A REVIEW OF FRACTURE FIXATION AS IT AFFECTS THE SMALL ANIMAL PELVIS.

AN ANATOMIC, ULTRASONOGRAPHIC, CROSS-SECTIONAL AND RETROSPECTIVE RADIOGRAPHIC STUDY.

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SUMMARY

The pelvis is a stable structure comprising of paired hemipelves. A thick layer of muscles covers the pelvis almost completely, leaving only a few bony prominences in a subcutaneous position. In order for this stable and well protected structure to be fractured, severe external violence must be applied. This trauma is due to road traffic accidents in the majority of cases. Fractures of the pelvis are common and constitute 20 to 30% of all fractures seen in veterinary practice. Despite this, the canine and feline pelvis has not been well studied. Little information is available regarding fracture locations, frequency of particular anatomical sites and overall severity of the pelvic disruption. The majority of pelvic fractures are surgically managed but there is a lack of accessible data regarding optimal fixation methodologies, the potential hazards and the rate of complication. There is also a difficulty in the assessment of concomitant pelvic soft tissue damage.

A review of the topographical canine musculature and cross sectional anatomy was carried out and an attempt was made to provide a correlation with image based registration extended field of view ultrasound. For the cross sectional study, greyhound type canine cadavers were sectioned transversely and radially. Lines, correlating to the lines of section on the cadavers were drawn on a live greyhound. These lines were used as markers for the ultrasound transducer to be scanned along. For the topographic study, extensive dissection was carried out in order to identify the pelvic musculature and to see if it was present in agreement with standard anatomical textbooks. The corresponding individual muscles were scanned on a live greyhound. It was found that although the ultrasonography demonstrated the cross sectional anatomy, it was difficult to identify individual muscles. Whereas, when the individual muscles and muscle groups were scanned a clearer picture was produced. It was hoped that as the normal pelvic anatomy was accurately displayed using this technology then it might have potential as a diagnostic tool for rapid exploration of clinical cases subjected to trauma.

The second part of the cross sectional study was carried out using both canine and feline cadavers, to try and localise safe, hazardous, and unsafe corridors for external skeletal fixation pin insertion. In a selection of dog and cat cadavers, sections were prepared. Although this gave a clear indication of the complexity of the pelvic anatomy, it was difficult to deduce the exact external skeletal pin insertion site from these sections. Greater success was attained through extensive dissection and the use of anatomy textbooks and an atlas. Three safe and three hazardous corridors were found in each hemipelvis. Although this part of the study is at present theoretical, it seems at this stage that external fixation of the pelvis is a plausible method of fracture fixation.

The blood supply to the pelvis was also investigated. This part of the study was divided in to two broad categories: observations of the nutrient foramina and arterial casting. There was a tremendous amount of variation of the positions and sizes of the pelvic nutrient foramina. Foramina were divided subjectively into principal (the largest) and secondary, and this was further subdivided into large and small. All results were recorded diagrammatically. Only a few principal foramina were notably present in the majority of specimens.

Many authors maintain that pelvic fractures heal rapidly due to the abundant blood supply but to date no demonstration of this has been found. Methylmethacrylate casting of the pelvic arteries clearly demonstrated the extensive pelvic vascular tree. In conjunction with the major and well-documented arteries, there were also dense arborisations of small vessels that would have lain between or within the musculature of the pelvis and proximal hindlimb.

A retrospective radiographic study was carried out. The main goal of this study was to elucidate which pelvic fractures were the most common in small animals. There is a lack of information in the literature pertaining to this. It was hoped that the information gained would aid in the future in the design and production of treatment protocols, especially for those locations damaged most often. A classification system was devised for all pelvic fractures. It was primarily based on the anatomical fracture location with a secondary emphasis on fracture type. A species difference was apparent in that fractures of specific anatomical locations were present in different frequencies in dogs and cats. As data was sourced from two different veterinary hospitals geographical differences in the relative amounts of specific anatomical fracture locations was also present. A vast number of potential fracture combinations were found which demonstrates the random and haphazard forces of the trauma. There were no actual common fracture combinations. The combinations that were classed as the "most common" were actually only present in slightly elevated numbers. Once again there was a species difference present.

The pelvic osteology was also imaged using image-based registration extended field of view ultrasound to endeavour to demonstrate the integrity and the continuity of the individual pelvic bones. Three-dimensional B-mode ultrasound was also used to image the hip joint. It was hoped that as the normal pelvic anatomy was accurately displayed using this technique, it might have potential as a diagnostic tool for rapid exploration of clinical cases subjected to trauma. The pelvic bones were clearly displayed using this technology. The ilium could be viewed from the dorsal, lateral and ventral aspects all with the same degree of clarity. The hip joint was shown with a high degree of success three dimensionally, although the transverse and para-sagittal planes were clearer then the dorsal plane.

The same retrospective cases were used in the next part of the investigation. The treatments used for each animal for each anatomical fracture location were recorded. Each case was evaluated and the fractures for each animal were compared to the standard criteria for surgery. It was subsequently deduced which animals were treated according to these criteria and which were not. The outcome was that many animals which fulfilled one or more surgical criteria were actually treated conservatively. It was found that there was an unacceptably high rate of complication, especially in the feline group. The time delay between fracture and surgery was evaluated. Despite a large number of cases in both the canine and feline group having surgery soon after fracture, there was still a high rate of complication.

I declare that the work presented in this thesis was carried out by me personally.

May 2002.

Research is the act of going up alleys to see if they are blind.

-Plutarch

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LITERATURE REVIEW

1.1. Bone

Bones form an essential part of the locomotor system, acting as lever arms during motion and resisting the force of gravity (Slatter, 1985). In addition to providing a framework on which the muscles can act, the bony skeleton offers rigid protection to vital structures such as the brain and spinal cord, as well as protection and a suspension rigging for the viscera of the thoracic and abdominal cavities (Weisbrode, 1995). In addition to these mechanical functions, bones serve an important chemical function, providing a reservoir for mineral homeostasis (Slatter, 1985). Although marrow is critically important to life because it produces cells of haemopoietic and immune function, it is not apparent why marrow might need the protection of such sturdy surroundings (Weisbrode, 1995).

There are three principal cell types in all bones: osteoblasts, osteoclasts and osteocytes. The osteoblast is responsible for synthesis of all matrix components. Matrix, which is all the extracellular material in bone other than mineral, can be considered in two major categories: collagen and ground substance (Hulse & Hyman, 1995). Collagen gives bone its strength rather than hardness and is the major component of bone matrix. Ground substance comprises of proteoglycans, noncollagenous proteins and lipids. All bones are specialised forms of connective tissue, and their form and function, like that of other connective tissues, depend upon the arrangement and interactions of the elements of the extracellular matrix. The component of the extracellular matrix that distinguishes bones from other connective tissues and enables it to perform its unique functions is the mineral (Slatter, 1985). The mineral found in bone is an analogue of the naturally occurring mineral hydroxyapatite $Ca_{10}(PO_4)_6(OH)_2$. Bone mineral crystals, in contrast to the large geological apatite crystals, are extremely small, usually 20 to 40nm in largest dimension. Bone mineral contains variable amounts of carbonate, magnesium, fluoride and citrate in addition to calcium and phosphorous. Bone mineral, as well as the entire bone matrix, is constantly being removed (by osteoclasts) and reformed (by osetcoblasts) in response to normal mechanical, biochemical and physiological stress (Slatter, 1985). This remodelling strengthens those areas subject to the most stress. Examination of the shape and organization of bone in radiographs or in slab sections reveals a pattern designed to withstand stress. In a weight bearing bone, it would correspond to the radiographic pattern of bone organization. The arrangement of this pattern corresponds to the nature and type of stresses applied to the bone. The ability of bone to adapt its architecture and external form in response to such stresses is one of the unique properties of bony tissue and is known as Wolff's Law (Slatter, 1985). In the late 19^{th} century, it was recognised that physiologic stresses had a direct bearing on bone structure and that it changed in accordance with type and intensity of the load (Braden *et al*, 1973).

One of the most remarkable features of the skeletal system is its ability to renew itself. Remodelling is renewal of bone by activation of resorption followed by formation. In theory the amount of bone replaced is equal to the amount of bone removed so that there is no net difference in bone volume (Weisbrode, 1995). The advantages of this are that minor damage such as microfracture that has accrued with time can be removed and replaced with new tissue. If microfractures were not "remodelled away" they could increase in size with time and result in structural weakening of the bone. Skeletal turnover continues throughout the life of an individual at the rate of about 5 to 10 % per annum (Ling, 1986).

1.2. Fractures

A fracture is a complete or incomplete break in the continuity of bone or cartilage (Brinker *et al*, 1990; Seligson & Pope, 1982). Force transmission through the bone is no longer possible in any direction (Schatzker, 1982). Fracture will occur when either the maximum tensile or shear strength is exceeded. The initial crack occurs in the plane of the maximum resolved stress. The actual details of crack initiation and propagation are complex, depending on the addition of stress, on the relationship between ultimate tensile and shear strengths for the material and on the presence of internal structural features and defects (Black, 1988). In most cases the disruption of the bone's continuity is not the only damage, which occurs during a fracture (Rahn, 1982). Often a fracture is accompanied by various degrees of injury to the surrounding soft tissues (Arnoczky *et al*, 1985), including blood supply, a compromise of locomotor system function (Brinker *et al*, 1990) extensive haemorrhage and variable laceration and crushing of muscle (Weisbrode, 1995). Severe trauma to the skin and soft tissue cover of a bone may produce circulatory disturbances and may also favour infection. The extent of vascular damage depends upon the level at which the circulation is interrupted. Disruption of the large vessels leads to a haemorrhage into the soft tissues, resulting in a more or less extended haematoma. Because of its local swelling a haematoma adds somewhat to the stability of the fracture. On the other hand the circulation on the low-pressure side is also impeded, which could retard the healing process. The coagulated blood makes a good growth medium for bacteria and, in the presence of infection, is not desirable (Rahn, 1982). It is now being recognised that the haematoma that forms around the broken ends of the bone is not an inert clot but a miraculous soup of chemical mediators that stimulate the formation of a bony callus to bridge the break and provide temporary stability (Olmstead, 1995).

1.3. Fracture healing

The ultimate goal of fracture healing is reconstruction of the original cortical bone. Because of the damage to bone and surrounding soft tissue during trauma, the cortical ends at the fracture site are avascular and necrotic during the initial stage of fracture healing. This inevitable vascular compromise does not prevent the fracture ends from playing an important biomechanical role in fixation or from serving as the mechanical supportive elements for any fixation device (Chao *et al*, 1989). Bone does not necessarily need to be treated to unite, but function may be impaired owing to the deformity. The main aim of all fracture treatment is to obtain final function as close to the prefracture situation as possible (Sumner-Smith, 1982). Mechanical conditions are one of the most important factors governing not only whether a fracture will heal but also the mechanism through which bone union will take place (Aro *et al*, 1993; Goodship & Kenwright, 1985).

The clinical value of limiting the motion of a fracture is not only to reduce the size of the callus, but also to reduce tension on the bone ends and avoid compromise of blood flow and therefore oxygen to the callus in order to keep fibrous tissue and cartilage formation to a minimum. The means by which the fracture heals depends on the size of the gap between the fracture ends. If stabilization is not achieved, callus formation occurs to varying degrees (Cunningham *et al*, 1988). The rule of thumb is: the greater the instability, the greater the callus. When surgery has been successful in achieving complete stability, the ends of the fracture should be in contact with each other or have a small gap between them (Olmstead, 1995).

Direct healing occurs through osteonal remodelling of the cortex and may be classified as:

1. Primary osteonal reconstruction
2. Secondary osteonal reconstruction.

Primary osteonal reconstruction occurs when there is precise anatomic alignment of the fracture ends, absolute stability (Palmer *et al*, 1992) and there is a sufficient blood supply (Chao *et al*, 1989). This includes both contact healing and gap healing. Primary bone healing was originally identified radiographically as the lack of external callus formation (Chao *et al*, 1989; Goodship and Kenwright, 1985). Secondary osteonal reconstruction is a form of direct healing of the fracture, which can occur in the presence of callus.

Primary contact healing, also known as Haversian remodelling (Chao *et al*, 1989) occurs in the zones of cortical bone contact and is characterised by osteonal remodelling across the fracture plane (Lewallen *et al*, 1984). In preparation for osteonal remodelling, cutting cones are formed at the ends of the osteons nearest the fracture (Arnoczky *et al*, 1985; Palmer *et al*, 1992; Weisbrode, 1995). Osteoclasts line the spearhead of the cutting cone for bone resorption whereas osteoblasts line the rear of the cutting cone in preparation for bone formation. Bone resorption and formation occur simultaneously as the cutting cones advance and cross the fracture plane from one fragment to the other at a rate of 50 to 80μm per day (Palmer *et al*, 1992). In contact healing the gap is so small that osteoclasts of the cutting cones can "jump" the gap and continue the drilling on the other side of the fracture. No temporary osseous tissue is deposited because there is no space into which it can be deposited (Weisbrode, 1985).

Primary gap healing occurs in the small fragment gaps between contact zones. Although the bone is not in direct apposition, adequate stability is provided by the contact zones on either side of the gap. Interfragmentary deformation must be less than 2% and the gap must not exceed 1mm for primary gap healing to occur. The gap is initially filled by blood vessels and loose connective tissue (Palmer *et al*, 1992) After approximately 2 weeks the vascular supply is established and osteoblasts deposit lamellar bone in the gap between the fragment ends at the rate of 1 to 2 μm per day. This is known as appositional formation of compact bone (Chao *et al*, 1989). This lamellar deposition is a site of structural weakness as its orientation is perpendicular to the axis of the bone in the ends of the fracture (Olmstead, 1985). Initially there is poor connection between the new bone and existing bone of the fragment ends, which makes this area mechanically inferior (Palmer *et al*, 1992). With time, the new lamellar bone in the gap will become longitudinally oriented and re-establish the anatomic and mechanical integrity of the cortex.

Secondary gap healing occurs at areas within the fracture plane, which are subject to instability and initially high levels of interfragmentary strain. Within these zones, bone resorption of the fragment ends occurs, which lengthens the fracture gap and decreases interfragmentary strain. Simultaneously, external callus is formed and proceeds to stabilize the fragment ends. Once the external callus unites, the deformation within the fracture gap is reduced to levels where bone tissue can survive. If the gap is less then 1mm wide, osteonal reconstruction of the cortex will proceed as for primary gap healing (Palmer *et al*, 1992)

Indirect healing, or intermediate callus formation, occurs when interfragmentary deformation, impairment of blood supply or width of the fracture gap will not allow direct formation of lamellar bone. Tissues are initially deposited within the fracture environment and subsequently prepare the fracture gap for survival of bone cells (Palmer *et al*, 1992). In gaps greater than 1mm, the gap is initially filled with a coarse woven bone (Olmstead, 1995), fibrous tissue or cartilage tissue (Palmer *et al*, 1992) with prominent vascular spaces. Within several weeks the vascular spaces begin to fill in with concentric layers of lamellar bone. The orientation of the woven bone is somewhat random but mainly perpendicular to the long axis of the bone. Remodelling of the repair bone is required to create osteonal bone in the gap with orientation parallel with the long axis of the bone.

If there is no initial stability provided by treatment, the process of healing has to undergo all stages of tissue differentiation. In addition external callus forms, which provides a longer lever arm for the early repair of tissues. If the method of treatment provides a certain stability the callus formation is only minor and the healing stages may be abbreviated.

1.4. Callus formation

The production of callus has been extensively studied (Court-Brown, 1985; Sumner Smith, 1982; Yamagishi & Yoshimura, 1955). The portion of the callus derived from the periosteum is called the external callus and that from the endosteum is called the internal callus. The earliest mineralised osseous matrix in the callus is present by 1 week, and a radiographic "shadow" is present by 2 weeks. (Weisbrode, 1995). As the osseous portions of the callus increase the clot portion decreases as the cells and fibrin are phagocytosed and removed. Ideally the pluripotent cells invading the clot all differentiate into osteoblasts and rapidly produce woven bone of repair. This however requires ideal conditions of compression and an adequate oxygen supply (Brinker *et al*, 1990; Court-Brown, 1985). If a fracture involves fleshy muscle attachments or is otherwise surrounded by loose connective tissue, it will tend to heal rapidly because of the abundance of capillaries that can be mobilised for new bone formation. (Rhinelander & Wilson, 1982). The local extra-osseous vascular bed is a major factor in supplying capillaries to invade the fracture site and help form callus (Brookes, 1971; Court-Brown, 1985). If however, severe soft tissue damage has occurred, callus formation may be diminished. If the supply of oxygen to the callus is decreased, more cartilage tends to form. Some hyaline cartilage in the callus is normal especially in the periphery of the thickest portion of the callus. This cartilage eventually undergoes mineralisation and subsequent endochondral ossification. The disadvantage of excessive cartilage in the callus is the decrease in rigidity and therefore stability at the fracture site until endochondral ossification of the cartilage is complete. In a stable fracture with adequate blood supply there should be a complete bony callus by 6 weeks. After 6 weeks the callus should begin compaction and remodelling. In general, the size of the callus and therefore the distortion of the bone depend on stability (Brookes, 1971). The less stable the fracture, the larger the callus. A large callus may not only create a cosmetic problem but could be in a location to interfere with locomotion by impinging on muscle, nerves or adjacent bones (Olmstead, 1995).

1.5. Pelvic fractures

Pelvic fractures in dogs and cats are relatively common and constitute 20-30% of all fractures seen in veterinary practice (Leonard, 1971; Chambers & Darnell, 1972; Robins *et al*, 1973; Alexander & Carb, 1979; Dunbar, 1984; Brinker *et al*, 1990; Tarvin & Lenehan, 1990; Bookbinder & Flanders, 1992; Betts, 1993; Houlton & Dyce, 1994) being second only to femoral fractures in frequency (Eaton-Wells *et al*, 1990). In order for this stable and well protected structure to be fractured, severe external violence must be inflicted, usually by means of a road traffic accident or a fall from a great height (Alexander *et al*, 1962; Denny, 1978; Poka, 1989; Eaton-Wells *et al*, 1990; Bojrab, 1990) or, less frequently, gunshot wounds, dog fights (Betts, 1993) or being stepped on (Eaton-Wells *et al*, 1990). Trauma of this magnitude not only damages osseous structures but may also injure soft tissues (Dunbar, 1984; Bosch *et al*, 1992; Pohlemann *et al*, 1994). Pelvic fractures however differ considerably in the degree of damage sustained (Betts, 1993). As a result of the box-like anatomy of the pelvis and the short musculotendinous support of the bones most fractures are multiple (Robins *et al*, 1973; Betts, 1993; Houlton & Dyce, 1994) and involve at least three or more bones (Brinker *et al*, 1990). Conversely, in 1978, Denny found 30 dogs, which displayed solitary pelvic fracture sites. Trauma is haphazard in its effects and extent and this is reflected in the great variety in the position and number of pelvic fracture sites recorded (Denny, 1978).

The pelvis of the dog and cat supports the trunk on the hind limbs, provides a site of attachment for numerous muscles and acts as a canal through which pass various nerves, blood vessels, the urogenital system and the bowel. Fracture of the pelvis can compromise these functions (Robins *et al*, 1973). Associated damage reported is extensive and varied in its severity and includes injury to the bladder, rupture of the urethra, ureteral avulsion, rectal compression (Betts, 1993), peripheral nerve injury (Tarvin & Lenehan, 1990; Betts, 1993) especially lumbo-sacral nerve damage (Eaton-Wells *et al*, 1990), pulmonary contusions, rib fractures (Tarvin & Lenehan, 1990), pneumothorax (Brinker *et al*, 1990), pleural effusion, spinal fractures, intestinal adhesions, vascular injuries (Houlton & Dyce, 1994; Poka, 1989) muscular and ligamentous injury (Eaton-Wells *et al*, 1990) and hip luxation (Denny, 1993).

1.6. Classification systems

There are many classification systems for pelvic fractures, ranging from simple to highly complex and multifactorial. One of the first classification systems for human pelvic fractures was devised by Judet *et al* in 1964 (Lowell, 1979). They described a system in which the classification is based on the anatomic relationship of the several portions of the acetabulum to the anterior and posterior rami, describing the fractures as:

1. anterior column.
2. posterior column.
3. transverse fractures or
4. combinations.

However Lowell in 1979 stated that pelvic fractures initially were divided into 5 groups corresponding closely to the epiphyseal divisions of childhood or some combination. These were:

1. inner wall fractures.
2. posterior fractures.
3. superior dome fractures.
4. bursting fractures.
5. anterior fractures.

Tile, in 1984, devised a system for use in human orthopaedics. He stated that a classification system is only useful if it aids in the management of the patient, otherwise it becomes simply an academic exercise. In the past, a precise definition of the injury patterns to the pelvis has been difficult, but now with more exacting radiological techniques, including computed tomography, this has become possible. In assessing the patterns of injury, the following questions should be addressed: first the degree of instability caused by these forces, and second the magnitude and direction of the forces involved. Tile divides all fractures into either stable, unstable or miscellaneous groups and attempts to predict the injurious force direction and resultant effect on the patient's sacro-iliac complex.

Classification	Direction of the Injurious Force	State of Posterior Sacro-iliac Complex
Stable	- anteroposterior compression (open book). - lateral compression.	- intact - impacted
Unstable	- vertical shear	- disrupted: unilateral or bilateral
Miscellaneous	- complex	- bilateral sacro-iliac dislocation with an intact anterior arch. There is also usually an acetabular fracture associated with the pelvic ring disruption.

Table 1.1. Pelvic fracture classification system by Tile, 1984.

In 1989 Poka stated that in recent years the classification of pelvic fractures has become increasingly complex and that a simple classification of the injuries according to the direction of the original forces is of far more practical value. Poka suggested that disruption of the pelvic ring might be identified as due to:

1. lateral compression
2. anteroposterior compression
3. vertical shearing forces or
4. a combination of all 3 forces

This is a simplified version of Tile's system.

Many other authors classify the pelvic fracture simply into being stable or unstable (Peltier, 1965; Dunn & Morns, 1968; Holdsworth, 1972; Thaggard *et al*, 1978; Young & Resnik, 1990; Edwards, 1993). The diagnosis of instability is of limited value in the treatment of the patient, indicating only the need for surgical stabilization rather than the type of stabilization required.

Burgess *et al* in 1990 devised a detailed classification system for human pelvic fractures, relating to the force vector causing the injury. They postulated that they could be classified according to

1. A combination of type and location factors such as crush and avulsion.
2. Interruption of the major line of weight transmission.
3. Direction of the impact.
4. Stability such as comminuted, unstable or stable.
5. Anterior or posterior.
6. Force of injury and its direction, such as lateral compression, anteroposterior compression or vertical shear.
7. Force of injury and its direction plus stability, i.e. stable vertically but unstable rotationally.

In veterinary orthopaedics, Denny in 1978 attempted to classify pelvic fractures in the dog according to their anatomical position. Over a decade later Eaton-Wells *et al* (1990) graded canine pelvic fractures in to three groups.

Group

1 These include fractures or separations that do not significantly reduce the size of the pelvic canal or involve the hip joint, or render the pelvis unstable. Fractures of the ilium, ischium and pubis with minimal displacement or separation of the pubic symphysis or sacro-iliac joint can usually be treated satisfactorily by conservative therapy.

2 The majority of pelvic fractures fall into this group. The fractures and displacement of fragments result in marked narrowing of the pelvic canal, instability of the pelvis, and there may be acetabular distortion or sacro-iliac joint involvement. These can be treated conservatively; however, long term complications, such as constipation, osteoarthritis, chronic lameness and dystocia may result. A more rapid recovery with a more normal anatomic resolution may be obtained with reduction and external or internal fixation.

3 These are multiple fractures of the pelvis with much gross deformity and severe soft tissue injury. Open reduction and internal fixation are mandatory.

Alexander & Carb in 1979 stated that all pelvic fractures fall into 2 broad categories, non-surgical and surgical. Houlton & Dyce in 1994 expanded this simple system where the pelvic fractures were generally classified in to 3 groups.

1. those which can be managed conservatively,
2. those that can be managed conservatively but which have a better prognosis if surgically managed.
3. those for which surgery is imperative if long-term complications are to be avoided.

1.7. Presenting signs

Because the clinical signs associated with a pelvic fracture vary with the organ or organs traumatized, an animal that has sustained a fracture of the pelvis will present with a variety of signs depending on the severity of the fracture and concurrent soft and hard tissue anomalies (Eaton-Wells *et al*, 1990). Presenting signs may vary from a weight bearing lameness to a total inability to walk (Bennett *et al*, 1975; Robins, 1973). In all cases the animals showed severe pain on palpation of the pelvis and asymmetry while abnormal mobility of the pelvic bones was apparent in many instances (Bennett *et al*, 1975). Some animals displayed a gross deformity of the hindquarters. Many patients were presented in hypotensive shock and required immediate supportive therapy (Eaton-Wells *et al*, 1990).

1.8. Treatment

Conservative treatment is used for animals with little or no displacement of the fracture segments, an intact acetabulum, essentially intact continuity of the pelvic ring (Brinker *et al*, 1990; Eaton-Wells *et al*, 1990; Betts, 1985) or minimally displaced ilial fractures that do not severely compromise the lumen of the pelvic canal and ischial fractures. Pubic fractures are non-surgically managed unless accompanied by prepubic tendon avulsion (Tarvin & Lenehan, 1990). Fractures in ambulatory patients with minimal lameness, immature animals and animals that do not tolerate confinement may also be treated conservatively (Eaton-Wells *et al*, 1990). The pelvic girdle provides an effective muscular sling for minimally displaced fractures (Betts, 1985) and the musculature serves very effectively in immobilizing the fracture segments (Brinker *et al*, 1990). Where the continuity of the pelvic ring remains essentially intact, spastic contraction of the pelvic muscles stabilizes non-displaced fractures internally (Dunbar, 1984). This non-surgical treatment involves reduction of the fragments by rectal or external manipulation (Tarvin & Lenehan, 1990). Conservative treatment is appropriate when cost is a strong consideration or when the pelvis is so badly comminuted that surgical repair may not be feasible (Bojrab, 1990).

The majority of pelvic fractures will heal satisfactorily with conservative treatment (Alexander *et al*, 1962; Robins, 1973; Denny, 1978). However in some cases, malalignment and / or instability of the fragments may result in a prolonged recovery period (Denny, 1978), dysuria (Betts, 1985), limited hip movement, permanent lameness (Robins, 1973) and distortion or narrowing of the pelvic canal and resultant chronic constipation or obstipation in both sexes. In the female, the resulting narrowing of the birth canal may lead to dystocia (Alexander *et al*, 1962; Alexander & Carb, 1979) and the possible need for caesarean section. In cases of excessive pelvic canal stenosis, severe treatments may be carried out such as a symphyseal distraction osteotomy using an autograft (McKee & Wong, 1994) or allogenic bone graft (Evans, 1980), a total or subtotal hemipelvectomy (Liptak, 1998; Alexander & Carb, 1979) or subtotal colectomy (jejunocolostomy) (Matthiesen *et al*, 1991). Potential long-term problems may develop if accurate reduction and stable fixation are not accomplished. Dogs with cranially displaced iliac shaft fractures or sacro-iliac luxations may have a noticeable gait abnormality (Betts, 1985). Amongst those dogs who make complete recoveries following conservative treatment of pelvic fractures, the recovery period can be prolonged especially when there was marked displacement of the fragments, bilateral pelvic fractures or displaced acetabular fractures (Denny, 1978). Dogs with significantly displaced acetabular fractures frequently develop severe secondary degenerative joint disease (Betts, 1985). Unless the acetabulum is involved, perfect anatomic alignment of the pelvic fragments is not necessary for union and acceptable function (Pohlemann *et al*, 1998; Eaton-Wells *et al*, 1990; Alexander & Carb, 1979). The fractured bones stabilize in their displaced positions (Bennett *et al*, 1975). The high cancellous to cortical bone ratio of the pelvic bones and the inherent stability favour fracture healing (Houlton & Dyce, 1994). The abundant soft tissue covering ensures adequate blood supply (Betts, 1985).

The conservative regime consists of confinement to comfortable quarters preferably a padded area (to prevent decubitus ulcers) with easy access to food and water (Bennett *et al*, 1975; Betts, 1985), cage rest (Brinker *et al*, 1990; Tarvin & Lenehan, 1990), restricted and supervised exercise, attention to hydration, alimentation, urination and defecation (Betts, 1985; Brinker *et al*, 1990; Tarvin & Lenehan, 1990) and possibly the use of non-weightbearing slings. Cage rest should be enforced for a minimum of 14 days and ambulation should be limited to toilet needs. Walking surfaces should be non-slip (Eaton-Wells *et al*, 1990).

The indications for surgical management of pelvic fracture in the cat are not well defined, although such guidelines are readily available for the dog (Betts, 1985; Newton, 1985; Eaton-Wells *et al*, 1990; Bookbinder & Flanders, 1992). Denny in 1993 stated that surgical treatment of pelvic fractures in the cat can be undertaken using the same indications and techniques as described in the dog. Many clinicians believe however that most pelvic fractures in the cat do not require surgical intervention, despite the absence of long-term evaluation of results of surgical versus conservative therapy. This impression may result from a difference in the type and severity of pelvic injury sustained during traumatic incidents in the cat compared to the dog or, alternatively, a greater ability of the cat to cope with similar types of lesions (Bookbinder & Flanders, 1992). Joshua in 1965 stated that surgical correction of pelvic fractures in a typical non-breeding cat seems to be rarely indicated although the degree of deformity present at the time of the original injury will persist (Bennett *et al*, 1975).

Surgery is sometimes performed to achieve a better cosmetic appearance, especially in shorthaired show dogs or to provide early relief of pain (Tarvin & Lenehan, 1990). Concomitant pelvic stabilisation may reduce damage to the lumbosacral plexus, diminish haemorrhage and prevent further genitourinary trauma (Betts, 1993). The purpose of performing a surgical procedure is to reduce and realign the fragments into reasonable alignment (Eaton-Wells *et al*, 1990; Betts, 1993) thus relieving compromise of the pelvic canal and to stabilise the weight bearing segments (Scott, 2001). Accomplishing this end does not require reducing and fixing all the fractures. In general, pelvic fractures that lead to surgical indications fall into 3 categories. These are sacro-iliac separation, ilial shaft fractures and acetabular fractures (Dunbar, 1984; Brinker *et al*, 1990) in isolation or combination. Sufficient stability can often be achieved by proper repair of only one of these fractures (Robins, 1973; Tarvin & Lenehan, 1990; Denny, 1993).

