical spine and contribute to the increased rate of upper cervical spine fractures in low-energy trauma compared to younger people.[21, 30]

1.3.5 Types and mechanism of fractures in the elderly

Cervical spine fractures can be caused by a variety of forces including combinations of flexion, extension, rotation and compression. They can range from being unstable and associated with dislocation, ligamentous injury and displacement of bone fragments to being stable and undisplaced. Falls are the most common mechanism of cervical spinal fractures in the elderly.(5) Falls from ground level cause significantly greater injury in geriatric patients than younger patients and are the most common cause of traumatic injury in the elderly population.(31) Injuries of the cervical spine resulting from falls from standing height or lower are seen with increasing frequency with each decade of life.(31) In one study of cervical spine fractures in patients over 65 years old it was found that patients with low energy mechanism (fall from standing height or less) were more likely to have sustained an upper cervical spine fracture than those with high energy mechanism (falls from greater than standing height and motor vehicle collisions).(21) There was also a significantly increased frequency of fracture of C1 and C2 in patients older than 75 years compared to patients aged 65 to 75 years.(21)

C1 specific fractures

A Jefferson fracture, also called a burst fracture of C1, is a fracture through the anterior and posterior arches of the atlas.(11, 32) It can be caused by compressive force transmitted through the occipital condyles driving the lateral masses of C1 outwards.(11, 32) Forced extension of the neck can cause an isolated posterior arch fracture as the posterior elements of the atlas are compressed between the occiput and the spinous process of the axis.(11, 32)

C2 specific fractures

Odontoid fractures are the most common fracture type in the elderly (see Figure 3).(11, 23) In the elderly, these fractures can result from a fall with impact to the cranium causing forceful flexion or extension of the neck.(33) The Anderson and D'Alonzo classification system is the most commonly used system for classifying fractures through the odontoid process of C2. It divides fractures into three types based in location of the fracture:

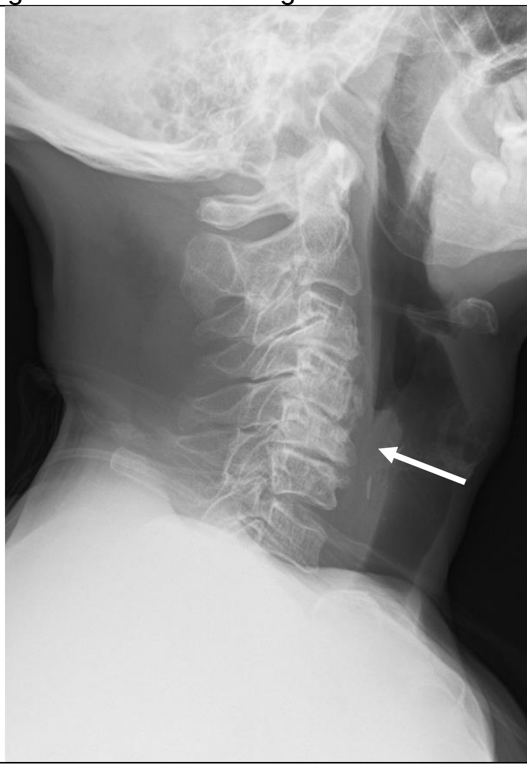
- Type I – fracture located above the level of the transverse band of the cruciform ligament

- Type II – fracture in the base of the odontoid peg below the level of the transverse band of the cruciform ligament
- Type III – fracture through the odontoid and into the body of the axis.(32)

Fractures of the ring of the axis are referred to as traumatic spondylolysis, also known as hangman’s fracture, which can happen when the neck is hyperextended usually as a result of a high speed motor vehicle accident.(11)

Figure 3: Odontoid process fracture

Figure 4: Anterior wedge fracture of C5



Other/any cervical vertebral fractures

Anterior wedge fractures can result from a vertebral body being compressed between adjacent vertebrae when the spine is flexed.(34) There is loss of height of the anterior portion of the vertebral body (see Figure 4). Compression fractures in the thoracic spine are frequently associated with OP but compression fractures can also occur in the cervical region as a result of minor trauma in the elderly.(34, 35) Compressive forces can also cause fragments of the vertebra shatter outwards resulting in a burst fracture. This appears as a loss in both anterior and posterior height of the vertebral body.(36)

Severe flexion and compression of the neck can cause a fragment of the anteroinferior portion of the superior vertebra to be displaced anteriorly as the two vertebral bodies collide (see Figure 5). This is known as a flexion teardrop fracture and usually occurs in the lower cervical spine.(37) An extension teardrop fracture occurs when the anterior longitudinal ligament avulses a triangular shaped fragment from the anteroinferior part of the vertebral body in abrupt neck extension.(38, 39) This type of fracture is found most commonly at C2 but can occur at other levels. It has been proposed that there is an association between OP and extension teardrop fractures of the axis, however there is some evidence to suggest old age and osteopenia are not risk factors for this type of fracture.(38, 39)

Figure 5: Flexion teardrop fracture

Figure 6: Clay-shoveler fracture

A clay-shoveler fracture is an isolated fracture of the spinous process of a lower cervical vertebra (see Figure 6). Direct blows to the spine and sudden forceful contraction of muscles attached to the spinous processes can lead to this type of injury.(40)

1.3.6 Imaging

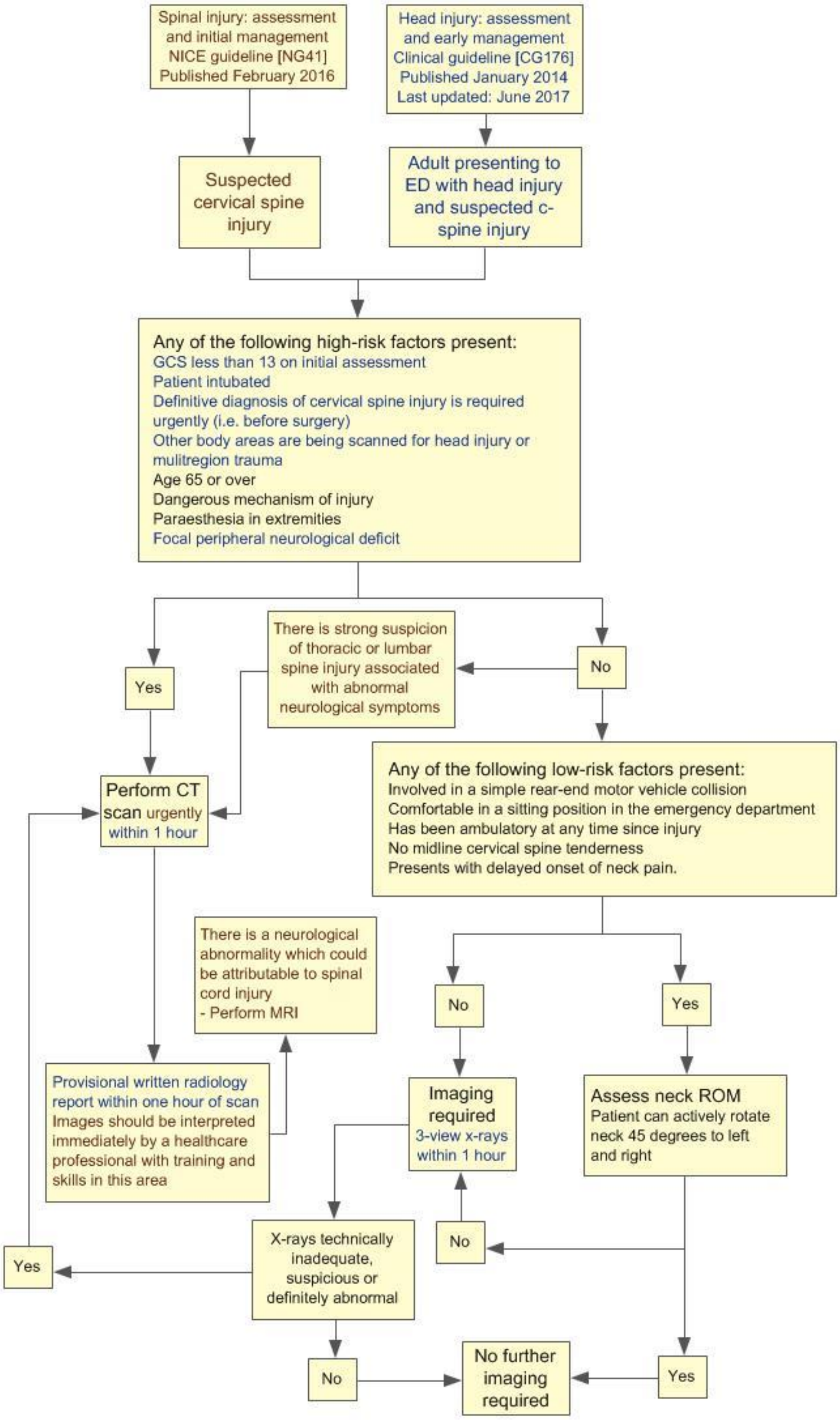
Guidelines for Imaging

The National Institute for Health and Care Excellence (NICE) recommends using Canadian Cervical Spine Rules (CCSR) to assess patients with suspected cervical spine injury to determine the need for diagnostic imaging.[41, 42] The CCSR has been validated for use in adult patients who are alert, stable and have no known vertebral disease (ankylosing spondylitis, rheumatoid arthritis, spinal stenosis, or previous cervical surgery).[43] The CSSR defines three high-risk factors which make likelihood of cervical spine fracture higher; age older than or equal to 65, paraesthesia in the extremities and dangerous mechanism of injury (axial load to the head, fall from three feet or higher, bicycle collision, or a motor vehicle collision involving high speed, rollover, or ejection).[43] It also identifies five low-risk factors that, if any are present, allow for safe assessment of neck movement; simple rear-end motor vehicle collision, sitting position in accident and emergency (A&E) department, ambulatory at any time since injury, delayed onset of neck pain, and absence of midline c-spine tenderness.[43] If any high-risk factors are present CT is recommended.[41] If no low-risk factors are present or the patient cannot rotate their neck to 45 degrees left and right the patient should undergo projection radiography.[41]

The other widely used rules for guiding decision making around the need for cervical spine imaging in blunt trauma patients come from the National Emergency X-Radiography Utilization Study (NEXUS). Radiography is indicated unless patients meet all five of the low risk criteria; no posterior midline cervical-spine tenderness, no evidence of intoxication, a normal level of alertness (score of 15 on the Glasgow Coma Scale), no focal neurologic deficit, no painful distracting injuries.[44] A 2012 systematic review found that the CCSR appears to have better diagnostic accuracy than the NEXUS criteria.[45]

For patients with head injury a separate NICE guideline exists which incorporates additional factors for consideration from the NEXUS criteria, such as level of alertness, when making a decision about imaging of the c-spine.[42] (A summary of the guidance can be found in Figure 7.) Cervical spine injury must be suspected in the elderly even in the absence of neck pain as one fifth of older patients with c-spine fractures may report no pain on initial presentation.[46]

Figure 7: Flowchart summarising NICE gudance on cervical spine imaging in suspected cervical spine injury



Points specific to “Spinal Injury: assessment and initial management”[41] in brown text. Points specific to “Head Injury: assessment and early management”[42] in blue text. Points included in both guidlines in black text.

CT

The guidance recommends performing a CT for all patients in the group this study is focusing on; those aged 65 and over who attend the Emergency Department with suspected cervical spine injury. For patients with head injury, NICE have set a quality standard that CT cervical spine scans should be performed within one hour of a high risk factor (shown in flow chart in Figure 7) for spinal injury being identified.[47] CT has a greater sensitivity of 98% compared to 52% sensitivity of projection radiography for identifying cervical spine injury.[48]

Projection Radiography

In trauma patients at low risk of cervical spine injury three projection radiographs can be sufficient in ruling out cervical spine fracture.[49] A standard three projection cervical spine radiograph series includes an anteroposterior (AP), a lateral and an open-mouth odontoid view. Patients receive a lower radiation dose than they would with CT scanning. It is important to keep ionising radiation dose to patients as low as reasonably achievable due to its potential to increase risk of cancer. However, this consideration is less imperative in elderly patients whose lifetime risk of radiation induced cancer is lower. Projection radiography may be less reliable in elderly patients and lead to more missed cervical injuries than in younger patients as they are more difficult to interpret due to an increased prevalence of degenerative changes.[50]

MRI

It is stated in the guidance that if after CT imaging there is a neurological abnormality which could be attributable to spinal cord injury (SCI) Magnetic Resonance Imaging (MRI) should be performed. MRI can show soft tissue injuries which are not visible on CT or projection radiography, such as epidural haematoma, vertebral artery injuries and spinal cord injuries.[51] MRI is unsafe in many patients with metal implants or foreign bodies and scans take longer to obtain than CT.

1.3.7 Management

Initial management

In a prehospital setting manual in-line spinal immobilisation should be performed on patients who have been involved in a motor vehicle collision, fallen from a height or are suspected to have sustained a spinal injury from any other mechanism.[41] Assessment should then be carried out according to the CCSR and spinal immobilisation should be maintained whilst the patient is transported to hospital if spinal injury cannot be ruled out.[41]

Definitive management

The general principles of definitive fracture management are to achieve reduction (if any malalignment has occurred), immobilisation and rehabilitation. In addition, in spinal fractures, neural decompression and minimising neurological injury is a priority. Reduction and immobilisation can be accomplished non-operatively or operatively. No UK guideline or randomised controlled trials regarding the treatment of cervical spine fractures exist. Choice of treatment depends on the fracture morphology and stability, bone quality, associated neurological injury and the patient's general health and personal preference.[52]

Surgical

Patients with unstable injuries to the cervical spine should be considered for surgical intervention. Surgical management of type II odontoid fractures can involve screw fixation or posterior fusion using instrumentation and bone grafting.[53] A recent systematic review of treatment of type II odontoid fractures in the elderly concluded that surgical treatment causes lower short and long-term mortality with no increase in complication rates.[54] A study from one US Trauma centre suggests that surgical management of type II odontoid fractures is cost effective (when using $100 000 per quality adjusted life year as a standard) in patients aged 65 to 84 but not in patients over 84.[55] However the study fails to report the number of patients included making it difficult to judge the validity of the conclusions. White et al. in a systematic review found the most frequently described major complication of odontoid fracture surgery in the elderly was pneumonia, which occurred in 9.9% of cases, followed by respiratory failure and cardiac failure.[56]

Conservative

Non-surgical treatment is suitable for stable injuries or if the risk of surgery is felt to be too high. Bracing with collars and halo devices is used to immobilise the spine and allow it to heal in alignment. Rates of non-union in type II odontoid fractures were 21 times greater in patient's aged 50 or over than in younger patients in one case-control study.(57) However, fibrous stable non-union may be achieved when radiographic osseous union is not, and this may provide an acceptable clinical outcome.(58) Although non-surgical management may often be thought of as having less associated risk, the complication rates are not significantly different from surgical treatment.(54) Halo-vests are reportedly poorly tolerated in the elderly and are associated with a high rate of dysphagia and aspiration.(59)

Morbidity and mortality

One systematic review by Jubert et al. found the median reported mortality rate for upper cervical spine fractures in the elderly across all treatments was 9.2% and median rate of short term complications 15.4%.(60)

In a large American study of patients aged 65 and over who sustained a cervical spine fracture from a low impact fall, 7.7% had an associated SCI.(61) The study compared these patient to patients aged 65 and over who sustained a hip fracture from low impact falls. The group with cervical spine fracture were more likely to die in hospital. The in hospital mortality was 8.5% of patients with cervical spine fracture and no SCI, 26.1% of patients with SCI and 3.2% of patients with hip fracture. The 30-day mortality (13.0% cervical fracture without SCI, 28.4% SCI, vs. 8.1% hip), 90-day mortality (cervical 18.5%, 35.6 SCI%, vs. hip, 14.7%) and 1 year mortality rates were also significantly higher (cervical 24.5% SCI 41.7%,vs. 22.7% hip). Those with cervical spine fractures were however more likely to be discharged from hospital back to their home than patients with hip fracture but were also more likely to need readmission to hospital within a year.(61)

1.4 OSTEOPOROSIS

OP is one of the most important predisposing factors for cervical spine fracture in the elderly therefore an understanding of OP and it's management is needed in order to evaluate the care of elderly patients with c-spine fractures.(6) This section will cover what OP is, who is affected by the disease and how, how patients are identified and what the evidence is for different management strategies.

1.4.1 Definition/pathophysiology

The word "osteoporosis" comes from the Greek terms for "bone" and "pore" literally meaning porous bones.(62) OP can be defined quantitatively as a BMD more than 2.5 standard deviations (SD) below the gender-specific young adult mean as measured by DXA.(63) In OP the strength of bone is compromised resulting in fragile bones which may fracture when subjected to relatively minor forces.(64) Both the bone density and quality of osteoporotic bone is reduced compared to healthy bone. Bone quality is contributed to by the rate of bone turnover, properties of the collagen-mineral matrix, bone trabecular architecture, and accumulation of micro-damage.(13)

Bone remodelling is a normal physiological process which happens throughout adult life. The process of remodelling begins with recruitment and differentiation of osteoclasts which attach to the bone, dissolve mineral and fragment collagen creating erosion pits. Osteoblasts then lay down an organic matrix mainly composed of collagen fibres. Primary mineralization then occurs; calcium and phosphate ions are incorporated into the collagen matrix. Secondary mineralization, addition and maturation of hydroxyapatite crystals, continues during quiescence (the resting phase).(13)

Peak bone mass and rate of bone loss determine bone mass in adult life and are influenced by genetic and environmental factors. Bone mass increases through childhood and adolescence until it peaks by the age of 20. Bone mass then begins decrease from around the age of 40 and loss is accelerated by menopause in women.(65)

Bone loss occurs with increasing age as a result of oestrogen deficiency and through oestrogen-independent age related mechanisms. Bone loss occurs as a result of the rate of resorption of old bone exceeding the rate of formation of new bone. Relative underactivity of osteoblasts or over-activity of osteoclasts causes this. Oestrogen normally acts to suppress remodelling. Increase in rate of bone turnover with increased resorption and formation, but relatively higher resorption, occurs at the menopause in women due to a drop in oestrogen levels. An increase in the rate of initiation of bone remodelling cycles amplifies the imbalance between bone resorption and formation.(13)

1.4.2 Fragility fracture

Fragility fractures are an important clinical manifestation of OP. Fragility fractures are fractures that result from low-level trauma which would not ordinarily result in fracture in healthy bone.(66) Low-level (or low energy) trauma is defined by the World Health Organization (WHO) as a mechanism of injury with forces equivalent to a fall from standing height or less.(66) Fragility fractures of the hip, wrist and spine occur most commonly however, fractures at almost any site can be attributed to OP in individuals with low BMD.(66-69)

Vertebral fractures often occur without a causative fall and may more often be caused by activities such as lifting objects or changing position.(69) The most common sites of osteoporotic vertebral fracture are T8, T12, L1 and L4.(70) Vertebral fractures may be asymptomatic but can cause pain, height-loss and progressive kyphosis. Resultant spinal column deformity can give rise to respiratory and gastrointestinal disorders due to reduced intrathoracic and intraabdominal space.(69) Vertebral fractures are associated with decreased life expectancy.(66) The reported excess mortality one year after a vertebral fracture varies in the literature from 1.9% to 42%.(71) The risk of further vertebral fracture following one pre-existing fracture in women is four times greater than women with no prior vertebral fracture, and with more than one fracture the risk of future fractures continues to increase.(72)