1.9. Criteria for surgery

These can be categorised as follows:

1. Decrease in size of the pelvic canal (Alexander *et al*, 1962; Denny, 1978; Dunbar, 1984; Brinker *et al*, 1990; Eaton-Wells *et al*, 1990; Betts, 1993; Houlton & Dyce, 1994) especially where a fragment can potentially impinge on viscera contained within the pelvic canal (Alexander & Carb, 1979).
2. Age, breed, sex and bodyweight of the animal (Houlton & Dyce, 1994).
3. Fracture of the acetabulum (displacement of the articular surfaces) (Denny, 1978; Alexander & Carb, 1979; Dunbar, 1984; Brinker *et al*, 1990; Tarvin & Lenehan, 1990; Betts, 1993; Houlton & Dyce, 1994).
4. Instability of the hip (fracture of the ilium, ischium and pubis on same side; segmental or Malgaigne fracture) (Denny, 1978; Dunbar, 1984; Brinker *et al*, 1990; Tarvin & Lenehan, 1990; VanGundy, 1990; Betts, 1993).
5. Unilateral or bilateral instability (Eaton-Wells *et al*, 1990; Tarvin & Lenehan, 1990; Betts, 1993) particularly if accompanied by coxofemoral dislocation or other limb fractures (Denny, 1978; Brinker *et al*, 1990).
6. Sacro-iliac luxation or fracture luxation (Eaton-Wells *et al*, 1990; Tarvin & Lenehan, 1990).

7. Ilial shaft fractures with craniomedial displacement compromising the pelvic canal, especially in intact bitches (Tarvin & Lenehan, 1990).
8. Gross fragment displacement (Dunbar, 1984; Tarvin & Lenehan, 1990; Houlton & Dyce, 1994).
9. Multiple bilateral pelvic fractures (Denny, 1978; Eaton-Wells *et al*, 1990).
10. Cases in which the owner's (Houlton & Dyce, 1994) or animal's attitude will render conservative treatment ineffective (Eaton-Wells *et al*, 1990).
11. Patients in which postoperative appearance and as near normal gait are important (Eaton-Wells *et al*, 1990).
12. Ability of the owner to pay (Houlton & Dyce, 1994).

Other factors, which should be taken into consideration, are the facilities available and the experience of the surgeon (Houlton & Dyce, 1994).

1.10. Timing of repair

The timing of the repair of pelvic fractures is an important factor (Alexander & Carb, 1979). Surgical repair should be attempted within 4 days of injury (Betts, 1993; Brinker *et al*, 1990; Slatter, 1985) but ideally within 48 hours of the injury (Robins, 1973). Reduction and fixation are accomplished much more easily and accurately if attempted within this time period (Brinker *et al*, 1990). Each additional day considerably increases the effort and iatrogenic trauma necessary for repair (Betts, 1993). After 5 days the surgical objectives are difficult to accomplish and they may be impossible to attain after 8 or 10 days (Scott, 2001; Alexander & Carb, 1979; Robins, 1973). Delay makes reduction more difficult because of spastic contraction of the muscles and inflammatory thickening of the soft tissue. In some cases, fixation can be accomplished when the patient is presented. In others it may be advisable to delay for a day or longer until the patient becomes an acceptable anaesthetic risk. It is also advisable to wait until the swelling has subsided before going ahead with reduction and fixation (Brinker *et al*, 1990).

1.11. Advantages of surgical management

Dogs with repaired pelvic fractures convalesce and rehabilitate more rapidly and completely. Hospitalisation and nursing care are less than required for conservative treatment (Betts, 1993). Healing is more rapid, the patient becomes ambulatory sooner and in all cases the gait remains normal (Chambers & Darnell, 1972). While there is reduced morbidity from concomitant injuries and associated complications such as pressure sores, pulmonary problems in recumbent animals and urine or faecal soilage. Postoperatively an animal that has minor musculoskeletal discomfort is much easier to treat and more responsive to therapy than one that has major fractures and is recumbent (Betts, 1993).

Obviously no one form of fixation is appropriate for all fractures. Certain fractures are best treated with internal fixation, others are best treated with external fixation, and many can be treated equally well with either or with coaptation (Egger, 1989). This was corroborated by Chao *et al* in 1989 who stated that no single bone fixation method or device could be applicable to all fracture types and locations.

1.12. External skeletal fixation

External skeletal fixation (E.S.F.) is a means of establishing fractures or joints using percutaneous fixation pins that penetrate the bone cortices internally and are connected externally to form a rigid frame or bridge (Egger, 1990). The basic components of an external fixator are these pins and the connecting bars or columns and clamps necessary to complete the frame (Anderson *et al*, 1997; Clary & Roe, 1995). This device, commonly called a Kirschner-Ehmer splint provides stable fixation of bone fragments without implants in the fracture site, with no or minimal damage to soft tissue vascularity, and without immobilizing adjacent joints (Egger, 1990).

Consequently, it is particularly useful for open or highly comminuted fractures with vascular compromise that require prolonged fixation (Ross & Matthiesen, 1993; Egger, 1990). In addition, the relatively low initial cost of fixators and the reusability of many of their components make them economically realistic for most practices and clients (Egger, 1990).

1.12.1. History of E.S.F.

External skeletal fixation was introduced in 1840 when Jean-Francois Malgaigne used a "point" which was a spike driven into a human tibia and held in place by a strap (Anderson *et al*, 1997). Parkhill developed the first half-frame fixateur in 1894. This device permitted translational reduction of the fracture. Blocking of the device after final reduction then resulted in immediate stability to the fracture (Seligson & Dudley, 1982). External skeletal fixation was described in 1897 as being appropriate for highly unstable, comminuted, or open fractures with significant soft tissue injury (Egger, 1990). It was not popularised until

World War II. At about this time, Otto Stader first described a full-pin transfixation splint in the veterinary literature (Anderson *et al*, 1997). In the two decades after World War II, however, its use declined to nearly zero in both the human and veterinary clinical settings. Undoubtedly the development of improved techniques for application of scientifically designed formal internal fixation contributed to the change. Certain advantages inherent to external fixation however have brought about a rebirth of research and clinical usage of the techniques used in the middle 1960s (Egger, 1989). In recent years there has been a renewed interest in the use of external skeletal fixation devices in small animal orthopaedics (Tomlinson & Constantinescu, 1991; Pollo *et al*, 1993; Ross & Matthiesen, 1993).

1.12.2. Advantages of E.S.F.

These can be categorised as follows:

1. Provides prolonged rigid stabilization (Ross & Matthiesen, 1993; Egger, 1989) but does not cause post-union osteopenia associated with rigid plate fixation (Chao *et al*, 1989).
2. Usefulness in treating open and closed reduced fractures (Brinker *et al*, 1990).
3. Fixation pins can be inserted proximal and distal to the wound (Brinker *et al*, 1990).
4. Reduces risk of wound contamination and resultant osteomyelitis (Egger, 1989).
5. Simplifies wound management (Brinker *et al*, 1990; Ross & Matthiesen, 1993) and delayed autogenous cancellous bone grafting procedures (Egger, 1989).
6. Lightweight but strong (Tomlinson & Constantinescu, 1991).
7. Compatibility for use in conjunction with other internal fixation devices (Aron *et al*, 1986; Brinker *et al*, 1990).
8. Toleration by both dogs and cats (Brinker *et al*, 1990).
9. Adaptable to many fracture configurations (Tomlinson & Constantinescu, 1991).
10. Allows bypassing of periosteal callus formation (Egger, 1989).
11. Can adjust degree of rigidity as fracture heals, enhancing rate of healing (Harris *et al*, 1981; Aro *et al*, 1989; Egger, 1989).
12. Simplifies fixation removal (Egger, 1989) without placing the animal under general anaesthesia (Brinker *et al*, 1990).

13. Requires minimal specialised equipment (Egger, 1989).
14. Relatively inexpensive (Egger, 1989; Brinker *et al*, 1990; Tomlinson & Constantinescu, 1991).
15. Ease of application (Brinker *et al*, 1990).

1.12.3. Use of E.S.F.

External skeletal fixation has been widely used in the management of open traumatic lesions. This includes infected non-unions and the stabilization of bone fragments in fusions, osteotomies and limb lengthening. Because of their adaptability to different anatomical locations and the ability to achieve varying degrees of rigidity, external fixation is also used in the treatment of tibial, pelvic and forearm fractures (Wu *et al*, 1964). An external fixator can be used as the primary method of fracture fixation or can be used to enhance the stability provided by another primary fixation modality (Aron, 1986). Not all authors advocate the use of external fixation. Court-Brown in 1985 stated that the comminution or bone loss associated with many fractures in which external fixation is used means that in the clinical situation inter-fragmentary compression is frequently neither possible nor desirable.

1.12.4. Indications for E.S.F.

There are essentially two indications for using an external frame in pelvic injuries.

1. To obtain stability (Harris *et al*, 1981; Brooker, 1983; Edwards, 1993).
2. To obtain and hold reduction of fractures (Brooker, 1983).

External skeletal fixation devices appear to be an effective method of treatment for severely comminuted open fractures of the extremities, infected non-unions and infected and failed septic joints (Mears *et al*, 1980). External fixation has a definite role in the management of pelvic fractures (Kellam, 1989).

1.12.5. Classification and instrumentation

The most commonly used external fixation device in veterinary orthopaedics is the Kirschner-Ehmer system, which provides 3 sizes of clamps and connecting bars. This system is limited to certain pin sizes and is not easily adapted to frame angulation or complex frame configurations (Ross & Matthiesen, 1993; Tomlinson & Constantinescu, 1991). The system also lacks easy adaptability to certain fractures or luxations, with some difficulty being occasionally encountered in achieving optimal pin to bone placement while avoiding soft tissue structures or defects in the bone, such as fissures (Ross & Matthiesen, 1993). Acrylic external fixation was developed to treat fractures not amenable to the K-E apparatus (Tomlinson & Constantinescu, 1991). Consistent nomenclature has not been developed for this type of equipment. Initially there was little need for classification of fixators because there were few devices and only one or two configurations. As in other areas of surgery, the devices were named for the developer (Roe, 1992). As understanding of the fracture healing improved, the science of external fixation also advanced, and the number of devices and possible configurations grew rapidly. With the resurgence in popularity of external fixation, there has been a great increase in the number of scientific communications concerning these devices. The major obstacle to developing a comprehensive classification system is the growing number of devices and the free-form nature of their application (Roe, 1992).

1.12.6. Elements used in E.S.F.

1.12.6.1. Pins

The external frame of the fixator is connected to the bone by pins or wires. Pins are made of rigid stainless steel and may be smooth or threaded. The thread may be cut into the pin or built onto the pin, the latter being stronger but more expensive. Pins are classified as half if they penetrate only one skin surface and the bone and full if they transfix the limb and penetrate two skin surfaces (Egger, 1990; Clary & Roe, 1995). Wires made rigid by being placed under tension, may also be used to connect frames to the bone fragments (Roe, 1992).

1.12.6.2. Connecting Bars

The connecting rod or bar may join a group of pins together or span the fracture site to immobilize the bone fragments. Stainless steel rods are primarily used in veterinary surgery, although free-form fixators using plaster or acrylics to bridge across pins can also be used. In humans adjustable rods are used with some systems so that continuous distraction can be applied to lengthen a limb (Roe, 1992). In recent years, acrylics such as polymethylmethacrylate have gained popularity for use in small animal and exotic species (Williams *et al*, 1997).

1.12.6.3. Clamps

The Kirschner system for veterinary surgery has double and single clamps. Double clamps join two connecting rods. Single clamps attach a pin to a connecting rod. Similar principles are used in the Synthes system (Roe, 1992). Stainless steel connecting clamps are durable and can routinely be reused many times (Egger, 1992).

1.12.7. Constructs used in E.S.F.

The stiffness, stability and clinical performance of the external fixator is dependent upon

1. Configuration, diameter and number of the connecting bars (Brinker *et al*, 1985).
2. Diameter of the pins (Egkher *et al*, 1984; Brinker *et al*, 1985).
3. Angle, location and geometric arrangement of pins in cortical bone (Brinker *et al*, 1985; Egkher *et al*, 1984).
4. Length of pins from the bar to the bone (Egkher *et al*, 1984; Brinker *et al*, 1985).
5. Inherent stability at the fracture site (Brinker *et al*, 1985).

Since fractures vary widely in type, stability, condition of soft tissue, activity and size of patient it becomes obvious that no one configuration is best suited for all fractures (Brinker *et al*, 1985). New fixator designs are more versatile and more flexible to avoid neurovascular damage and muscle fibrosis and scarring (Seligson *et al*, 1982)

The goals of external fixation are

1. Maximum versatility with a minimal number of parts, to facilitate application and reduction of the fracture (Brinker *et al*, 1985).
2. A single external bar and pin system which controls lateral bending and torque forces while permitting controlled distraction, compression or dynamic axial loading once callus formation begins (Brinker *et al*, 1985).
3. Maximal rigidity, which can be easily achieved after reduction and maintained during the first phase of fracture healing (Brinker *et al*, 1985).
4. A pin design, which maximises stability, minimises potential trauma to soft tissues during application and decreases the incidence of long-term pin complications (Brinker *et al*, 1985).
5. Lightness of weight and freedom from cumbersome features, which might prevent the patient from functioning normally (Brinker *et al*, 1985).

6. Ease of removal of the frame (Brinker *et al*, 1985).

1.12.8. Complications experienced with E.S.F.

The most frequently encountered complication is premature pin loosening with or without pin tract infection (Matthews *et al*, 1984; DeCamp *et al*, 1988; Pettine *et al*, 1993; Pollo *et al*, 1993; Clary *et al*, 1995; Anderson *et al*, 1997). Pin loosening causes severe pain, poor limb function, and instability (Palmer *et al*, 1992). Percutaneous pin placement, into the bone, penetrates the integument, which is one of the body's primary mechanisms of defence against bacterial invasion, thus exposing the bone to potential pathogens (Clary & Roe, 1995). The most serious complication of external fixation is infection at the pin sites, which can lead to osteomyelitis and preclude future options for internal fixation (Edwards, 1993). Occasionally implant failure involving the transfixation pins, pin clamps or external bar is seen. Each of these complications can contribute to patient morbidity through poor limb use, loss of fracture reduction, fracture site instability (DeCamp *et al*, 1988) and delayed unions or non-unions (Pollo *et al*, 1993).

1.12.9. Pin insertion

Traditionally avoiding any form of power insertion has been advocated in the application of external skeletal fixation to human fractures because of thermal necrosis. However a study by Egger *et al* in 1986 failed to demonstrate significantly greater temperatures with low speed power insertion than with manual methods and in conjunction with a lack of a significant difference in forces required for axial extraction, suggests that low speed power insertion is acceptable for canine application. These findings were substantiated by Gumbs *et al* in 1988. Only high-speed power insertion (1200 rpm) of pins resulted in significantly increased temperatures, resultant thermal necrosis of bone surrounding the pin and subsequent premature pin loosening (Palmer *et al*, 1992). A histological study carried out by Gumbs *et al* in 1988 showed that insertion of pins using a hand chuck resulted in more mechanical damage to the bone that other methods of pin placement. Clary *et al* in 1995 noted that manual insertion of pins without the predrilling of a pilot hole resulted in temperatures exceeding 55°c, whereas average temperatures were not in excess of 55°c when predrilling was performed. It has been noted that subjecting rabbit cortical bone to a temperature elevation of over 55°c causes death of osteocytes.

1.12.10. Pin placement

Avoidance of skin, muscle and bone necrosis is of great importance during pin insertion (Aro *et al*, 1993b). In general, fixation pins should not penetrate large muscle masses and areas of high skin movement because such penetrations often cause poor postoperative limb use and serum drainage from the pin tract (Egger, 1990). Correct pin placement is essential to obtaining stable fixation. Pins must never pass through the fracture site (Brooker, 1983b). Pins adjacent to the fracture should be placed approximately 1.5 to 2cm from the fracture (Palmer *et al*, 1992). Pins placed close to the fracture decrease the working length of the connecting rod, thereby increasing frame stiffness and stability (Brooker, 1983b; Palmer *et al*, 1992). Placement of pins too close to the fracture, however, may allow contaminating bacteria from the external environment to enter the area of the fractured bone and highly traumatized soft tissue. The remaining pins are customarily spread throughout the remaining bone stock of each fracture segment (Palmer *et al*, 1992). The iliac crest is a frequent insertion site for external fixation pins in treating unstable pelvic or acetabular fractures and in iliofemoral distraction for dislocated hips (Liu *et al*, 1995). Pins tend to follow the curvature of the wing, which makes straight clamps somewhat difficult to apply. Individual pin-bar clamps avoid that situation (Kellam, 1989).

1.12.11. Pin-bone interface (P.B.I.)

The fixation of all implants used in orthopaedic surgery depends initially on the establishment of a mechanical interlock between the implant and the bone (Ling, 1986). The weakest link and most highly stressed portion of any external skeletal pin fixation system is the pin-bone interface (Brinker *et al*, 1985; Palmer *et al*, 1992; Aro *et al*, 1993b). The integrity of the external skeletal fixator relies heavily on the P.B.I. (Clary & Roe, 1995). Stress transfer from bone to metal occurs only at P.B.I.s and over time, stress concentration at these parts can lead to pin loosening (Aron *et al*, 1986) which is the most common complication of external fixation (Palmer *et al*, 1992). Fresh screw holes in bone act as stress raisers and significantly weaken the bone (Burnstein *et al*, 1972).

1.12.12. Axial extraction

The pullout force of a pin affords an accurate method of evaluating holding power, but is influenced in vivo by bone quality, pin tract integrity, and the implant itself (Liu *et al*, 1995). Mechanical and thermal damage while inserting pins or screws has long-term effects on the biologic response of the pin tract (Liu *et al*, 1995). Liu *et al* suggested that the pullout force (***P***) of a screw increases with a larger diameter (***C***), increased cortical thickness (***L***) or material shear strength (***S***). The following predicting formula has been suggested $\boldsymbol{P = C \times L \times S}$. Another formula is $\boldsymbol{P = n \times G \times S}$, where ***n*** = turns of thread and ***G*** = the factor describing the geometry of the screw (Hughes & Jordan, 1969).

Because of the positive linear relationship between the pullout force and the major diameter (Clary & Roe, 1995), the larger pins should have a larger pull out force; however it is well known that too big a screw will increase the risk of iatrogenic fracture. Therefore increasing the diameter is not a safe way to increase pullout force. Another factor that also has influence is the core or minor diameter. It has been found that the difference between major and minor diameter (total thread depth) has a linear relationship with the pullout force (Halsey *et al*, 1992). Wider and deeper threads have stronger purchase on the bone. The turns of the fixing thread can be calculated with the insertion length divided by the pitch. Thus, the formula can be modified into: $\boldsymbol{P = k \times (M - m) \times n\ (or\ {}^{L}/_{p}) \times S}$. Here ***k*** is a constant, ***M*** is the major diameter (mm), ***m*** is the minor diameter (mm), ***n*** = turns of the thread, ***L*** is the thread length (mm), ***p*** is the pitch of the thread (mm) and ***S*** is the shear strength (MPa). The thread profile has no influence on pullout force (Koranyi *et al*, 1970, Hughes & Jordan, 1969), but the pitch has a varied effect (Halsey *et al*, 1992, Evans *et al*, 1990).This formula may also apply to external fixating pins on the iliac crest by interpreting "L" as the insertion length of pins (Liu *et al*, 1995).

Stability of smooth pins undoubtedly arises from frictional forces between pin and adjacent bone, pull out strengths of smooth pins appear to be less affected by bone position (Clary & Roe, 1995). One explanation for this could be that cancellous bone contributes more to the stability of the smooth pin, which relies only on surface area contact, whereas the stability of the threaded pin depends primarily on the interaction of its threads with reciprocating cortical bone threads.

1.12.13. Dynamization

Excessively rigid fixation has a reputation for contributing to fracture union problems (Aro, 1990). Properly timed, staged disassembly enhances the rate of fracture healing and should decrease the problems of stress protection associated with prolonged plate and screw fixation (Ross, 1993; Egger, 1989; Aron *et al*, 1986). Dynamization is a method to increase the load transmission through the healing bone (Aro, 1990). Saramiento *et al* in

1977 supported the concept that progressive physiologic loading may encourage fracture healing.

Early destabilization at 0 to 4 weeks results in an increase in periosteal callus but less bending strength. This increase in callus suggests early destabilization promotes a secondary pattern of bone healing. Destabilisation after 6 weeks results in increased mechanical strength and an increase in vascularity crossing the fracture site. 12-week destabilization results in no significant difference in either callus proliferation or mechanical strength, suggesting a limited "window of time" during which dynamization is advantageous (Egger, 1989). Aron *et al* 1986 recommended this time window to be 4 to 12 weeks, when soft tissue damage has healed.

CROSS SECTIONAL ANATOMY OF THE DOG AND CAT

The cross sectional anatomy of the human body has been well documented. Studies have been carried out on the body as a whole (McGrath & Mills, 1984; Bo *et al*, 1980) or based on specific regions such as head and neck (Lillie & Bauer, 1994; Romrell, 1994) or forearm and hand (Meals & Seeger, 1991). Many of these investigations attempt to correlate the gross anatomical findings with diagnostic imaging modalities (Bo, 1990) such as ultrasound (Morley *et al*, 1983), computed tomography (Ellis *et al*, 1991; Potter, 1971), magnetic resonance imaging, radiography or a combination of these (Ellis *et al*, 1999; Kieffer & Heitzman, 1979; Carter, 1977).

2.1. MATERIALS & METHODS

A total of four cadavers were used for this investigation. These comprised of two canine and two feline cadavers. Both dog cadavers were entire male greyhound types, both with palpably normal symmetrical pelves. The cats were both domestic short hairs, one was a neutered male, again with a palpably normal pelvis while the other, a female had a palpably asymmetrical pelvis. All cadavers were frozen in the standing position at minus 20 degrees centigrade. The cranial face of each slice was photographed as soon as possible after sectioning while still frozen. The cut surfaces were washed with hand hot water and scrubbed with a nailbrush to remove any debris prior to photography. All transverse sections were numbered from cranial to caudal.

2.1.1. Dog 1

This cadaver was serially sectioned transversely. Approximate lines of section were drawn on the coat with a permanent marker pen before sectioning took place. It was placed in right lateral recumbency, supported manually and then sectioned using a band saw. Six sections were taken of the pelvic area each approximately 1.5cm wide. The most cranial cut was made at the mid lumbar region. The cranial face of each slice was photographed.

2.1.2. Dog 2

This cadaver was serially sectioned radially using the greater trochanter of the femur as a focal point for each section (Figure 2.1). Approximate lines of section were drawn on the coat with a permanent marker pen before sectioning took place. The hindlimbs were cut in a dorsal plane at the level of mid femur and the whole animal was cut transversely caudal to the last rib. The remaining area used for sectioning comprised of the lumbar and pelvic regions only. The cadaver was placed in ventral recumbency, supported manually and sectioned with a band saw into 4 pieces.

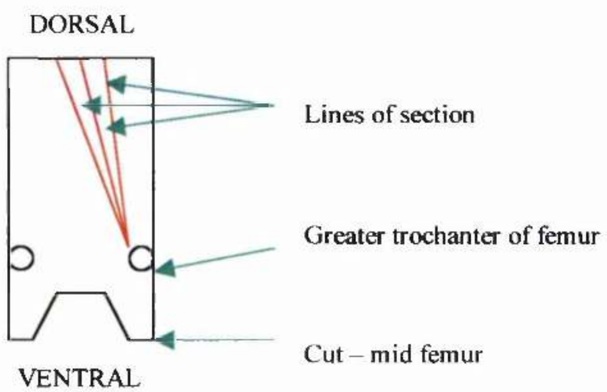


Figure 2.1. Schematic diagram of caudal view of dog 2 illustrating lines of radial section.

Although the canine cadavers were successfully immobilised manually while being sectioned, it was felt that due to the smaller overall size of the cats and the proportionately narrower transverse sections required, another method of retaining was necessary. A sheet of 0.6cm thick clear perspex measuring 121cm x 82cm (Figure 2.2) was cut into 3 smaller sheets each measuring approximately 45 x 76cm, 37 x 76cm, 45 x 77cm (Figure 2.3). Holes were drilled around the perimeter of each smaller sheet at 1.5cm intervals, 1.5cm from the edge, using an electric drill and bit (Figures 2.4 and 2.5).

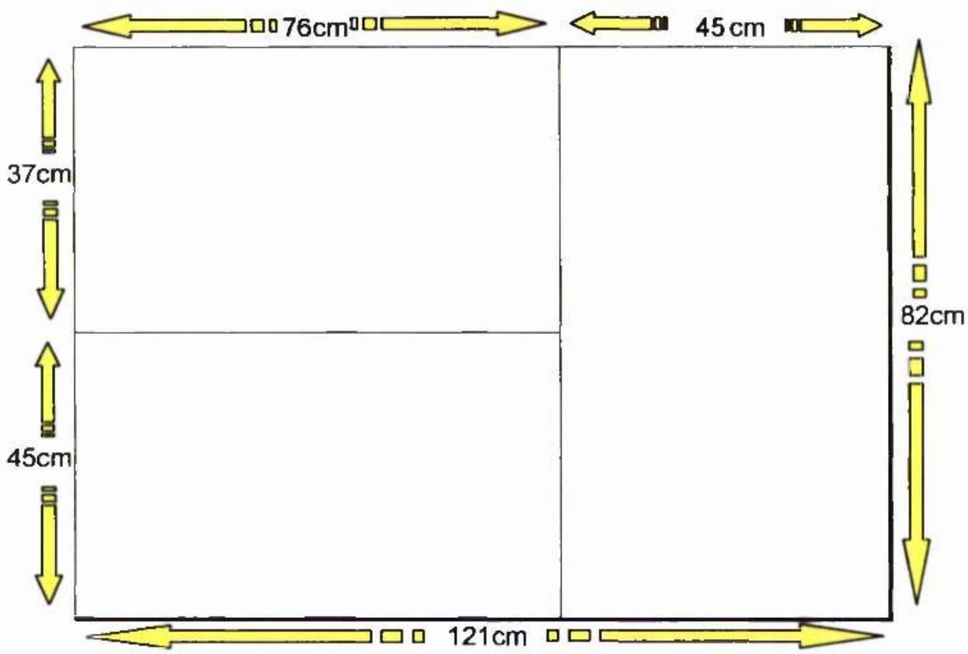


Figure 2.2. Dimensions of original sectioning board.

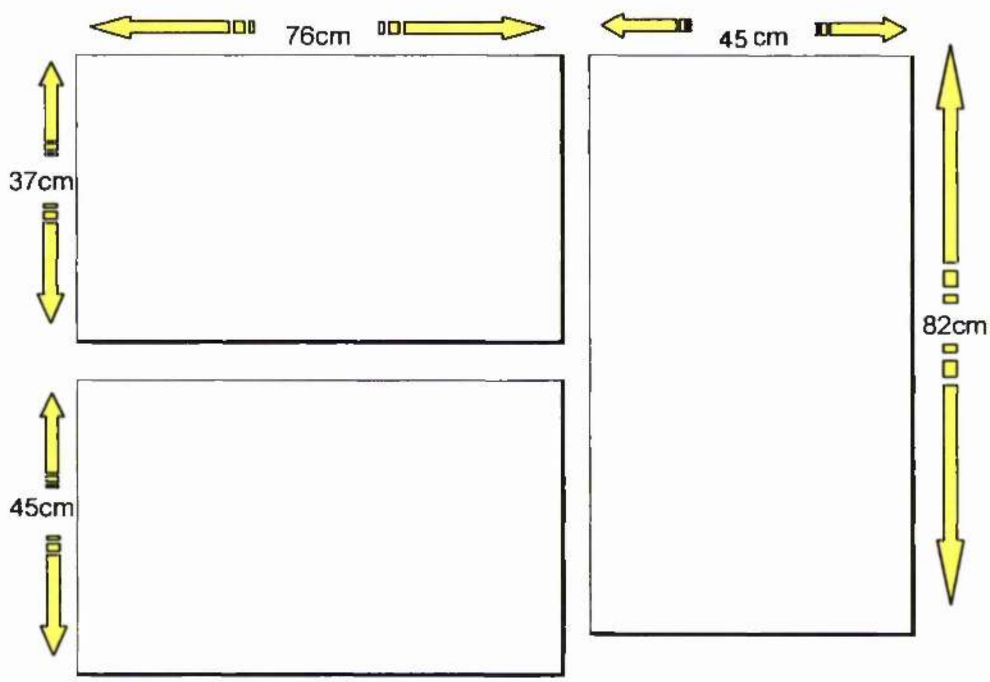


Figure 2.3. Dimensions of original sectioning board shown exploded.

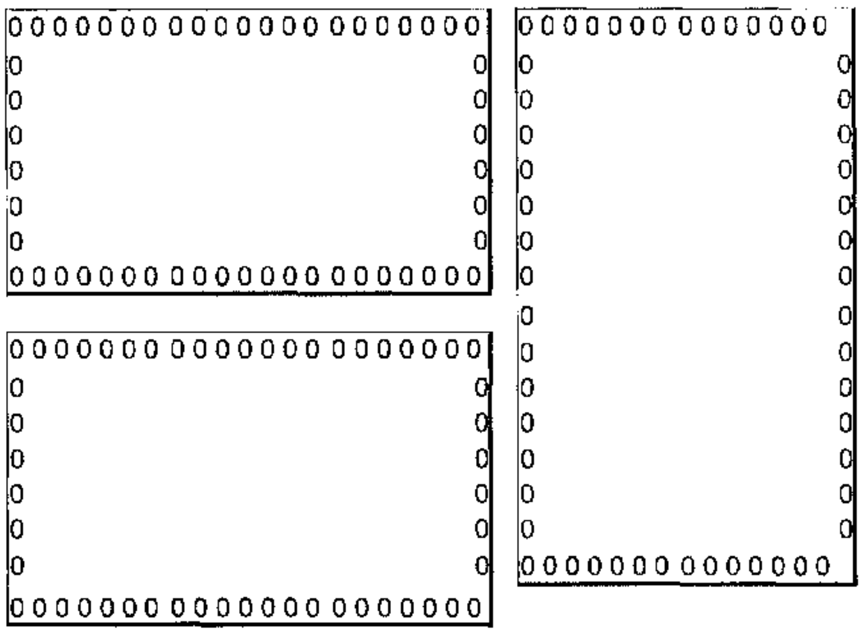


Figure 2.4. Dimensions of original sectioning board (drilled).

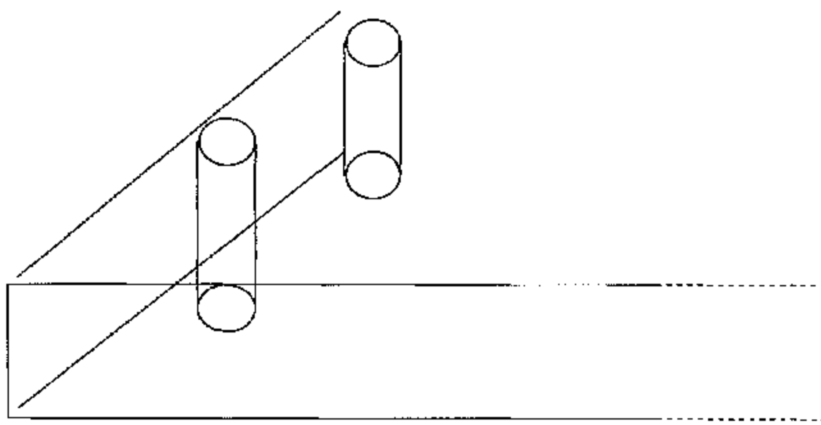


Figure 2.5. Close up of drilled holes.

2.1.3. Cats 1 and 2

Each cat was sectioned mid femur with a band saw in a dorsal plane. They were each then placed in ventral recumbency on boards approximately 2cm from one of the short edges. Another line of holes were drilled on the other side of the cat approximately 2m from its body (Figures 2.6 & 2.7). The cat was secured in position using a series of releasable ties passed through a short edge hole, over the dorsal aspect of the cat, back through the middle row of holes, attaching to the initial tie.

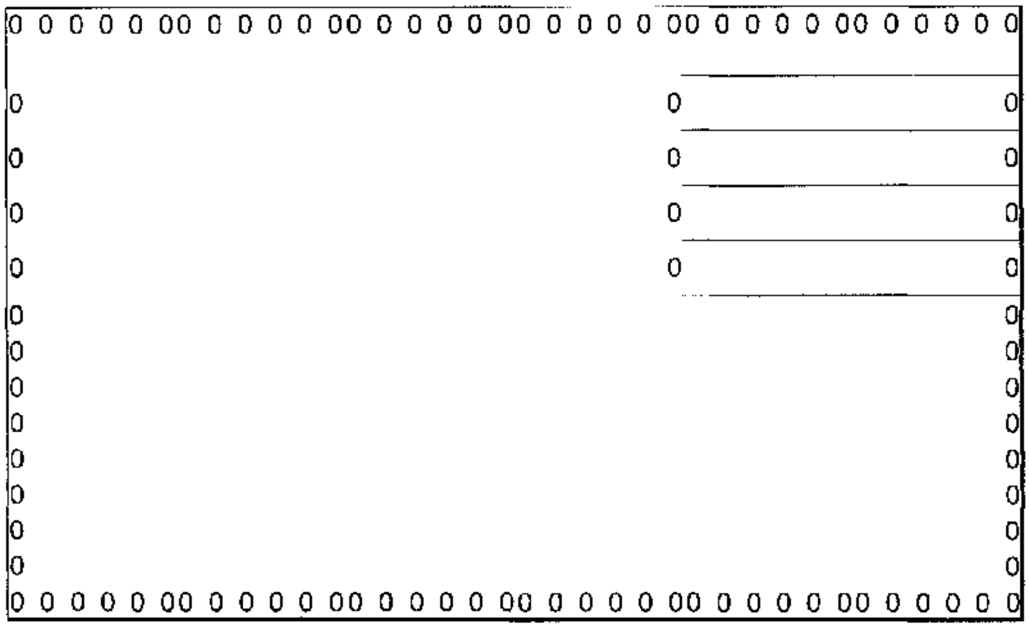


Figure 2.6. Board used for sectioning cat 1.

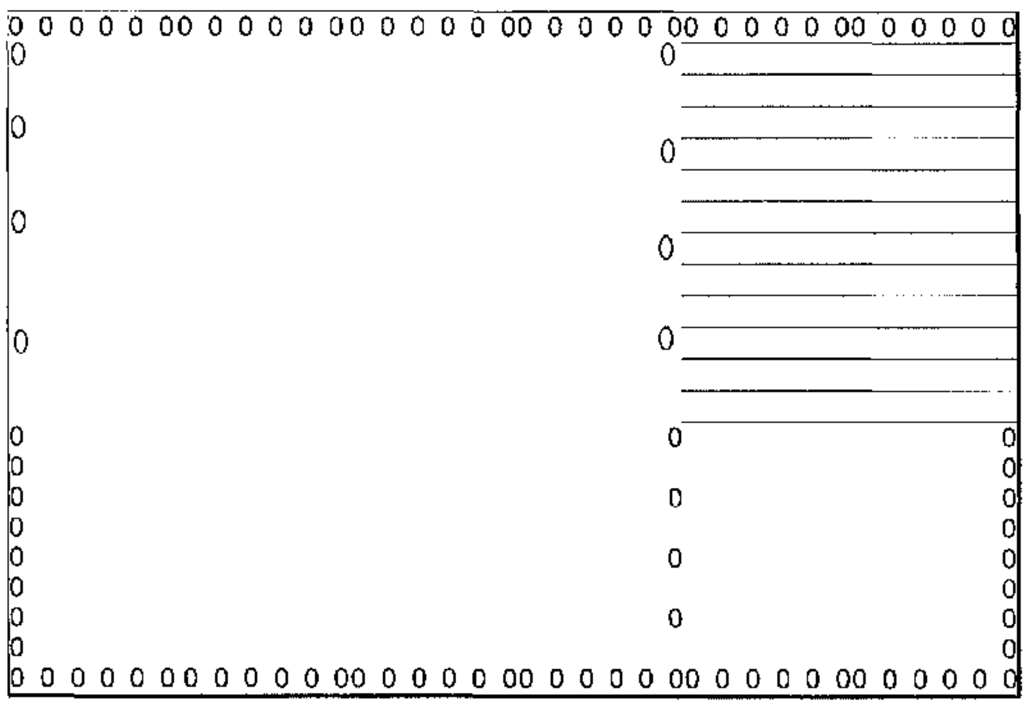


Figure 2.7. Board used for sectioning cat 2.

Approximate lines of section were drawn on the coat with a permanent marker pen before sectioning took place A band saw was used to serially section the cat and perspex board transversely. Cat 1 was cut into 5 sections (Figure 2.8) with an average width of 2.6cm

(Table 2.1). A total of 13 sections were cut from cat 2 (Figure 2.9) with an average width of 1cm (Table 2.2).

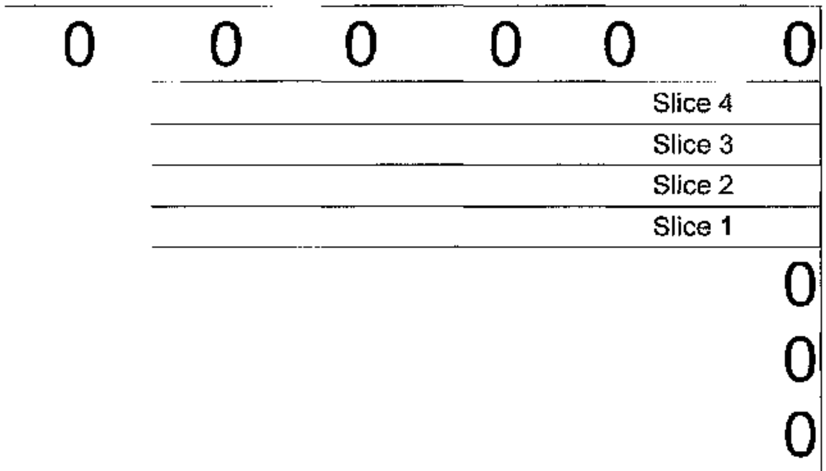


Figure 2.8. Sections from cat 1.

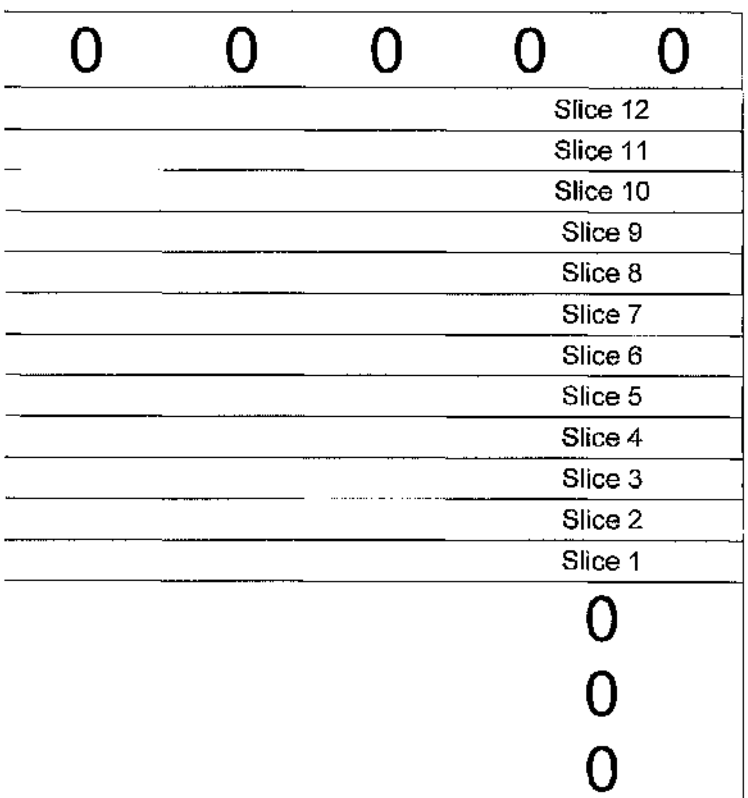


Figure 2.9. Sections from cat 2

Cat 1

Slice	Width
1	25mm
2	26mm
3	27mm
4	27mm
5	endpiece

Table 2.1. Width of sections from cat 1.

Cat 2

Slice	Width
1	6mm
2	8mm
3	11mm
4	8mm
5	11mm
6	6mm
7	10mm
8	14mm
9	10mm
10	13mm
11	9mm
12	12mm
13	endpiece

Table 2.2. Width of sections from cat 2.

All transverse sections are displayed: caudal to the left, cranial to the right, dorsal to the top and ventral to the bottom.

2.1.4. Sonography

The pelvic region of a live entire male greyhound was clipped to remove all hair and expose the skin. Lines of section, corresponding approximately to the cadaveric lines of section, were drawn on the skin using a coloured permanent marker pen. The dog was positioned initially in the standing position followed by lateral recumbency. The purpose of this study was to evaluate the potential use for this type of display in demonstrating the sonographic anatomy of this region in dogs. The greyhound was scanned using a Siemens Elegra scanner with extended field of view technology and the images acquired digitally. These sonograms were compared to the cross sectional anatomical preparations.

Ultrasonographic exploration of this region has previously proved unsatisfactory as the transducer aperture is small and there is limited continuity of the images. The innovation of extended field ultrasonography now allows for the integrated display of seamless real-time segments into one large composite image. This can cover a field of up to 60cms, thus eliminating the need to subjectively piece together a picture. This is a new, unique and highly sophisticated imaging technology called SieScape. It is designed to provide a seamless ultrasound image covering an area substantially larger than a normal transducer aperture. As the transducer is scanned over a region of the body, real time segments are analysed and then combined with prior images stored in the memory. The similarities between successive images are evaluated, compared to detect the probe motion, aligned with one another and displayed together as a single large composite image. These images provide a visual link of contiguous organs and anatomical structures into one image, eliminating the need to subjectively piece together a picture. This extended field of view ultrasound makes use of the Fuzzy Logic technique to increase simplicity, flexibility and performance. Fuzzy Logic simplifies the analysis of continuous phenomena not easily broken down into discrete segments.

2.1.5. Radiography

Before sectioning, cat 2 was noted to have an irregular and palpably unsymmetrical pelvis. After sectioning, the bony areas were obviously unbalanced and irregular. In order to demonstrate this atypical anatomy more effectively, each section was radiographed on an 18cm x 24cm Ultravision cassette, using an accelerating voltage of 47kV / 3.2mAs. The radiographs were then compared to the original sections.

2.2. RESULTS

2.2.1. Transverse sections and sonograms of dog 1

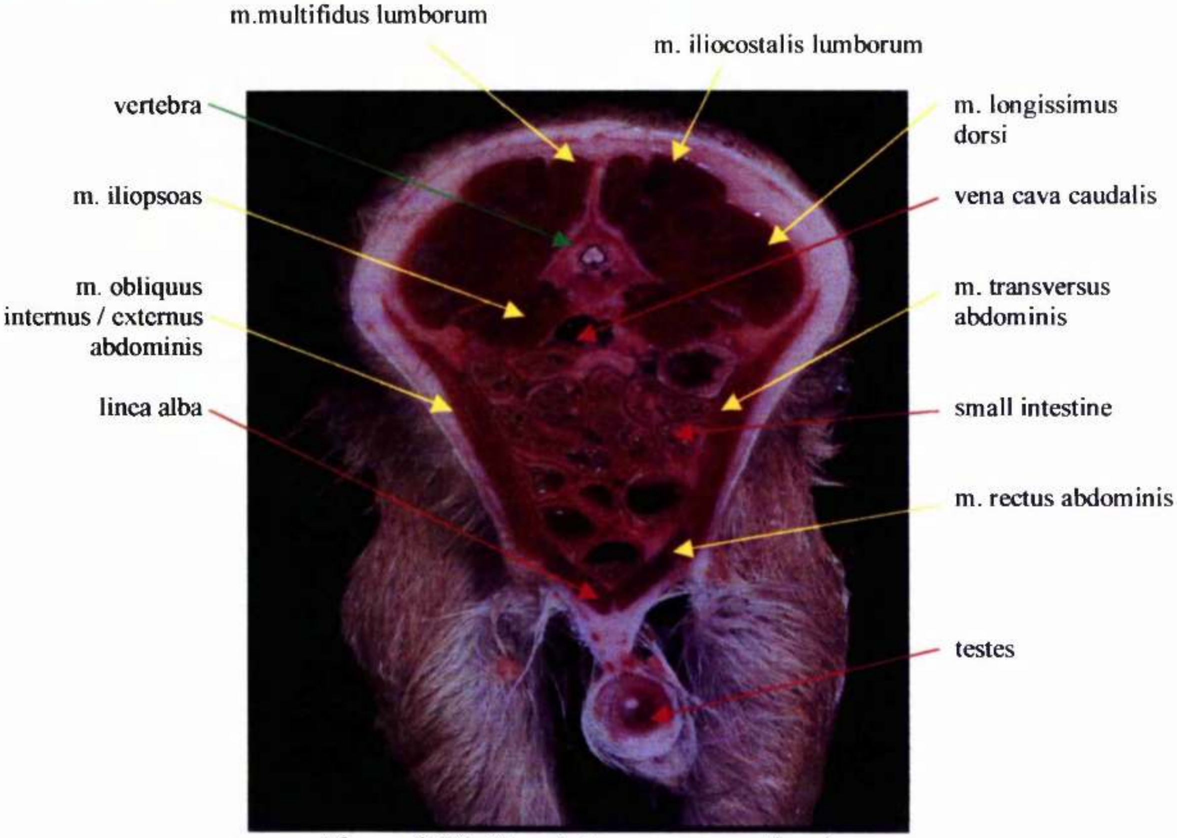


Figure 2.10. Dog 1, transverse section 1.

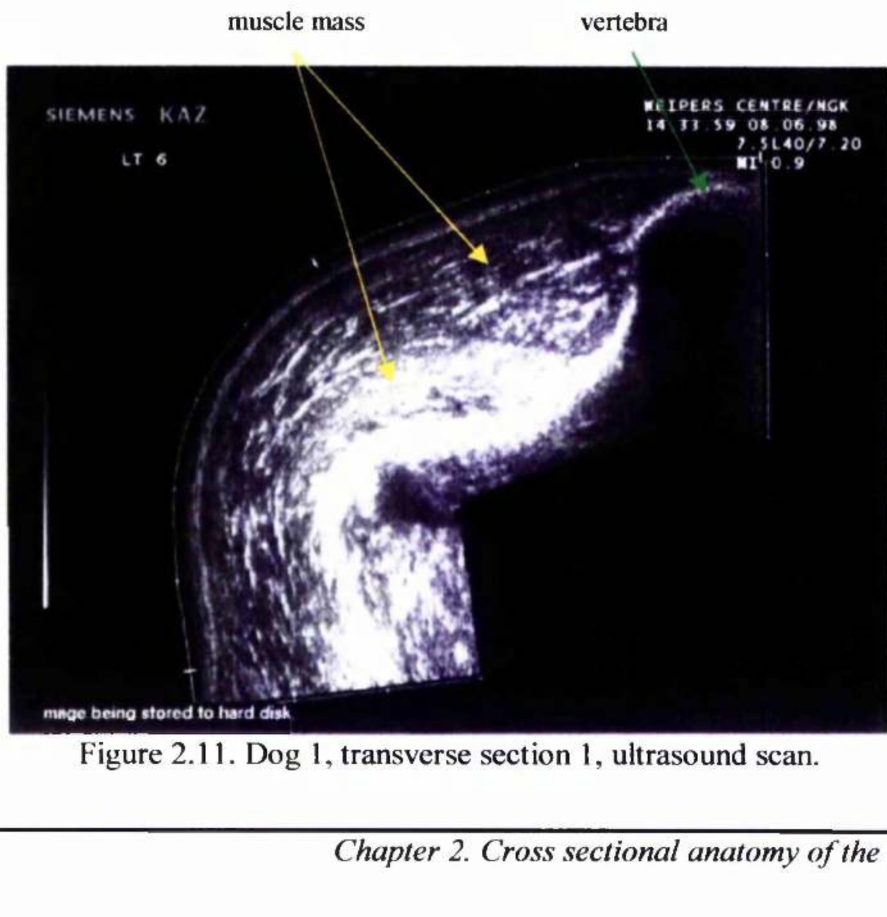


Figure 2.11. Dog 1, transverse section 1, ultrasound scan.

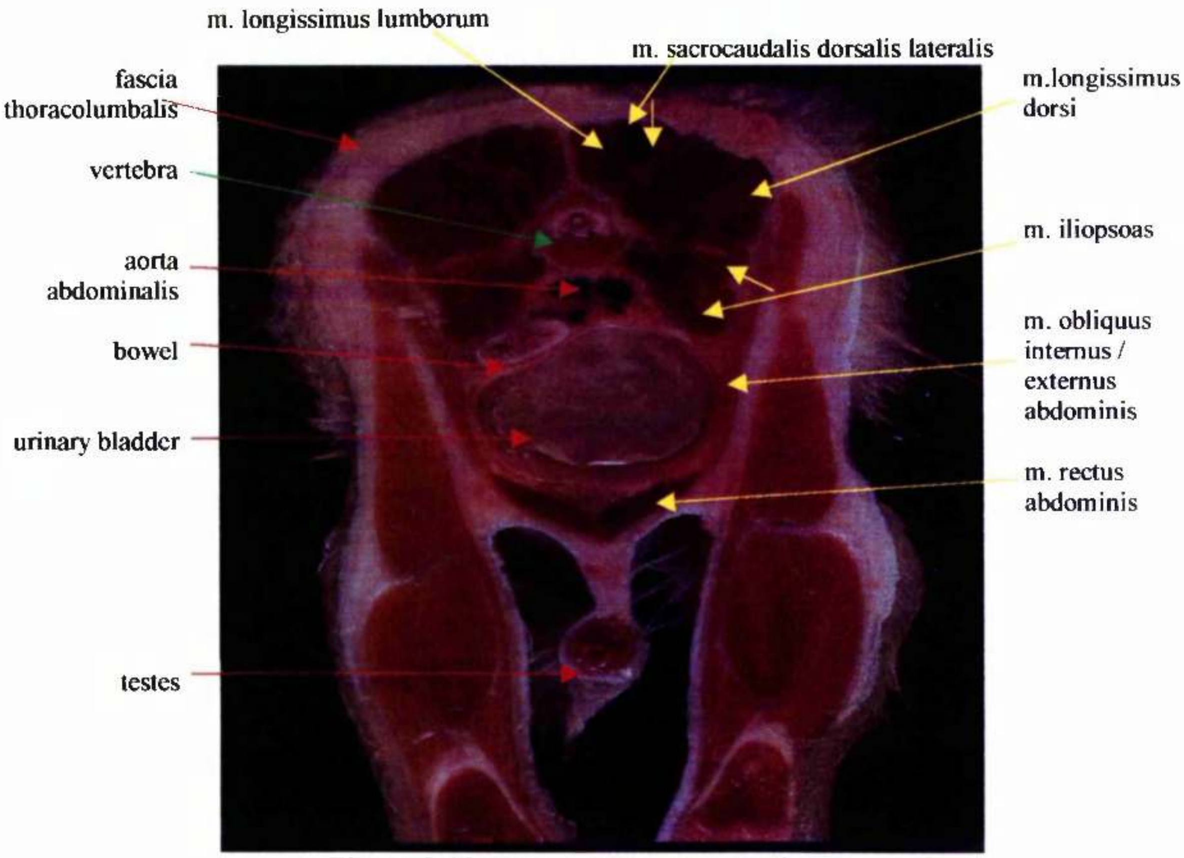


Figure 2.12. Dog 1, transverse section 2.

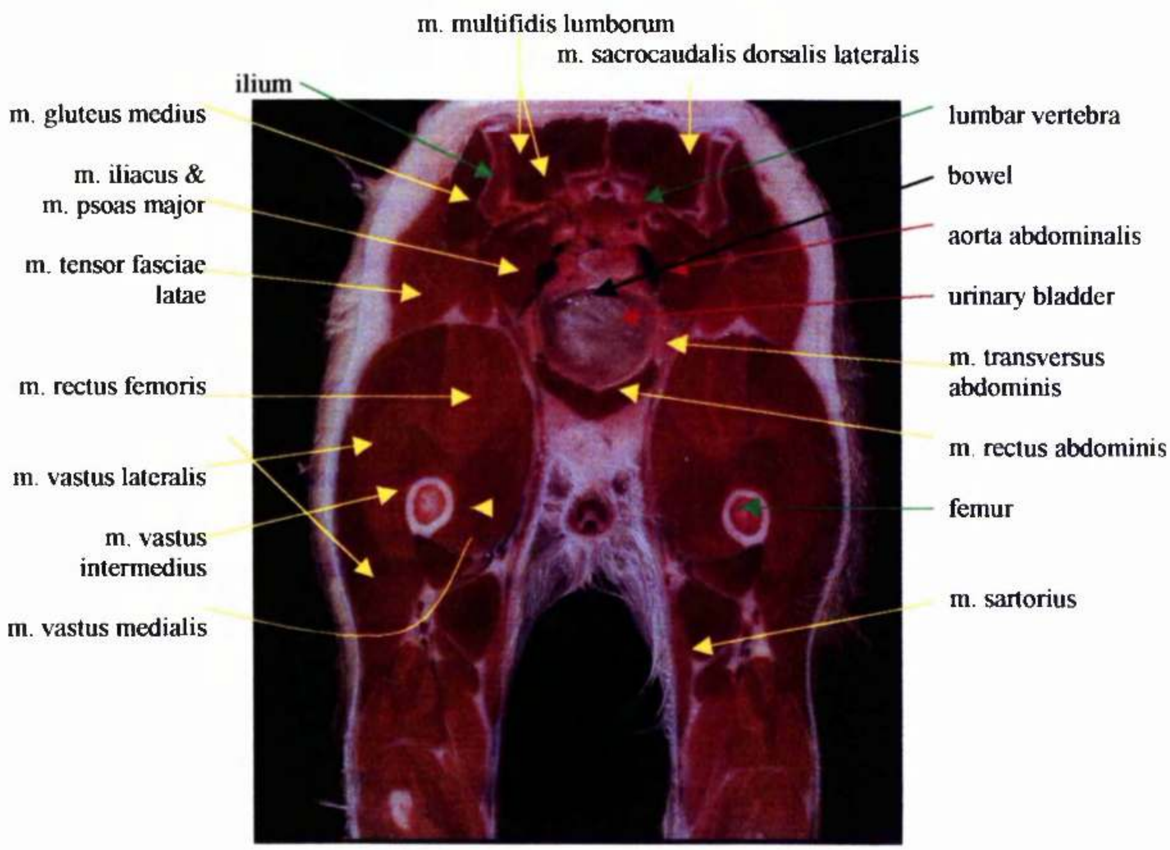


Figure 2.13. Dog 1, transverse section 3.

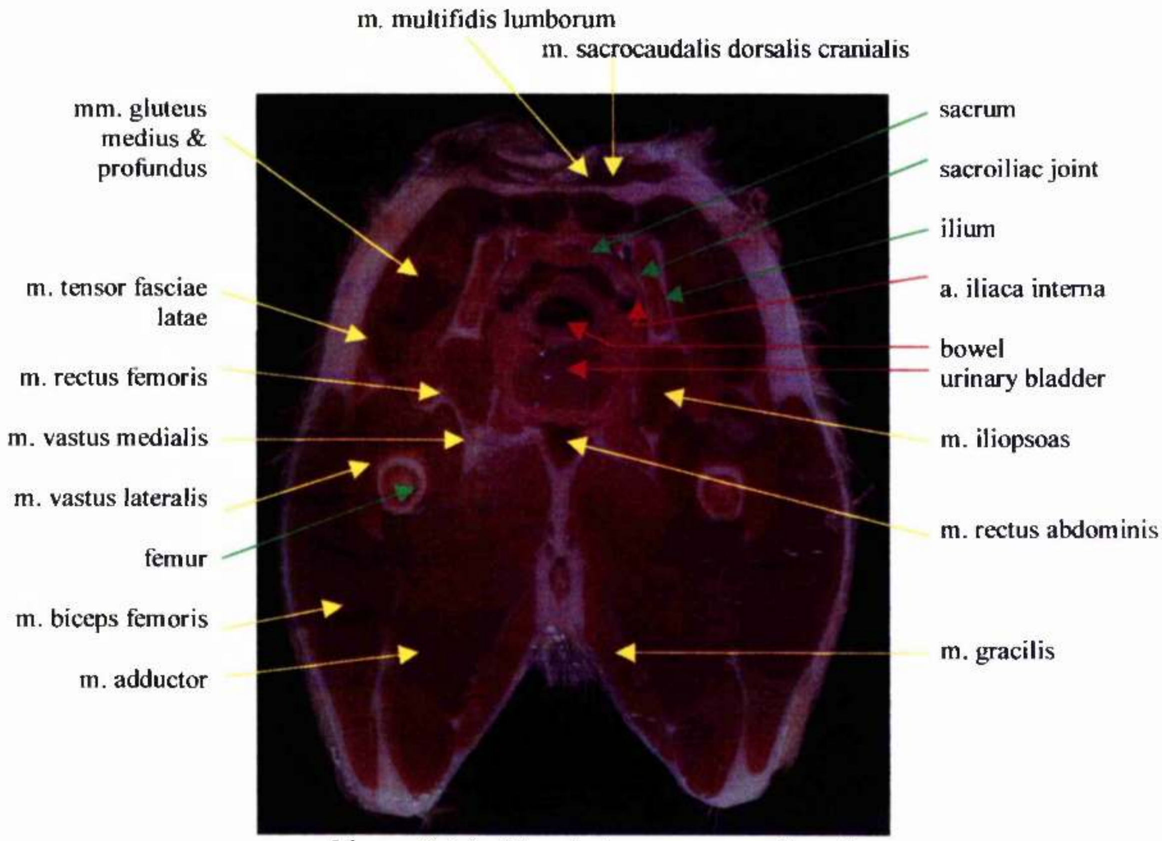


Figure 2.14. Dog 1, transverse section 4.

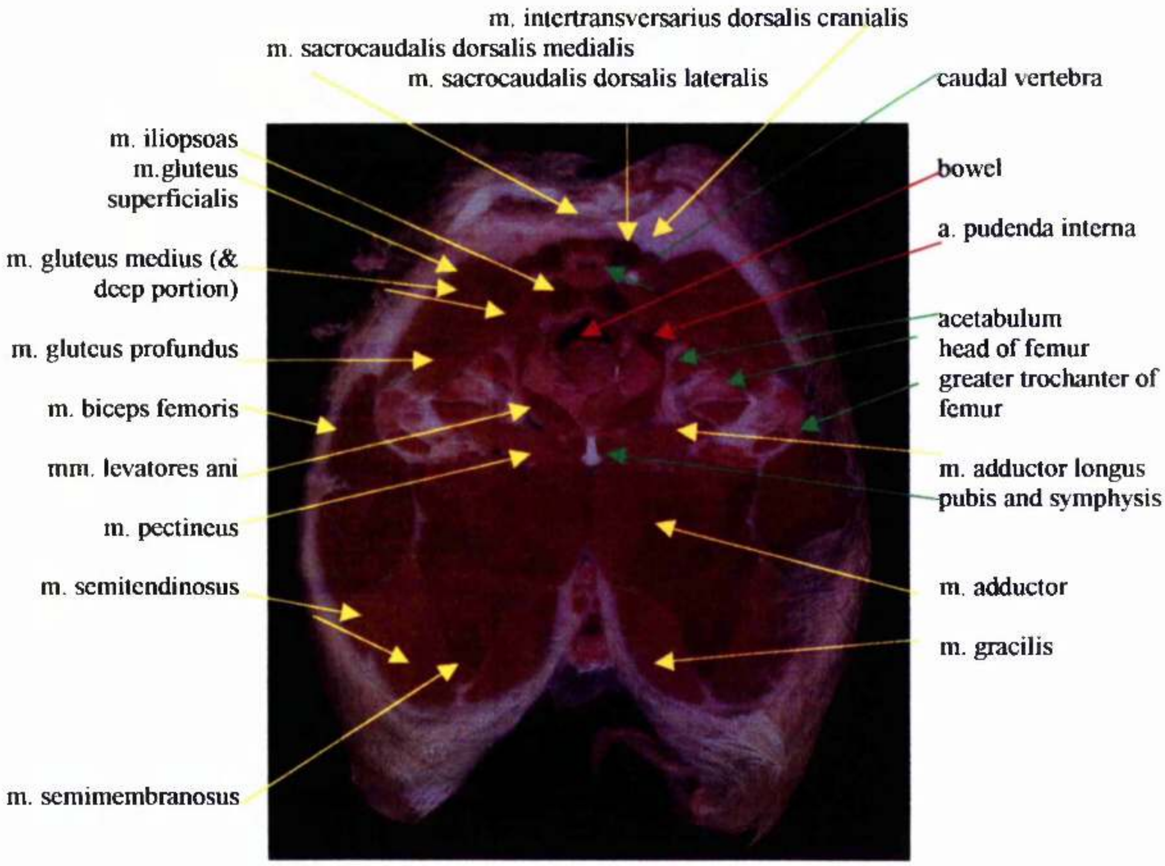


Figure 2.15. Dog 1, transverse section 5.