More than 300 000 patients are treated at hospitals for fragility fractures in the UK each year.(73) The estimated yearly cost of medical and social care as a result of fragility fractures is around two billion pounds with hip fractures representing the majority of these costs.(73)

1.4.3 Epidemiology

In the year 2000 there was an estimated nine million new osteoporotic fractures worldwide, 51% of which occurred in the Americas and Europe.(74) Scandinavia has a particularly high incidence of osteoporotic fractures and there is generally an increasing incidence with distance from the equator.(75-77) There may also be an increased fracture risk in the urban elderly population compared to rural.[78] Data from 1988-1998 showed that half of women and a fifth of men in England and Wales will sustain a fracture over the age of 50, a large proportion of which are likely to be attributable to low bone density.[79] Rates of OP and related fractures increases with age and are higher in women than men.[67, 74] The increased rates of fractures in women compared to men may be contributed to by their increased tendency to fall and their longer life expectancy as well as their reduced BMD.[75] Prevalence of OP differs between ethnicities. In one UK study, rates of fragility fracture were 4.7 times greater in white women than black women and 2.7 times greater in white men than black men.[80]

Fracture is the most important clinical consequence of OP. Therefore most epidemiological studies focus on the rate of fractures due to OP rather than prevalence of the disease itself. The majority of studies found were more than ten years old. Several studies have predicted an increase in global incidence of osteoporotic fractures over time, and the data may therefore underestimate the disease burden today.[81, 82] Conversely, one study of UK trends in fracture incidence noticed no significant difference in fracture incidence in those aged 50 and over in the period between 1990 and 2012.[83] However, the rates of individual fracture types did change including an increased incidence of clinical vertebral fractures in women.[83]

1.4.4 Risk factors

Risk factors for fragility fracture comprise of risk factors for OP and risk factors for falls that are independent to bone strength. Analyses suggest that age is the strongest predictor of fracture risk followed by prior fracture history, and BMD.[84] Some risk factors vary in importance with age, such as those that contribute to falls.[84] Risk factors can also have differing relative importance for different fracture sites.[85]

Non-modifiable risk factors for OP include older age, female sex, white race, postmenopausal status.[64] A family history of hip fracture in parents is associated with a 1.5 times increased risk of all osteoporotic fractures and more than two times the risk of hip fracture irrespective of BMD.[86] Several abnormalities of endogenous hormones are associated with increased fracture risk and OP. OP can occur secondary to endocrine disorders including hyperthyroidism, hyperparathyroidism, hypercortisolism and diabetes mellitus but the most important hormonal risk factor is insufficient sex hormone production, in particular oestrogen deficiency.[87, 88]

Low body weight and Body Mass Index (BMI) are associated with lower BMD and an increased risk of fractures in the elderly.[89, 90] Weight alone is a better predictor than BMI of BMD.[90] The risk of fracture is increased at lower BMI but not when adjusted for BMD, with the exception of hip fractures in patients with a BMI of 20kg/m^2 or below. When compared to patients with a BMI of 25kg/m^2, individuals with a BMI of 20kg/m^2 have a 33% higher risk of hip fracture independent of BMD.[89]

Smoking has been shown to increase risk of OP. Although smoking has no effect on BMD of premenopausal women, postmenopausal bone loss is greater in smokers by an additional 0.2% per year. The risk of hip fracture at age 60 is estimated to be 17% higher in current smokers than non-smokers and increases with age.[91] High alcohol intake has been identified as a risk factor for fracture.[66] Although there is evidence of a positive effect of light to moderate drinking on BMD there may be an increased risk of osteoporotic fracture in men and women consuming more than two units of alcohol per day.[92, 93] This effect may be in part related to increased risk of falls, coexisting morbidity and impaired protective reflexes.[92]

A number of drugs, including aromatase inhibitors, anticonvulsants and heparin, have been linked to an increased risk of OP. Glucocorticoids pose the most substantial increase in fracture risk and are the most common secondary cause of OP.[94] People aged 50 and over who have used glucocorticoids have more than 1.5 times the risk of fracture than individuals with the same BMD who have never used glucocorticoids.[94] Glucocorticoids are often taken for inflammatory and autoimmune conditions which may themselves also increase the risk of OP.[87]

Physical activity, particularly weight-bearing exercise, during childhood and adolescence has a positive effect on peak bone mass.[65] Exercise in postmenopausal women may have a small effect on bone density, as concluded by a 2011 Cochrane review, however the quality of evidence for an effect is low.[95] Prolonged immobility is associated with loss of BMD.[88]

Adequate intake of calcium and vitamin D are essential for bone health. Calcium is necessary in mineralisation of bone and vitamin D aids in absorption of calcium. Deficiency of these in young people can impair attainment of peak bone mass.[64] The effect of dietary calcium intake on risk of fracture and OP in older adults is unclear. A 1997 systematic review concluded that increased intake of calcium decreased osteoporotic fracture risk.[96] A number of more recent large studies have found no association.[97-99] Vitamin D deficiency has been observed in a large proportion of people with OP, however increased dietary intake and supplementary vitamin D (without calcium supplementation) have not been shown to reduce fracture risk or affect BMD.[97, 98, 100-103]

1.4.5 Diagnosis

Assessment tools

OP does not become clinically apparent until a fracture occurs and is therefore often only diagnosed after a fragility fracture has occurred. Identification of patients with risk factors for fragility fracture and formal assessment with an assessment tool aims to make a diagnosis of OP before a fragility fracture has occurred in order to administer treatment which will prevent fractures. NICE recommends considering assessing the risk of fragility fracture in all women aged 65 and over and all men aged 75 and over as well as patients over 50 with risk factors and people younger than 50 with major risk factors (see Figure 8).[66] Groups that are particularly important to assess are adults who have had a fragility fracture, use systemic glucocorticoids or have a history of falls as outlined in NICE Quality Standard [QS149].[104]

Figure 8: "Targeting risk assessment" From; NICE Clinical guideline [CG146] Osteoporosis: assessing the risk of fragility fracture. Published August 2012. Last updated Feb 2017.

Targeting risk assessment

1.1 Consider assessment of fracture risk:

- In all women aged 65 years and over and all men aged 75 years and over
- in women aged under 65 years and men aged under 75 years in the presence of risk factors, for example:
    - previous fragility fracture
    - current use or frequent recent use of oral or systemic glucocorticoids

- history of falls
- family history of hip fracture
- other causes of secondary osteoporosis
- low BMI (less than 18.5 kg/m^2)
- smoking
- alcohol intake of more than 14 units per week for women and more than 21 units per week for men.

1.2 Do not routinely assess fracture risk in people aged under 50 years unless they have major risk factors (for example, current or frequent recent use of oral or systemic glucocorticoids, untreated premature menopause or previous fragility fracture), because they are unlikely to be at high risk.

Two assessment tools are recommended for use by NICE; FRAX (Fracture Risk Assessment Tool) and QFracture. Both assessment tools provide a predicted risk of major osteoporotic fracture over ten years without a measured BMD and FRAX can update the risk calculation to incorporate BMD. QFracture was found in a recent meta-analysis to have greater accuracy in prediction of ten year fracture risk than FRAX both without and with BMD measurement.(105) QFracture requires more clinical information to be inputted whereas FRAX uses easily obtained clinical risk factors. QFracture can predict hip, wrist and spine fractures and FRAX can predict humerus fractures in addition to these.(66) Both the risk of fracture and the risk of death are taken into account by FRAX in the calculation of fracture probability and models have been developed for 63 countries using country-specific data, however geographical and ethnic variation within countries is not taken into account.(106, 107) Criticisms of the FRAX model include that it does not take account the level of exposure to risk factors, such as dose of glucocorticoids or number of prior fractures, and does not consider falls risk - a major risk factor - in calculation of fracture probability.(106)

Dual-energy X-ray absorptiometry

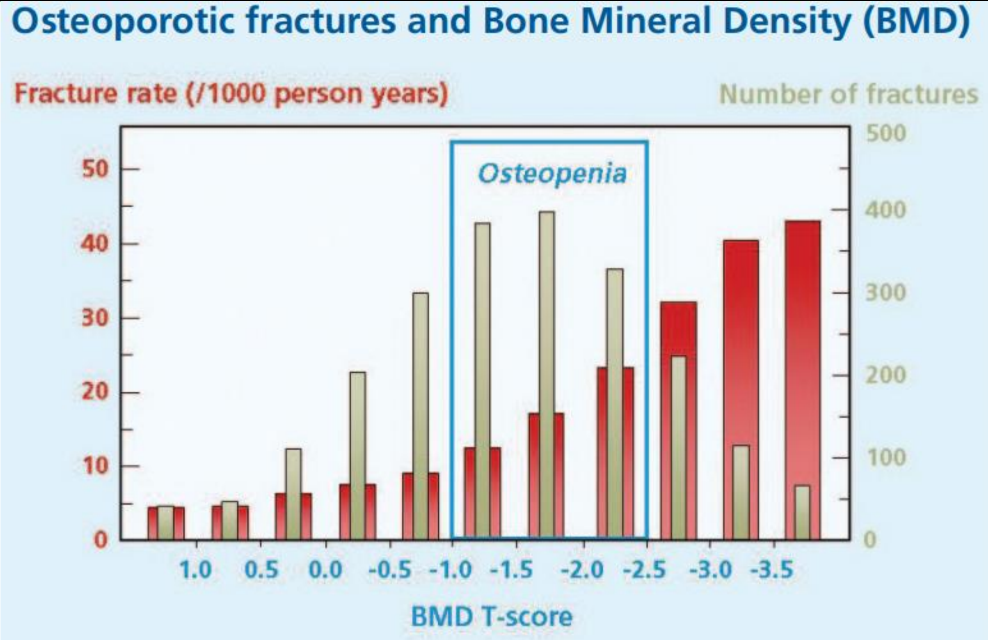
BMD is the only property of bone strength measured routinely in clinical practice. DXA is the most commonly used method of measuring BMD and is widely available across UK hospitals. BMD should be measured in patients whose predicted ten year fracture risk is at a threshold where intervention would be considered. Intervention thresholds vary with age, BMI and clinical risk factors.(108) Patients can be started on treatments for OP without measurement of BMD if they have significant risk factors for OP, such as a history of fragility fractures and long-term glucocorticoid use, however DXA scanning can be useful in monitoring the effect of therapy. It may also be appropriate to measure the BMD of patients about to undergo therapies which can have an adverse effect on bone mass.(66)

DXA technology uses two different energy X-ray beams to calculate the contribution of different tissue types to the total attenuation of the beams. This allows it to isolate the attenuation attributable to the bone within the other tissues and calculate the bone density in mass per unit area.(109) The radiation dose to patients from DXA is relatively low compared to other X-ray imaging procedures and delivers a similar amount of radiation to one day of background radiation.(109) Most centres measure lumbar spine and proximal femur BMD but forearm measurements may be taken if the other sites are thought to be unreliable or unfeasible although their use is limited. BMD measurement of the femoral neck are preferred for diagnosis of OP; spine measurements can often be increased due to artefact from degenerative changes but are useful for monitoring response to treatment.(108)

The BMD as measured by DXA can be expressed as a T-score or a Z-score. The T-score quantifies the difference between the patient's BMD and normal young adult peak bone mass. It is calculated by the formula $T\ score = \frac{patient's\ BMD - population\ peak\ BMD}{standard\ deviation\ of\ population\ peak\ BMD}$.(110) The Z-score evaluates the difference between the patient's BMD and a gender and age-matched population. It is calculated by the formula $Z\ score = \frac{patient's\ BMD - age\ matched\ population\ BMD}{standard\ deviation\ of\ age\ matched\ population\ BMD}$.(110) The International Society for Clinical Densitometry and the WHO recommend a standardised reference database - the National Health and Nutrition Examination Survey III - is used to calculate femoral neck T-scores for all men and women of all ethnic groups.(111, 112) This reference data is based upon femoral neck BMD measurements of white American women aged 20-29 however differences in fracture risk and rates between different ethnic and geographical groups exist and it has been argued that population-specific reference data may be more useful.(112-114) Application of this recommendation may not be consistent between different machines and areas and reference data for other measured sites (such as spine and forearm) may vary according to manufacturers.[115] Where possible, the same machine should be used for monitoring of BMD in a single patient due to the inconsistency in T-score calculation.[115]

According to the WHO definition a T-score of -2.5 or less equates to a diagnosis of OP, between -2.4 and -1.0 osteopenia, and above -1.0 normal.[63] Although a patients with a T-score in the osteoporotic range are at the highest risk of fracture, most fractures occur in individuals with osteopenia as there are far more people in this group (see Figure 9).[115, 116] BMD measurement can be helpful in identifying patients who would benefit from interventions to reduce fracture risk but T-scores cannot predict which patients will incur fractures as other factors not measured by DXA, such as bone quality and clinical risk factors, are also important.[115]

Figure 9: Fracture rate and number of fractures with different T-scores. From; McCloskey E. FRAX® Identifying people at high risk of fracture WHO Fracture Risk Assessment Tool, a new clinical tool for informed treatment decisions. Switzerland: International Osteoporosis Foundation; 2009.



Other imaging modalities

OP or osteopaenia (a term that refers to low bone density which may not be as severe as OP and can also encompass osteomalacia) may be suspected from projection radiography or CT, however a diagnosis of OP would not be made on the basis of this imaging and a DXA scan would be requested for quantitative analysis.[117] Features of

OP on projection radiography include cortical thinning (especially in the metacarpals), reduced number of trabeculae with those remaining appearing more prominent and vertebral body fractures.(117) Other techniques, such as quantitative ultrasound (QUS) and quantitative computed tomography (QCT), have been investigated for use in diagnosis of OP but are not widely used in clinical practice. T-scores derived from QCT may be seen as equivalent to those from DXA but QUS derived scores, although they may correlate with fracture risk, do not correlate as tightly with DXA T-scores.(108, 111, 118, 119)

1.4.6 Management

Management of OP mainly concerns reducing fracture risk, done through a number of different strategies to increase bone strength and reduce incidents that could lead to fracture.

Lifestyle intervention

One of the biggest risk factors for fragility fracture is falls. Although osteoporotic fractures can occur with no preceding injury, most fractures happen as a result of a fall. Interventions that NICE recommend to reduce falls risk in older people include strength and balance training, home hazard assessment and intervention, vision assessment and referral, and medication review with modification/withdrawal.(120)

A 2011 Cochrane review found a small but significant effect of exercise on BMD. Non-weight bearing high force exercise such as resistance training was found to be the most effective intervention for neck of femur BMD and combination exercise programs for spine BMD. However there was no effect on risk of fracture and the quality of included studies was low.(95)

A 1997 meta-analysis found that although smoking has no effect on BMD of premenopausal women, postmenopausal bone loss is greater in smokers by an additional 0.2% per year. The risk of hip fracture at age 60 is estimated to be 17% higher in current smokers than non-smokers and increases with age.(91) A number of studies have reported a lower fracture risk among former smokers than current smokers which suggests that smoking cessation reduces fracture risk.(121-125) There may be an association between smoking and other risk factors for osteoporosis such as glucocorticoid use (for smoking-related lung conditions), low BMI, decreased physical activity and poor diet which may complicate the relationship between smoking and bone mass.[121]

High alcohol intake has been identified as a risk factor for fracture.[66] Although there is evidence of a positive effect of light to moderate drinking on BMD there may be an increased risk of osteoporotic fracture in men and women consuming more than two units of alcohol per day.[92, 93] This effect may be in part related to increased risk of falls, coexisting morbidity and impaired protective reflexes.[92] Although an increased risk of fractures has been observed in people with a high alcohol intake, there is a lack of evidence base regarding the reversibility of this risk and what the impact of reducing alcohol intake is on fracture risk.[121] However, reducing alcohol intake to two or less units a day is still recommended as this is likely to have health benefits beyond just those on fracture risk.[108]

Increasing calcium and vitamin D intake through dietary sources and supplements has been thought to reduce fracture risk however there is little evidence to support this. Increasing calcium intake has been shown to result in small increases in BMD but the clinical significance of this is unclear.[126] A recent systematic review found no evidence that dietary calcium intake effects fracture risk and weak inconsistent evidence for an effect of calcium supplementation on fracture risk.[127] However there have been concerns over the safety of calcium supplementation after two meta-analyses, in 2010 and 2011, concluded there may be an increased risk of cardiovascular events although the numbers needed to harm is unclear.[128, 129] Conversely, a 2015 meta-analysis concluded that current evidence did not establish an increased risk of hospitalization and death from coronary heart disease in postmenopausal women on calcium supplementation.[130] Using the precautionary principle, avoiding calcium supplementation unless there is a clear indication for its use may be safer.[131] Vitamin D given alone has been found to have little or no use in preventing fractures but when combined with calcium may prevent hip fracture and other osteoporotic fractures.[100, 102, 103]

Pharmacological therapies

Bisphosphonates are the first line drug treatment for OP. They work by inhibiting osteoclast activity and consequently reducing bone resorption, slowing turnover and prolonging the mineralization phase. NICE recommends the use of the oral bisphosphonates alendronate, ibandronate and risedronate in patients with a ten year probability of osteoporotic fracture of at least one percent, and the use of the intravenous bisphosphonates ibandronate and zeledronate in adults with a ten year risk of at least ten percent or in patients who are unable but eligible to take oral bisphosphonates.[(132)] Alendronate, at 10mg a day dose, results in a significant relative risk reduction of 45% for vertebral fractures when used for both primary and secondary prevention (people with a history of fragility fracture) of fractures in postmenopausal women. This dose also results in a significantly decreased risk of non-vertebral, hip and wrist fractures when used for secondary prevention but a non-significant decrease in risk when used for primary prevention.[(133)] All other recommended bisphosphonates have similar efficacy and choice of treatment is based on patient preference and ability to adhere to particular medication regimens as well as cost/benefit analysis.[(134)]

Upper gastrointestinal discomfort is a commonly reported side effect of oral bisphosphonates in clinical practice however a Cochrane review found no statistically significant difference in adverse drug events compared to placebo and no significant difference in patients discontinuing treatment due to side effects between alendronate and placebo.[(133)] The incidence may be higher in clinical practice as patients with existing gastrointestinal disorders were excluded from many of the randomised controlled trials. Atypical femoral fractures and osteonecrosis of the jaw have been reported as potential rare side effects of bisphosphonate treatment mainly in case reports. No cases were reported in the clinical trials included in the Cochrane review however these trials may not have been designed to capture adverse drug events.[(133)] The incidence of osteonecrosis of the jaw in patients on bisphosphonate treatment is thought to be around 1-90 per 100,000 years of patient exposure and atypical femoral fracture 3.2-50 cases per 100,000 person-years.[(108)] Rates of osteonecrosis of the jaw in the general population are not well known.[(133)]

Concerns over possible adverse events with long term bisphosphonate use has led to recommendations to consider a drug holiday in certain patients. This applies to patients who have been receiving zoledronic acid for three years, or other bisphosphonates for five years, on the conditions that: they have had no fractures whilst on treatment, FRAX indicates they are below treatment threshold and their BMD T-score is above -2.5.[108] There is a lack of evidence to suggest a drug holiday reduces the rate of adverse skeletal effects.[135] The Fracture Intervention Trial Long-term Extension, which studied 1099 postmenopausal women, found an increased incidence of clinical vertebral fractures in patients who discontinued bisphosphonates after five years compared to those who continued but no statistically significant difference in rates of other fractures.[136]

Denosumab is a monoclonal antibody against Receptor Activator of Nuclear factor Kappa B Ligand (RANKL) which is important in the regulation of osteoclast activity. Denosumab binds to RANKL preventing it from binding to a receptor on osteoclasts and consequently inhibiting resorption.[137] Denosumab has a similar clinical efficacy as bisphosphonates with a fracture risk ratio of 0.58 when compared to placebo in postmenopausal women with low BMD.[138]

Raloxifene (a selective oestrogen receptor modulator), teriparatide (recombinant human parathyroid hormone), calcitriol (the active form of vitamin D) and hormone replacement therapy have all been approved for use in OP management.[108] Strontium ralenate is only approved for use as a last resort under specialist supervision as there is a significant risk to people with a history of cardiovascular disease.[139]

Fracture Liaison Services

Fracture liaison services (FLS) are designed to identify patients who have sustained a fragility fracture, assess them and commence treatment and refer them to appropriate services for additional care.[140] They aim to reduce the risk of sustaining subsequent fractures. A 2013 systematic review concluded that FLS with higher intensity interventions, those with a dedicated co-ordinator who identifies patients and an all-encompassing service as opposed to services which prompt primary care practitioners or only educate patients, were more effective at initiating treatment.[141] FLS appear to be successful in reducing re-fracture rates, with one centre reporting around 40% reduction in the three-year risk of major fracture, but more higher quality evidence with longer term follow up is needed to reliably quantify this effect.[141-143] Many studies also report that FLS are highly cost effective and have the potential to save approximately

£8.5 million at a national level over five years.[141, 144] Commissioning of FLS has been recommended by many professional bodies and policy makers, including the Department of Health, yet only 37% of local health services in England, Wales and Northern Ireland had any kind of FLS in 2010.[108, 145, 146]

1.5 SPONDYLOSIS

Cervical spondylosis occurs frequently in the elderly and may have an association with c-spine fractures.[21, 25, 26, 29, 30] This section gives an understanding who is affected by cervical spondylosis, its classification management and relation to OP.