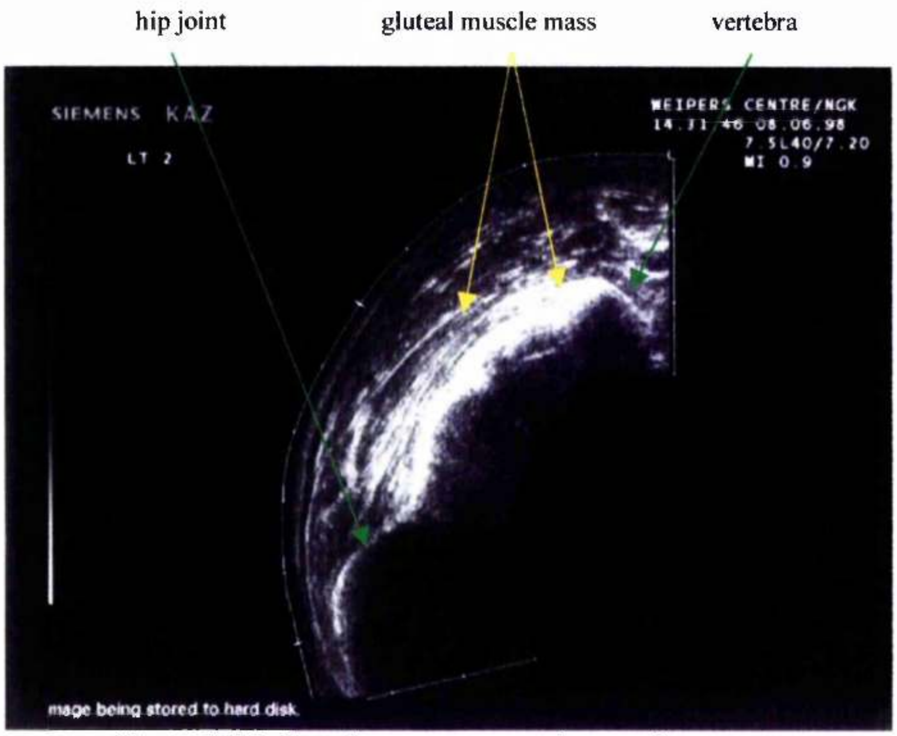


Figure 2.16. Dog 1 transverse section 5, ultrasound.

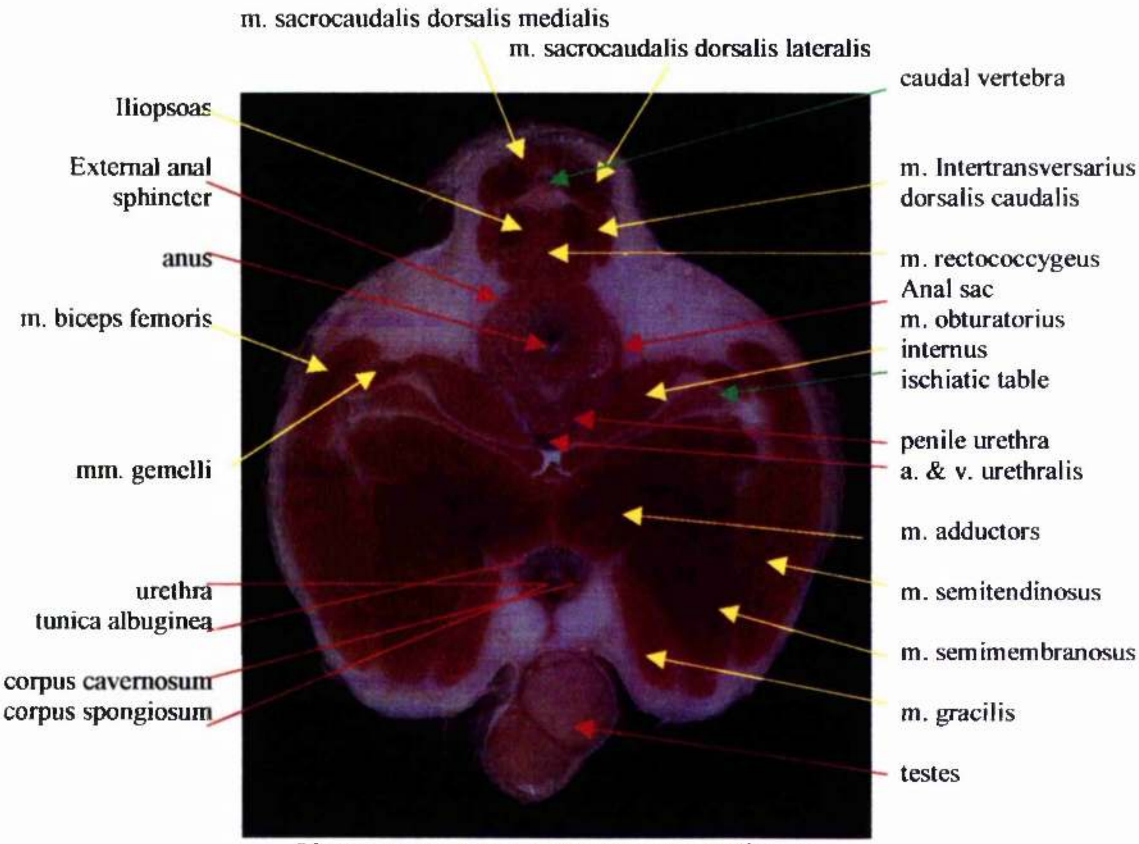


Figure 2.17. Dog 1, transverse section 6.

2.2.2. Radial sections and sonograms of dog 2

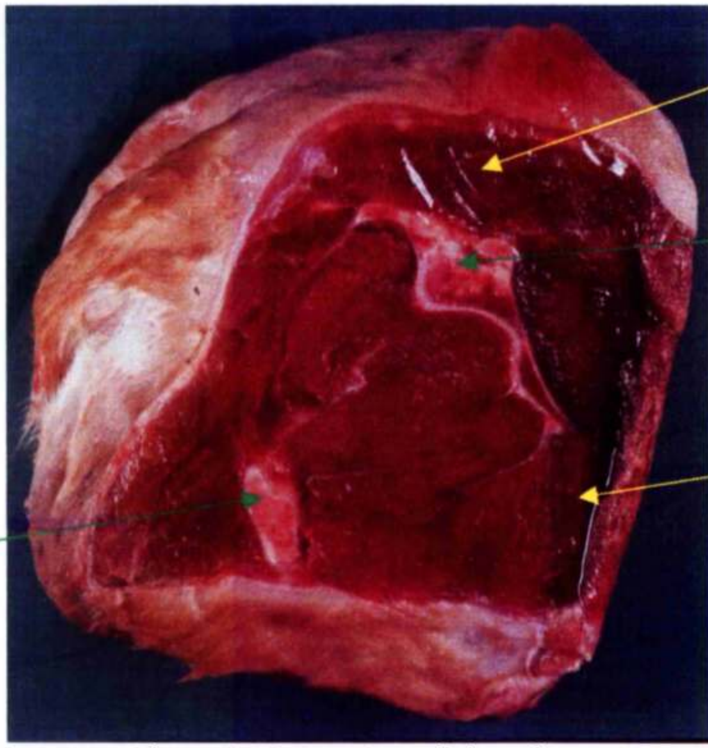


Figure 2.18. Dog 2, radial section 1.

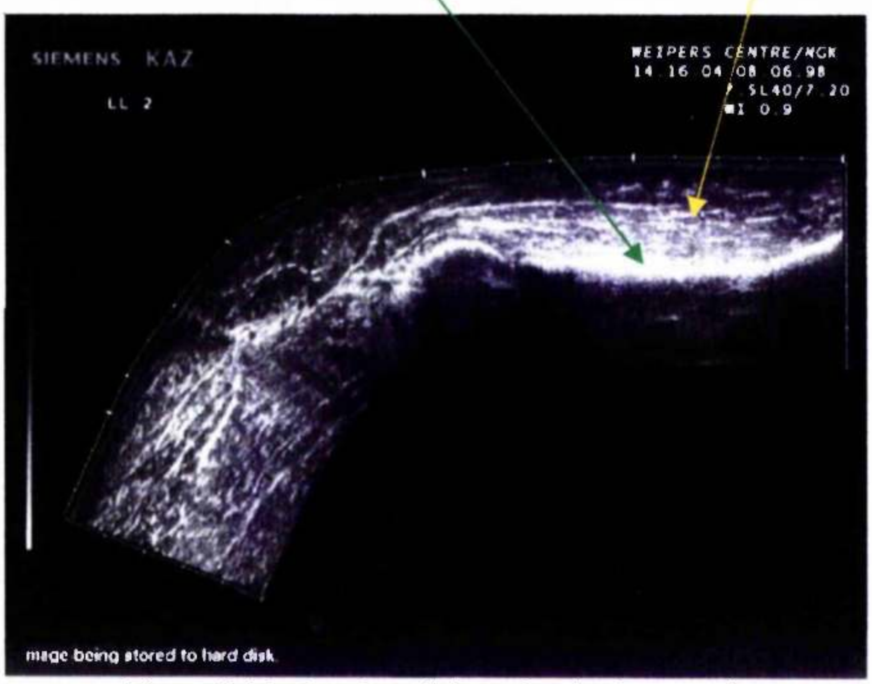


Figure 2.19. Dog 2, radial section 1, ultrasound.

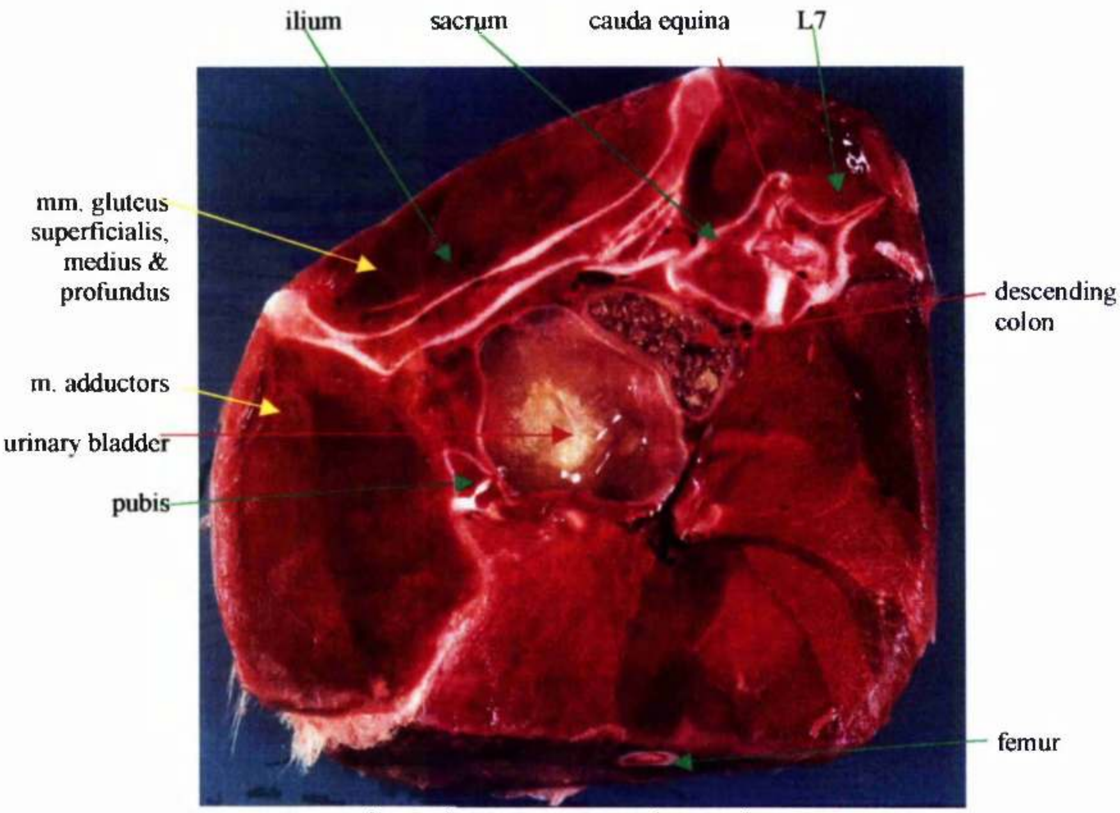


Figure 2.20. Dog 2, radial section 2.

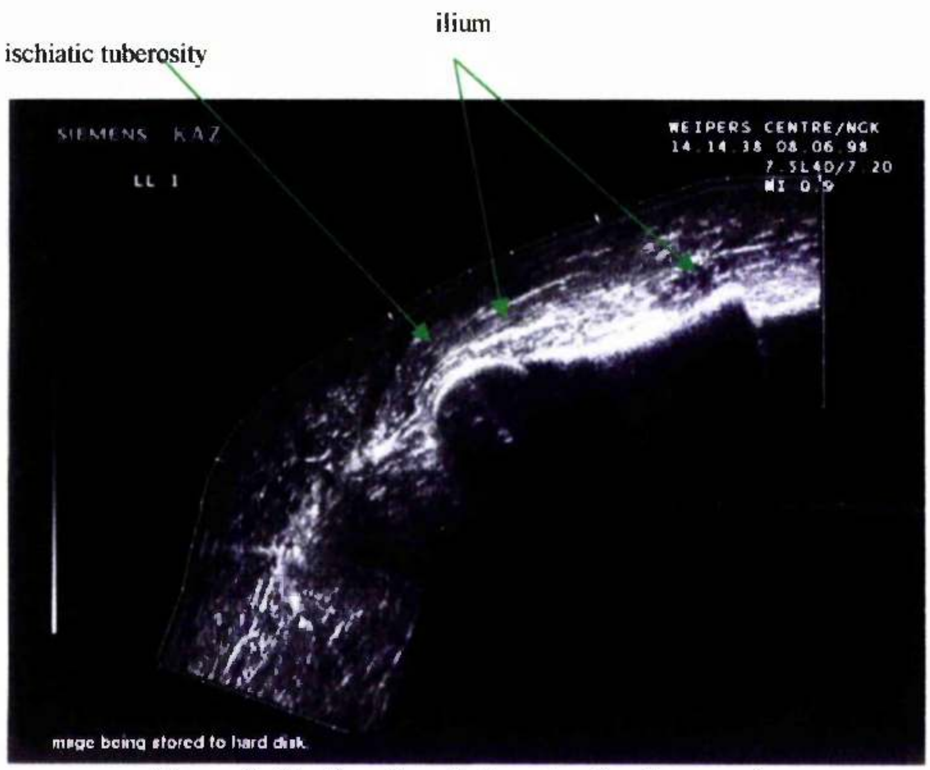


Figure 2.21. Dog 2, radial section 2, ultrasound.

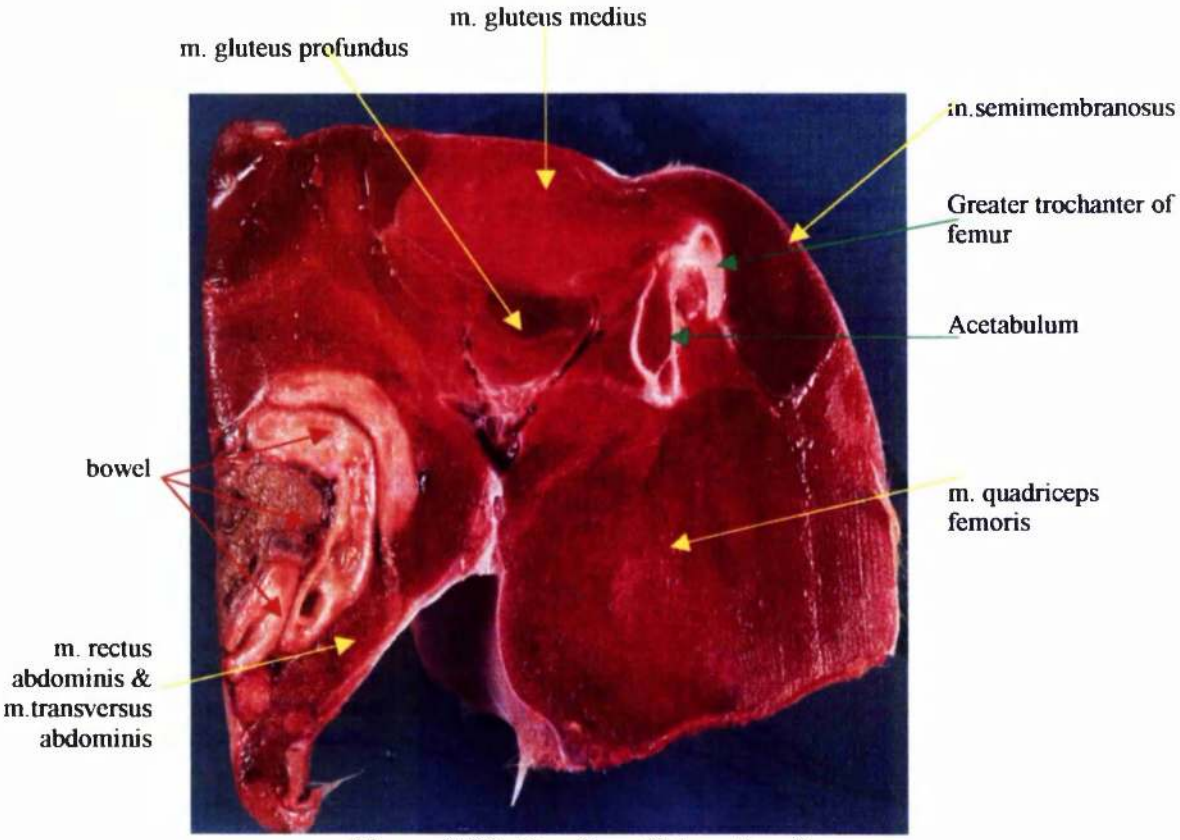


Figure 2.22. Dog 2, radial section 3.

2.2.3. Ultrasonography of transverse sections

Figure 2.11 is the sonogram, which corresponds to the gross section illustrated in Figure 2.10. It was possible to image the dorsal lumbar muscles, which are clearly seen in the cross section. Figure 2.16 is the ultrasound scan which corresponds to the section illustrated in Figure 2.15. Both the gluteal muscle region and the hip joint are well illustrated by the continuous hyperechoic line.

2.2.4. Ultrasonography of radial sections

Figure 2.19 is the ultrasound scan which corresponds to the section illustrated in Figure 2.18. Using the hip joint as a marker the continuity of the musculature of the region can be seen. Figure 2.21 is the ultrasound scan which corresponds to the section illustrated in Figure 2.20. Again using the hip joint as a marker the extended field gives us maximum benefit to demonstrate the muscle groups. The hyperechoic contour of the ilium and ischium are clearly illustrated with the overlying gluteal muscle mass.

2.2.5. Transverse sections of cat

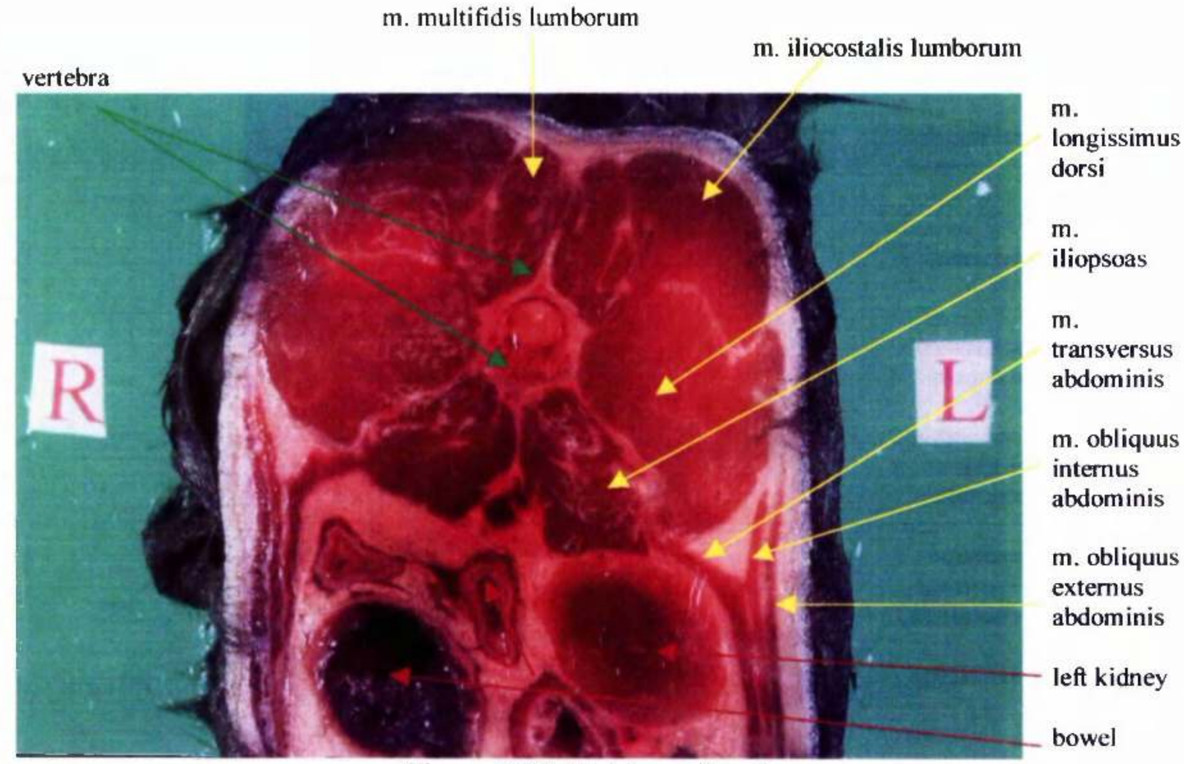


Figure 2.23. Cat 1, section 1.

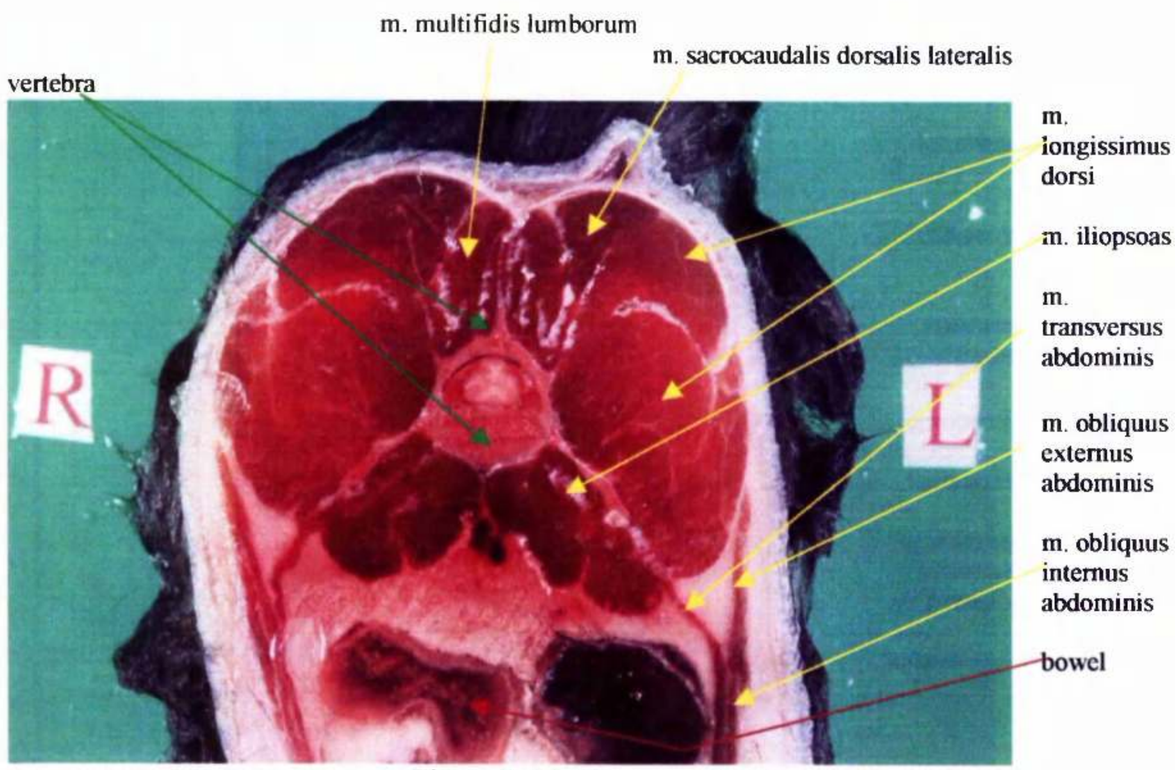


Figure 2.24. Cat 1, section 2.

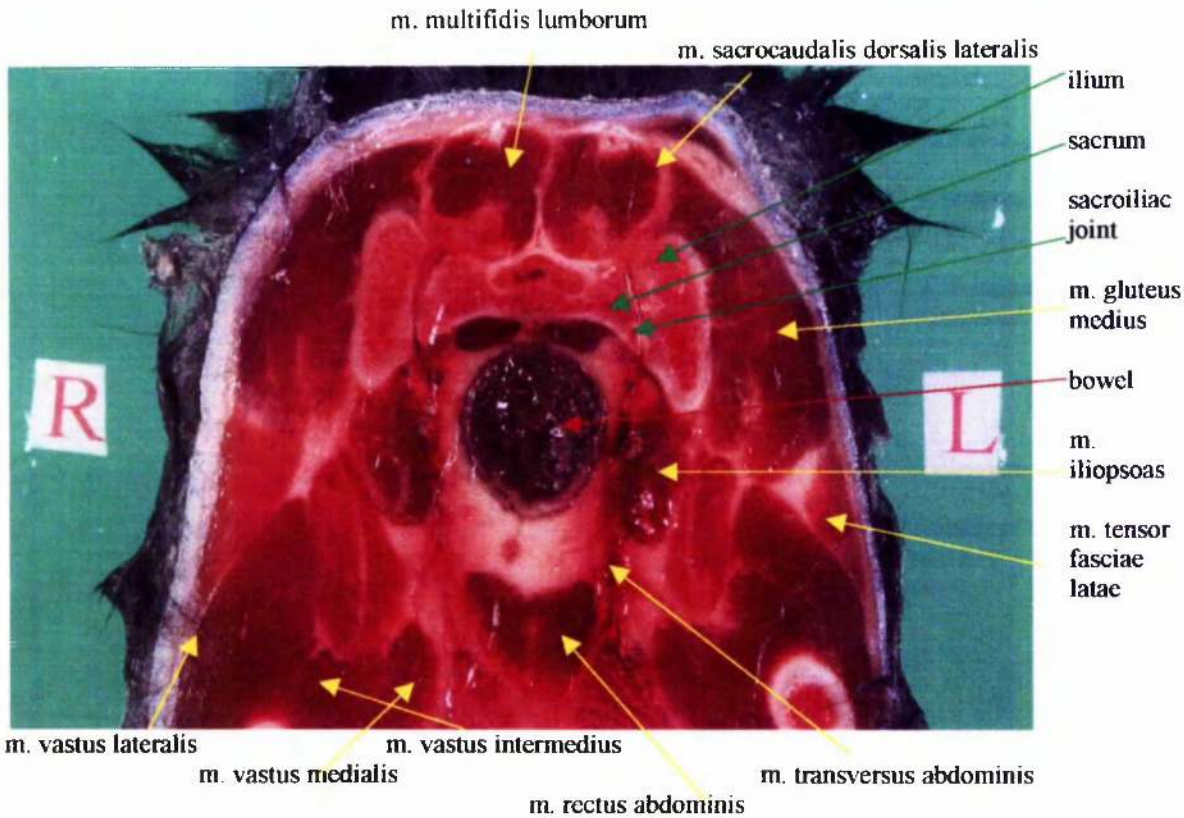


Figure 2.25. Cat 1, section 3.

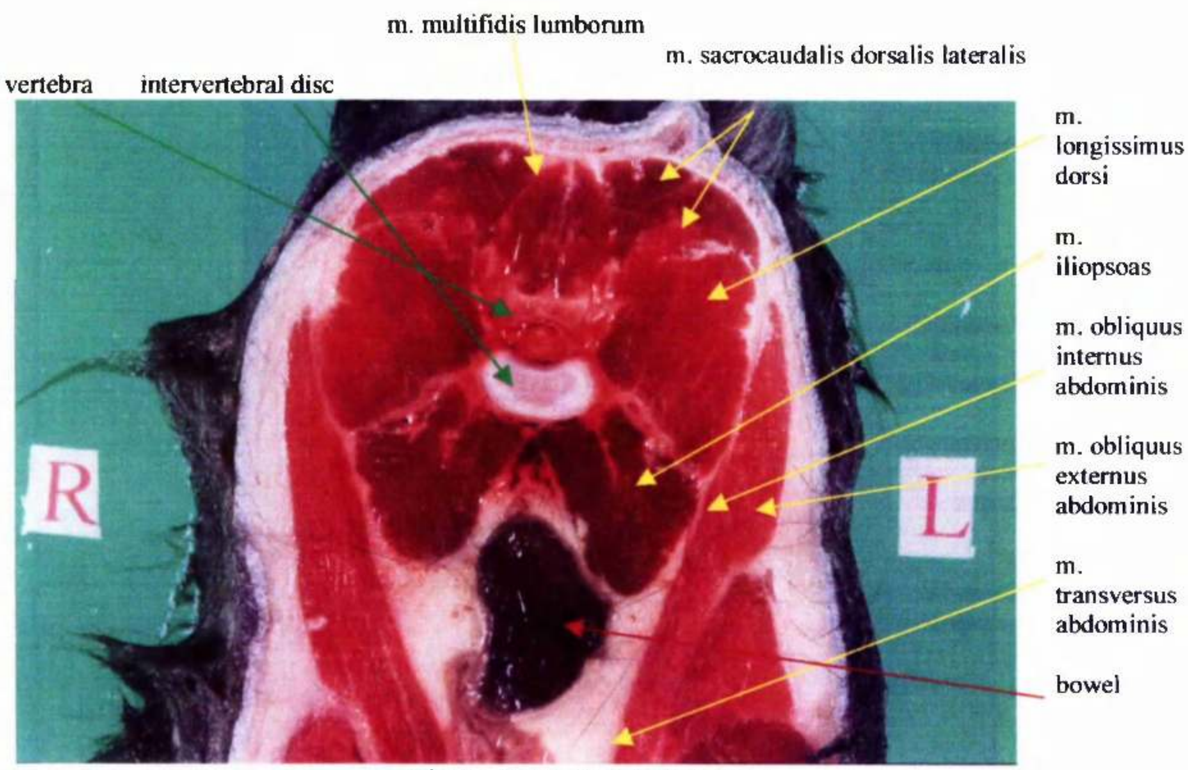


Figure 2.26. Cat 1, section 4.

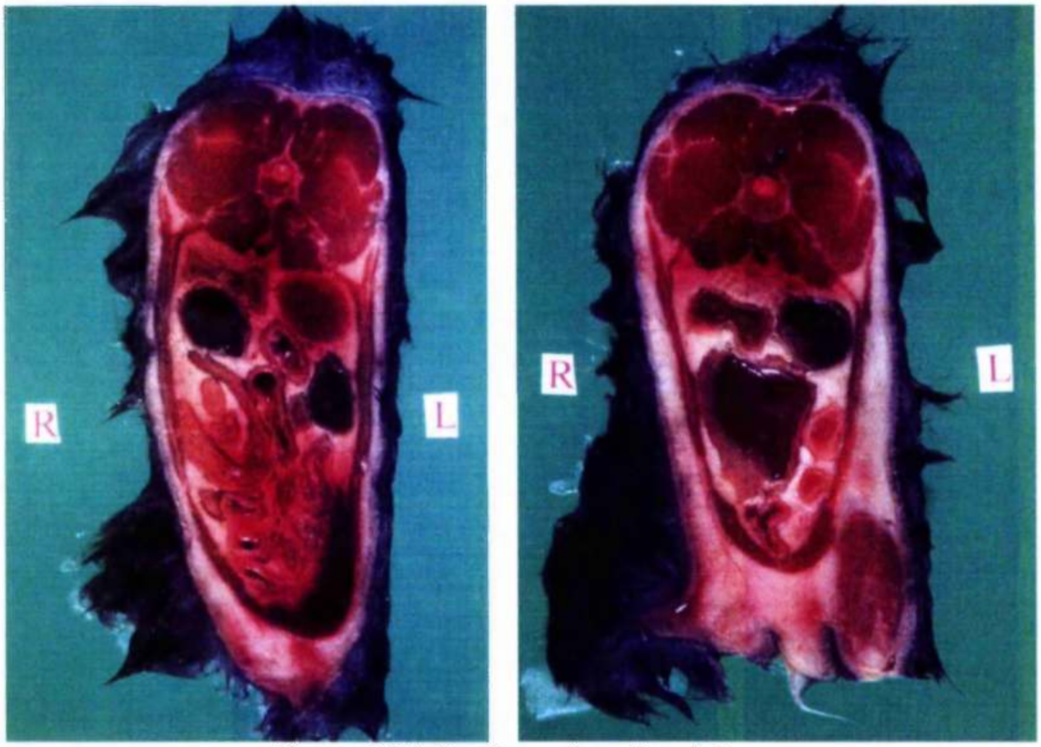


Figure 2.27. Cat 1, sections 1 and 2.

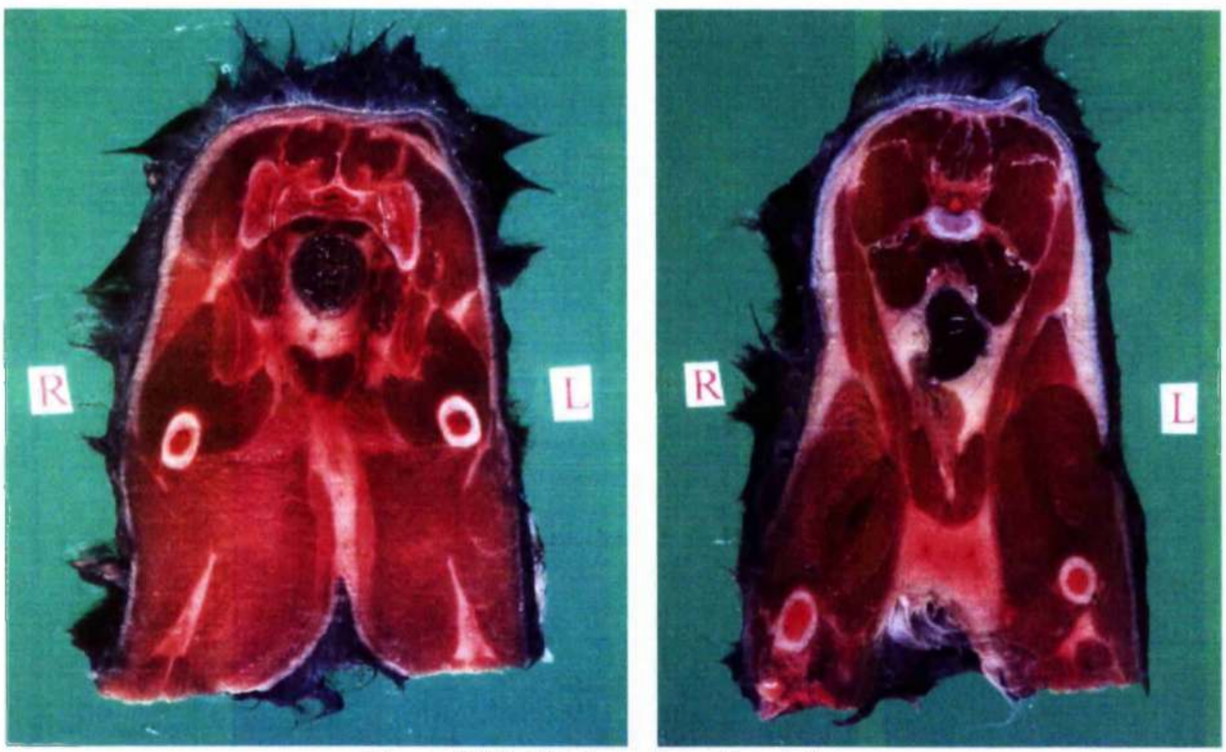


Figure 2.28. Cat 1, sections 3 and 4.

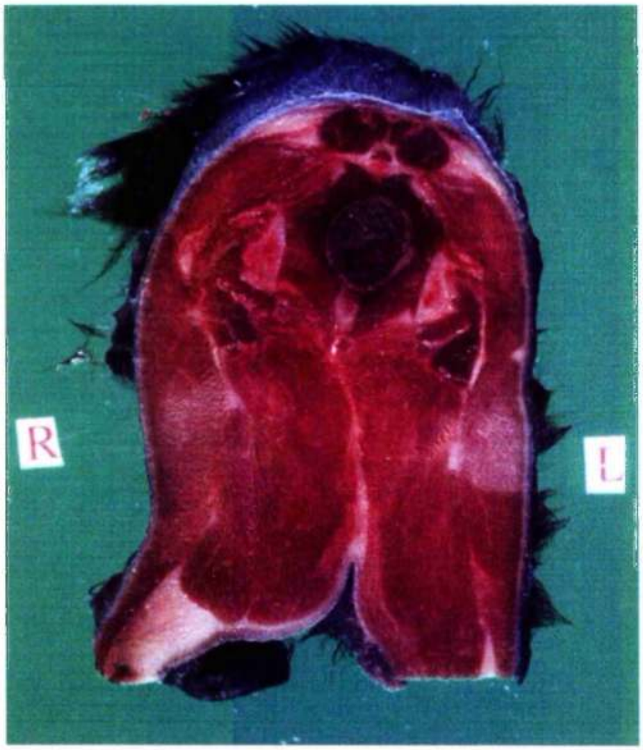


Figure 2.29. Cat 1, section 5.

2.2.6. Transverse sections of cat

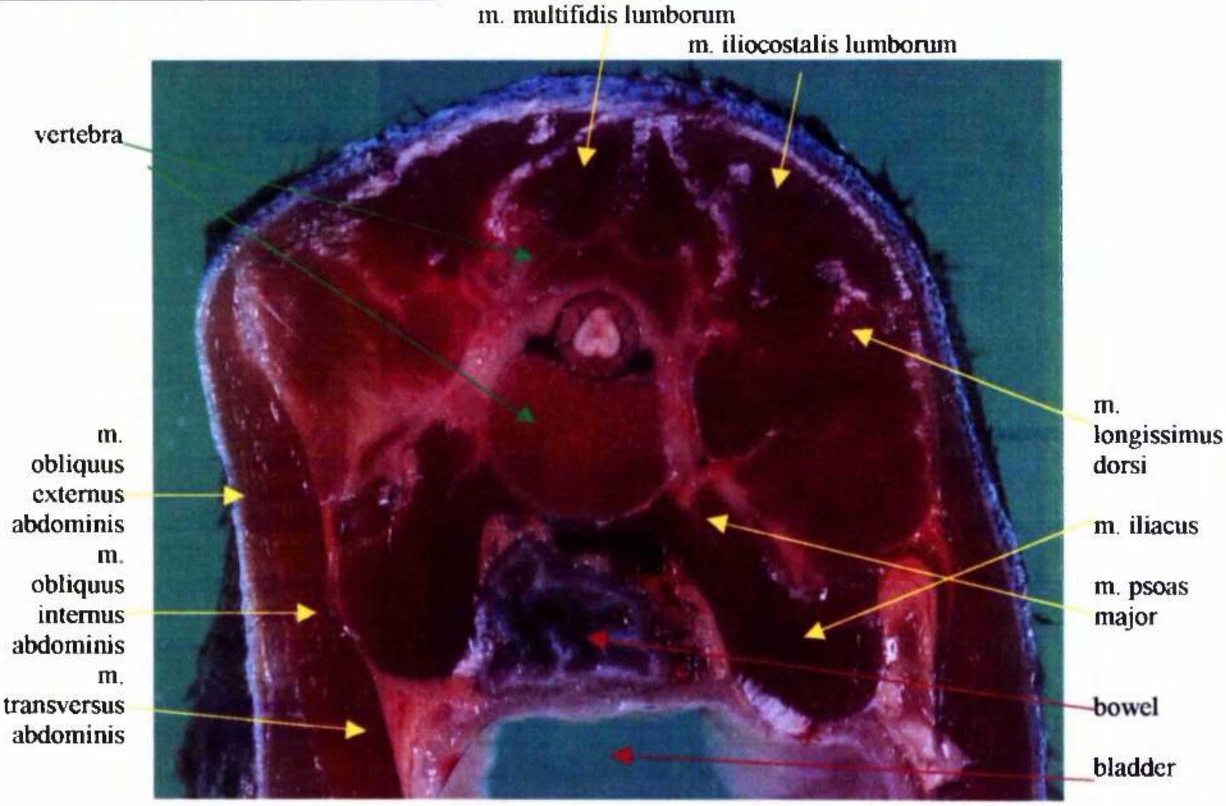


Figure 2.30. Cat 2, section 8.

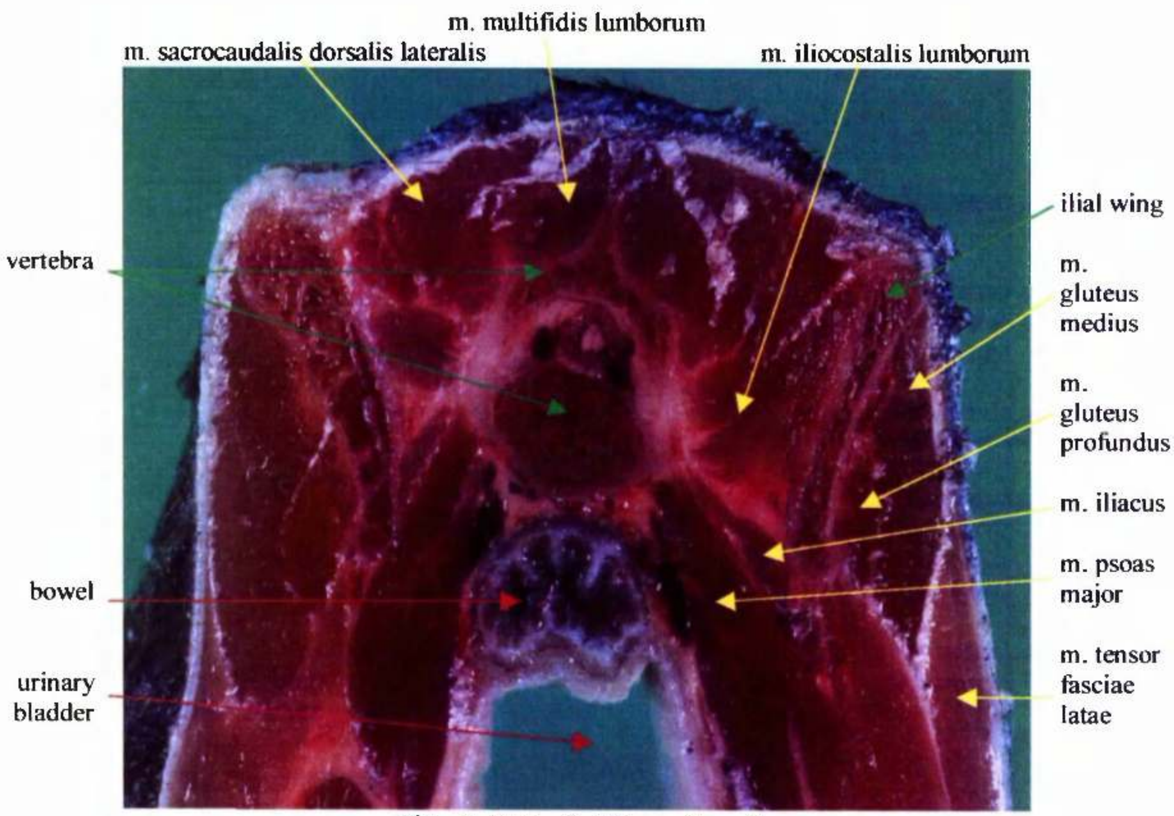


Figure 2.31. Cat 2, section 9

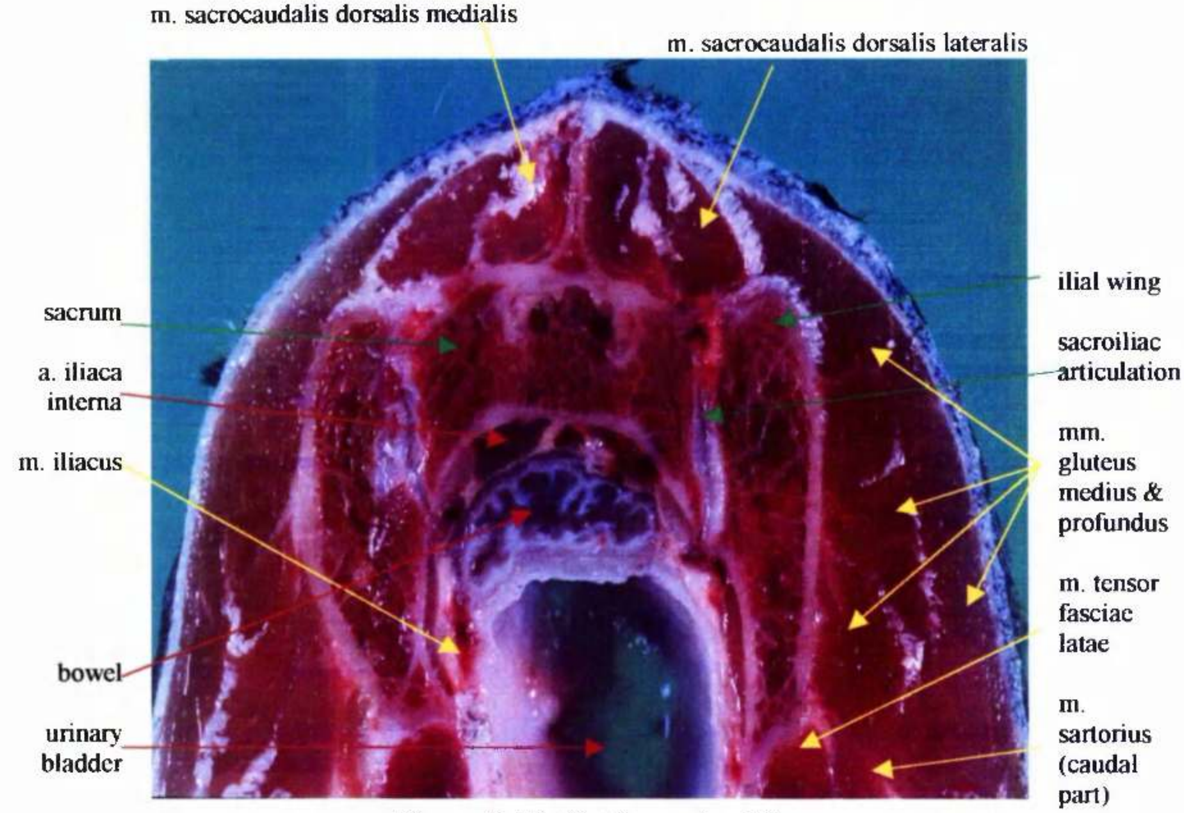


Figure 2.32. Cat 2, section 10.

Figure 2.33. Cat 2, section 11.

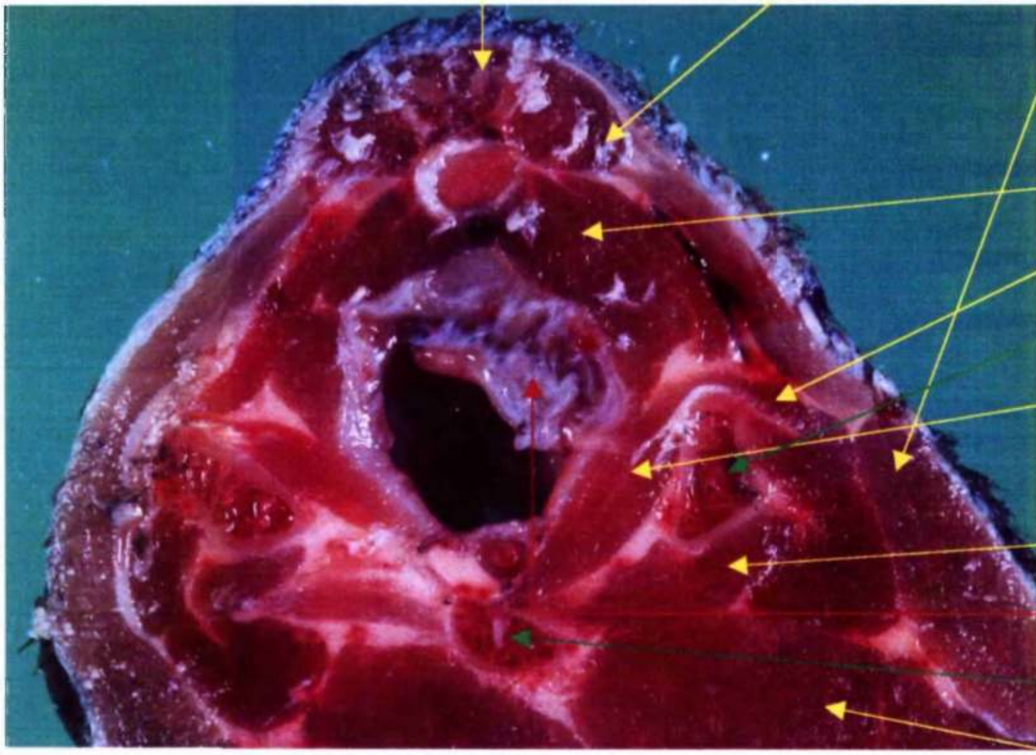


Figure 2.34. Cat 2, section 12.

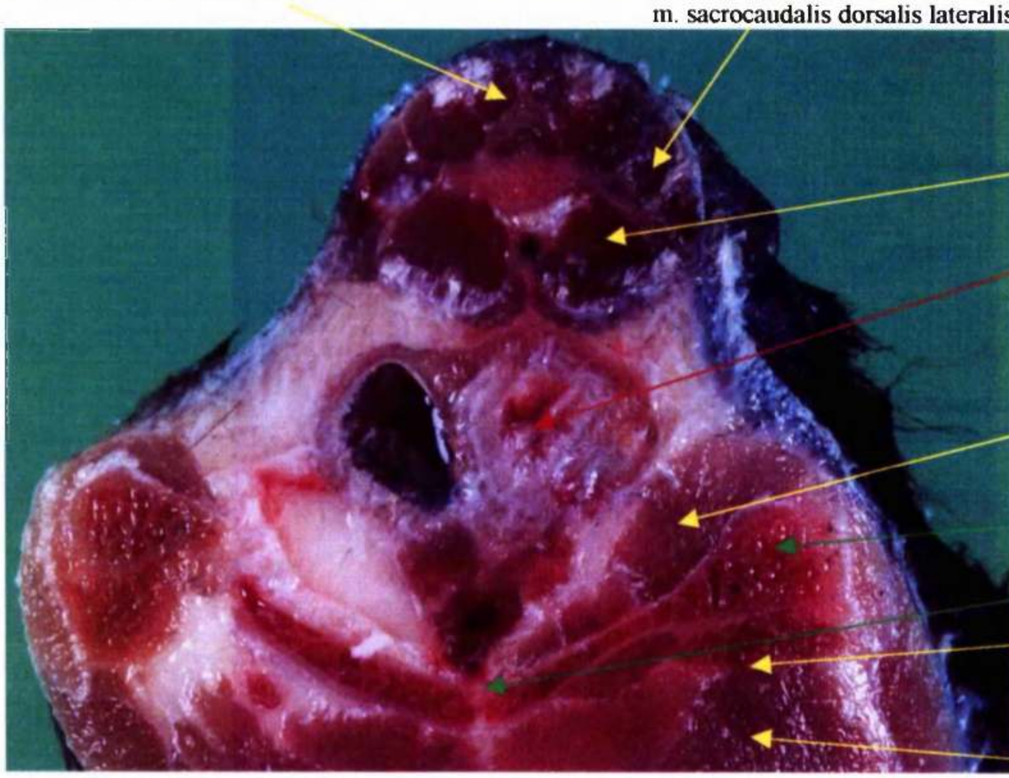


Figure 2.35. Cat 2, section 13.

2.2.7. Transverse sections and radiographs of cat

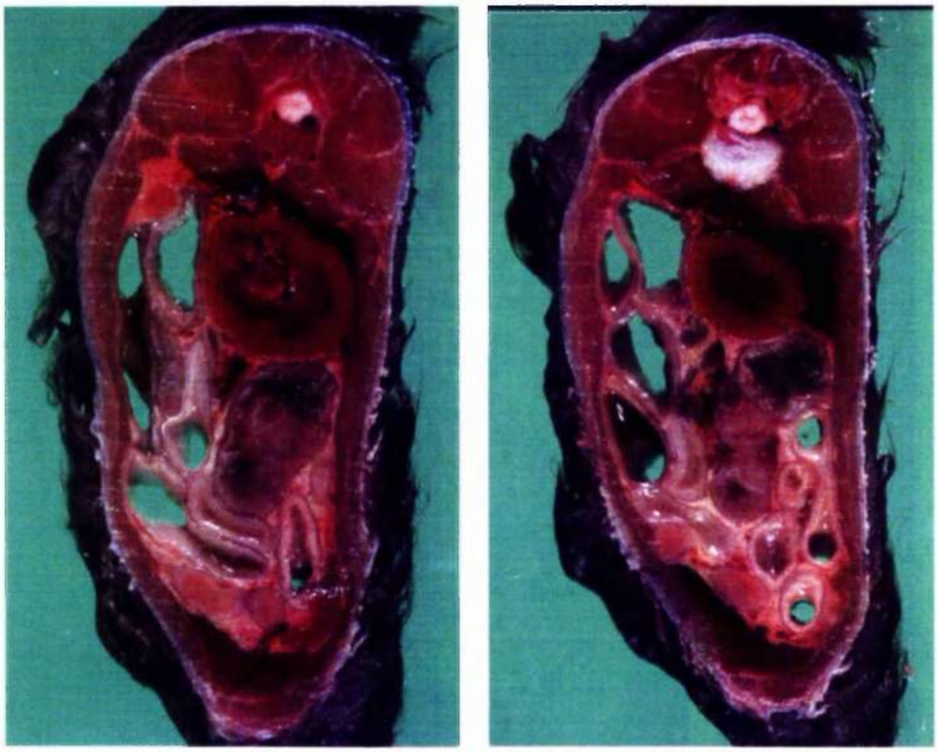


Figure 2.36. Cat 2, sections 1 and 2.

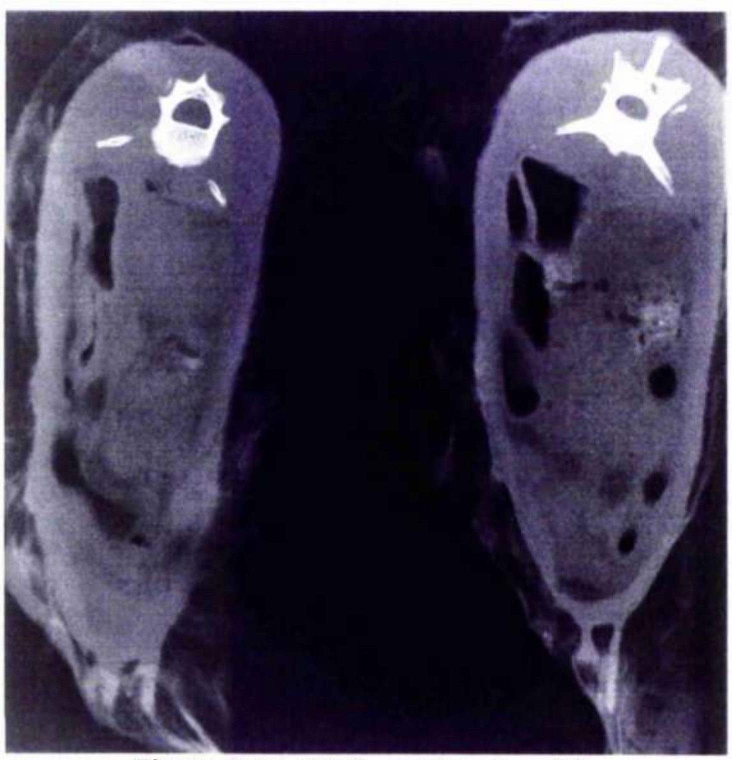


Figure 2.37. Cat 2, sections 1 and 2.

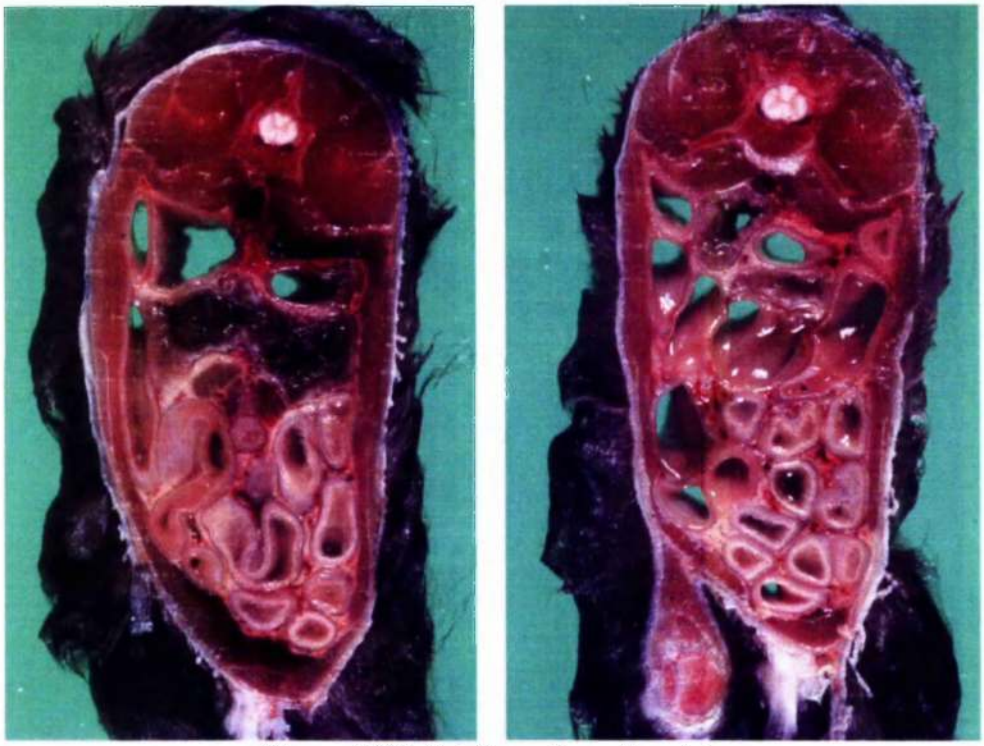


Figure 2.38. Cat 2, sections 3 and 4.

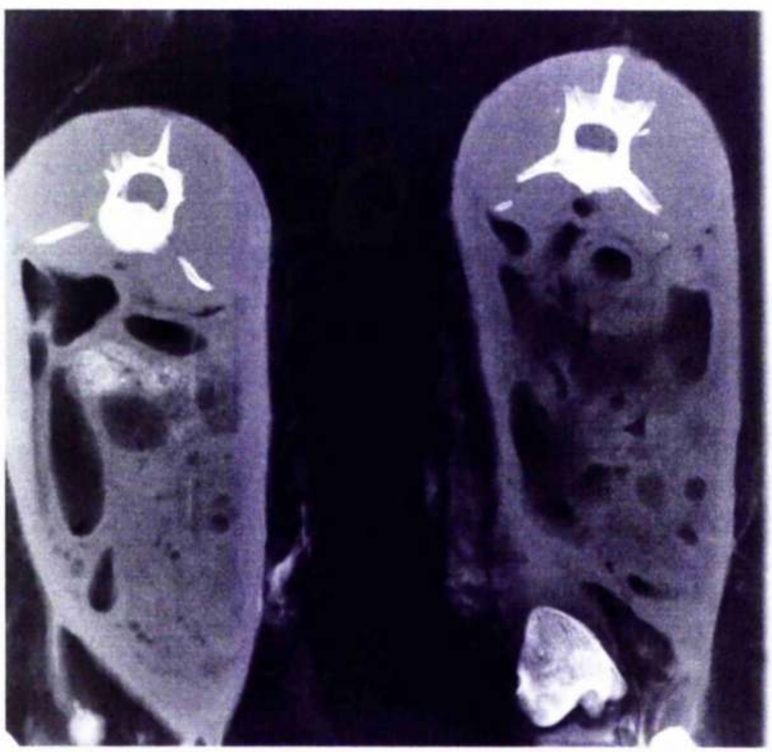


Figure 2.39. Cat 2, sections 3 and 4.

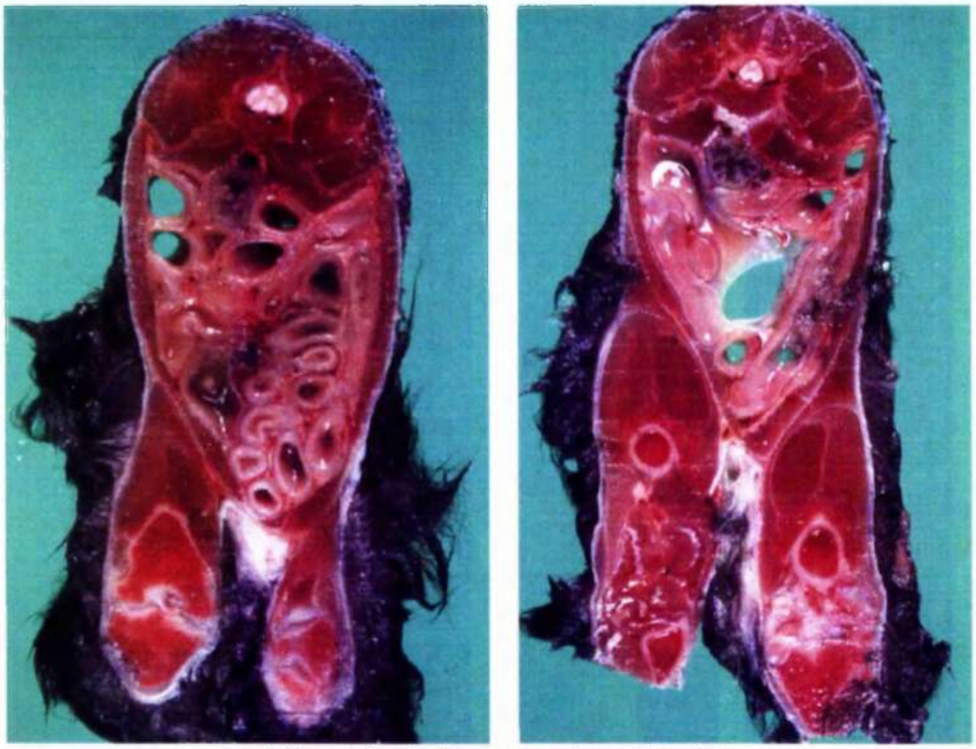


Figure 2.40. Cat 2, sections 5 and 6.