1.5.1 Definition/Pathophysiology

Cervical spondylosis is a term that can be used to cover a number of degenerative changes of the joints of the cervical spine often seen together; intervertebral disc degeneration with height loss, endplate sclerosis and osteophyte formation.[147, 148] Cervical spondylosis may be synonymous with cervical osteoarthritis (OA) of intervertebral disc or facet joints, degenerative disc disease and cervical degenerative disease. One theory of the pathophysiology of spondylosis is that desiccation of the intervertebral discs occurs as a result of compromised vascular supply from the thinning endplates leading to a degeneration of elastic and hydrophilic materials. These changes can lead to disc bulging and herniation resulting in the posterior longitudinal ligament peeling off adjacent vertebral bodies, irritation of vertebrae, increased stress on uncovertebral joints and osteophyte formation. Changes in the posterior elements of the spine, such as hypertrophy of the facet joints and ligamentum flavum, can accompany these together causing a reduction in spinal canal and intervertebral foramina diameter. Clinically, it may be asymptomatic or manifest as neck pain and stiffness, radiculopathy or myelopathy.[147]

1.5.2 Epidemiology

The prevalence of degenerative changes of the cervical spine evident on medical imaging increases with age. One study reported disc degeneration being present in 17% and 12% of men and women respectively in their twenties and in 86% and 89% of men and women over 60.[149] Clinical symptoms may develop in 15% to 34% of asymptomatic adults in a ten year period and correlate with progression of degenerative changes.[150, 151] One 2016 Chinese study found the incidence of clinical symptoms of cervical spondylosis increases with age until it peaks around the age of 50 and decreases thereafter.[152] They also suggest that there is a decrease in incidence of degenerative changes seen after the age of 60.[152] There are a number of flaws in this study which make the reliability and relevance of the conclusions unclear; the methodology of the study is described as a case controlled study but has 1276 cases and no controls, it doesn't make clear the reason for the identified patients being on hospital lists (whether it was related to their spondylosis or another condition) and age specific incidence is described without any reference to the population. Other studies have however found the highest prevalence of neck pain is in the 50 to 59 age group and while there is some correlation with radiological signs of degenerative disease there may be a stronger association with neurotic personality traits.[153, 154]

1.5.3 Imaging

MRI and projection radiography are the most common imaging modalities used in assessment of spondylosis. Imaging studies are not usually required to diagnose non-specific neck pain or neck pain with radiculopathy in primary care as the high prevalence of degenerative changes in the general population means the diagnostic value is quite low.[155, 156] If compression of the spinal cord (myelopathy) is suspected, there are objective neurological signs of radiculopathy or clinical symptoms of radiculopathy persist for more than four to six weeks MRI may be indicated.[156]

Grading

A 2006 systematic review found 12 different grading systems for cervical spondylosis but only the system by Kellgren et al. had interobserver reliability that fulfilled criteria for recommendation.[157] This system grades lateral cervical spine radiographs from zero to four based on the degree of osteophyte formation, disc height narrowing and endplate sclerosis (see Figure 10).[148, 158]

Figure 10: "Kellgren et al. Cervical degenerative changes" from; Namdev R. Cervical degenerative spondylosis (grading): Radiopaedia; 2017.[158]
Kellgren et al. Cervical degenerative changes 0. normal

- no degenerative changes

1. minimal/early
   - minimal anterior osteophyte formation
   - no reduction of intervertebral disc height
   - no vertebral endplate sclerosis
2. mild
   - definite anterior osteophyte formation
   - subtle or no reduction in Intervertebral disc height (<25%)
   - just recognisable sclerosis of the endplates
3. moderate
   - definite anterior osteophyte formation
   - moderate narrowing of the disc space (25-75%)
   - definite sclerosis of the endplates and osteophyte sclerosis
4. gross
   - large and multiple large osteophyte formation is seen
   - severe narrowing of the disc space (>75%)
   - sclerosis of the endplates with irregularities

1.5.4 Management

The most commonly employed management strategy for adults with non-specific neck pain or neck pain with radiculopathy is to leave time for symptoms to resolve on their own with advice to take simple analgesics.[153, 156] Physiotherapy, manipulation, mobilisation, acupuncture and collar use may have some advantage in reducing symptoms over no intervention though there is no high quality evidence to support this.[159-161] There is also insufficient evidence to conclude whether surgical interventions for myelopathy and radiculopathy caused by spondylosis have an effect on outcome.[162] Cervical interlaminar epidural injections may be effective in relieving chronic neck pain.[163]

1.5.5 Relationship between osteoporosis and osteoarthritis

OP and OA are both common skeletal disorders seen with aging but the relationship between the two and fracture risk is complicated and not fully understood. An inverse relationship has been described between the two conditions as OA is associated with increased BMD and OP reduced BMD.[164-166] It is unclear whether OA leads to an increased or a decreased rate of bone loss, and fragility fracture rates in individuals with OA is no lower than in those without.[164-166] In addition, disc space narrowing and disc degeneration are associated with an increased risk of vertebral and other osteoporotic fractures.[167, 168]

CHAPTER 2. METHODS

This chapter concerns the process of how the study was conducted. It describes the methodology of the study, summarises a patient story which helped to shape research priorities and outlines the methods used for data extraction and analysis.

2.1 APPROVALS

The study was classified as a service evaluation based on the Health Research Authority (HRA) decision tool and discussion with Research and Development at the RD&E and the University of Exeter Clinical Governance Team.[(169)] The study proposal was sent to the Orthopaedics Directorate Governance Group at the RD&E who approved the study going ahead in their department. This was done by the research supervisors so that these approvals were already in place before the primary researcher started the project. This was necessary because time was limited to one year for the primary researcher and these processes can take several months. The primary researcher then presented the Information Governance (IG) Team at the RD&E with a plan for how patient records would be used, anonymised and stored safely. Access to patient records for the purpose of the study was granted through the Caldicott Guardian and the IG Team at the RD&E. An honorary contract with the RD&E and mandatory training allowed the researcher view-only access to the Clinical Data Management system (CDM), with the ability to search only by hospital number or NHS number, and the Picture Archiving and Communication System (PACS).

Service evaluations do not require HRA approval or Research Ethic Committee approval. This is because a service evaluation is carried out only to appraise current care and does not involve a change to patients' management. The participants are service users, as opposed to volunteer research participants. The service users care plans have already been determined and carried out in the usual manner and therefore the service evaluation involves analysis of the existing data on their care. It differs from clinical audit in that there is no set standard to which the service is being measured. The aim of a service evaluation is to use systematic collection and analysis of data to objectively assess the performance of the service in order to increase knowledge of the current effectiveness of the service, identify good practice and make evidence based improvements. Service evaluation can be used to assess a variety of factors including patient health outcomes, the process of service delivery and appropriateness of the service for the needs of the service users.[170, 171]

2.2 PATIENT PUBLIC INVOLVEMENT

The proposed research project and its aims were discussed with a patient who had sustained a cervical spine fracture and been treated at the RD&E ten years ago. In addition, she shared her experience of the service, treatment and follow up care. Although the fracture was sustained in 2007, so this patient would not be included in this study which is assessing the care of patients between 2014 and 2017, her opinion of the research priorities and experience is still useful in confirming the need for this study.

The patient sustained an upper cervical spine fracture after a fall down a couple of steps at home when she was in her fifties. She was initially managed with a Halo but was ultimately treated with surgical fusion as a result of fracture non-union. Despite a strong family history of OP, she was not diagnosed with OP until several years after the fall which resulted in the cervical spine fracture in which time she had sustained additional fractures of other bones.

One of the priorities of this research is to discover whether patients with cervical spine fractures are being assessed and treated for OP. The patient remarked that:

> "Although it [osteoporosis] was mentioned at the time there was no follow-up at all… When I was wearing the Halo I was prescribed alendronic acid, "just in case" so I took two doses of it and it made me feel extremely ill so I couldn't take it… I didn't have any other form of treatment other than calcium. Nobody picked up on the fact that I wasn't taking it [alendronic acid] anymore which is a bit strange, but I didn't worry because that wasn't my main concern at the time… I mentioned this to my GP that nobody had diagnosed osteoporosis, I didn't want to take them [calcium tablets] for no reason. I requested a DXA scan it took me quite a few goes to actually get one… it [osteoporosis] wasn't diagnosed until my first DXA scan five or six years later… I have been the one motivated to get treatment to be honest. It's just sort of disappeared in the ether after the neck fracture really."

This patient struggled with taking alendronic acid which is something commonly reported by patients who are prescribed the drug. It appears that although the possibility of OP was considered and appropriate action of prescribing a bisphosphonate was taken, this wasn't communicated adequately to the patient or their GP. In addition, responsibility for making sure the patient wanted and was able to comply with the prescribed therapy was not taken by any healthcare professional. The patient felt that it was her who pushed to get assessment and treatment for OP and that it shouldn't have been so difficult. She was pleased that determining whether patients were being assessed and treated for OP was a priority for this study. She consented to having this summary of the discussion included in this thesis.

2.3 IDENTIFICATION OF PATIENTS

Patients were identified using PACS at the RD&E. A list of patients who had c-spine CT imaging between 01/01/14 and 31/12/17 was obtained and reports from patients over the age of 50 years at the time of the imaging were checked to select patients who had sustained a cervical spinal fracture. These patients were assigned a study number as they were identified. Patients who had initial treatment or were followed up at hospitals other than the RD&E were excluded. Patients were also excluded if clinician review of the imaging revealed there was no fracture and the patient was therefore not treated as if they had a fracture.

2.4 DATA EXTRACTION

2.4.1 CDM data

The CDM system was used to find the following information, in Table 1, for the identified patients. These were set prior to the data collection and approved through IG. The proforma was piloted on ten patients and reviewed to ensure there was no additional data available that would also be useful to record. There was only one data collector so verification of consistency over different users was not needed. The data collected was discussed with and reviewed by an Information Analyst at the RD&E.

Table 1: information collected from CDM

Field	**Details/description**
Study ID number	Unique number assigned when patient was identified

Age at time of fracture	Number
Sex	Male/Female
Fracture level	Numbers between 1 and 7
Fracture details	Type/description of fracture
Level of trauma	High trauma/low trauma/other
Details of mechanism of injury	Description of how injury was sustained
Other injuries	Soft tissue injuries and fractures elsewhere sustained in same incident
Reported symptoms	Related to incident
Imaging on presentation	Projection radiographs, CT, MRI or a combination of these performed on day of presentation
Reported prevalent vertebral fractures	Either prevalent on imaging from this presentation or from previous spinal imaging and mentioned in report
Mention of suspicion of osteopenia on imaging	At any time on CT or projection radiograph reports
Previous fractures (not vertebral)	Any recorded in imaging or e-notes
Subsequent fractures	Any recorded in imaging or e-notes
Prior osteoporosis diagnosis	Recorded in e-notes, clinical details on image requests, from DXA reports. Assumed diagnosis if prescribed bisphosphonate
Prior osteoporosis treatment	Recorded in medication lists in discharge summaries/outpatient letters
Fracture treatment	Conservative, halo or surgical
Details	Details of collar type, surgical procedure etc.
DXA scan	Whether one has been performed and when – before or after c-spine fracture
T-score	From DXA report
Total related imaging	Total radiographs, CTs and MRI's as a result of the c-spine injury
Osteoporosis medication post fracture	Recorded in medication lists in discharge summaries/outpatient letters. Continued or newly started
Date fracture identified	Date
Date follow up to	Date of death or day data collected
Weeks follow up	Length of time between previous two dates
Nights in hospital	Inpatient stay length
Previously resident	Home, residential home, etc.
Discharged to	Home, residential home, other hospital, deceased, etc.
Recorded comorbidities	From discharge summaries/outpatient letters
Complications due to treatment/hospital stay	Hospital acquired infections, fall in hospital, loosening of metalwork, pressure ulcers, affected swallow, etc.
Osteoporosis considerations mentioned in ortho letters/discharge summary	Any mention of having considered osteoporosis assessment or treatment or asking GP to follow up
No. of ortho outpatient appointments	As a result of the c-spine fracture
Falls clinic	Suggested or attended, if mention of falls assessment as inpatient
Short term outcome for patient	Range of movement, pain, return to normal activities, etc. – if recorded
Deceased	Within 1m, or 1y

Patients were given an American Society of Anesthesiologists Physical Status Classification System (ASA I-VI) score[172] based on their diagnoses listed in their electronic notes as a way of categorising their comorbidity status. However caution should be taken in interpreting these results as this measure is intended for classifying patients' physical status preoperatively not for generally classifying morbidity. BMI was not recorded and therefore some patients may have been wrongly classified based on an assumption of BMI under 35. The score may be inaccurate as without seeing the patient it is very difficult to determine their functional status however no better alternative method for classifying comorbidities was identified. The ASA score was chosen over the Charlson Comorbidity Index, another method of classifying comorbidities used in some studies, as this requires more knowledge of presence of specific conditions than is available from the CDM system.

The FRAX tool was used to estimate need for intervention or further assessment based on 10-year probability of fracture.[107] The calculator was run for each participant six times; for each chosen BMI (see Table 2) before and after cervical spine fracture. Where information about risk factors was available this was included in the calculation, otherwise the option giving the lowest fracture probability was used.

Table 2: FRAX risk factors and how they were determined.

Risk factor	**Notes**	**Known or unknown and values used for study participants**
Age	Between 40 and 90 years.	Known. At ages above 90 the programme computed probabilities as equal to 90 year old.
Sex	Male or female.	Known.
Height	cm	Unknown. Average height for each sex was used: male 175.3cm, female 161.6cm.[173]
Weight	kg	Unknown. Three weights were used for each sex to create three different BMIs. BMI 18: male 55kg, female 47kg. Average height and weight: male 83.6kg, female 70.2kg. BMI 30: male 92kg, female 78.5kg.
Previous fracture	Arising from trauma which in a healthy individual would not have resulted in fracture.	Prior fractures which could be clearly determined as fragility fractures from what was documented in e-notes – yes. Where there was insufficient information or fractures were from a level of trauma that would be expected to cause a fracture in a healthy adult – no.

Parent fractured hip	History of hip fracture in patient’s mother or father.	Unknown. Treated as no.
Current smoking	Yes or no.	Unknown. Treated as no.
Glucocorticoids	Patient is currently or has been exposed to oral glucocorticoids for more than 3 months at a dose of prednisolone of 5mg daily or more.	Where explicitly documented – yes. Otherwise no.
Rheumatoid arthritis	Yes where patient has a confirmed diagnosis.	Where explicitly documented – yes. Otherwise no.
Secondary osteoporosis	Yes if the patient has a disorder strongly associated with osteoporosis.	Where explicitly documented – yes. Otherwise no.
Alcohol 3 or more units per day	Yes if the patient takes 3 or more units of alcohol daily.	Where explicitly documented – yes. Otherwise no.
Bone mineral density	T-score at femoral neck.	Used where available.

2.4.2 Image grading

Images of the cervical spine for each patient were viewed on PACS and graded by the primary researcher (a medical student) and a consultant spinal surgeon together. All grading of images by the primary research was reviewed by the surgeon so inter-rater reliability was not needed in this study. Lack of a second qualified professional meant independent validation was not possible. Lateral radiographs, or MRI when no radiographs were available but MRI was, were graded 0-4 using the system by Kellgren et al. presented in Figure 10. This system was used because it appears to be used most frequently in the literature and was found by a 2006 systematic review to be the only one of 12 grading systems found for cervical spondylosis to have interobserver reliability that fulfilled criteria for recommendation.(157) This system grades lateral cervical spine radiographs from zero to four based on the degree of osteophyte formation, disc height narrowing and endplate sclerosis (see Figure 10 for grading system and Figure 11 for examples).(148, 158)

Figure 10: “Kellgren et al. Cervical degenerative changes” from; Namdev R. Cervical degenerative spondylosis (grading): Radiopaedia; 2017.(158)
Kellgren et al. Cervical degenerative changes 5. normal • no degenerative changes

6. minimal/early
    - minimal anterior osteophyte formation
    - no reduction of intervertebral disc height
    - no vertebral endplate sclerosis
7. mild
    - definite anterior osteophyte formation
    - subtle or no reduction in intervertebral disc height (<25%)
    - just recognisable sclerosis of the endplates
8. moderate
    - definite anterior osteophyte formation
    - moderate narrowing of the disc space (25-75%)
    - definite sclerosis of the endplates and osteophyte sclerosis
9. gross
    - large and multiple large osteophyte formation is seen
    - severe narrowing of the disc space (>75%)
    - sclerosis of the endplates with irregularities

Figure 11: Lateral cervical spine radiographs illustrating Kellgren et al. grades 0, 2 and 4 of degenerative changes

a) grade 0

b) grade 2

c) grade 4

No existing verified grading system for classification of degenerative changes of the AOJ were found so a grading system was decided by the consultant spinal surgeon based on his knowledge and experience of appearances of degenerative changes of the AOJ. Axial CT images of the AOJ were graded 0-3:

- 0 – No loss of joint space
- 1 – Mild loss of joint space but no other features of degenerative change
- 2 – Mild to moderate loss of joint space with other features of degenerative change including subchondral cysts and osteophytes
- 3 – Complete loss of joint space in at least one site within the joint

2.4.3 Data from Information Analyst

Information was requested from a data analyst at the RD&E and information that could be provided is shown in Table 3. Data were extracted from several computer systems; Patient Administration System (PAS), Computerised Radiology Information System (CRIS), Patient First (Accident and Emergency attendance information).