Figure 2.41. Cat 2, sections 5 and 6.

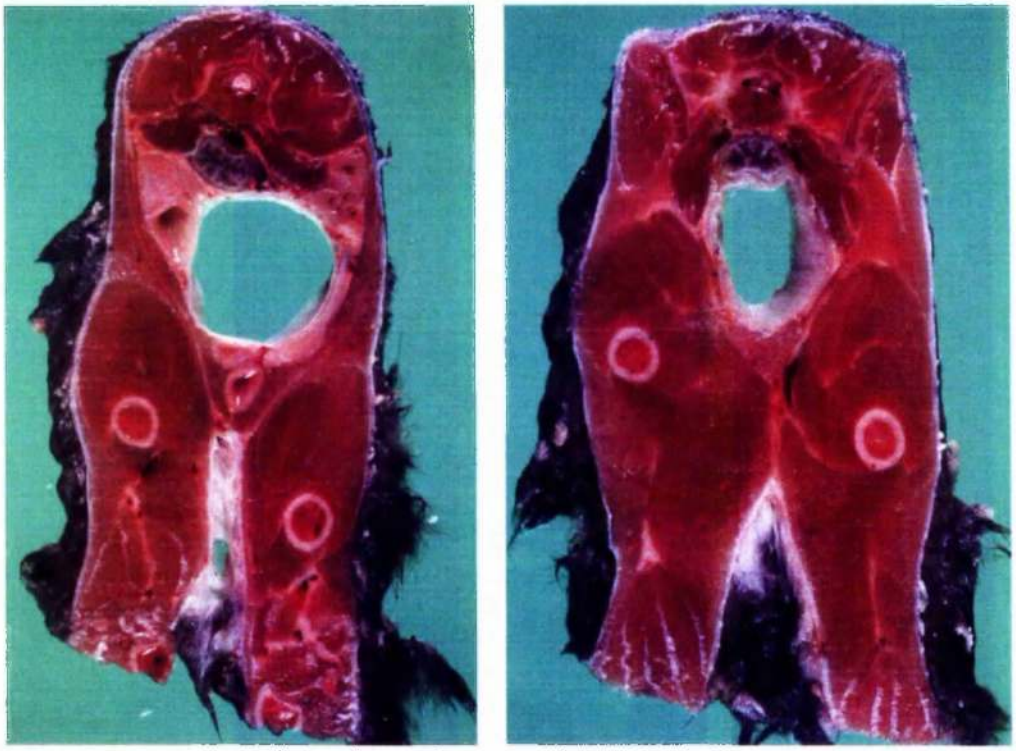


Figure 2.42. Cat 2, sections 7 and 8.

Figure 2.43. Cat 2, sections 7 and 8.

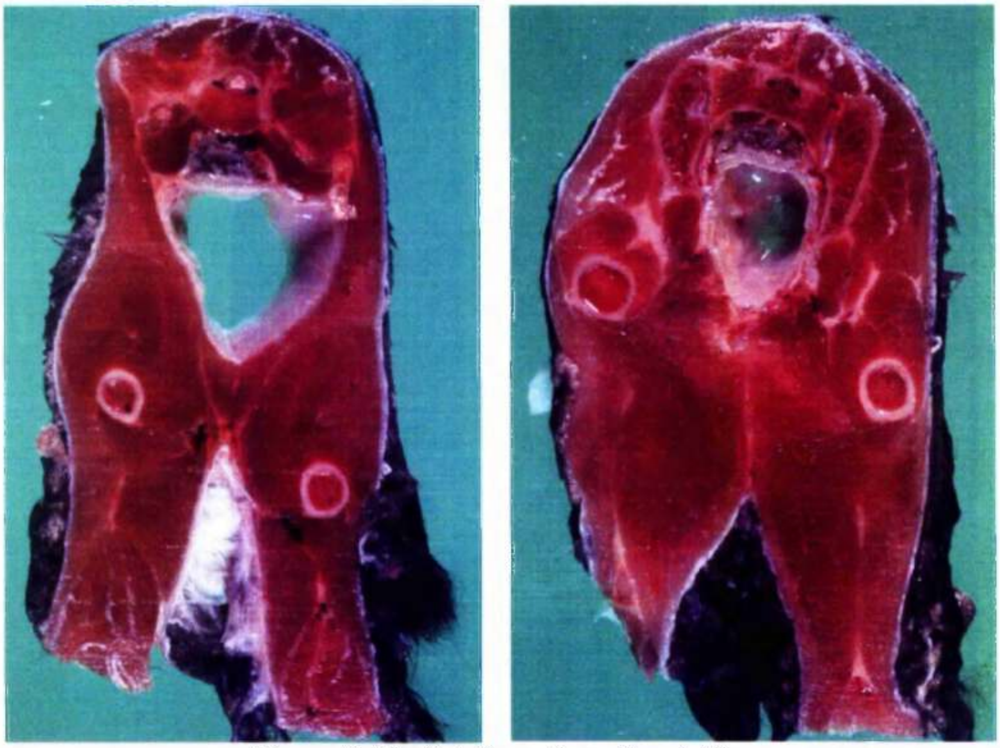


Figure 2.44. Cat 2, sections 9 and 10.

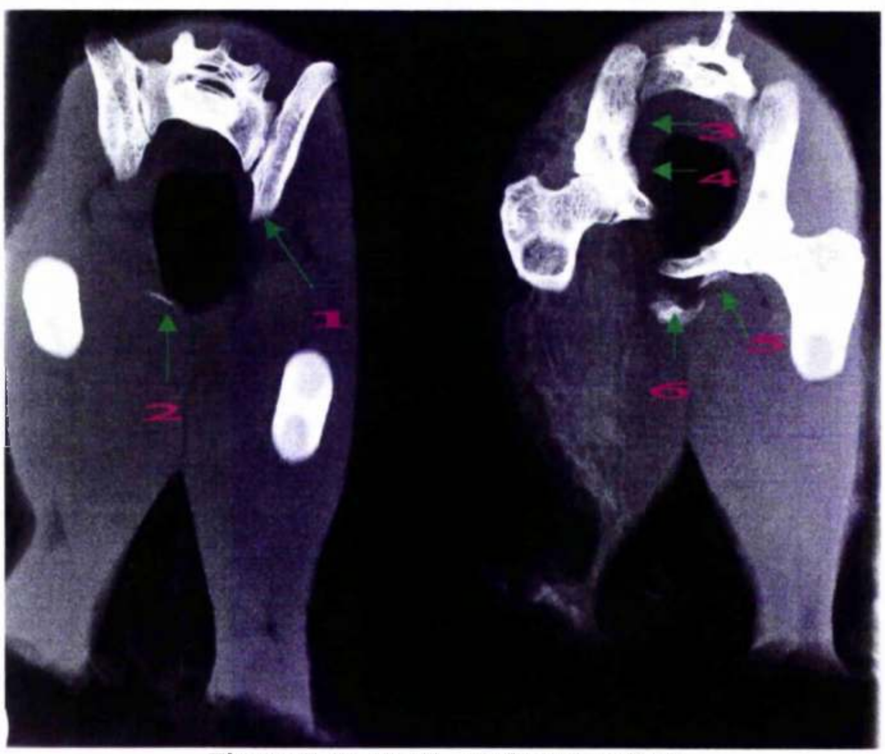


Figure 2.45. Cat 2, sections 9 and 10

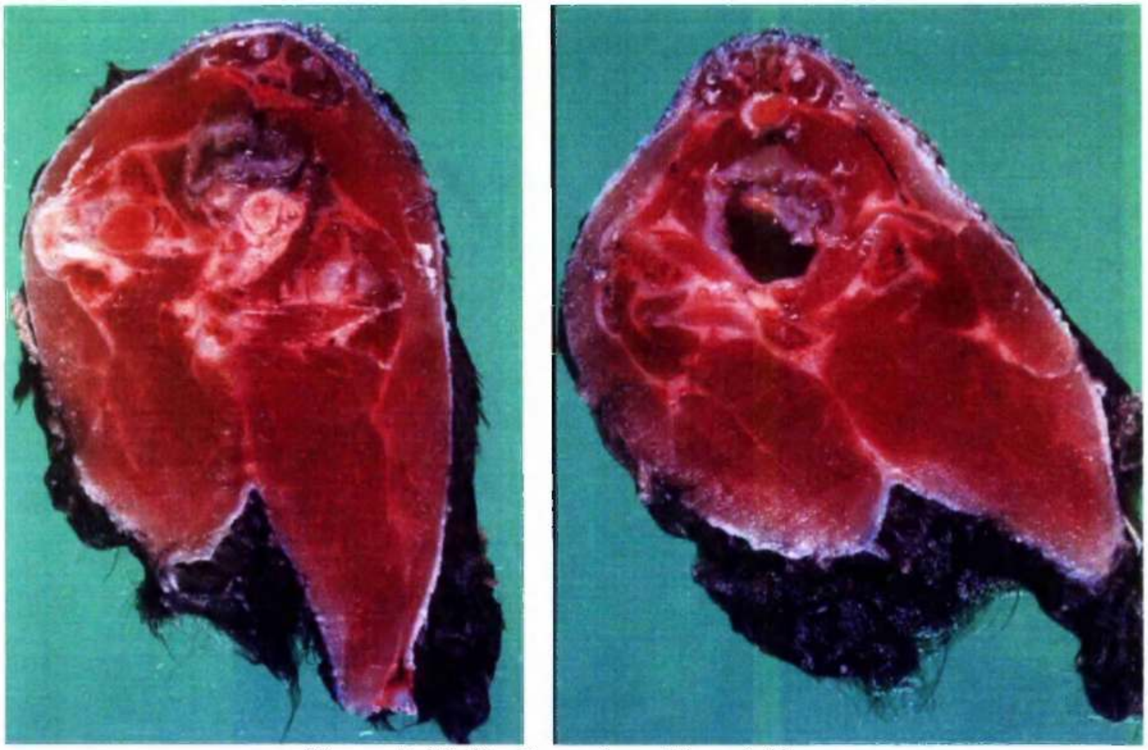


Figure 2.46. Cat 2, sections 11 and 12.

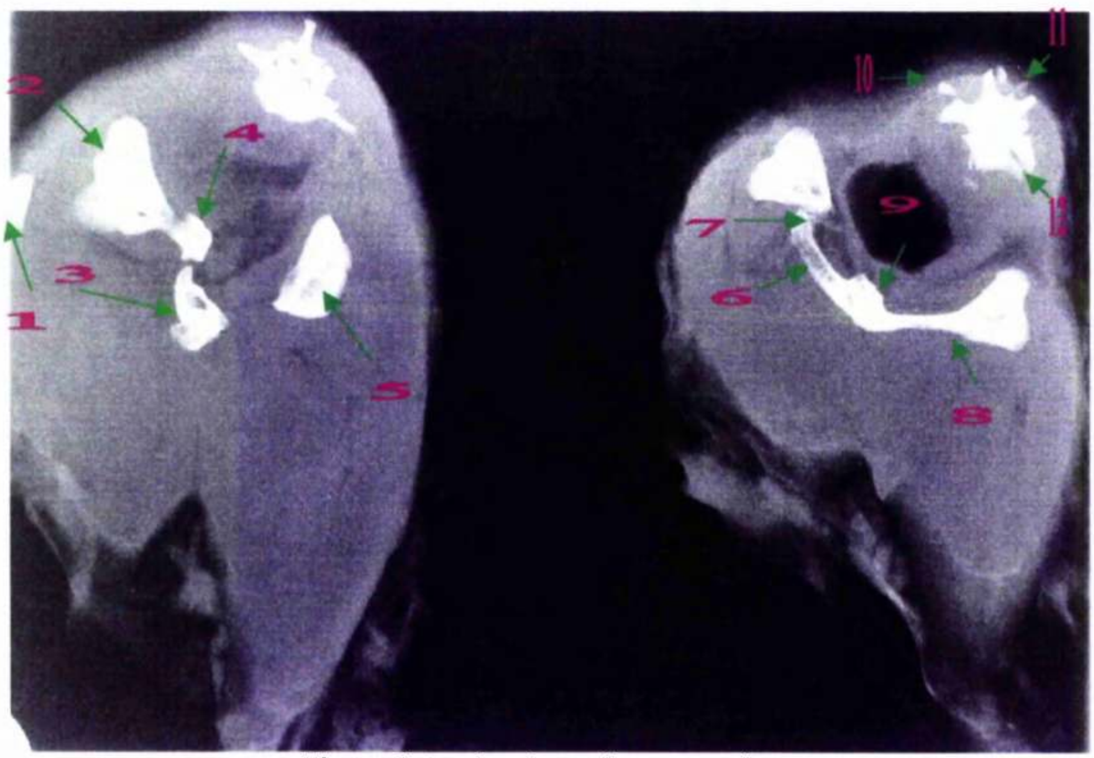


Figure 2.47. Cat 2, sections 11 and 12.

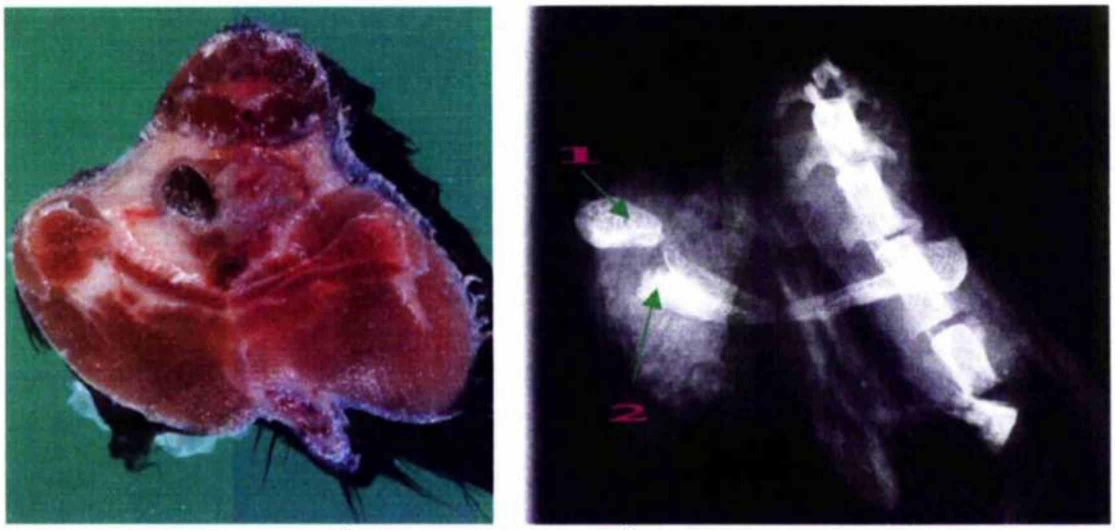


Figure 2.48. Cat 2, section 13.

The radiographs in Figure 2.37 correspond with the gross sections in Figure 2.36. These sections are from the mid lumbar region. In this region the only bones present are the lumbar vertebrae, which seem typical and symmetrical. The radiographs in Figure 2.39 correspond with the gross sections in Figure 2.38. These sections are again from the mid lumbar region. The bones present include the lumbar vertebrae and a part of the stifle joint in section 4. The vertebrae again seem typical and symmetrical. The radiographs in Figure 2.41 correspond with the gross sections in Figure 2.40. They are from the caudal lumbar region. The bones highlighted are the lumbar vertebrae in both sections, the stifle region in 5 and the mid femur and proximal stifle in 6. The vertebrae are both normal and symmetrical. The hindlimbs are not symmetrical, probably due to the differing position of the limbs. They were placed nearly parallel to each other. The radiographs in Figure 2.43 correspond with the gross sections in Figure 2.42. Section 7 is taken at the caudal lumbar region, section 8 is from the area just cranial to the sacrum. In both sections the vertebrae appear normal and symmetrical. In section 8 the ilial wings are just coming in to view. The wing on the right (2) is smaller and narrower indicating that it is sectioned at the cranial end. The wing on the left (1) seems larger and wider signifying that it is sectioned slightly more caudally than the right. The radiographs in Figure 2.45 correspond with the gross sections in Figure 2.44. Sections 9 and 10 were taken at the sacroiliac region. In section 9 the sacrum is nearly symmetrical but the ilia look dissimilar. The ilial wing on the left appears wider and shorter then that on the right. The right ilial wing protrudes further dorsally (1). On section 9 there is a small fragment of bone at (2). The bony configurations in section 10 are asymmetric. The sacroiliac joint appears relatively regular and proportioned. However there are small prominences of bone on the ilial body at (3) and on the medial acetabulum at (4). There is also an irregularly placed piece of bone at (5) and a free fragment at (6). The radiographs in Figure 2.47 correspond with the gross sections in Figure 2.46. Section 11 was taken at the level of the hip joint and section 12 was taken caudal to this across the ischiatic table. Section 11 is unsymmetrical. Acetabular bony pieces are present on both sides (2) and (5). However (2) is adjacent to a unilaterally placed bony fragment (4). Fragment (3) is from the pubic/ischial junction between the obturator foramina but is asymmetric and rotated. (1) is a slice from the greater trochanter of the femur. Section 12 is also asymmetric and irregular. The vertebra has small bony satellite fragments (10), (11) and (12). The ischiatic table (6) and (8) is of varying thickness. (6) is thicker but less radio-opaque than (8). There is an uneven protrusion at (9). The ischiatic table is detached from the lateral ischium on the left of the picture only, at (7). The radiograph in Figure 2.48 correspond with the gross section in Figure 2.48. This section was taken at the caudal end of the ischiatic table. The ischiatic table appears relatively symmetrical except that the bone again is more opaque at the right. There is loss of continuity of the bone at (1) where there is a small gap. Also present is a fragment of bone (2) superimposed on the ischium.

2.3. DISCUSSION

The cross sectional anatomy of the human body in its entirety has been extensively researched (Lillie & Bauer, 1994; Romrell, 1994; Meals & Seeger, 1991; McGrath & Mills, 1984; Bo *et al*, 1980). Many of these studies match up their gross anatomical findings with a spectrum of diagnostic imaging modalities. A small number of studies have been carried out on the cross sectional anatomy of small animals although they focus on the head and neck (Probst *et al*, 1996; Zook *et al*, 1981), thorax of the dog (Zook *et al*, 1989) or specific organs of the dog, cat and pig (Breiling, 1994; Makita & Tominaga, 1987).

This study was carried out to try to deduce safe, hazardous and unsafe corridors for external skeletal fixation pin insertion, a concept introduced by Marti in 1993. In each specimen, sections of the pelvis were prepared. One dog and both cats were sectioned perpendicular to the dorsal plane, the other dog was sectioned radially using the greater trochanter of the femur as a focal point, using an electric band saw at specific points. The number of sections made in the dog correspond with the potential number of pins that would be used in a uniplanar unilateral external skeletal fixation frame. In the cats, as many sections were taken as possible, as the feline pelvis is relatively unexplored and potential pin insertion sites were an unknown entity.

In the canine group an attempt was also made to image certain planes of section using extended field of view ultrasound. Lines of section, corresponding approximately to the cadaveric lines of section, were drawn on the skin of a live greyhound. This animal was then scanned using extended field of view ultrasound. It was thought at this juncture that this would be the most effective way of imaging the pelvic musculature and osteology. It was hoped that if the normal pelvic anatomy was accurately displayed using this technology then it may have potential as a diagnostic tool for rapid exploration of clinical cases subjected to trauma.

2.3.1. Canine Group

Two skeletally mature greyhound type dogs were used for this study. Each animal had a palpably symmetrical pelvis. Both animals were sectioned using a band saw, and were aligned, positioned and immobilised manually. Six transverse and four radial sections were obtained. Each section was photographed and subsequently all muscles, bony structures and major blood vessels were identified and labelled. The canine gross cross sectional anatomy was compared to the sonographic cross sectional anatomy. It was found that the anatomy of the pelvis was accurately displayed using the SieScape technology. Although it demonstrated clearly the normal anatomy of the pelvis, it was difficult to perform. The irregular contours of the animal caused a loss of transducer to skin contact in certain regions, especially those areas with subcutaneous bone. Although the individual patterns of musculature were easily identifiable in the gross sections, it was difficult to define muscle borders using ultrasound. Greater success and precision was accomplished when muscles and bones were imaged individually (Chapters 3 & 5).

2.3.2. Feline Group

Two skeletally mature domestic short hair cats were used for this study. As the cats were smaller than the dogs and proportionately narrower sections were required, manual positioning and immobilization were thought to be impractical. To ensure a uniform thickness of section and to increase operator safety, prior to sectioning by a band saw, each animal was secured using releasable ties to a specially designed perspex board. Five sections were obtained from cat 1 and thirteen from cat 2. Each section was photographed and subsequently all muscles, bony structures and major blood vessels were named and labelled.

Cat 1 had a palpably symmetrical pelvis. Cat 2 was noted to be have an irregular and palpably asymmetric pelvis. After sectioning, the bony areas were obviously unbalanced and irregular. In order to demonstrate this atypical anatomy, each of these sections was radiographed and the positions of the bones were noted. This specimen had a possible malunited old pelvic fracture. The radiographs showed that the bones were distorted and as a consequence, the muscle coverage was disturbed. When these sections were compared to those from Cat 1 the asymmetry could be seen. Cat 1 was completely symmetrical and balanced.

2.3.3. Conclusions

These cross sections were initially taken in order to investigate the potential insertion sites for external skeletal fixation pins. It is advisable to avoid inserting pins through musculotendinous units. It is also imperative to avoid the puncture or impingement of neurovascular structures. It was subsequently realised in this study that it was impossible to localise nerves and to identify small vascular structures using deep frozen cross sections.

Both the canine and feline pelvis had musculature, osteology and large vessels, which were readily identifiable using dissection, prior knowledge and anatomical textbooks and atlases. Their anatomy was similar although the bony proportions and proportionate muscle coverage were different. After trauma, malalignment of the bones causes the musculature to distort resulting in not only a bony asymmetry but in addition a soft tissue asymmetry.

The normal canine pelvis can be successfully imaged using extended field of view ultrasound. However the practicalities of this were difficult and equally good if not superior results were obtained by scanning the individual muscles and bones (Chapters 3 & 5)

MUSCLES ATTACHED TO THE PELVIS

Muscles acting primarily on the hip joint: the muscles acting at the hip are arranged in gluteal, medial, caudal (hamstring) and deep groups, a classification based primarily on topography (Dyce *et al*, 1996). These muscles are all symmetrically repeated on the left and right sides of the pelvis. They are therefore described in the results for each hemipelvis.

3.1 MATERIALS & METHODS

All muscles, which attached to the pelvis, were identified using dissection and standard anatomy text books (Evans & DeLahunta, 2000; Evans, 1993) and an atlas (Boyd & Paterson, 1991). They were initially described in groupings and then individually. The origin, insertion, action and nerve supply of each muscle is stated. The continuity of selected muscles was shown using extended field of view ultrasonography with SieScape technology.

3.1.1. Ultrasound imaging of m. gluteus profundus and m. gluteus medius.

These muscles were scanned in a cranial to caudal direction, in the direction of the muscle fibres.

3.1.2. Ultrasound imaging of m. gluteus superficialis.

Although m. gluteus superficialis does not have any actual attachments to the pelvis, it was scanned as it overlies the pelvis. This muscle was scanned from the midline of the animal to lateral, across the muscle fibres.

3.2. RESULTS

There are 25 pairs of muscles, which attach to the ossa coxae. Three from the gluteal group, five from the medial group, three from the caudal group, four from the deep group, three sublumbar muscles, one stifle muscle, two pelvic diaphragm muscles, two epaxial muscles, one abdominal wall muscle and one other.

3.2.1. Gluteal group

The gluteal group attaching to the pelvis comprises of the m. gluteus profundus, m. gluteus medius and m. tensor fasciae latae.

3.2.2. Medial group

The medial group is principally employed to adduct the hindlimb, a term that includes the prevention of unwanted abduction. Most muscles in this group are supplied by the n. obturatorius and these – m. adductor, m. obturatorius externus, m. gracilis, m. pectineus, and are sometimes specifically termed "the adductors". M. sartorius has a rather different origin and relationship described later.

3.2.3. Caudal group

The muscles of the caudal group (hamstring) consist of m. biceps femoris, m. semimembranosus and m. semitendinosus.

3.2.4. Deep group

The deep muscles of the hip form a heterogeneous community of small and essentially trivial muscles, the m. articularis coxae, mm. gemelli, m. obturatorius internus and m. quadratus femoris. Most are supplied by n. ischiadicus (Dyce *et al*, 1996). These have also been called the "small pelvic association" (Evans & Christensen, 1993).

3.2.5. Sublumbar group

The sublumbar musculature arises on the ventral surfaces of the caudal thoracic vertebrae and lumbar vertebrae and insert on the os coxae and femur. They lie on one another in several layers and of them the m. iliacus and m. psoas minor attach to the pelvis.

3.2.6. Stifle

One muscle of the cranial thigh attaches to the pelvis, this is m. rectus femoris.

3.2.7. Pelvic diaphragm

The pelvic diaphragm (Evans & Christensen, 1993) in quadrupedal mammals is the vertical closure of the pelvic cavity through which the rectum passes. The two muscles of the pelvic diaphragm are m. coccygeus and m. levator ani.

3.2.8. Epaxial group

The epaxial division of the muscles surrounding the vertebral column is placed dorsal to the line of the transverse processes of the vertebrae and receives its nerve supply from rami dorsales of nn. spinales. The epaxial muscles, which attach to the pelvis, are m. iliocostalis and m. longissimus lumborum.

Figure 3.1. Left canine os coxae, showing areas of muscle attachment, lateral aspect. (Taken from Evans & Christensen, 1993 and modified).

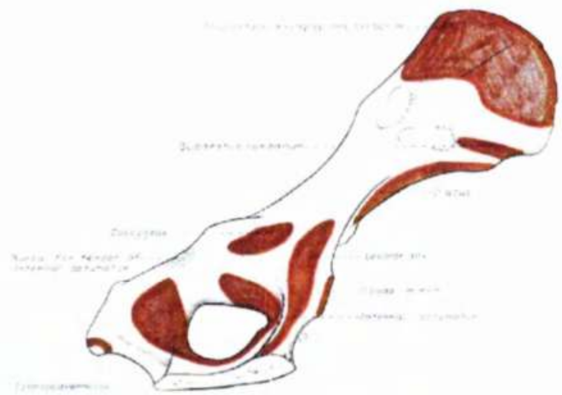


Figure 3.2. Left canine os coxae, showing areas of muscle attachment, medial aspect. (Taken from Evans & Christensen, 1993 and modified).

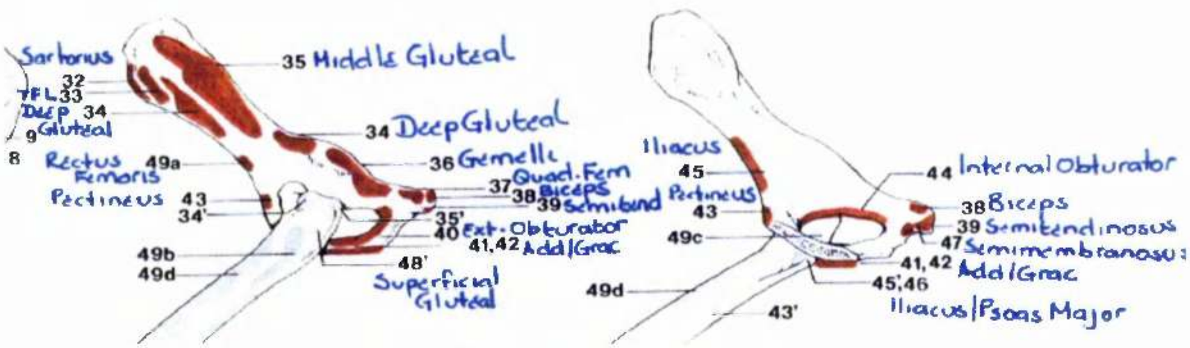


Figure 3.3. Left feline os coxae, lateral view (a) and medial view (b). (Taken from Hudson & Hamilton, 1993 and modified).

3.2.9. M. gluteus profundus

This muscle is part of the gluteal group and is completely covered by the m. gluteus medius and m. piriformis. It originates on the body of the ilium and ischiatic spine and inserts on the cranial aspect of the greater trochanter. The primary action is to extend and abduct the hip but it also rotates the pelvic limb. Innervation is by the n. gluteus cranialis.

-Imaging (Figure 3.4).

The greater trochanter of the femur can be distinguished. m. gluteus medius is seen overlying m. gluteus profundus.

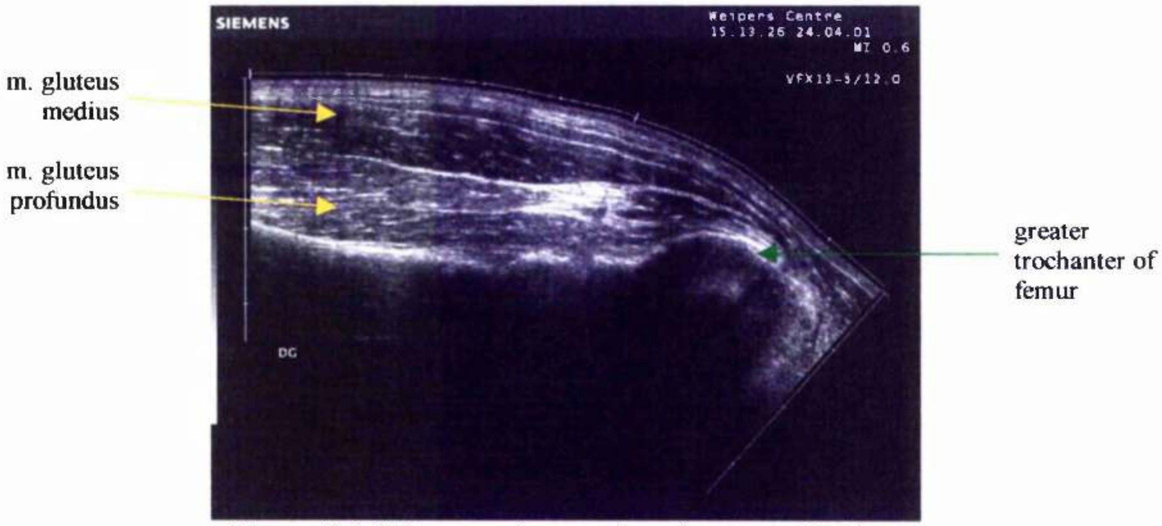


Figure 3.4. Ultrasound scan of m.gluteus profundus.

3.2.10. M. gluteus medius

This muscle is by far the largest of the gluteal group. It takes origin in the crest and gluteal surface of the ilium (Dyce *et al*, 1996) also from both angles of the ilium (Evans & Christensen, 1993). The insertion point is on the greater trochanter of the femur. It is a very powerful extensor of the hip and rotates the pelvis medially. Innervation is via the n. gluteus cranialis.

-Imaging (Figure 3.5).

The separation of the two muscle bellies can be seen in the gluteal fossa. The insertion point on the greater trochanter of the femur can be distinguished.

3.2.11. M. gluteus superficialis

-Imaging (Figure 3.6)

The greater ischiatic spine and greater trochanter of the femur can be seen. The insertion of m. gluteus superficialis on to the greater trochanter of the femur can be distinguished.

Figure 3.5. Ultrasound scan of m.gluteus medius

Figure 3.6. Ultrasound scan of m. gluteus superficialis.

3.2.12. M. tensor fasciae latae

This muscle is the most cranial of the gluteal group. It originates at the tuber coxae, adjacent part of ilium and aponeurosis of the m. gluteus medius. The insertion is on the fascia lata. Its action is primarily to flex the hip, tense the fascia lata and extend the stifle. It is innervated by the n. gluteus cranialis.

3.2.13. Mm. adductors

The mm. adductor magnus *et* brevis make up part of the medial group. As a group they originate on the entire pelvic symphysis by means of the tendo symphysialis, the adjacent part of the ischiatic arch, and ventral surface of the pubis and ischium. Insertion is on the entire lateral lip of the caudal rough face of the femur. The action is to adduct the limb and extend the hip. This muscle group is supplied by the n. obturatorius.

3.2.14. M. obturatorius externus

This muscle forms part of the medial group. Its origin is the ventral surface of the pubis and ischium, and it inserts on the trochanteric fossa. The action of this muscle is to rotate the pelvic limb laterally. Innervation is via the n. obturatorius.

3.2.15. M. gracilis

This broad but thin muscle makes up part of the medial group. It takes origin on the pelvic symphysis by means of the tendo symphysialis and inserts on the cranial border of the tibia and the tuber calcanei via the tendo calcaneus communis. Its purpose is to adduct the limb, flex the stifle and extend the hip and hock. Innervation is provided by the n. obturatorius.

3.2.16. M. pectineus

This is a small fusiform muscle, which forms part of the medial group. Its origin is on the body of the pubis on each side and from the iliopubic eminence to the pubic tubercle. The insertion is on the distal end of the medial lip of the caudal rough face of the femur. M. pectineus is an adductor of the limb. It is innervated by the n. obturatorius.

3.2.17. M. sartorius

This muscle is part of the medial group. In the dog it consists of 2 parallel bellies, the cranial one forming the cranial contour of the thigh. It is set apart from the other medial muscles by its innervation from the rami saphenus of the n. femoralis. The cranial part originates at the crest of the ilium and fascia thoracolumbalis, the caudal part at the cranial ventral iliac spine and adjacent ventral surface of the ilium. The cranial part inserts on the patella, the caudal part on the cranial border of the tibia. The m. sartorius primarily flexes the hip but also adducts the thigh and extends the stifle. It is innervated by the n. femoralis (Evans & Christensen, 1993) or n. saphenus according to Dyce *et al*, 1996.

3.2.18. M. biceps femoris

This muscle forms part of the caudal group. Its origin is the lig. sacrotuberale and the ischiatic tuberosity. The insertion is by means of the fascia lata and fascia cruris to the patella, lig. patellae, and cranial border of the tibia; by means of the fascia cruris to the subcutaneous part of the tibial body. The is also an insertion on to the tuber calcanei via the tendo calcaneus communis. The action of m. biceps femoris is to extend the hip, stifle and hock. The caudal part of the muscle flexes the stifle. Innervation is by the n. ischiadicus.

3.2.19. M. semimembranosus

This muscle also forms part of the caudal group. It originates on the ischiatic tuberosity and inserts on the distal medial lip of the caudal rough surface of the femur and the proximal end of the tibia. The m. semimembranosus primarily extends the hip. The part that attaches to the femur extends the stifle; the part that attaches to the tibia flexes or extends the stifle, depending on the position of the limb. It is innervated by the n. ischiadicus.

3.2.20. M. semitendinosus

This muscle also forms part of the caudal group. It originates on the ischiatic tuberosity and inserts on the medial surface of the body of the tibia and the tuber calcanei by means of the fascia cruris. This muscle extends the hip, flexes the stifle and extends the hock. It is innervated by the n. ischiadicus.

3.2.21. M. articularis coxae

This small spindle shaped muscle forms part of the deep group. It is placed lateral and caudal to the m. rectus femoris. It arises with the m. rectus femoris on the iliopubic eminence and courses laterally over the capsule of the hip joint, inserting on the neck of the femur. Its action is to protect the capsule from being nipped between the femoral and acetabular surfaces (Dyce *et al*, 1996), and flexion of hip (Evans & Christensen, 1993). Innervation is by means of the n. femoralis.

3.2.22. Mm. gemelli

This deep muscle consists of two small twin bundles, which originate on the lateral surface of the ischium, caudal to the acetabulum and ventral to the lesser ischiatic notch. They insert on the trochanteric fossa. The mm. gemelli rotates the pelvic limb laterally at the hip. Innervation is supplied by the n. ischiadicus.

3.2.23. M. obturatorius internus

This thin muscle forms part of the deep group. The origin is medial to the obturator foramen on the pelvic surfaces of the rami of the pubis and ischium, and from the ischiatic arch. The insertion is on the trochanteric fossa. Its action is external rotation of the thigh. Innervation is via the n. ischiadicus.

3.2.24. M. quadratus femoris

M. quadratus femoris is a deep muscle. Its origin is the ventral surface of the caudal part of the ischium. The insertion is just distal to the trochanteric fossa. Its action is to extend the hip and rotate the pelvic limb laterally (Evans & Christensen, 1993). Dyce *et al*, 1996 also describe it thus but state that it can be of no significance in this role. Innervation is by the n. ischiadicus.

3.2.25. M. iliacus

This is a sublumbar muscle, which originates on the ventral aspect of the wing and shaft of ilium and inserts on the lesser trochanter of the femur. This muscle is a flexor of the hip, being innervated by the rami ventrales of nn. lumbales spinales and n. femoralis.

3.2.26. M. psoas minor

This muscle is sublumbar. It originates on the bodies of the thoracolumbar vertebrae and its insertion is on the psoas minor tuberosity of the ilium. This muscles action primarily is to stabilise the vertebral column, rotate the pelvis at the sacroiliac joint (Dyce *et al*, 1996), steepen the pelvis and flex the lumbar part of the vertebral column (Evans & Christensen, 1993). It is innervated by the lateral branches of the rami ventrales of nn. lumbales spinales one to four or five.

3.2.27. M. quadratus lumborum

This is the most dorsal sublumbar muscle. It originates from the last two ribs and transverse processes of the lumbar vertebrae and inserts on the sacral wing and sometimes the ilium. Its function is to stabilise the lumbar portion of the vertebral column. The innervation is via direct twigs from the rami ventrales of the last few nn. thoracici and lumbales spinales.

3.2.28. M. rectus femoris

This muscle acts primarily on the stifle. It takes origin in the caudolateral ilium just cranial to the acetabulum and inserts on the tibial tuberosity. The action is to extend the stifle and flex the hip. Innervation is by the n. femoralis.

3.2.29. M. coccygeus

This is a muscle of the pelvic diaphragm. It takes origin from the ischiatic spine cranial to the m. obturatorius internus and inserts on the lateral surface of the tail, passing medial to the lig. sacrotuberale. Its function is bilateral; to press the tail against the anus and genitals and in conjunction with the depressors, to draw the tail between the rear legs. It also works unilaterally, providing lateral flexion. Innervation is by way of rami ventrales of the third n. sacrales spinales.

3.2.30. M. levator ani

Most medial muscle of pelvic diaphragm. Its origin is on the medial edge of the body of ilium and the dorsal surface of the pubis and the pelvic symphysis. The insertion is on caudal vertebrae three to seven. Its action is bilateral, as for the m. coccygeus. In common with the levators of the tail it will cause the sharp angulation between the sixth and seventh caudal vertebrae, which is characteristic for defecation with compression of the rectum. Innervation is by means of the rami ventrales of the third (last) n. sacrales spinales and first n. caudales spinales.

3.2.31. M. iliocostalis

M. iliocostalis makes up part of the lateral column of the epaxials. It is composed of many fascicles that overlap. The origin of this muscle is on the wing of the ilium in common with the m. longissimus lumborum. It inserts on the transverse processes of the lumbar vertebrae and the last four or five ribs. It serves to bend the trunk to the side. The nerve supply is from the rami dorsales of nn. spinales.

3.2.32. M. longissimus lumborum

This muscle forms part of the middle column of the epaxials. It takes origin from the crest and ventro-medial surface of the wing of the ilium. The insertion is on various processes of the lumbar and thoracic vertebrae. It is supplied by the rami dorsales of the nn. thoracici and lumbales spinales. Its role is running in conjunction with the m. longissimus thoracis, to extend the vertebral column, raising the cranial portion of the trunk from the pelvis, sacrum and loin, and sudden raising of the caudal portion of the body, initiated by the hindquarters.

3.2.33. M. rectus abdominis

This is an abdominal wall muscle, which takes origin on the pubis via the tendo prepubicus.

Its insertion is on the sternum and ventral surfaces of rib cartilages. It serves to flex the thoracolumbar part of the vertebral column and assists in all functions, which are dependant on abdominal pressing and bringing the pelvis forward. It is supplied by the rami mediales of the n. iliohypogastricus and n. ilioinguinalis.

3.2.34. M. ischiocavernosus

M. ischiocavernosus comprises of powerful paired muscles, which originate on the ischiatic tuberosity and insert distally on the corpus cavernosum.

The lig. sacrotuberale in the dog extends from the caudolateral part of the apex of the sacrum and the transverse process of the first vertebra to the lateral angle of the ischiatic tuberosity (Evans & Christensen, 1993). This however does not exist in the cat (Hudson & Hamilton, 1993).

3.3. DISCUSSION

At dissection, the pelvic musculature was found to exist as described in the anatomical textbooks (Evans & DeLahunta, 2000; Evans, 1993). The pelvis was exceptionally well covered with muscles (Brinker *et al*, 1990).

It is possible to image the pelvic musculature effectively using extended field of view ultrasound with SieScape technology. Conventional b-mode ultrasound has been used in the past to image muscles (Goddard, 1995; Barr, 1990) but recently extended field of view ultrasound has received favorable reports (Weng *et al*, 1997; Weng & Tirumalai, 1996).

BLOOD SUPPLY OF THE CANINE PELVIS

1. OBSERVATIONS ON THE NUTRIENT FORAMINA OF THE CANINE PELVIS

Vascular channels, also known as nutrient foramina and perforating canals, penetrate the dense, mineralised matrix of bone and are essential for bone cell metabolism. Numerous nutrient foramina are found on all bones and facilitate vascularisation of interior regions of the bone by allowing entry and exit of blood vessels (Jojić, 1982). Impairment of blood flow in these nutrient foramina is the suspected cause of several clinical conditions and postoperative complications (Kaderley *et al*, 1981). Nutrient arteries may be damaged as a result of traumatic pelvic injuries or during surgery (Ebraheim *et al*, 1997). Knowledge of the location of nutrient foramina and the course of nutrient arteries may be of importance to minimize intraoperative haemorrhage (Ebraheim *et al*, 1997).

There have been several investigations on bone vascularisation in humans (Court-Brown, 1985; Richardson & Montana, 1985) and animals (Rhinelander & Wilson, 1982; Kato *et al*, 1970). The pelvis has however received little attention (Richardson & Montana, 1985; Jojić, 1982). Few veterinary small animal surgical textbooks or published literature document the presence of any vascular channels or nutrient arteries in the pelvis. A greater emphasis is put on the extraosseous blood supply (Harari, 1996; Lipowitz *et al*, 1993; Brinker *et al*, 1990; Ammann *et al*, 1978).

The first mention was made of a main ilial nutrient foramen by Wheaton and her co-workers in 1973 (Figure 4.1). It was illustrated as part of the lateral surgical approach to the ilium but was not referred to in the text. However Piermattei & Greeley in 1979 illustrated the principal ventral ilial body foramen and made reference to it in their protocol for the surgical approach to the ilium through a lateral incision. They stated that elevation of the iliacus muscle along the ventral border of the iliac shaft usually results in severing of this nutrient artery on the ventral aspect of the shaft. This foramen is illustrated in Figure 4.2 and is shown by the yellow arrow. In 1982 Kaderley *et al* documented that this was the iliolumbar artery and was the nutrient artery of the ilium. This was substantiated in 1996 by Dyce *et al* who named and also illustrated this nutrient artery.

The objectives of this observational investigation of nutrient foramina was to describe and illustrate the vascular channels present on each of the pelvic bones, to document their relative size, frequency, location and density and to record any inter specimen variations present. Common patterns and positions would therefore be deduced.

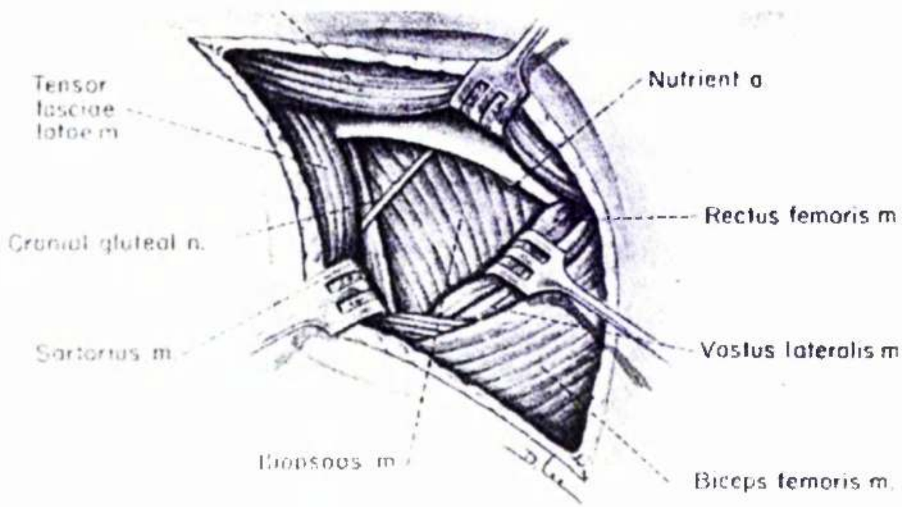


Figure 4.1. Nutrient artery foramen as illustrated by Wheaton *et al*, 1973.

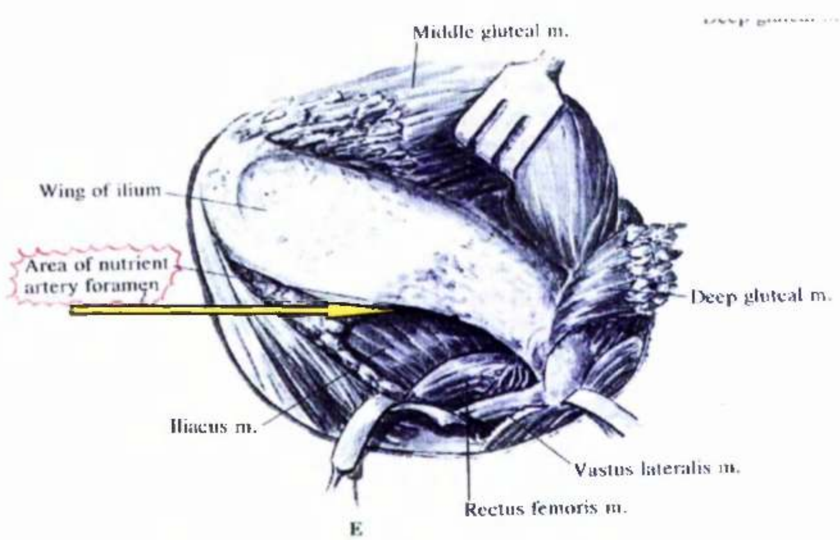


Figure 4.2. Nutrient artery foramen as illustrated by Piermattei & Greeley, 1979.

4.1. MATERIALS & METHODS

A total of 33 macerated canine pelves were studied. They were sourced from demonstration specimens in the Division of Veterinary Anatomy bone collection. The breed was known in 27 cases, the sex in 21 cases and the age of the animal in 15. All pelves were undamaged and separated from the sacrum. The dorsal, ventral, lateral and medial surfaces of each bone were examined. Positions of the foramina were documented and divided subjectively into principal and secondary foramina, with the secondary foramina being further subdivided into large and small. The principal foramina were obviously the largest. Secondary foramina were clearly smaller with small secondary foramina being minute perforations.

Number	Breed	Sex	Age
1	Springer Spaniel	Female	5 years
2	Boxer	unknown	6 years
3	Labrador	Male	11 years
4	Corgi	Male	unknown
5	Fox Terrier	Male	unknown
6	Cairn Terrier	Male	unknown
7	Dalmatian	Female	unknown
8	Fox Terrier	Male	unknown
9	Dachshund	Female	3 years
10	Cairn Terrier	Male	14 years
11	Greyhound	Male	6 years
12	Keeshond	unknown	unknown
13	unknown	unknown	unknown
14	Labrador	Male	13 years
15	Spaniel	Female	unknown
16	Cairn Terrier	Male	6 years
17	Poodle	Male	6 years
18	unknown	unknown	unknown
19	Basenji	unknown	unknown
20	unknown	unknown	unknown
21	unknown	unknown	unknown
22	unknown	unknown	unknown
23	Boxer	Male	2 years
24	Boxer	unknown	3 years
25	unknown	unknown	unknown
26	Lakeland Terrier	unknown	unknown
27	Pekingese	unknown	unknown
28	Cavalier King Charles Spaniel	Male	10 years
29	Labrador	Male	3 years
30	Yorkshire Terrier	Male	12 years
31	Staffordshire Bull Terrier	Male	unknown
32	West Highland White Terrier	Male	unknown
33	Labrador	Male	12.5 years

Table 4.1. Macerated canine pelvis data.

4.2. RESULTS

4.2.1. Ilial wing

4.2.1.1. Lateral Side

There were many foramina present here in all cases. They were randomly positioned and of varying sizes. There was a predominant aggregation on the gluteal fossa of the ilial wing where the bone is thinnest. Most wings displayed least foramina between the cranial and caudal dorsal iliac spines where the bone is thickest. The larger foramina apparently perforated the bone perpendicular to its surface.

4.2.1.2. Medial Side

This area was densely perforated in 33% of cases (Specimens 1, 2, 3, 6, 11, 15, 19, 28, 30, 31, 33) with 30% displaying a sparse scattering of foramina (Specimens 4, 5, 7, 8, 9, 10, 12, 13, 14, 25) 30.3%. The foramina were relatively uniformly scattered over the wing with a slight predomination towards the crest. A few pelves (21.2%) showed larger openings adjacent to the articular surface. These were primarily in the smaller breeds (Specimens 4, 6, 13, 21, 26, 31, 32).

4.2.2. Ilial body

There was typically one principal foramen on the ventral surface of each ilial body. This was present bilaterally in 69.7% of cases, and unilaterally in 15.1% (Specimens 22, 24, 26, 27, 30). It was absent in 15.1% (specimens 11, 15, 16, 19, 20). This foramen is located about half to two thirds of the way from the caudoventral iliac spine to the tuberosity at the cranioventral acetabulum. It was situated near to the lateral edge of the ilial body. The blood vessel almost certainly entered parallel to the bone as indicated by a groove on the bone surface, which led in to the oblique entrance of the foramen. On selected specimens there was an additional principal foramen on the lateral side of the ilial body. This was unilateral in 30.3% (Specimen 2, 8, 12, 13, 15, 17, 22, 27, 28, 30) and bilateral in 12.1% (Specimen 5, 11, 14, 26). Specimens 18, 19, 25, 27, 28 and 32 (18.1%) had a unilateral and Specimen 23 and 33 (6.1%) a bilateral diffuse scattering of small foramina in this location.

4.2.3. Acetabulum

There was commonly a principal foramen at the dorsal mid acetabulum about halfway or a third of the distance between the acetabular rim and the medial border. This was unilateral in 33.3% (Specimens 1, 11, 12, 15, 17, 19, 21, 26, 30, 32, 33) and bilateral in 30.3%

(Specimens 2, 7, 9, 10, 13, 14, 18, 23, 25, 29). Frequently if this was absent on one side or both, there were many smaller secondary foramina sprinkled along the rim. This was present in 33.3% (Specimens 3, 12, 15, 19, 20, 21, 22, 26, 30, 32, 33). In a few animals there was a scattering of foramina on the lateral wall adjacent to the lunate surface, unilaterally in 18.1% (Specimens 1, 3, 6, 9, 12, 19) and bilaterally in 6.1% (Specimens 2, 7). In 12.1% there were no foramina present on the acetabular rim (Specimens 4, 5, 6, 27).

4.2.4. Pubis

The majority of animals displayed a diffuse blood supply to the pelvic symphysis. On the dorsal side 45.5% displayed a few bilateral large principal foramina (Specimens 1, 2, 3, 5, 6, 7, 12, 14, 22, 23, 24, 26, 30, 32, 33) in isolation. 63.6% were accompanied by an irregular scattering of secondary foramina (Specimens 2, 3, 4, 6, 7, 8, 9, 10, 17, 18, 19, 22, 23, 24, 26, 27, 28, 29, 31, 32, 33) whereas on the ventral side it was more common (70.0%) for a larger number of smaller openings to be present (Specimens 1, 2, 3, 4, 5, 6, 7, 12, 14, 15, 17, 18, 21, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33). No consistent pattern was found on the pubic rami. Frequently a solitary or small cluster of small secondary foramina was sited beside the iliopubic eminence in the ventral aspect in 30.3% (Specimen 3, 6, 8, 10, 13, 18, 21, 23, 24, 33) or dorsal aspect in 24.2% (Specimen 3, 4, 9, 10, 11, 12, 14, 33). These were either unilateral (18.2%) (Specimens 8, 9, 13, 18, 21, 24) or bilateral (27.3%) (Specimens 3, 4, 6, 10, 11, 12, 14, 23, 33).

4.2.5. Ischium

4.2.5.1. Table

The ischiatic tables are usually well supplied. On the dorsal face 66.7% had one or two large principal foramina located centrally (Specimens 1, 2, 3, 5, 7, 8, 11, 12, 13, 14, 17, 18, 19, 21, 22, 23, 24, 25, 26, 28, 31, 32). These were accompanied in 39.4% (Specimens 1, 7, 8, 11, 14, 18, 19, 21, 23, 24, 26, 28, 32) or replaced in 18.2% (Specimens 4, 6, 9, 10, 27, 33) by many smaller secondary foramina. Ventrally there were no large openings, with the exception of specimen 18 (3.0%), but many more smaller ones than on the dorsal side (66.7%) (Specimens 1, 2, 3, 4, 5, 6, 7, 10, 12, 14, 17, 18, 22, 23, 24, 25, 26, 27, 28, 30, 31, 32). In 57.6% of cases these foramina were principally restricted to the caudal edge of the bone (Specimens 1, 2, 3, 7, 9, 11, 12, 13, 15, 17, 18, 19, 20, 23, 24, 25, 28, 31, 32).

4.2.5.2. Tuberosity

Most animals (54.5%) displayed both large and small secondary foramina here in large numbers (Specimens 1, 2, 3, 4, 8, 9, 11, 15, 17, 18, 22, 23, 24, 28, 30, 31, 32, 33). The larger breeds (15.1%) had a predominance of larger foramina (Specimens 2, 3, 11, 24, 33).

4.2.5.3. Lesser Sciatic Notch

There is typically (36.4%) one large foramina (Specimens 1, 2, 5, 9, 11, 17, 20, 22, 25, 27, 28, 33) in addition to (15.2%) (Specimens 5, 11, 22, 27, 28) or instead of (30.3%) (Specimens 3, 6, 8, 10, 15, 18, 26, 29, 31, 32) a few small secondary foramina on the lateral ischium just ventrolateral to the lesser sciatic notch. These were unilateral in 30.3% of cases (Specimen 6, 10, 15, 17, 18, 20, 25, 26, 31, 32) and bilateral in 36.4% (Specimen 1, 2, 3, 5, 8, 9, 11, 22, 27, 28, 29, 33).

4.2.6. Obturator Foramen

There was with the exception of specimen 20, one, two or three foramina on the dorsal ischium on the medial wall ventral to the lesser ischiatic notch, beside each obturator foramen. Frequently, one, or occasionally two (Specimen 13) of these would have contained a vessel entering parallel to the bone as indicated by an oblique groove continuous with the foramina.

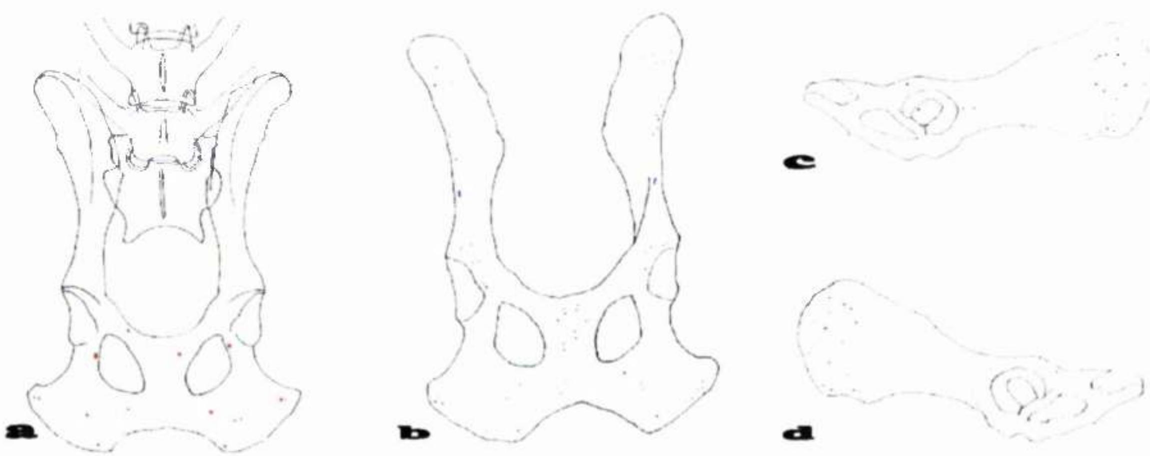


Figure 4.3. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 1.

Figure 4.4. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 2.

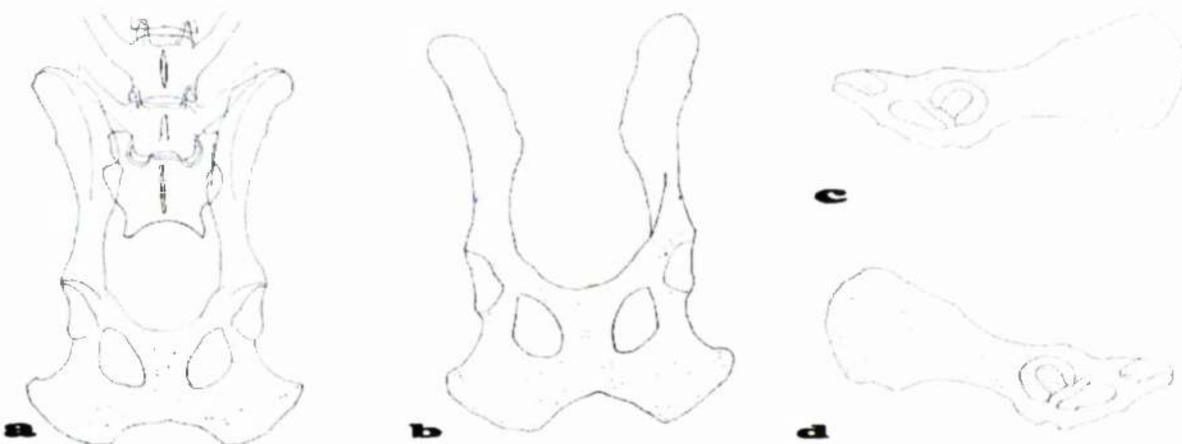


Figure 4.5. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 3.

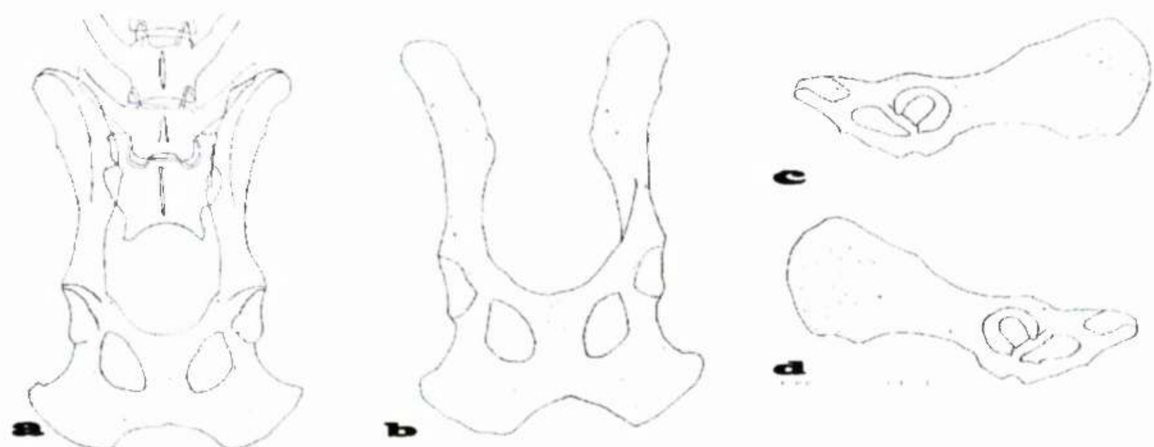


Figure 4.6. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 4.

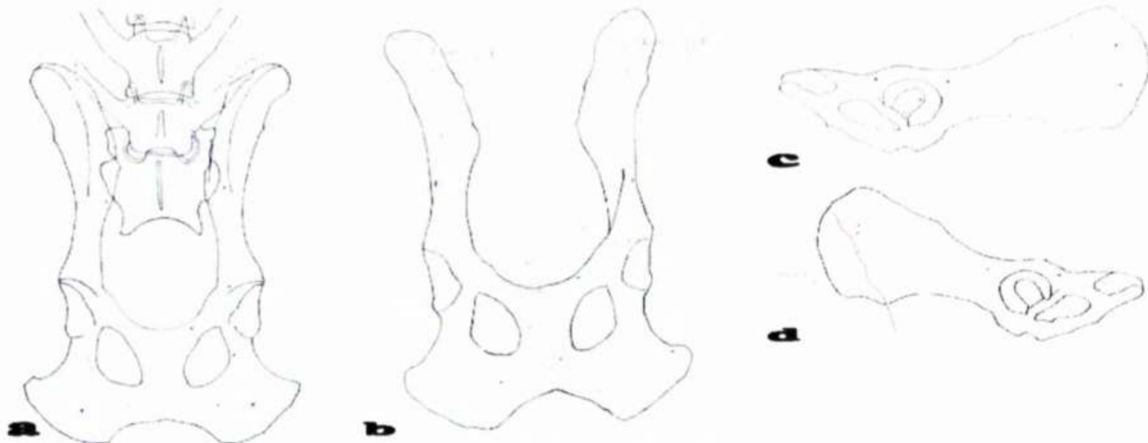


Figure 4.7. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 5.