Table 3: Data items requested and received from data analyst

Requested data items	**Received**
Sex	Yes
Age (or age group)	Yes
Date and time of arrival in department	Yes
Living at home or residential care	No
Level of care needed at home/Package of Care (POC)	No
Time of Triage	Yes, and locations within A&E
Level of trauma	No
Presenting symptoms	No
Injuries sustained	No
Spinal cord injury (severity) [on admission and discharge]	No
Time initially seen by A&E doctor	Yes
Time imaging requested	Date but no time
What type of imaging requested	Yes
Anatomical area(s) requested for imaging	Yes
Time imaging carried out	Yes
Date and time imaging reported	Yes
Fracture level and type	No
Other reported vertebral fractures	No
Degenerative changes/OA of cervical spine reported	No
Admitted or discharged (or deceased)	Yes, and time leaving A&E
Where admitted to	Yes
Details of treatment - surgeries, external immobilization, medications (steroids)	No
Hospital acquired infections during stay	No
Pressure ulcers acquired during admission	No

Date of discharge (if admitted)	Yes
Where discharged to - home or residential care	Yes, and ward discharged from
Level of care discharged with - POC	No
Previous fractures sustained	No
Prior diagnosis of OA cervical spine	No
Prior diagnosis of osteoporosis	No
Prior treatment for osteoporosis	No
DXA scan date(s)	No
BMD on DXA	No
Osteoporosis medication post fracture (prescribed or recommended to GP to prescribe [or nothing])	No
History of falls	No
Existing co-morbidities (particularly important are conditions affecting spine i.e. spondyloarthropathies)	No

2.5 DATA ANALYSIS

Microsoft Excel was used to process the data. Analysis of the data was performed primarily through descriptive statistics. A *t*-test was used to determine the significance of the difference between two means in all instances where it could be applied using the Excel function "=TTEST". Fisher's exact test was used to determine the significance of associations between two categorical variables. Graph Pad, an online calculator, was used for this.[174] Spearman correlation was used to test the strength of associations between ordinal variables using the Excel function "=CORREL". Significance of these correlations were tested by determining a t-value with the equation $t = r_s \times \sqrt{\frac{n-2}{1-r_s^2}}$ then putting that into the function "=T.DIST.2T". P-values less than 0.05 were considered significant.

CHAPTER 3. RESULTS – PATIENT POPULATION

This chapter discusses the data gathered about patients' histories, management and outcomes from the CDM system.

3.1 RESULTS

3.1.1 Demographics

109 potential patients were identified from CT reports and 24 were subsequently excluded (see Figure 12), leaving 85 patients who meet the inclusion criteria. The 44 men ($\bar{x}$ age 73.6 $\sigma \pm 12.3$) were significantly younger ($p<0.01$) than the 41 women ($\bar{x}$ age 81.2 $\sigma \pm 12.0$). ASA grades are shown in Table 4. The proportion of people graded as ASA I – healthy – decreased with age (see Figure 13).

Figure 12: Summary of patient demographics

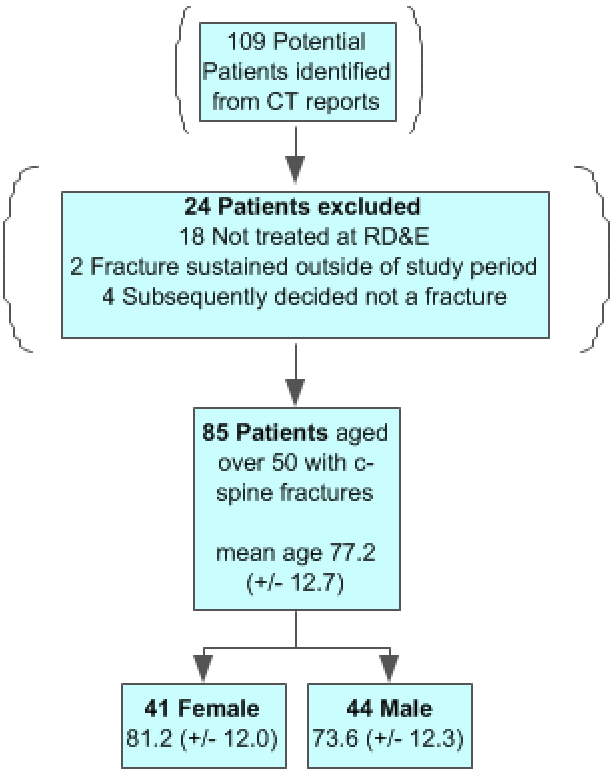
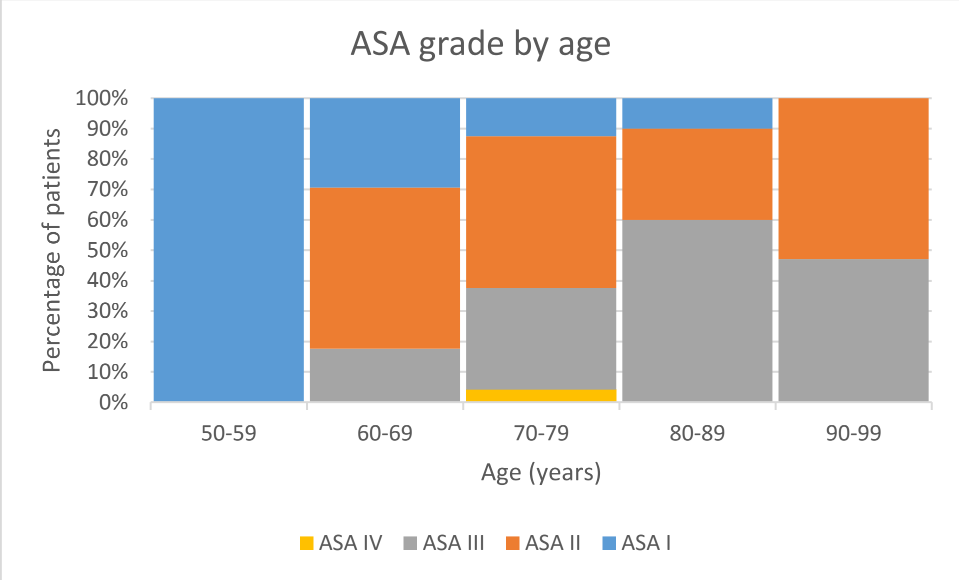


Table 4: ASA grades

ASA Grade	Frequency n=85	Mean age (st dev)
I	17 (20.0%)	62.9 (±11.2)
II	36 (42.4%)	78.7 (±10.8)
III	31 (36.5%)	83.4 (±9.4)
IV	1 (1.2%)	78 (only one person)

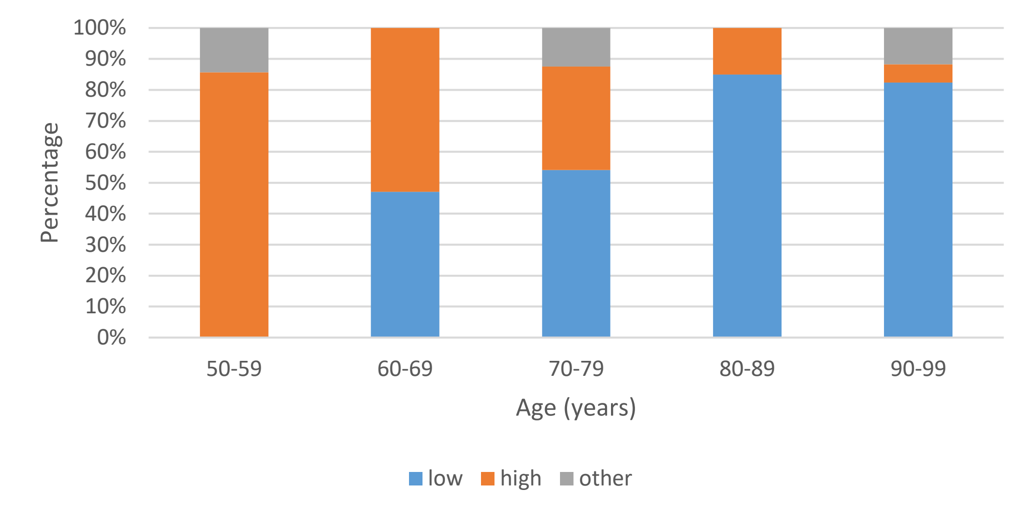
Figure 13: Proportion of patients with each ASA grade by age group



3.1.2 Mechanism of injury

The most common mechanism of injury was ground level fall which was the only mechanism of injury categorised as low trauma (54.5% of males, 68.3% of females, 61.4% combined). 69.2% of 50-64 year olds sustained their cervical spine fracture from a high trauma mechanism of injury versus 25.0% of patients aged 65 and over (see Figure 14 for level of trauma by age group). High trauma mechanisms of injury included road traffic collisions, bicycle accidents, falls from a height and falls down stairs. Other mechanisms of injury included pathological fracture and unknown. Five patients were unable to determine how they sustained their cervical spine fracture which would suggest they were sustained from a low trauma mechanism which they may have not thought significant at the time. The group who sustained cervical spine fractures from a low trauma mechanism of injury ($\bar{x}$ age 81.8 $\sigma \pm 10.1$) were significantly older ($p<0.01$) than those from high trauma ($\bar{x}$ age 68.5 $\sigma \pm 11.6$). There is no significant association between sex and mechanism of injury.

Figure 14: Level of trauma of mechanism of injury by age group



<u>3.1.3 Level of fracture</u>

Over the 85 patients 120 vertebrae were fractured. Just under a third of people fractured more than one vertebra (see Table 5). Upper cervical spine fractures (UCSF) - fractures of C1 and C2 - were more common than lower cervical spine fractures (LCSF) - fractures of C3-7. The patients with only an UCSF ($\bar{x}$ age 80.1 $\sigma \pm 11.9$) were significantly older ($p<0.01$) than those with only a LCSF ($\bar{x}$ age 70.7 $\sigma \pm 12.6$). There is a significant association between low trauma mechanism of injury and UCSF, and high trauma mechanism of injury and LCSF ($p<0.05$). The most commonly fractured vertebra was C2, with C3 being the least commonly fractured vertebra, fractured in only two patients.

Table 5: Number and location of fractures

No. of vertebrae fractured	**Frequency**	**Percentage of patients**
1	58	68.2%
2	21	24.7%
3	4	4.7%
4	2	2.4%
UCSF and LCSF		
Upper cervical spine only	58	68.2%
Both	5	5.9%
Lower cervical spine only	22	25.9%
Vertebrae fractured		
C1	22	25.9%
C2	57	67.1%
C3	2	2.4%

C4	5	5.9%
C5	4	4.7%
C6	17	20.0%
C7	13	15.3%

3.1.4 Management and complications

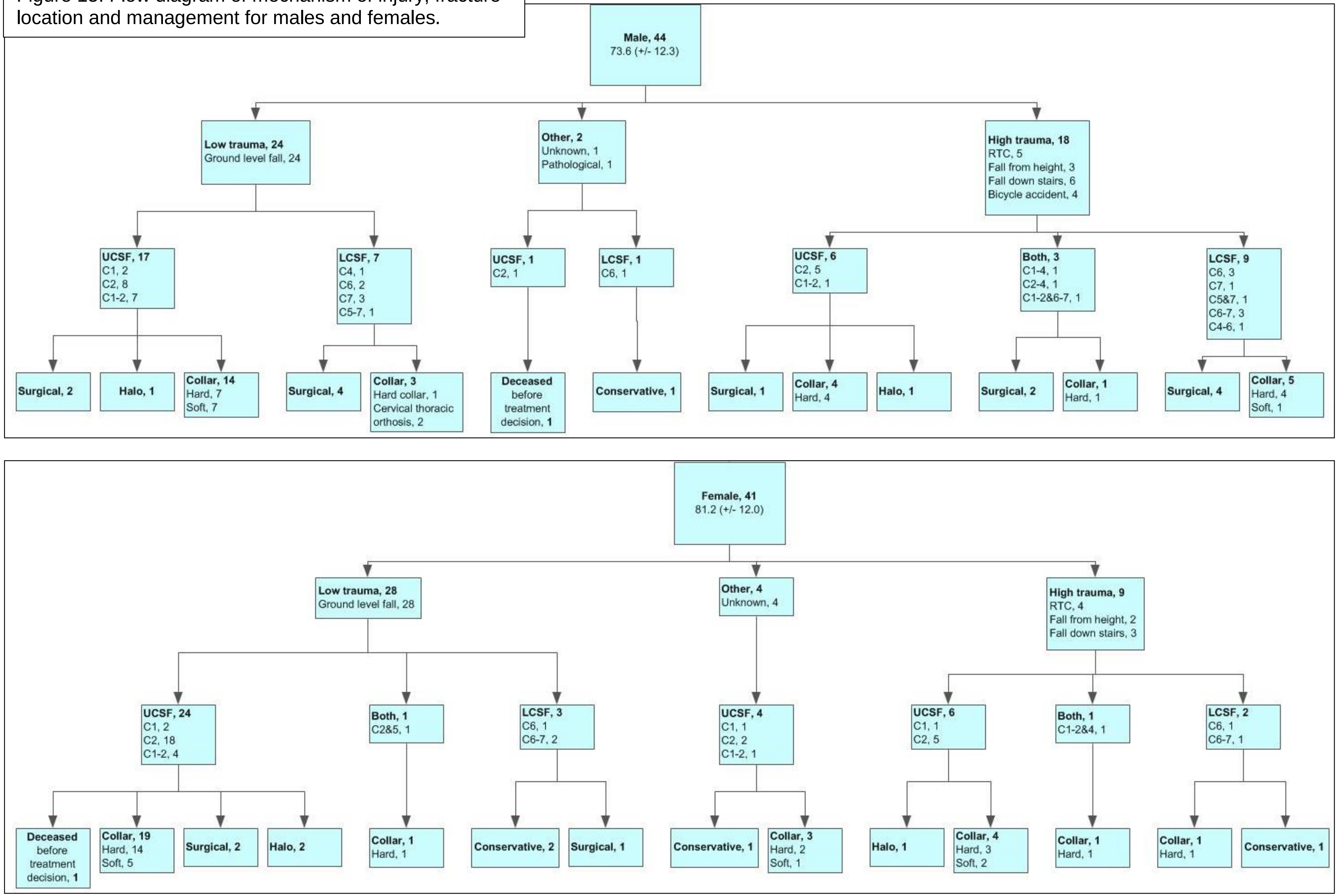
Two patients died before a treatment decision was made. The majority of patients were treated non-surgically (see Table 6). Of the non-surgically managed patients, five were treated with analgesia alone/no active management. These included four patients with spinous process fractures and one with a non-displaced Jefferson fracture thought to have been sustained some time before recognition. A hard collar was the most common mode of management followed by soft collar. Only five patients were managed with halo fixation, one of which was initially managed with a hard collar and halo fixation was performed two months after the initial injury. Almost a third of the patients managed surgically were initially intended to be managed conservatively. A change of management plan was made due to displacement or instability in four cases, and patient wishes in one case. There was no significant difference in age between patients managed surgically and conservatively.

Table 6: Patient management

Management	Frequency n=83 (percentage)	Mean age (st dev)	Complications
Conservative *None* *Soft collar* *Hard collar* *CTO* *Halo*	67 (80.7%) *5 (7.5%)* *16 (23.9%)* *39 (58.2%)* *2 (3.0%)* *5 (7.5%)*	78.0 (±13.2)	25.4%
Surgical *Initially treated non-surgically*	16 (19.3%) *5 (31.3%)*	72.9 (±9.8)	50.0% (25.0% when failure of metalwork excluded)

Significant complications related to treatment were recorded in 27.7% of all treated patients; 25.4% of the non-surgically managed group and 50.0% of the surgically managed group. The complication rate in the surgically managed group when excluding patient’s whose only complication was metal work failure, was very similar to the conservatively managed group. The most common category of complication was infections requiring antibiotic treatment (most commonly hospital acquired pneumonia followed by urinary tract infection) which affected 15.7% of treated patients with similar rates in both surgically and non-surgically managed patients. The most commonly recorded complication among the surgically managed patients was failure of or loosening of metalwork which affected five out of the 16 surgically treated patients (31.3%). Four patients, one surgical and three non-surgical, were reported to have an affected swallow; one requiring nasogastric tube insertion, one requiring percutaneous endoscopic gastrostomy insertion and one requiring a radiologically inserted gastrostomy. Three patients, one conservatively managed and two surgically managed, required an admission to the Intensive Therapy Unit (ITU). Whether union across the fracture site was achieved was not well documented and therefore rates of non-union could not be reliably calculated.

Figure 15: Flow diagram of mechanism of injury, fracture location and management for males and females.



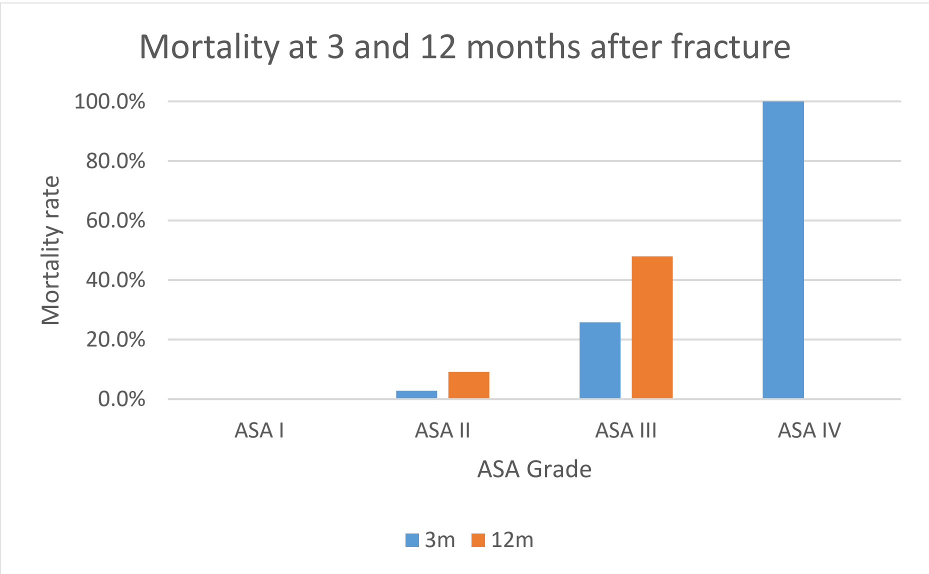
3.1.5 Mortality

Mortality at three months was 11.8% and 20.8% at one year (one year mortality calculated only for the patients who sustained a fracture a year or more before data was collected, 72 patients) (see Table 7). No patients graded ASA I were deceased within three months (0/17) or a year (0/14) of fracture versus 2.8% (1/36) and 9.1% (3/33) ASA II, 25.8% (8/31) and 48.0% (12/25) ASA III (see Figure 16). The one patient graded ASA IV died one day after fracture. Two patients died before a treatment decision was made. Mortality rates for the non-operatively manged group were higher, however there was no significant difference between groups.

Table 7: Mortality rates

Patient Group	Mortality at 3 months	Mortality at 1 year
Surgically managed	1/16 (6.3%)	1/16 (6.3%)
Non-surgically managed	7/67 (10.4%)	13/55 (23.6%)
All patients	10/85 (11.8%)	15/72 (20.8%)

Figure 16: Mortality by ASA grade



3.1.6 Prevalent and incident fractures

Around forty percent of the patients had previously sustained a fracture of one or more bones most of which were fragility fractures; the remaining previous fractures were either sustained from a high trauma mechanism of injury or insufficient information about the fracture was recorded to determine if the fracture was a fragility fracture (see

Table 8). Twenty percent of the patients had prevalent vertebral fractures, the majority of which were lumbar or thoracic vertebral wedge fractures with unknown mechanism of injury. Almost forty percent of the patients who sustained a c-spine fracture from a low trauma or unknown mechanism had previously sustained a fragility fracture. Five out of the 72 patients followed up for a year attended the RD&E with another fracture within a year of their cervical spine fracture. Four of these five sustained a neck of femur (NOF) fracture. The fifth patient had rib fractures and a distal radius fracture on two separate occasions.

Table 8: Prevalent and incident fractures	
Before C-spine Fracture	
Any prior fracture	35 (41.2%)
Prior fragility fracture	28 (32.9%)
Prior vertebral fracture	17 (20.0%)
C-spine fracture	
People who sustained c-spine fracture without high level of trauma with prior fragility fracture	22/58 (37.9%)
After C-spine Fracture	
Subsequent fracture within 1 year	5 (6.9%)
Subsequent NOF fracture within 1 year	4 (4.7%)

3.1.7 Osteoporosis management

Eleven patients (12.9%) had a prior OP diagnosis (see Table 9); nine female (22.0% of all women) and two male (4.5% of all men). Eight of the patients with an OP diagnosis had evidence of previous or current bisphosphonate treatment in conjunction with Adcal-D3 or TheiCal-D3 (vitamin D3 with calcium carbonate); whether the other three had received any OP treatment was unclear. Seven people were recorded as taking a calcium D3 preparation alone with no other bone protective medication. In the year following the c-spine fracture, one more person was recorded as taking a bisphosphonate. One additional patient was recorded as taking a bisphosphonate more than a year later. There was a single reference to taking bisphosphonates in the letters of two other patients but they were never subsequently recorded as taking them. The discharge summary for another patient recommended that the patient should start a bisphosphonate when their swallow improved however there is no evidence of this ever being arranged. Seven additional patients were taking a calcium-D3 supplement with no other bone protective medication within a year after fracture. No bone-sparing agents other than bisphosphonates were mentioned in any patient’s records.

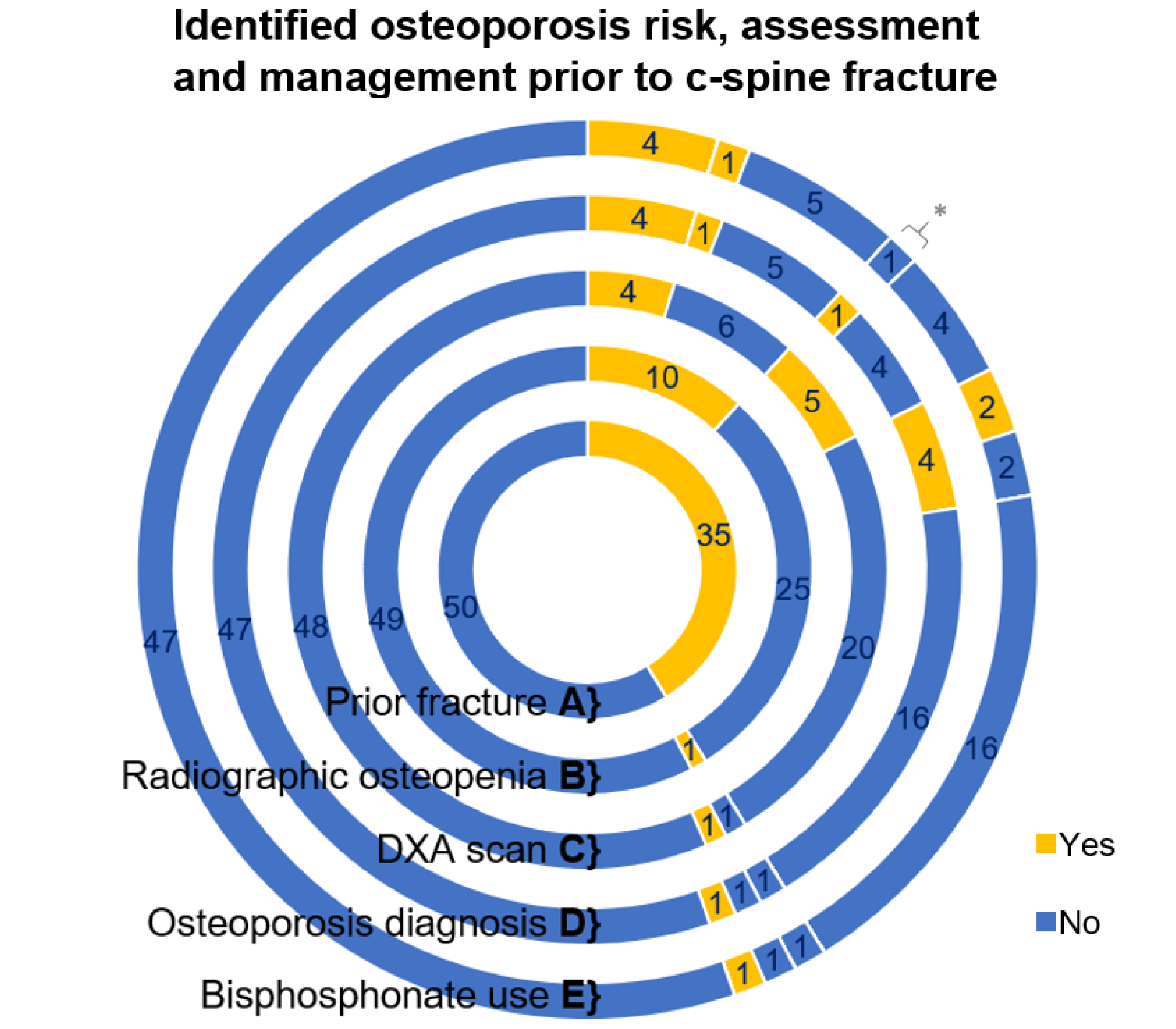
Table 9: Osteoporosis management	
Prior to c-spine fracture	
Reported radiographic osteopenia [Reported on day of c-spine fracture]	11 (12.9%) [4 more (17.6%)]
DXA	10 (11.8%)
Osteoporosis diagnosis	11 (12.9%)
On bisphosphonate	8 (9.4%)
Calcium vitamin D alone	7 (8.2%)
People with prior fractures who had DXA scan or treatment with bisphosphonates before c-spine fracture	12 (34.3%)
1 year after c-spine fracture	
DXA	5 more
On bisphosphonate	1 more
Calcium vitamin D alone	7 more

Just under twelve percent (10/85) of patients had undergone a DXA scan at some point before their c-spine fracture. As defined by the WHO Criteria, the T-scores were: one normal, five osteopenic, three osteoporotic, and one unknown (not on PACS).[63] Five further patients had a DXA within a year after injury; one normal, three osteopenic and one osteoporotic. Of patients with prevalent fractures, two thirds had no DXA scan or treatment with bisphosphonates recorded before they sustained their c-spine fracture.

Bones of an osteopenic or osteoporotic appearance were mentioned in image reports on PACS for projection radiographs and CTs in 11 patients before the day of their c-spine fracture (see Figure 17), with an additional four patients on the day of presentation for c-spine fracture; 17.6% of patients all together. Of these, half (53.3%) do not appear to have a DXA scan, diagnosis of OP or treatment with bisphosphonates at any point before or after c-spine fracture.

Figure 17: The doughnut chart shows which patients, identified by the study as having certain red flags for osteoporosis, went on to have a diagnosis of and treatment for osteoporosis. The starting point is in the middle - this ring shows the proportion of the 85 patients with prevalent fractures (before the day of c-spine fracture). The next ring shows the proportion of patients with an imaging report that mentioned radiographic osteopenia for both the group of patients with a prior fracture and without a prior fracture. The rings progress in a similar fashion outward through DXA scan and OP diagnosis ending with recorded bisphosphonate use. Not only is each patient identified as a proportion of the whole at each stage, but also each patient's individual path can be tracked as a straight line from the centre to the outer ring.

For example; the patient at the starred position * has had a prior fracture, no radiographic osteopenia mentioned in imaging reports, has had a DXA scan, has had an osteoporosis diagnosis and has no recorded bisphosphonate use.



Of the patients who sustained their fracture as a result of a ground level fall, a fall down stairs or the notes clearly stated the fracture mechanism was as a result of an unexplained collapse (excluding patients who died within one week of c-spine fracture), 3.1% had been seen at a falls clinic and a further 6.2% had evidence of having undergone investigations for falls as an inpatient. The notes of one additional patient noted they had received support from physiotherapy and occupational therapy in the past to try and minimise their falls risk. The remaining 89.2% had no evidence of investigation or intervention to reduce future risk of falls/collapse. In two of these patients there was a clearly written recommendation to carry out a falls assessment but no evidence of it ever being carried out.

3.1.8 FRAX modelling

FRAX was used to estimate numbers of patients who may need treatment or BMD measurement before and after c-spine fracture (see Table 10).[107] These calculations were made using the limited information available in patients' electronic records and therefore do not take into account parental hip fracture and many of the other risk factors unless explicitly mentioned. Where hip t-scores were available they were included. FRAX scores varied substantially with BMI. In all simulations less than 60% of the patients fell into the "offer lifestyle advice and reassure" category. Actual numbers of patients recorded as receiving treatment was well below the recommended number and highest in the patients with a FRAX score in the "Treat" category as defined by the National Osteoporosis Guideline Group. The majority of female patients aged 65 and over who sustained a low trauma c-spine fracture were in the "Treat" category (see Table 11).

Table 10: FRAX scores before and after c-spine fracture with different patient BMIs

Simulation	**Treat** (number of patients)		**Measure BMD** (number of patients)		**Lifestyle advice and reassure** (number of patients)	
	Pre	Post	Pre	Post	Pre	Post
Average height and weight	12	24	27	26	46	35
BMI 18 (Average height, low weight)	21	30	23	27	41	28
BMI 30 (Average height, high weight)	10	22	26	21	49	42
Actual treated patients						
Patients with bisphosphonate use recorded	4	4	3	5	1	0

Table 11: Female patients with a non-high trauma c-spine fractures who were in the FRAX “Treat” category		
Simulation	**Percentage of female patients who sustained a c-spine fracture from a low trauma or unknown mechanism of injury in “Treat” category**	
	65 years and over	75 years and over
Average height and weight	71.0%	81.5%
BMI 18 (Average height, low weight)	93.5%	96.3%
BMI 30 (Average height, high weight)	67.7%	77.8%

3.2 DISCUSSION

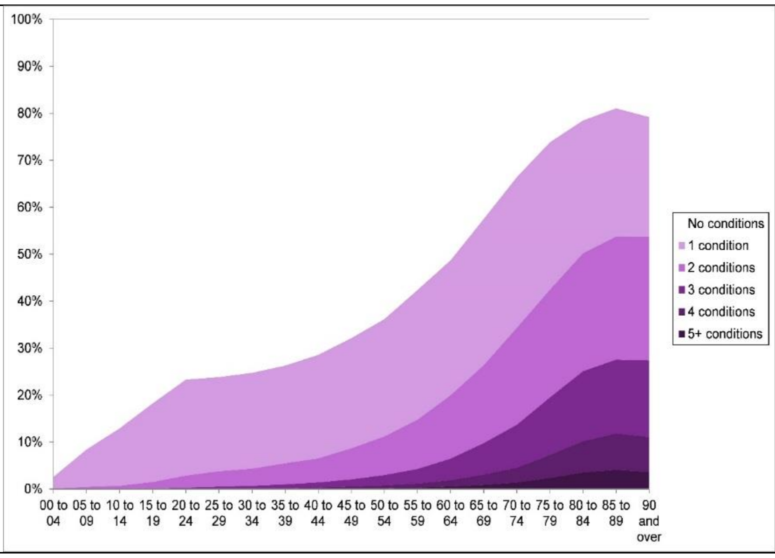
3.2.1 Incidence and Demographics

There were 85 c-spine fractures identified in the four year period included in the study, which is an average of 21.25 fractures per year. Using population estimates from Devon County Council for 2016 this equates to an annual c-spine fracture incidence of approximately 14.6 per 100,000 of the population aged 50 and over in Exeter, Mid and East Devon – the area covered by the RD&E.[175] Other studies that have estimated incidence for the whole population, rather than specifying those over 50, have found an annual incidence of 12 per 100,000.[17, 18] It would be expected for there to be a higher incidence among the population aged 50 and over than the general population due to a peak in c-spine fractures in the elderly. The annual incidence of hip fracture in Devon in people aged 65 and over is around 539 per 100,000.[176] There were 72 c-spine fractures in people aged 65 and over during the study period which could equate to an estimated annual incidence of 22.3 per 100,000. This shows that c-spine fractures are far less common than hip fractures. The estimated incidences calculated here may be overestimates as they are using only the estimated population of Exeter, Mid and East Devon when patients may also come from areas outside of this for a variety of reasons. The estimated incidences could contrarily be underestimates as some patients with c-spine fractures may have been missed because of CT c-spine scan image sets being within a set of CT head images and therefore not being included when searching through scans labelled as CT c-spine. In addition it is possible that there were patients who were identified as having a c-spine fracture on projection radiographs or MRI and were not imaged further with CT so would not have been identified by this study. There may be additional patients who sustained c-spine fractures from minimal trauma and were not identified by healthcare professionals either through non-presentation or through healthcare professionals not suspecting and investigating for c-spine fracture. Patients who died before admission to hospital or CT scan would also be missed.

There was a fairly even divide between males and females in the study population with the average age of the men being lower than that of the women. Kaesmacher et al 2017 conducted a retrospective analysis of patients aged 60 and over admitted to a level I trauma centre with c-spine fractures. They also had a similar number of males to females with 55.4% being female.[(6)] Malik et al. 2008 found 32.7% of 107 patients aged 65 years and over with c-spine fractures were female. If patients under 60 years are removed, the proportion of the remaining study population that are female is 51.3% which is closer to the figure described by Kaesmacher et al 2017, and in patients ≥65 years 51.4% are female. Other studies have found that the incidence of fracture, both of the c-spine and at most other sites, is higher in men than women until around 50 to 70 years after which the sex balance reverses.[(3, 23, 80)] This could be attributed to more risk taking behaviour/exposure to trauma in younger men and decreased bone density in older women. The average age of the men in this study could be lower as there are more men at the younger end of the study population who sustained their fractures from high trauma mechanisms such as bicycle accidents compared to the women, however in this study there is no significant association between male sex and high trauma mechanism of injury.

The severity of comorbidity status in the study population increased with age as would be expected. A Devon County Council Report of multi-morbidity shows (in Figure 18) there is an increase in a number of specified conditions with age which plateaus around the age of 85 which generally reflects the trend in health status of the c-spine study population. However, it is difficult to verify whether the c-spine study population is representative of the general Devon population, or if they are generally in poorer health to start with, as comorbid status is being measured differently, the study numbers are fairly low especially in certain age groups, the reliability of recording of health condition in the patients records is unknown and the validity of using ASA scores in this way is questionable.

Figure 18: Estimated percentage of population with selected long-term conditions by age group in Devon, 2013-14 from South West Academic Health Science Network, Symphony Project Data.[177]



3.2.2 Mechanism of injury and level of fracture

Ground level fall was the most common mechanism of injury and the proportion of fractures that were sustained from a low trauma mechanism increased with age. The group who sustained c-spine fractures from a ground level fall were significantly older than the group who sustained fractures from high trauma mechanisms of injury. Other studies that have looked at the mechanism of injury of cervical spine fractures in the elderly have also found that falls are the most common mechanism of injury but with less of a majority than was the case with these data. Wang et al. 2014 found 50.8% of patients aged ≥60 years and over, Malik et al. 2008 found 60% of ≥65, Wang et al. 2013 found 53.96% of ≥65 year olds and Lomoschitz et al. 2002 found 40% of >75 year olds sustained c-spine fractures from a low trauma mechanism.[5, 21, 178, 179] In this study 61.2% of all patients (aged ≥50 years) and 66.7% of ≥60 year olds, 68.1% of ≥65 year olds and 72.5% of >75 year olds sustained c-spine fractures from ground level fall; larger proportions than reported in other studies. There is an increase in incidence of c-spine fracture from ground level falls with age and it has been hypothesised that changes in craniopelvic alignment resulting in a forwards shift in centre of gravity, slowing of reaction times of protective reflexes and reduced BMD all contribute to this.[30, 31] As low trauma mechanisms of injury are the most common cause of c-spine fractures in the elderly, patients with apparent low levels of trauma should not be considered at low risk of injury and investigated appropriately.

Upper cervical spine fractures are more common than lower cervical spine fractures with C2 being the most commonly fractured vertebra. This is consistent with other studies that have found the most common site of c-spine fracture in the elderly is C2 particularly the odontoid process.[5, 18, 21, 23, 30, 179] The group of patients with UCSF are significantly older than those with LCSF and there is a significant association between low trauma mechanism and UCSF. These findings reflect the existing literature. Lomoschitz et al. 2002 found associations of age and mechanism with location of fracture which were independent of one another; older elderly patients were more likely to sustain UCSF independent of mechanism and patients with low trauma mechanism were more likely to have UCSF independent of age.[21] It has been suggested that reduced mobility of the lower c-spine due to degenerative changes associated with age mean that C1-C2 is the most mobile motion segment and therefore more predisposed to injury.[21, 179]

3.2.3 C-spine fracture management, complications and mortality

The majority of patients were managed non-surgically with a collar and rates of complications were similar between operatively and non-operatively managed patients. The optimal management strategy for older patients with c-spine fractures is unclear as many other studies have reported similar complication rates between conservatively and surgically managed patients although many of these studies focus on odontoid fractures only rather than c-spine fractures in general.[54, 180, 181] Complication and mortality rates are similar in this study to the existing literature.[54, 179-184] This study did appear to have better survival amongst the surgically managed group (6.3% vs 23.6% at one year) however, the size of the surgically managed group is very small, with only 16 patients, and should therefore be interpreted with caution; there was no significant association between management approach and mortality. Other studies have also found no significant difference in survival between treatment modality or slightly superior survival for surgically managed patients.[54, 180, 181, 183]

However this could be in part due to selection bias as healthier patients may be more likely to be offered surgery.

Mortality appears to increase with severity of comorbidities. This finding has been observed in other studies of c-spine fracture in elderly populations.[183, 185, 186] The higher mortality in patients with more severe comorbidities could mean that these deaths are unrelated to c-spine fracture and the contribution of c-spine fracture towards death is unclear. However, as is anecdotally observed in hip fracture in the elderly, the fracture may initiate a period of more rapid decline. Cause of death was not often recorded in electronic notes so whether any deaths were directly attributable to c-spine fracture could not be determined. The one year mortality rates appear to be higher than the expected mortality in a year (see Table 12) however low numbers of patients particularly in certain age groups make comparisons difficult. In addition, general health status is not adjusted for. Klop et al. 2017 found mortality 1 year after first fracture at several major sites (hip, wrist, humerus, clinical spine, ribs or pelvis) in people aged ≥50 years was more than three times higher than the general population and increased with age.[187] This study was not able to establish such a strong association. Mortality rates are also similar to those recorded for hip fractures in the elderly which are around 20-30% at one year.[188-191]

Table 12: One year mortality compared to expected population mortality

Age range (years)	Age specific mortality rates England and Wales 2016 (%) [192]	Age specific 1 year mortality rates in study population (%)
65-69	1.19	0
70-74	1.93	0
75-79	3.36	17.6
80-84	5.91	16.7
85-89	10.78	12.5
90 and over	21.49	23.5

3.2.4 Osteoporosis and fracture prevention

A prior diagnosis of OP was recorded in 12.9% of the study population and 22.0% of the women. Melton 1995 estimated that 30% of white women aged 50 or over had OP according the WHO definition.[193] Siris et al. 2001 found 7% of a sample of postmenopausal women with no previous diagnosis of OP to have a t-score in the osteoporotic range and personal history of fracture to concur a significantly increased risk of OP.[194] This suggests it is likely there are women with undiagnosed OP in this study population as the figure found in this study is lower than what might be expected for a similar population. In addition, this is a group of people who have sustained fractures and therefore are potentially more likely than the general population to have low BMD.

Prior fractures of any bone had been sustained by 41.2% of this study population and 20.0% had sustained prior vertebral fractures. The majority of these patients had no evidence of assessment of or treatment to reduce future fracture risk. Additionally, very few patients had a DXA scan or were prescribed medication to reduce their fracture risk subsequent to their c-spine fracture. Previous fracture is a known risk factor for subsequent fracture independent of BMD.[195] Other studies have however also observed that there is a lack of action regarding secondary fracture prevention particularly after non-NOF fractures with around 20% of patients receiving treatment with bisphosphonates or other effective medication after fracture in many studies.[196-200] Data from the National Hip Fracture Database (NHFD) shows that secondary fracture prevention after hip fracture in the elderly is considered and acted upon in a much higher proportion of cases; 97% had a recorded assessment for bone protection medication, 58% treated and a 17.4% awaiting further investigation before a treatment decision is made (see Table 13).[188] The NHFD shows a similar proportion of patients already taking bone protection medication prior to fracture as this study (8.2% in NHFD vs 9.4% in this study).[188]

Table 13: Bone protection medication at discharge. From NHFD 2017 report[188]

Action taken		
Assessed but no bone protection medication needed or appropriate		21.6%
Oral medication	Continued from pre-admission	7.3%
	Started on this admission	42.4%
Injectable medication	Continued from pre-admission	0.9%
	Started on this admission	7.4%
No treatment, pending DXA scan or bone clinic assessment		17.4%
No assessment or no action taken		2.9%

Poor recording of medication lists and discussions surrounding OP risk may make the data unreliable. There may be cases similar to that described by the patient involved in the shaping of this project (in Chapter 2.2), where there was a discussion between a healthcare professional and the patient regarding OP risk and the options regarding medication, that was not recorded in letters or communicated to the patient's GP. It was also noted that the orthopaedic discharge summary pro forma included boxes for "calcium/vitamin D" and "bisphosphonates" but these were frequently left blank.

Seven patients were taking calcium/vitamin D3 supplements alone prior to their c-spine fracture with an additional seven taking them within a year post fracture. There is little evidence to support the use of calcium and vitamin D3 supplementation to reduce fracture risk.(100, 102, 103, 126, 127, 201) Despite this it appears that they are more readily prescribed than bisphosphonates. This could be due to lack of awareness of the inefficacy of calcium/vitamin D3 supplements at reducing fracture risk amongst prescribers as well as the perceived safety and side effect profile of these supplements. However there have been concerns over the safety of calcium supplementation after two meta-analyses, in 2010 and 2011, concluded there may be an increased risk of cardiovascular events although the numbers needed to harm is unclear.(128, 129) Conversely, a 2015 meta-analysis concluded that current evidence did not establish an increased risk of hospitalization and death from coronary heart disease in postmenopausal women on calcium supplementation.(130) Using the precautionary principle, avoiding calcium supplementation unless there is a clear indication for its use may be safer.(131)

Healthcare professionals may be reluctant to prescribe bisphosphonates as they may be viewed as difficult for patients to tolerate leading to low adherence to medication regimens and potentially dangerous due to high profile reports of rare side effects.(202) One third to half of patients may not take medication for OP as directed and persistence at one year may be around 50%.(203, 204) Patients may decline medication for OP despite physician recommendation. Due to poor recording of conversations about medication it is unclear who made the decisions not to prescribe bisphosphonates in this study. Weaver et al. 2017, an American study, found that both doctors and patients may make the decision not to prescribe/take medication for OP due to concerns over side effects and belief that there were alternatives.(205)

Only 6.9% of patients followed up for a year attended the hospital with a subsequent fracture. The risk of subsequent fracture within a year following fracture at a broad range of sites is markedly increased.(72, 206-208) Lindsay et al. 2001 found that in the year following vertebral fracture 20% of women will have a new vertebral fracture.[207] In this study subsequent fracture rates are likely to be higher than the recorded figure of 6.9% as this only captures fractures that were identified when patients attended hospital with an injury. Vertebral compression fractures can frequently go unnoticed, patients would be unlikely to present to the hospital and fractures may only be identified incidentally on imaging for other indications. In addition, patients may not be sent for appropriate imaging investigations when presenting with fracture-like pain and vertebral fractures are often not reported even when present.[209, 210] A false negative rate of 34% for vertebral fracture on projection radiographs was found by the international IMPACT study in 2009 which suggested that underdiagnosis of vertebral fractures is a worldwide problem.[210]

FRAX score estimates indicated a larger proportion of the patients should be receiving treatment and BMD measurement both before and after c-spine fracture. These estimate are likely to be modest, due to the large contribution of unrecorded factors such as parental hip fracture and smoking status to FRAX score, and unreliable without knowledge of patients' height and weight. Despite this they indicate that the c-spine fractures in this population should have prompted initiation of OP treatment in around ten more patients as opposed to one, the actual figure. The majority of female patients aged 65 years or over who have sustained a low impact fracture would be eligible for OP treatment without needing BMD assessment. Despite this, only a minority of these patients were on bisphosphonates already and none were started on them as a consequence of their c-spine fracture. Secondary fracture prevention is not integrated into c-spine fracture care.

Very few patients are receiving a falls risk assessment and individualised intervention. Poor recording in electronic records of assessments carried out as an impatient may also contribute to the apparently low number. NICE recommends multifactorial falls risk assessments are carried out for older adults presenting to hospital after a fall and are performed by an appropriately qualified professional normally in the setting of a specialist falls service.[120] If patients are not receiving falls risk assessments then interventions to reduce future falls risk will not be appropriately offered.

3.3 CONCLUSIONS

Many characteristics of the study population and their injuries fit with what would be expected from the existing literature with a high proportion of patients sustaining fractures of C2 from low trauma mechanisms of injury. Complication and mortality rates were comparable to other studies of c-spine fractures in the elderly and showed no clear superior management strategy. There appeared to be many underused opportunities for secondary fracture prevention both before c-spine fracture and as part of c-spine fracture care. A very low proportion of patients are being started on bisphosphonates in response to c-spine fractures despite the fact that most female patients aged ≥65 years with a history of falls and fracture from low impact would be above treatment thresholds defined by NICE.

CHAPTER 4. RESULTS – IMAGING FINDINGS

This chapter discusses the data obtained from grading patients imaging for spondylosis of the cervical spine. This was undertaken viewing lateral radiographs to explore general spondylosis as well as using CT images of the AOJ. Data concerning patients' ages, sex and location of fractures are also linked to these data to determine whether there are any associations between these factors and severity of cervical degenerative changes.

4.1 RESULTS

4.1.1 Cervical degenerative spondylosis

Lateral radiographs or MRI images were available for all 85 patients. Over half of the patients had gross cervical degenerative changes apparent on lateral radiographs or MRI (see Table 14). Only 12.9% of patients had no, minimal or mild cervical spondylosis. It was not possible to determine the grade of spondylosis in one patient due to ankylosing spondylitis. There were no significant differences in grades between males and females or between patients who sustained upper and lower cervical spine fractures. Patients with images graded as 0-2 were significantly younger ($p<0.01$) than grades 3-4. Additionally patients with moderate (grade 3) cervical degenerative changes were significantly younger ($p<0.01$) than those with gross (grade 4) changes.

Table 14: Cervical degenerative spondylosis assessed on lateral radiographs or MRI where no radiograph was available.

Cervical degenerative spondylosis grade	**Number of patients (percentage)**	**Mean age, years (standard deviation)**
0 (normal)	1 (1.2%)	50.0 (n/a)
1 (minimal/early)	4 (4.7%)	60.8 (±7.4)
2 (mild)	6 (7.1%)	71.0 (±11.8)
3 (moderate)	29 (34.4%)	73.1 (±12.2)
4 (gross)	44 (51.8%)	82.8 (±10.2)
Unable to determine due to ankylosing spondylitis	1 (1.2%)	

4.1.2 Atlanto-odontoid joint

CT images of the AOJ were available for 84 of the 85 patients. It was not possible to determine the severity of degenerative changes in five patients; one patient due to ankylosing spondylitis affecting the cervical spine and four due to Jefferson fractures affecting the anterior arch of the atlas distorting their usual anatomy. Almost 70% of patients had moderate to severe degenerative changes of the AOJ and only 6% had no apparent degenerative changes on CT (see Table 15). There was no association found between sex or location of fracture and severity of degenerative changes. Patients with complete loss of joint space, grade 3, were significantly older than those with less severe degenerative changes graded 0-2.

Table 15: Degenerative changes of the atlanto-odontoid joint assessed on CT.

Severity of degenerative changes	**Number of patients (percentage)**	**Mean age, years (standard deviation)**
None (grade 0)	5 (5.9%)	64 (±17.4)
Mild (grade 1)	15 (17.6%)	76.4 (±12.2)
Moderate (grade 2)	31 (36.5%)	72.8 (±12.9)
Severe (grade 3)	28 (32.9%)	85.7 (±7.1)
Unable to determine due to: *ankylosing spondylitis* *fracture through anterior arch of atlas* *missing CT*	6 (7.1%) *1 (1.2%)* *4 (4.7%)* *1 (1.2%)*	

4.1.3 Combined scores

There is a significant but weak positive correlation between the severity of degenerative changes in the cervical spine in general and of the AOJ (r_s=0.24 $p<0.05$). Only one patient had a difference of four between their two grades; despite severe degenerative changes visible on projection radiography, they had no signs of degenerative disease of the AOJ. In the patients in which both grades could be calculated, the most frequent combination of grade was four and three, the most severe grade of both scores (see Figure 19). Almost three quarters of patients had a combined score more than four (see Table 16). Patients with a score of more than four were significantly older than those with a score of four or less. No relationship between score and sex or location of fracture was identified.

Figure 19: Chart showing number of patients with each combination of grade of cervical degenerative spondylosis and atlanto-odontoid joint degenerative changes.

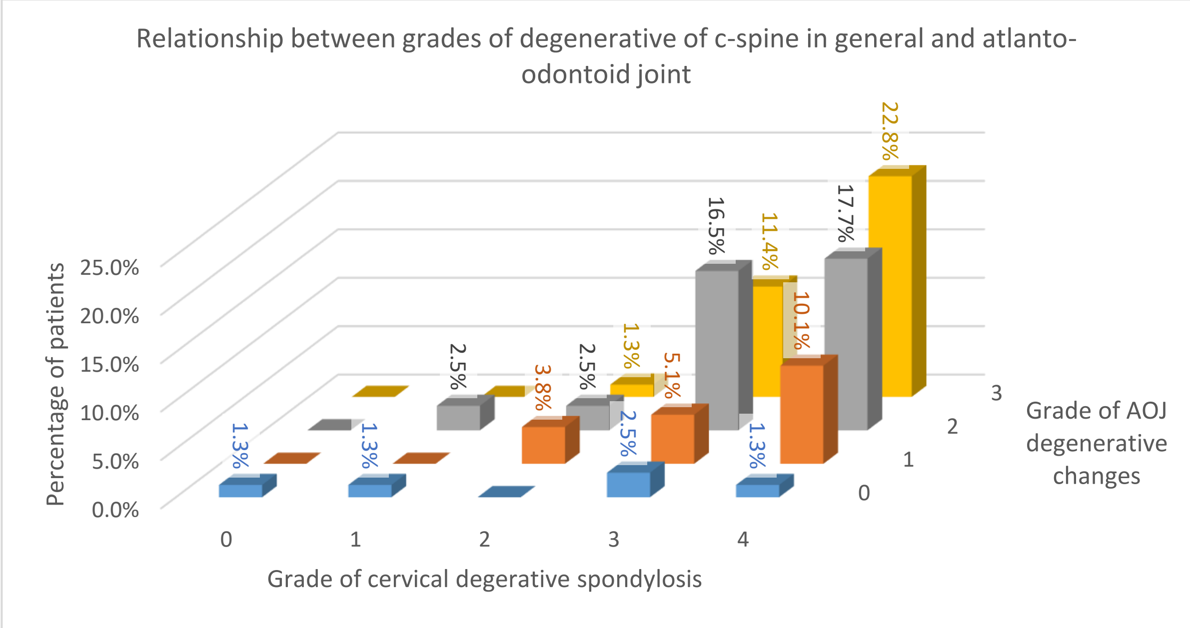


Table 16: Combined scores calculated by adding cervical degenerative spondylosis grade and grade of atlanto-odontoid joint degenerative changes.

Combined score	**Number of patients** (percentage)	**Mean age, years** (standard deviation)
0	1 (1.2%)	50.0 (n/a)
1	1 (1.2%)	51.0 (n/a)
2	0 (0.0%)	n/a
3	7 (8.2%)	64.4 (±9.0)
4	7 (8.2%)	75.1 (±10.1)
5	22 (25.9%)	73.5 (±13.8)
6	23 (27.1%)	81.1 (±9.9)
7	18 (21.1%)	86.8 (±7.4)
Unable to determine	6 (7.1%)	

4.2 DISCUSSION

There was a high prevalence of radiological signs of degenerative changes in the cervical spine in the studied patients. Age was the only factor found to have an association with severity. This association was expected; it is widely accepted that prevalence of degenerative changes of the cervical spine increase with age and it has been referred to as part of the natural aging process.[149, 150, 211, 212] Watanabe et al. 2010 suggested an association between degenerative changes of the lower cervical spine and fractures of the upper cervical spine in the elderly.[30] This was based on a review of 103 patients with upper cervical spine fracture and no patients with lower cervical spine fracture so does not explore if there is a difference in prevalence in patients with lower fractures. My data showed that with increasing age there is both an increase in prevalence of degenerative changes and proportion of fractures that are of the upper c-spine. However, there is no evidence to establish a causal link between these two factors. In addition there was no association found between severity of spondylosis and location of fracture.

The majority of patients, all those graded as having moderate or severe degenerative changes of the AOJ, had one or more subchondral cysts present in the odontoid peg. In addition, all patients graded as mild, moderate or severe had some degree of joint space narrowing, with those graded as severe having a complete loss of joint space at one or more site(s) in the joint. Shinseki et al. found presence of interosseous cysts was significantly associated with dens fracture but there was no significant association with joint space narrowing.(29) Lakshmanan et al. 2005 found an increased prevalence of loss of joint space in patients with Type II odontoid fracture.(25) My data did not find an association between upper cervical spine fractures and severity of degenerative changes of the AOJ. Limitations of the grading system, i.e. not considering separately specific degenerative features, and grouping of fractures of the upper and lower cervical spine made it not possible to analyse the relationship between cysts and dens fractures specifically. However, as the majority of upper cervical spine fractures were of the odontoid, and severity of grade of AOJ changes was closely linked to cyst presence, if an association was present in my data it may be expected to become apparent in analysis regardless. Another limitation of the study design are that there is no control group to compare the relative frequency of degenerative changes in those with no cervical spine fracture to those with.

A correlation between severity of degenerative changes of the cervical spine as a whole and specifically of the AOJ was expected based on an assumption of a similar pathophysiology and close anatomical proximity. No previous studies examining how closely related degenerative changes of the AOJ and the rest of the cervical spine are could be found. Lack of research in this specific area suggests that the cervical spine may be usually considered as a whole, or whether degenerative changes affect all vertebral levels equally is thought of as unimportant. Significance of cases where there is a large difference in severity of degenerative changes at the AOJ compared to the rest of the cervical spine is unknown.

4.3 CONCLUSIONS

Degenerative changes of the cervical spine visible on imaging increase with age and are prevalent in the study sample. Several studies have proposed an increased prevalence of degenerative changes in patients with upper cervical spine fractures, however no relationship could be established in this study. The importance of degenerative changes in older patients with cervical spine fractures remains unclear.

CHAPTER 5. RESULTS – SERVICE DETAILS

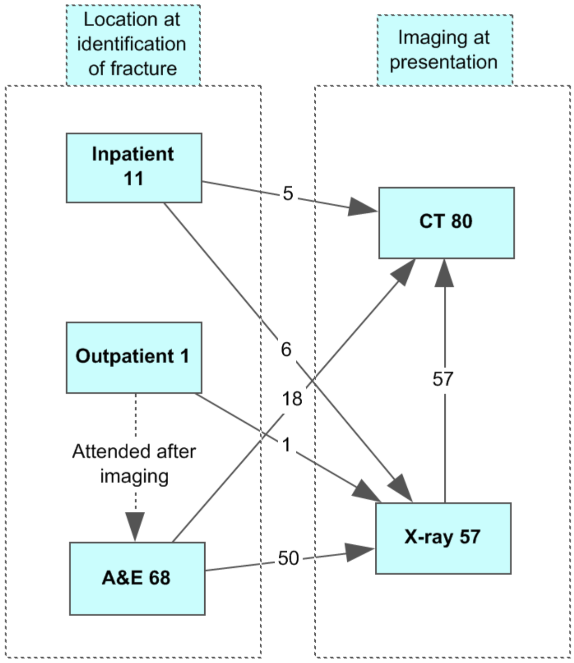
This chapter discusses the data provided by the RD&E information services team extracted from multiple hospital computer databases regarding the same 85 patients identified previously as being 50 years of age or older and having sustained a cervical spine fracture within the defined time period. This includes information about timings and locations of patients during hospital stays, A&E visits and imaging procedures. Some information collected from CDM previously discussed in Chapter 3 has also been used to corroborate, clarify and explore these data.

5.1 RESULTS

5.1.1 Identification of c-spine fracture

Information about initial location and imaging was unavailable in this dataset for five patients from 85 patients originally identified for inclusion in this study. Of the remaining 80 patients, the majority (85.0%) were in A&E when their c-spine fracture was identified (see Figure 20). One additional patient who had attended A&E was admitted before their c-spine fracture was identified later that day as an inpatient and became part of the 13.8% who were inpatients at fracture identification. In one case a patient had a radiograph and a CT scan as an outpatient and subsequently attended A&E after the fracture was identified. Before having a c-spine CT scan, 71.3% of the 80 patients had projection radiography. Although a higher proportion of inpatients went straight to CT rather than projection radiography initially, there is no significant association between these factors and whether these patients had undergone a c-spine radiograph earlier on in their inpatient stay was not noted.

Figure 20: Location and imaging of patients presenting with c-spine fracture

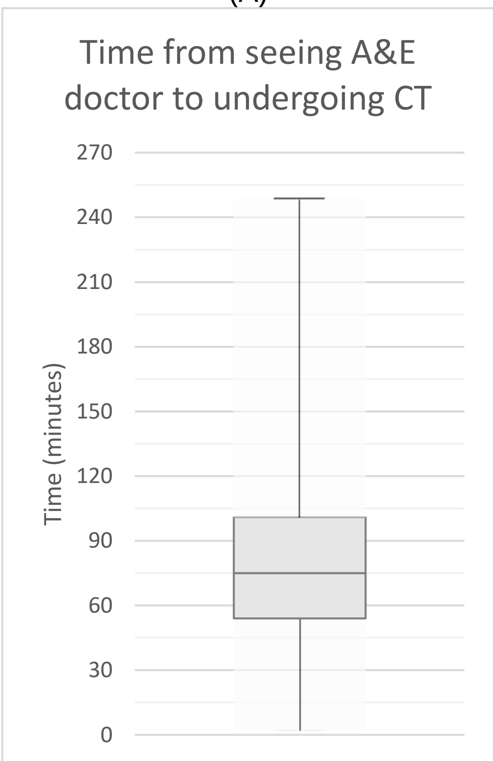


For patients attending A&E, the time of consultation with a doctor is recorded, however these data were missing or incomplete for four of the 68 A&E attenders. In two cases, patients were seen in A&E and discharged after having just projection radiography then were diagnosed with a c-spine fracture on CT when they re-attended at A&E the next day. A CT scan was performed prior to the consultation with a doctor in seven patients. After excluding the aforementioned cases, the time taken for the remaining 55 patients to receive a CT scan after the time they were recorded as seeing a doctor ($t_{Dr\text{-}CT}$) is summarised in Figure 21 (A). The $t_{Dr\text{-}CT}$ was under one hour in 46.8% of cases (including patients who had a CT before seeing a doctor). Patients who had undergone projection radiography prior to CT had a significantly longer $t_{Dr\text{-}CT}$ ($\bar{x}$=94.5min σ±54.3 vs $\bar{x}$=53.8min σ±40.8, $p<0.05$) and were significantly less likely to have a $t_{Dr\text{-}CT}$ under one hour ($p<0.01$).

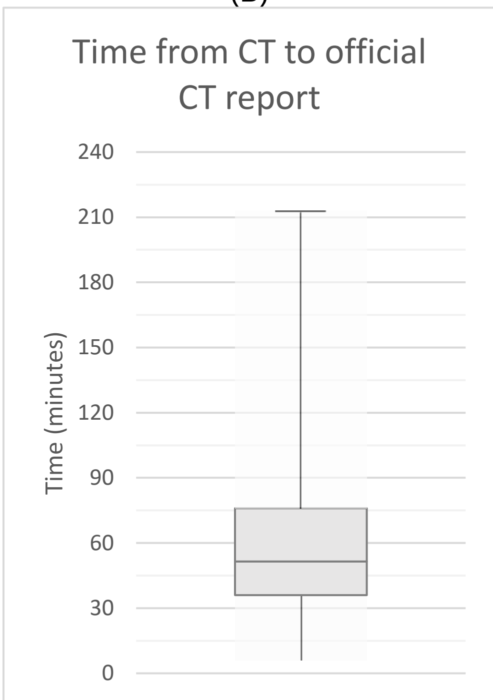
Data about the time taken for the CT report to be completed was available for all but eight of the 85 patients and is summarised in Figure 21 (B). In 64.5% of cases, reports were completed in under one hour.

Figure 21: Box plots showing; (A) the time taken for A&E patients from seeing the doctor to undergoing CT excluding patients who had a CT before seeing the doctor and patients with incomplete data and (B) for all patients for which complete data were available, the length of time taken for a CT report to be completed on CRIS.

(A)



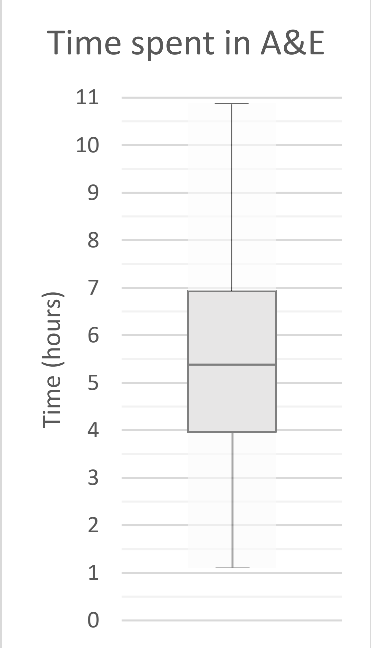
(B)



5.1.2 A&E stay

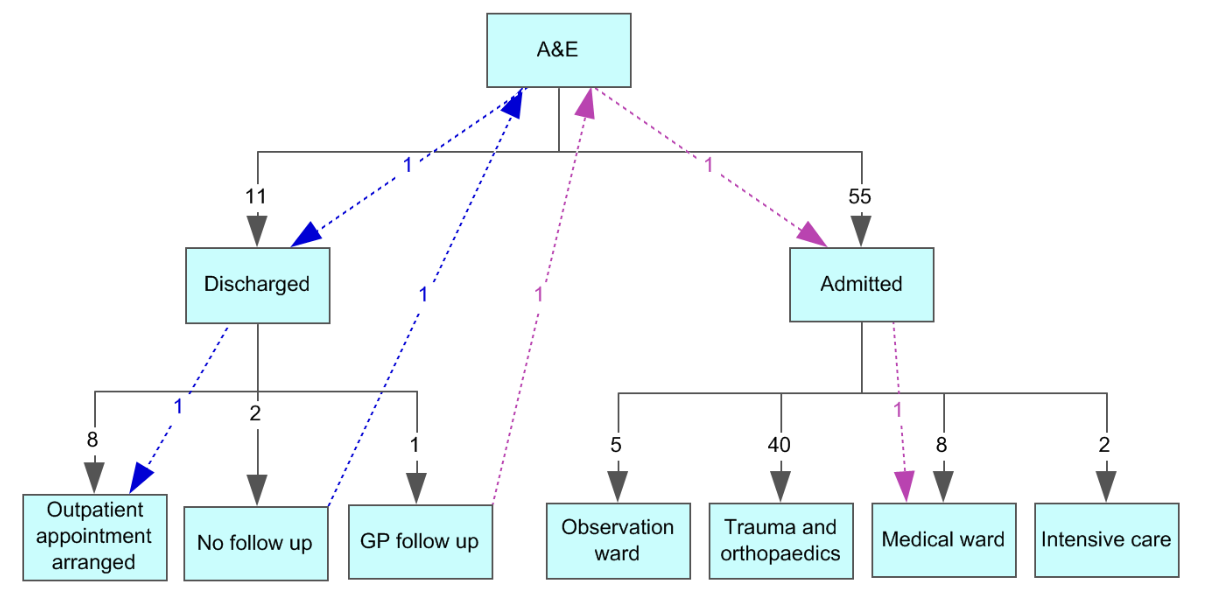
Fractures were identified in A&E in 68 patients. Data about length of A&E stay was missing for four of these patients. Two patients attended A&E on two consecutive days and therefore represent two A&E stays each. One patient whose fracture was identified as an outpatient and one as an inpatient also attended A&E the same day as fracture identification. This means data were available for 68 A&E stays which is summarised in Figure 22. Length of stay was under four hours in 38.2% of cases. Almost a fifth (19.1%) of A&E stays were >3:55 and ≤4:00 hours long. No association was found between age and length of A&E stay and there was no significant difference in ages of patients who stayed over four hours or under four hours. The initial recorded location of patients in A&E was most commonly majors (60.3%) followed by waiting room (30.9%), minors (7.4%) and resus (1.5%). There was no significant difference in A&E stay length between patients who were initially in majors or resus and patients who were in minors or waiting room. No correlation between time from seeing doctor to undergoing CT, time from undergoing CT to CT report or total time from seeing doctor to CT report and A&E stay length was found.

Figure 22: Box plot summarising the length of A&E stays.



A&E data showed whether patients were discharged or admitted and where they were admitted to. The majority of patients were admitted to a trauma and orthopaedics ward (see Figure 23). There were some conflicts with the A&E dataset and data from a different hospital computer system recording inpatient stays. One patient who was admitted to a trauma and orthopaedics ward according to A&E data, was recorded in inpatient data as having ITU as their initial admission location. One patient who was discharged with outpatient follow up on A&E data, was recorded as having been admitted to a medical ward on inpatient data. It also included initial admission locations for six patients who were missing from the A&E dataset; four of which were admitted to a trauma and orthopaedics ward and two to a medical ward. All of the patients who were discharged from A&E returned to their usual place of residence. One 95 year old patient died just two days after being discharged home with an outpatient appointment arranged. Two patients returned to hospital for an inpatient stay within 30 days of discharged from A&E.

Figure 23: Flow diagram showing location of patients after leaving A&E. Dotted lines represent the patients re-admitted to A&E the day after discharge when their c-spine fractures were not diagnosed on their first A&E visit.



5.1.3 Inpatient stay

Data about initial inpatient stays were available for 73 patients; data were absent for three patients and nine patients were discharged after their A&E visit. Ward on admission was recorded for all 73 patients. Ward on discharge was recorded unless the patient was transferred to another hospital within the same provider (in six cases) or the patient died during their inpatient stay (in three cases). The majority of patients were admitted to a trauma and orthopaedics ward (see Figure 24). Patients whose fracture was discovered as an inpatient were significantly more likely to be on a medical ward than patients whose fracture was discovered when in A&E. There was no significant association between where patients were admitted to and whether they were treated surgically or conservatively.

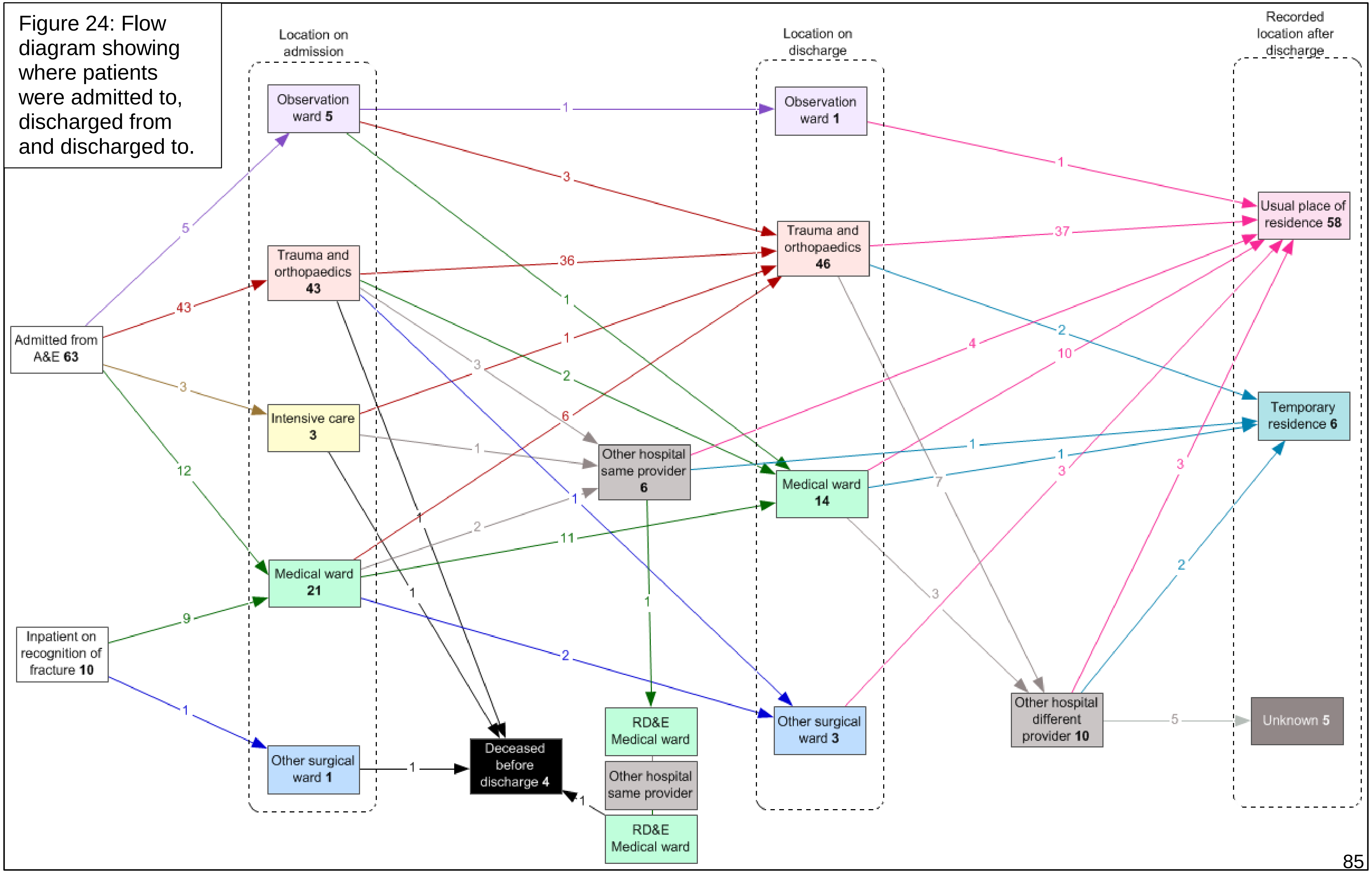
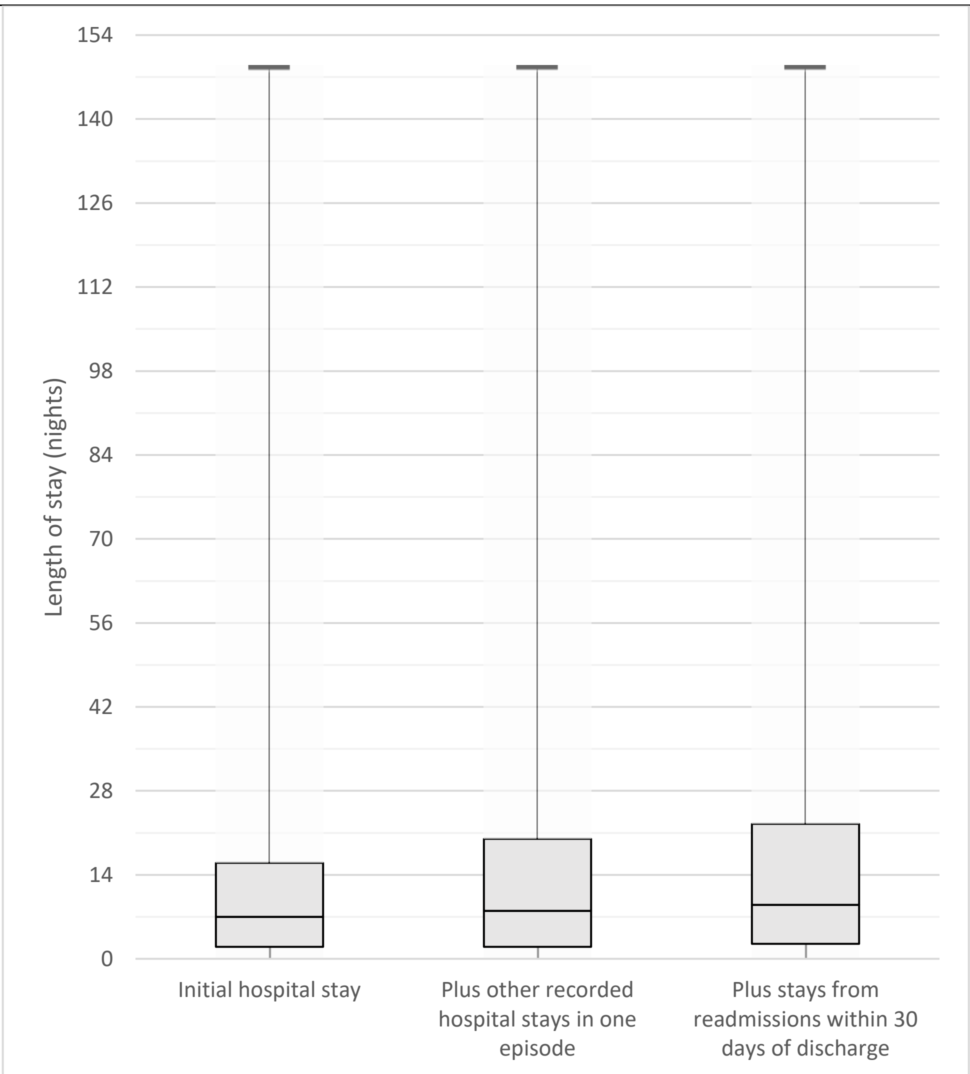


Figure 24: Flow diagram showing where patients were admitted to, discharged from and discharged to.

The modal length of stay was one night and the majority of patients stayed less than two weeks (see Figure 25). The length of stay in other hospitals was recorded for eight patients who were transferred to other hospitals as part of one extended hospital stay and when these nights were added median stay length increased from seven nights to eight nights. Eleven patients were re-admitted to the RD&E within 30 days of discharge as an inpatient and an additional two patients after discharge from A&E. When the length of these thirteen additional stays were added, the median stay length increased again to nine nights. Re-admission rate at 30 days was 15.9% (out of the 83 patients whose inpatient stay data were available, this doesn't include readmission to A&E that didn't result in inpatient admission). There was no significant difference in re-admission rates between patients with different ASA grades.

Figure 25: Boxplots summarising length of hospital stay



There was no significant difference in stay length between patients who were managed surgically or non-surgically although mean stay length, of both initial stay and with re-admissions added, was longer in surgically manged patients (see Table 17). There was no significant difference in stay length between admission wards. There was no significant difference in initial stay length between ASA grades. The total stay length of patients with the lowest ASA grade was significantly shorter than those graded 2-3 ($p<0.05$). There was no significant association between age and length of stay.

Table 17: Stay length in different patient groups		
Management	**Initial stay length mean, nights** (standard deviation)	**Total stay length mean**, **nights** (standard deviation)
Surgical	21.2 (±36.7)	25.2 (±40.0)
Non-surgical	11.8 (±15.9)	18.2 (±24.4)
Ward admitted to		
Trauma and orthopaedics	13.1 (±24.8)	19.5 (±30.4)
Medical	16.3 (±18.8)	21.8 (±28.1)
Observation ward	6.6 (±8.2)	7.2 (±8.4)
ITU	15.7 (±13.3)	36.7 (±49.7)
Other surgical	28 (one patient, died after 28 days)	28 (one patient, died after 28 days)
ASA Grade		
I	3.8 (±3.9)	4.3 (±4.3)
II	17.1 (±27.8)	19.4 (±31.0)
III	14.0 (±16.5)	27.7 (±29.1)
IV	28 (one patient, died after 28 days)	28 (one patient, died after 28 days)

The majority (78.1%) of the 73 patients who stayed as an inpatient were discharged to their usual place of residence (see Table 18). More than a fifth of patients (21.9%) were discharged to another hospital before finally being discharged from this hospital stay episode. One of these patients who was discharged to another hospital then returned to the RD&E before going back to the other hospital again and once again returning to the RD&E where they died. This brings the in-hospital mortality rate for all 85 patients to 4.7%.

Table 18: Discharge destination		
Discharge destination	**Initial** (number of people) **Subsequent**	**Final recorded** (number of people)
Usual place of residence	51	58
Temporary residence	3	6

Other hospital *same provider* *different provider*	16 *6* *10*	Usual place of residence	7	
		Temporary residence	3	
		Back to RD&E medical ward then back to other hospital then back to RD&E then deceased before discharge	1	
		Unknown	5	
Deceased before discharge	3			4
Unknown				5

5.2 DISCUSSION

5.2.1 Initial imaging

Most cervical spine fractures were identified when the patient was in A&E. it is unclear whether patients with fractures identified as inpatients sustained their fracture as a result of a fall as an inpatient or there was a failure to identify the fracture until after the patient was admitted. Cervical spine fractures may not have been identified on initial presentation in these cases due to a low suspicion of cervical spine injury resulting in inadequate investigation. Healey et al. 2017 reported a fifth of patients aged 55 years and over with cervical spine fracture had no pain on presentation or tenderness on palpation.(46) A healthcare professional seeing a patient after a ground level fall not complaining of neck pain may not consider cervical spine fracture.

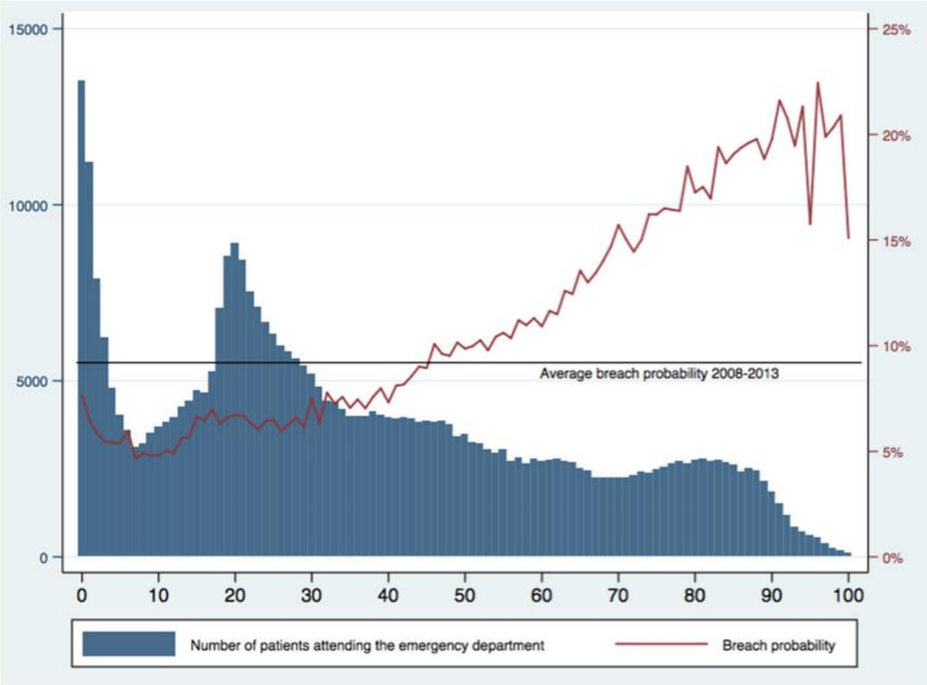
Two patients were sent home from A&E after projection radiography and re-attended the next day whereupon CT revealed a fracture. Most patients underwent projection radiography before CT despite guidelines recommending patients aged 65 years and over (which most of the study patients were) should go straight to CT. This recommendation is due to higher prevalence of cervical spine fracture in the elderly, reduced reliability of clinical examination and reduced sensitivity of projection radiographs which are more difficult to interpret.(43, 50) In line with the significant proportion of patients that are asymptomatic, Goode et al. 2014 suggest NEXUS may also be unreliable in those aged over 65 years with a sensitivity of 65.9% compared to 84.2% in younger patients.(213) Projection radiographs are frequently inadequate in patients of all ages and have a lower sensitivity than CT. Baneke et al. 2012 found that, in a specialist trauma unit for head injury in the UK, in 85% of patients at least one of their initial lateral or peg projection radiographs was inadequate yet only 74% of these underwent repeat imaging before being sent home.[214] A meta-analysis conducted by Holmes et al. 2005 found a sensitivity for projection radiography of 52% and CT of 98% for cervical spine fracture.[48] Healthcare professionals may be exercising caution in their choice of initial imaging modality when the perceived risk of fracture is low due to higher levels of radiation, higher cost and longer scan time for CT and lack of knowledge of the low sensitivity of projection radiographs. However, if risk of fracture is deemed high enough to warrant any imaging, guidelines should be adhered to and CT the initial imaging modality of choice. The significantly longer times to CT for patients who underwent projection radiography first suggest this may be delaying definitive diagnosis. Further study of the number of patients sent home after just projection radiography and their outcomes would be useful in determining if any clinically significant cervical spine injuries are missed as a result of not following imaging guidelines.[41, 42]

The $t_{Dr\text{-}CT}$ was under one hour in 46.8% of cases and 64.5% of reports were completed in under one hour. The 2010 College of Emergency Medicine guideline on management of patients with potential cervical spine injury recommend CT should be performed within one hour of request.[50] In addition, in patients with head injury NICE recommend cervical spine CT should be performed within an hour of a high risk factor for cervical spine injury being identified and a report available within an hour of CT scan being performed.[42, 47] The NICE guideline on assessment of spinal injury has less specific standards set out of a CT scan to be performed “urgently” and interpreted “immediately” by a healthcare professional with skills and training in this area.[41] The dataset did not have a request time for CT c-spine however “time seen by doctor” was used to approximate when risk factors for cervical spine injury are formally identified and imaging requested. However the reliability of recording of the time of consultation with a doctor is unknown and the validity of using it as a proxy for these time-points is uncertain. No studies were found reporting the compliance of other centres with the one-hour targets.

5.2.2 Length of A&E stay

The time spent in A&E was under four hours in 38.2% of visits with a clustering of discharges from the department at just under four hours. Data from NHS digital reflects this clustering with a large number of patients being discharged or admitted between 3:51 and 4:00 hours.(215) A target set by the Department of Health that 90% of patients should spend less than four hours in the A&E department has not been met annually since 2013-14 and the proportion of patients seen and discharged or admitted in four hours has declined year on year to 89% in 2016-17. Clustering just below four hours demonstrates efforts to get patients out of the department before breaching this target.(215) Bobrovitz et al. 2017 found that older patients are more likely to breach the four-hour target (see Figure 26).(216) Although these data are from several years ago and general breach probability has increased, it can still be assumed that older patients are more likely to breach. However, no significant difference in ages of patients who stayed over and under four hours was found in our study patients. The average age of our study patients was higher than the general population so an increased rate of breaches would be expected, however even taking into account that patients aged 90 are about twice as likely to breach, the figure is much worse than would expected which implies that age does not account for the entirety of the high breach probability in these patients. No existing studies about length of A&E stay in c-spine fracture patients were found so whether these patients have longer A&E stays in other age groups is unknown. Bobrovitz et al. 2017 also found that patients requiring complex imaging are more likely to have length of stay over four hours.(216) No association between time to CT and time in A&E was found in the study patients which suggests waiting for imaging is not contributing to long stays. The proportion of patients seen in under four hours is similar to that found in patients with hip fracture. Forty percent of patients in the NHFD Report in 2017 were admitted to a ward within four hours.(188)

Figure 26: Bobrovitz et al. 2017 Graph showing breach probability by patient age (x-axis) from 2008-2013[216]



5.2.3 Inpatient admission

Most patients were admitted to a trauma and orthopaedics ward. It may have been expected that more conservatively managed patient would be admitted to medical wards and surgically managed to surgical or trauma orthopaedics wards but no such association found. Patients whose fracture was recognised as an inpatient were more likely to be on medical wards. This would be expected as they may have come in for an unrelated condition or their injury was not recognised as their primary reason for admission.

The median length of stay was seven nights. No studies of length of stay of cervical spine fracture patients were found for comparison however several studies of length of stay of hip fracture patients were identified. The NHFD 2017 reported a median stay length of 15 days.[188] A shorter stay length might be expected for patients with cervical spine fracture as if patients are managed with a collar and have no neurological injury they may be able to walk and perform activities of daily living more easily than a patient with a hip fracture. The most common stay length was one night which is likely to represent patients discharged with a collar or no active management who are able to independently carry out activities of daily living. Comorbidities may contribute to longer stay in hospital. Castelli et al. 2015 found hip fracture patients with greater co-morbidities, older age and from more deprived areas had longer length of stay and associated healthcare costs.(217) Greenberg et al. 2016 found hip fracture patients in the US admitted to a medical service stayed about 50% longer than those admitted to a trauma and orthopaedics service even when adjusted age and ASA grade although they received similar treatment.(218) In our study no significant difference in stay length between wards or with older age was found but total stay including readmissions within 30 days was significantly lower in patients graded ASA I compared to ASA II and III.

There was a longer average stay length for surgical patients although this difference was not statistically significantly. No studies reporting stay length differences between conservative and surgically managed c-spine fracture patients were found for comparison. Surgically managed patients may be expected to have a longer initial hospital stay because no patients are likely to be discharged after one night as there may be a wait before surgery then time for recovery and observation after surgery would be needed. Patients requiring surgery may also have more complicated or unstable fractures or other related injuries.

5.2.4 Readmission and discharge

Rate of readmission for any cause at 30 days was 15.9%. This is similar to Cooper et al. 2015 who found rates of readmission in elderly patients with fall related c-spine fractures at 30 days to be 18.6%.(61) Spector et al. 2012, an American study looking at injury related admissions in the elderly, found a 30 day re-admission rate of 13.7% and found that more severe injuries had higher readmission rates.(219)

Almost 80% of the study patients had a final recorded destination as their usual place of residence and the in-hospital mortality was 4.7%. The reported proportion of patients returning to their usual place of residence and in-hospital mortality is variable. Cooper et al. 2015 reported that only 30.1% of their elderly patients with fall related c-spine fractures were discharged home and had in-hospital mortality of 8.5%.[61] Sander et al. 2013 studied a group of surgically managed c-spine fracture patients aged 65 and over and found 81.8% returned to their usual residence and the in-hospital mortality was 21.7%.[184] The NHFD found 67% of hip fracture patients in 2017 returned to their usual place of residence by 4 months after surgery.[188] The discharge destination in our data does not capture if there is an increased need for support from family, friends and carers. It also does not report if patients' usual place of residence was a care home, their own home or with family.

5.3 CONCLUSIONS

Projection radiography was carried out before CT most of the time despite the fact that following NICE guidelines would lead to CT as the initial imaging modality in patients aged 65 years and over. Carrying out projection radiography before CT is contributing to the proportion of patients who wait more than an hour from seeing a doctor to having a CT thought it is not contributing to overall A&E stay length. A&E stay length is longer than the general A&E population and worse than what might be expected for older people though it is similar to that for hip fracture patients. Most patients are admitted to the appropriate ward and length of stay is shorter than for hip fracture. Length of stay may be related to comorbidity status. Failed discharge rates are similar to published data for an elderly population experiencing falls. More patients return to their usual place of residence than do for hip fracture.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

This chapter draws together the main findings of the study, identifies opportunities where improvements could potentially be made and proposes some evidence based strategies to aid with this. Areas where further investigation would be useful are also highlighted.

6.1 STRENGTHS AND LIMITATIONS OF THE STUDY

Limitations of the study design included the absence of a control group. This meant it was not possible to compare factors such as the mortality rate, comorbidity status, spondylosis prevalence and osteoporosis risk factors to patients who did not sustain a cervical spine fracture from the same level of trauma. The small sample size, although unavoidable due to being a fairly infrequent occurrence, meant some forms of statistical testing were not possible in and significance of conclusions were often uncertain. Only looking at one centre meant the wider applications of these conclusions to other hospitals is unclear however, this does allow the RD&E to make specific changes that will help in their hospital. In addition, these factors meant the study could be carried out by mainly one person in one year.

The method of identification of patients may mean several groups of patients were no included in the study. Patients with c-spine fractures may have been missed because of CT c-spine scan image sets being within a set of CT head images and therefore not being included when searching through scans labelled as CT c-spine. It is possible that there were patients who were identified as having a c-spine fracture on projection radiographs or MRI and were not imaged further with CT so would not have been identified by the researcher. There may be additional patients who sustained c-spine fractures from minimal trauma and were not identified by healthcare professionals either through non-presentation or through healthcare professionals not suspecting and investigating for c-spine fracture. Patients who died before admission to hospital or CT scan would also be missed.

The quality of electronic medical records posed a limitation. Non-recording of height and weight and many other parameters that are needed for FRAX meant accurate calculation of fracture risk was not possible. No access to records of prescribed medications meant relying on medication lists in discharge summaries and letters which many not have been comprehensive or accurate. A strength of the study was the number of different parameters looked at which gave a comprehensive picture of the care of elderly patients with cervical spine fracture at the RD&E.

6.2 THE PATIENTS

Although cervical spine fractures in the elderly are relatively rare compared to other fractures, such as hip fractures, there are still a significant number of patients sustaining these injuries with around one cervical spine fracture resulting from a ground level fall seen every month at this hospital. The patients included in this study had similar patterns of injury to those in previous studies looking at older patients with cervical spine fractures; C2 was the most commonly fractured vertebra and ground level fall the most common mechanism of injury especially in older patients.

Existing health conditions can predispose people to cervical spine fracture as well as affect patient outcomes after fracture. Both OP and spondylosis have been proposed to increase likelihood of cervical spine fracture by previous studies. The design of this study did not allow for determination of the contribution of these conditions to fracture likelihood. The study did however, find no association between fracture level and severity of degenerative changes as some other studies have proposed. Further high quality research into the contribution of cervical spondylosis to cervical spine fracture is needed to ascertain whether there is a link, however this is unlikely to affect patient management. Existing co-morbidities did appear to contribute towards mortality though no statistically significant difference in mortality rates between patients with different ASA grades was found.

6.3 FRACTURE IDENTIFICATION AND MANAGEMENT

The centre studied appeared to be providing a good level of care to these patients. The complication and mortality rates in this study were similar to previous studies of similar patients. No clearly superior management method was found which was consistent with other studies of c-spine fracture management in the elderly. In general, patients were admitted to an appropriate ward and hospital stay length was shorter than for hip fracture. Readmission rates at 30 days were unremarkable and a larger proportion of patients returned to their usual place of residence than do for hip fracture. Unfortunately this study did not capture whether there was an increased need for assistance when patients did return to their usual residence and therefore may underestimate the amount of patients who required an increased level of care after discharge. There was also poor reporting of ongoing symptoms and functional outcomes. Further follow up of impact of cervical spine fracture on patients' lives after discharge would give a better understanding of the long-term outcomes of treatment approaches and whether sufficient rehabilitation services are provided.

6.3.1 Initial imaging

Most patients underwent projection radiography before CT which was inconsistent with NICE guidelines. This appears to be contributing to the proportion of patients waiting more than one hour for a CT after identification of risk factors for significant spinal injury. Evidence suggests low sensitivity of projection radiography and less obvious signs and symptoms of cervical spine fracture in the elderly. Therefore there should be a low threshold of suspicion for sending elderly patients for cervical spine CT after a fall. Study of outcomes of elderly patients discharged from A&E after just projection radiography of the cervical spine may reveal whether any injuries were missed as a result of not adhering to guidelines.

6.3.2 Patient flow

Length of stay in A&E was over four hours in a higher proportion of cases than is usual or aimed for in A&E departments in England. However the length of time spent in A&E is similar to that for hip fracture patients. It may not always be appropriate to discharge these patients from A&E within four hours and it may not be possible to admit them due to high levels of bed occupancy. The majority of patients are admitted to an appropriate ward which shows that patients are not just being admitted to any free bed to move them on from A&E but appropriate beds are being arranged which may be more beneficial to their care.

There is a large volume of literature reporting interventions focus on moving through less complicated or less seriously injured people more quickly to reduce the total number of people in A&E at once and preventing inappropriate or avoidable attendances.[220-222] Although these approaches may help general patient flow in A&E, they are unlikely to have a big impact on stay length for this group of patients. Fast-track systems for patients with hip fracture have been shown to improve outcomes and reduce time spent in A&E and hospital.[223, 224] Similar systems may not be appropriate for cervical spine fracture patients as they are seen less frequently, a lower proportion require surgery and are not as immediately identifiable. Rapid Assessment and Treatment models, where there is early assessment of patients brought into majors by senior clinicians, may reduce time to assessment and time to treatment for these patients however high quality evidence to support this is currently scarce and higher staffing levels needed to implement this may not be achievable.[225-227] A number of studies have reported trialled schemes with some success in reducing bed occupancy and patient flow aimed at elderly and frail patients providing more comprehensive assessments of patients' needs in A&E, advanced care planning and supported discharge as well as changing patterns of staffing.[228-231] These interventions may require more resources and time investment and need staff to have training in further skills. As the A&E department does not operate independently of the rest of the hospital, it stands to reason that interventions that improve patient flow throughout the hospital can reduce bed occupancy, and therefore A&E waiting times, as well as length of hospital stay.

6.4 SECONDARY FRACTURE PREVENTION

Fracture prevention is not an integrated part of c-spine fracture care despite their association with OP in the elderly. A high proportion of patients had sustained previous fractures but very few had been assessed or received interventions to reduce future fracture risk even after sustaining a cervical spine fracture. The rate of anti-OP medication initiation after cervical spine fracture does not measure up to care after hip fracture. Recording and reporting of fracture prevention measures after hip fracture to the NHFD, awareness of the link between hip fractures and osteoporosis and awareness of efficacy of bisphosphonates at reducing future hip fracture may contribute to how much more likely patients are to be assessed and managed for fracture risk after hip fracture. C-spine fractures in the elderly may not be as readily recognised as a fragility fracture, they are seen less often so protocols and routines in management are less likely to have been developed, and patients have a shorter stay length meaning healthcare professionals have less time to think about non-acute management. There also may be an assumption by hospital doctors that GPs will take care of long-term management, including secondary fracture prevention, but a lack of knowledge of this by GPs. Further study into the attitudes and awareness of hospital staff and GPs about the link between non-hip fractures and osteoporosis and perceptions of who's responsibility it is to asses fracture risk and initiate risk reducing interventions would enable areas of weakness to be identified.

It is important that fractures resulting from a low trauma mechanisms of injury in elderly patients, including cervical spine fractures, are recognised as fragility fractures and action is taken to reduce future fracture risk. Better use can be made of existing prompts to initiate therapy already in place by ensuring boxes at the bottom of the orthopaedic discharge summary are not ignored. Improved recording of discussions about fracture risk and medication is needed to determine the validity of these conclusions. Communication with patients' GPs about fractures sustained and concerns over future fracture risk must happen if they are expected to be responsible for taking action. Additional data about dispensed anti-OP prescriptions and if patients are taking them as prescribed would reveal more about the quality of care of these patients. Close working of radiology departments and clinical teams is needed to ensure action is taken when radiographic osteopenia or incidental fractures are noticed.

Ganda et al. in their 2013 systematic review and meta-analysis found four general models of care for secondary fracture prevention. “Type A models” were services with a dedicated co-ordinator identifying patients after fracture, carrying out assessments and initiating interventions. “Type B models” were similar to type A but outcomes of assessments were communicated to primary care practitioners who were expected to initiate treatments. “Type C models” were less intensive interventions which involved educating patients about osteoporosis and lifestyle interventions which could reduce fracture risk and informing primary care practitioners of the patient’s recent fragility fracture who were then expected to carry out assessment and management of fracture risk. “Type D models” involved patient education only. Trends towards better outcomes - higher rates of BMD testing, treatment initiation and self-reported adherence to medications - was found with more intensive interventions. Type A and B interventions were classed as cost-effective.(141)

The most successful service model for reducing rates of fragility fractures is the FLS with a dedicated co-ordinator responsible for identifying patients, carrying out assessments, commencing treatment and referring patients for further interventions as necessary.(140, 141) Close working of FLS teams with orthopaedics, radiology and other departments is essential for case identification and successful running of services. The FLS model of care has been shown to be cost-effective and successful at reducing fracture rates and consequently commissioning of FLSs has been recommended by several professional bodies.(140, 146, 232)

6.5 SUMMARY OF RECCOMENDATIONS

- CT should be the initial imaging modality for patients aged 65 and over with a suspected cervical spine injury and should be considered in all patients over 50.
- Interventions improving patient flow through the hospital may reduce A&E waiting times.

- Commissioning of a FLS is highly recommended.
- Assessment of falls and fracture risk should be integrated into care for patients following cervical spine fracture from ground level falls and bone sparing therapy prescribed where not contraindicated.
- Discussions with patients about fracture risk and bone sparing therapies should happened and be documented.

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