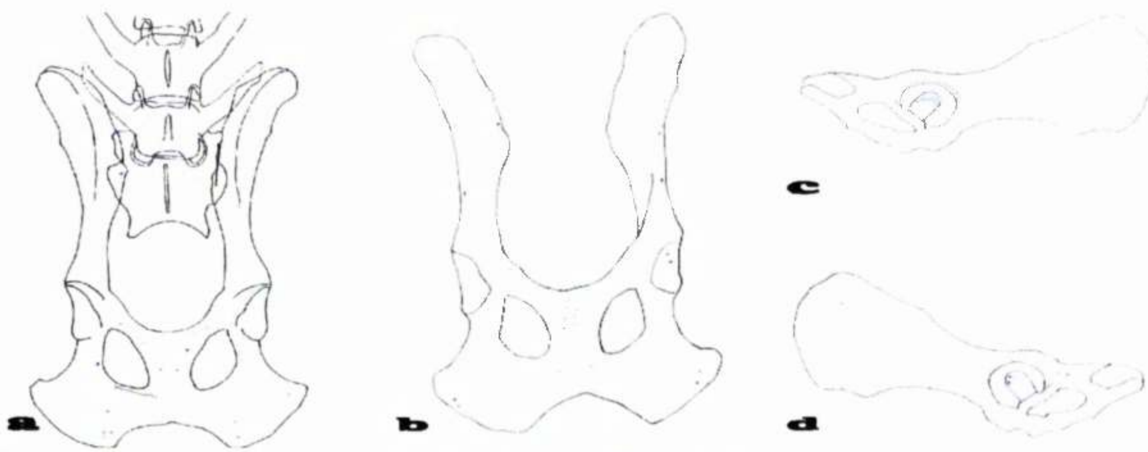


Figure 4.8. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 6.

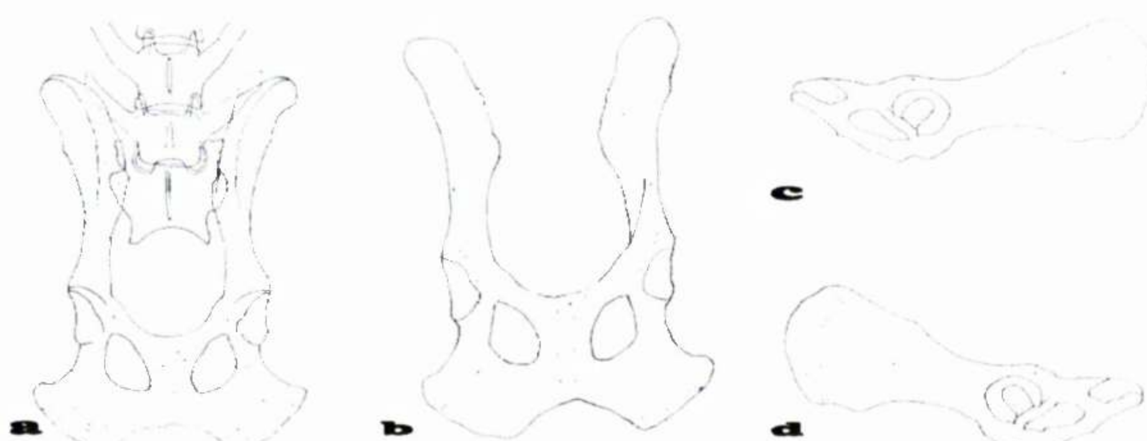


Figure 4.9. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 7.

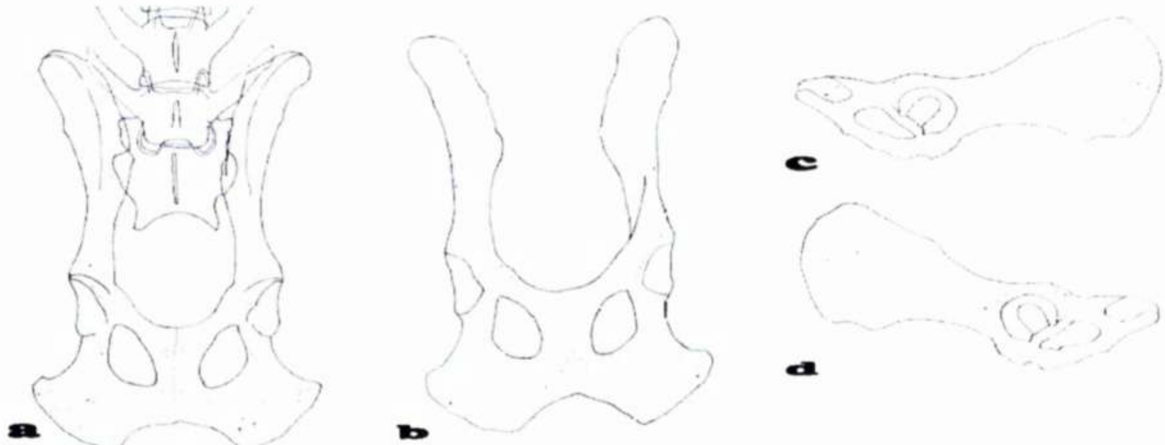


Figure 4.10. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 8.

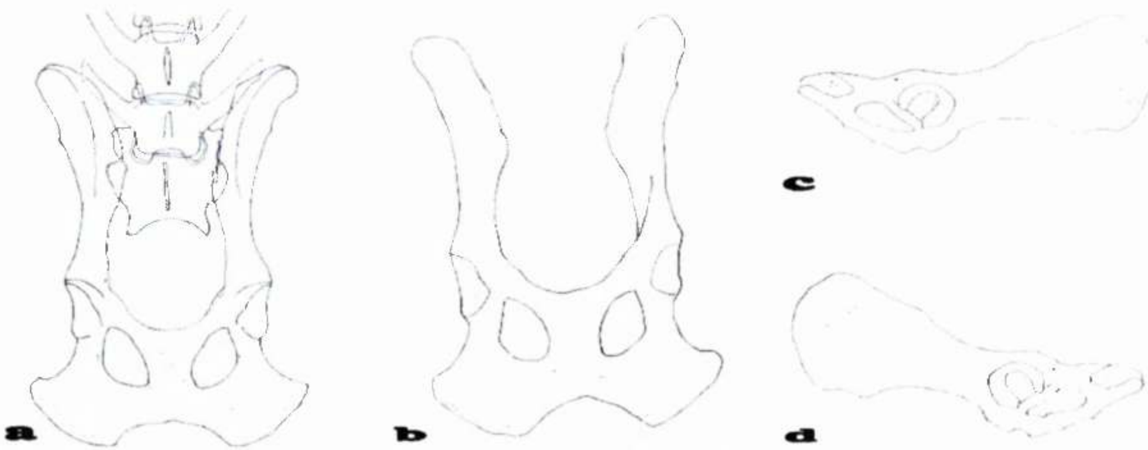


Figure 4.11. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 9

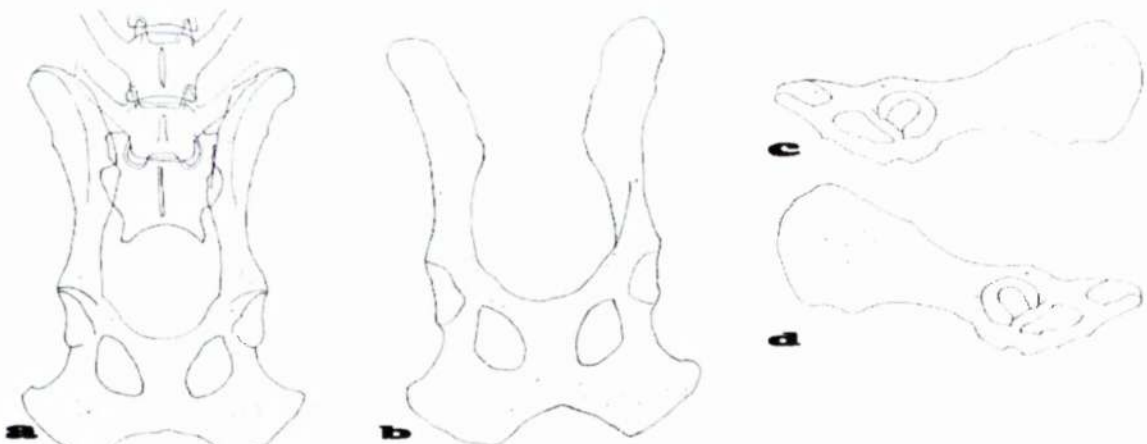


Figure 4.12. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 10.

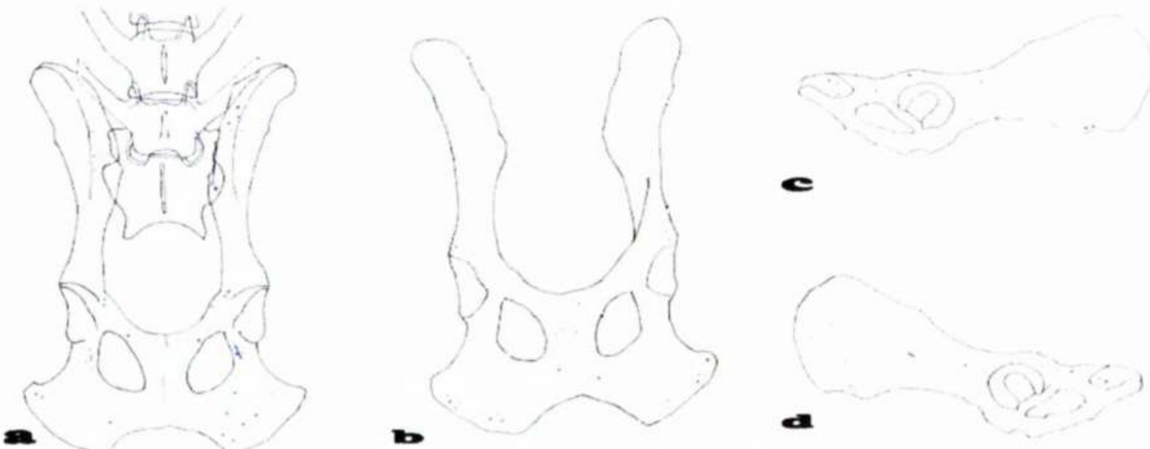


Figure 4.13. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 11.

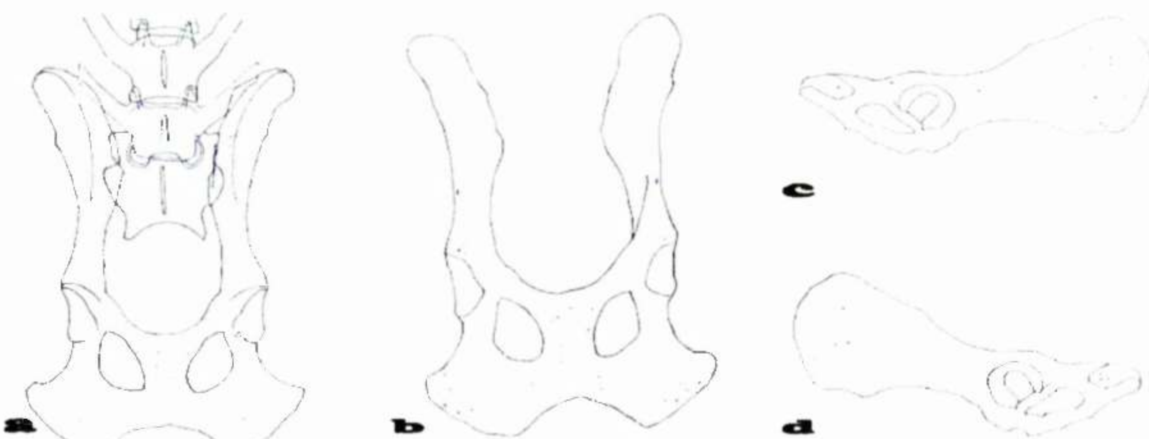


Figure 4.14. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 12.

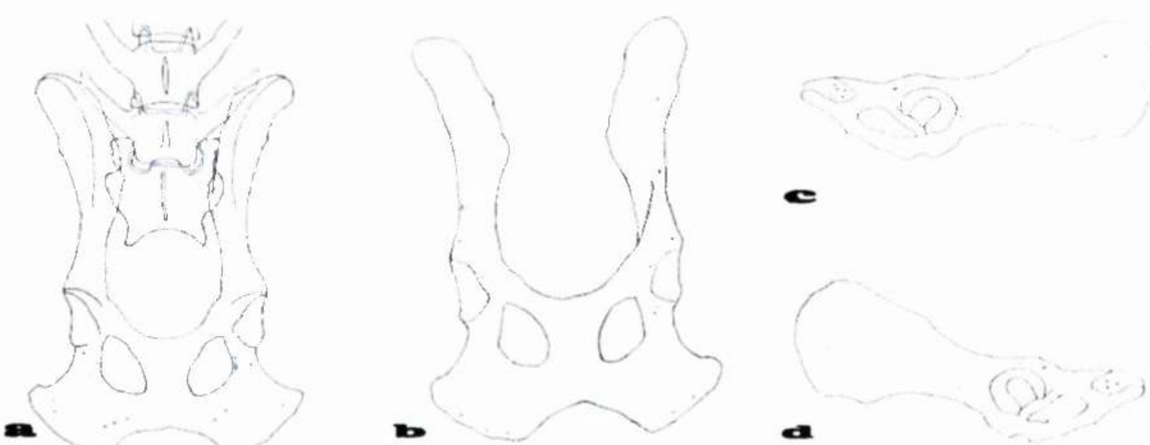


Figure 4.15. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 13.

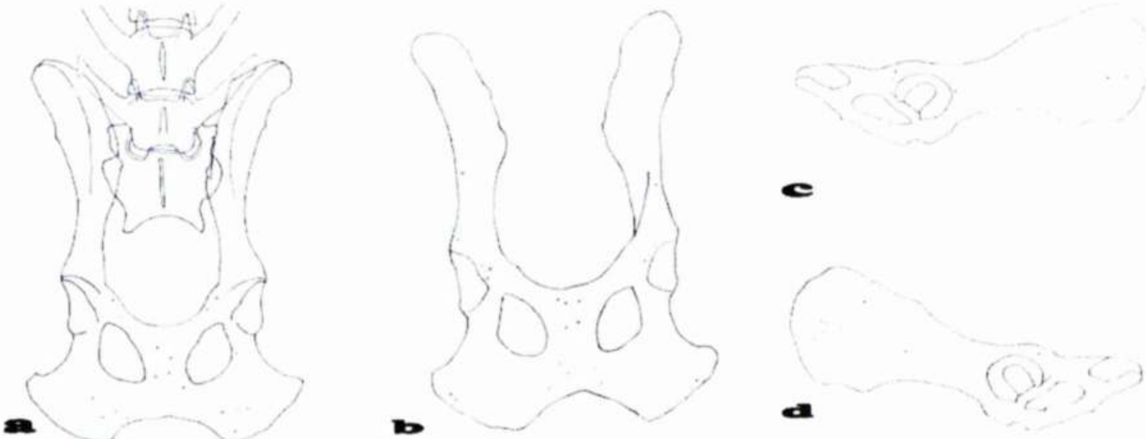


Figure 4.16. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 14.

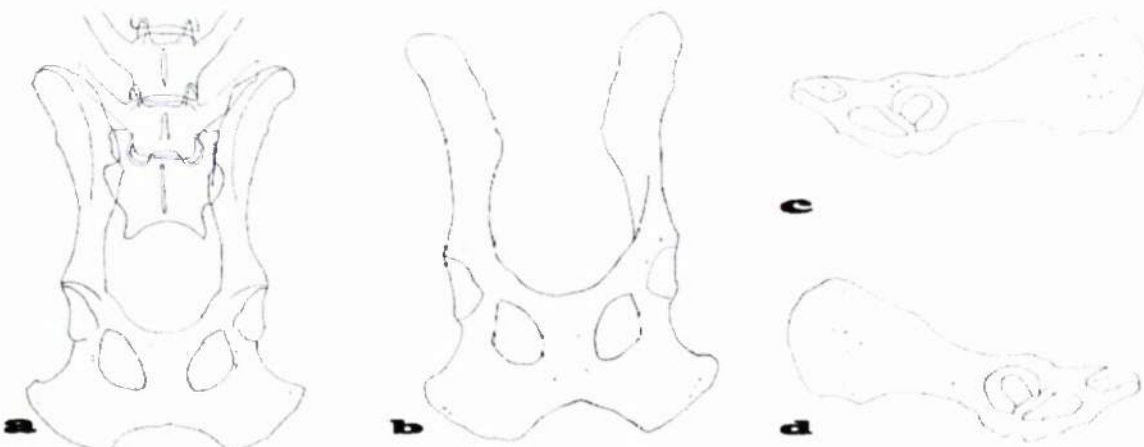


Figure 4.17. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 15.

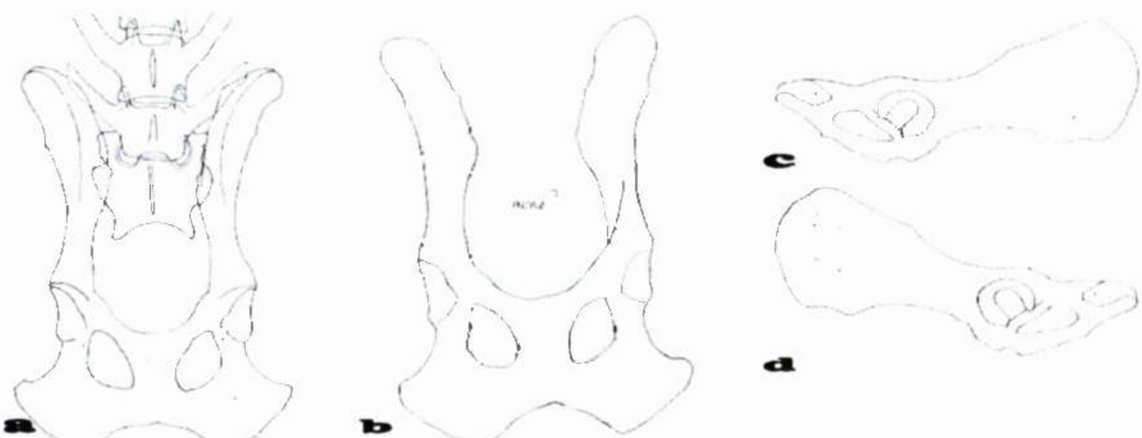


Figure 4.18. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 16.

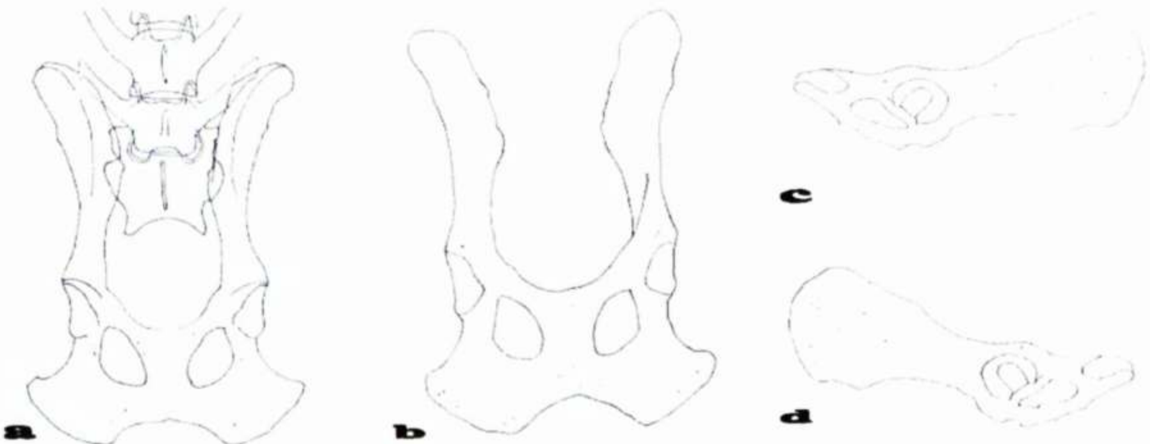


Figure 4.19. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 17.

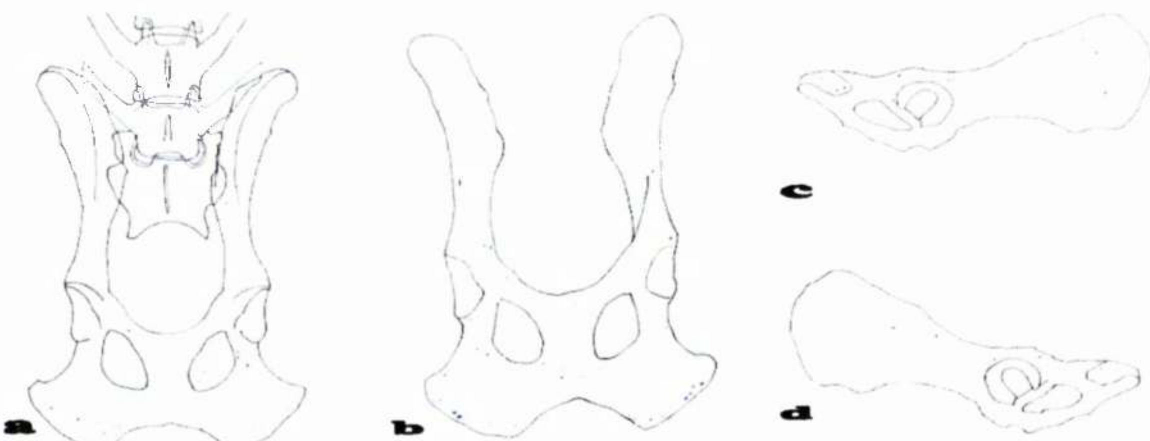


Figure 4.20. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 18.

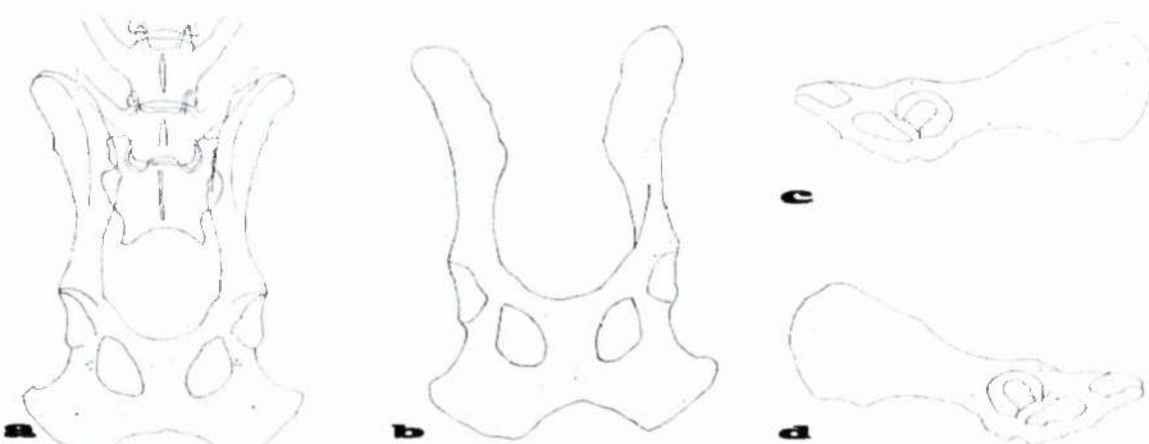


Figure 4.21. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 19.

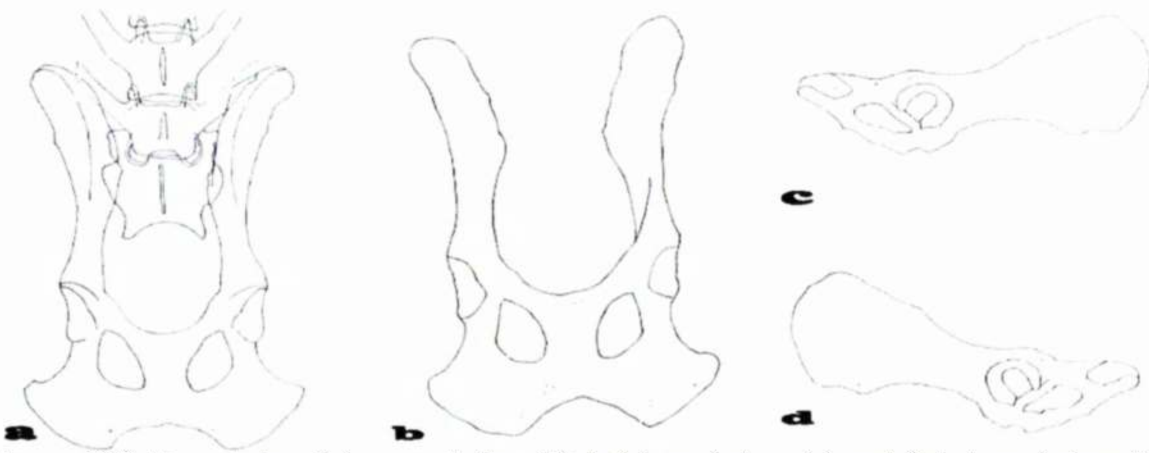


Figure 4.22. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 20.

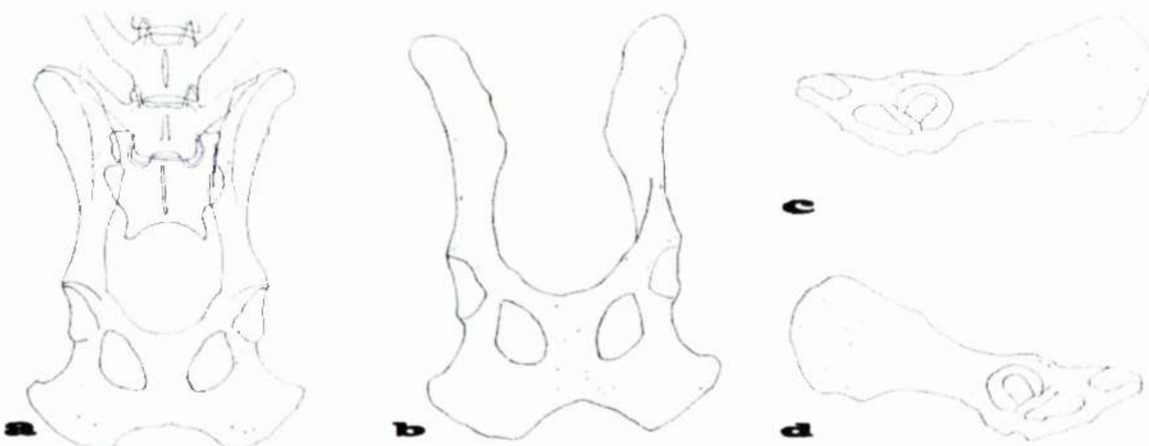


Figure 4.23. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 21.

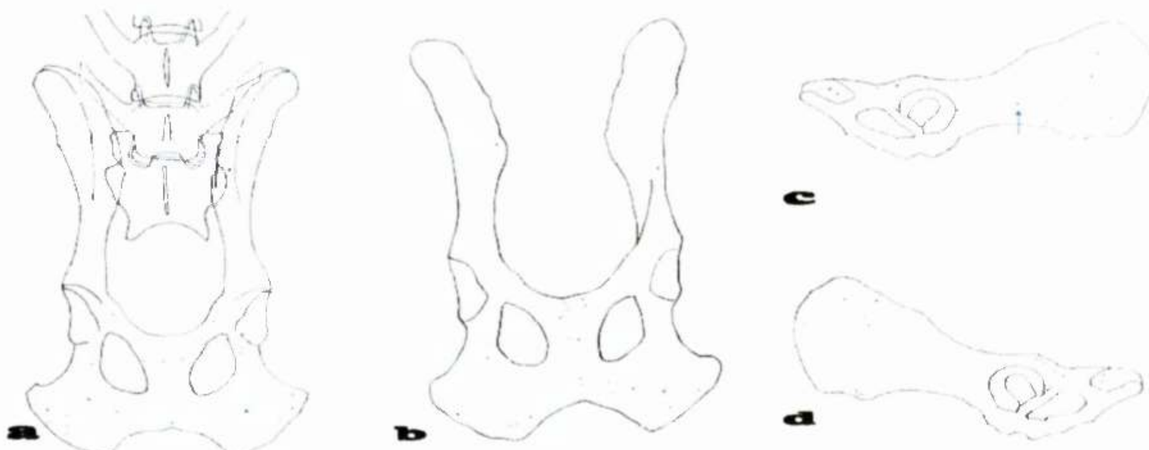


Figure 4.24. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 22.

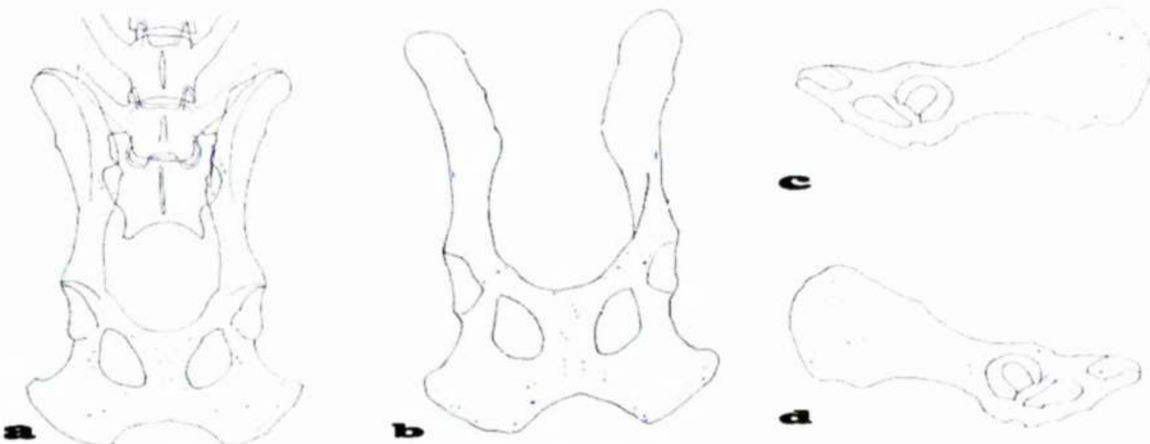


Figure 4.25. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 23.

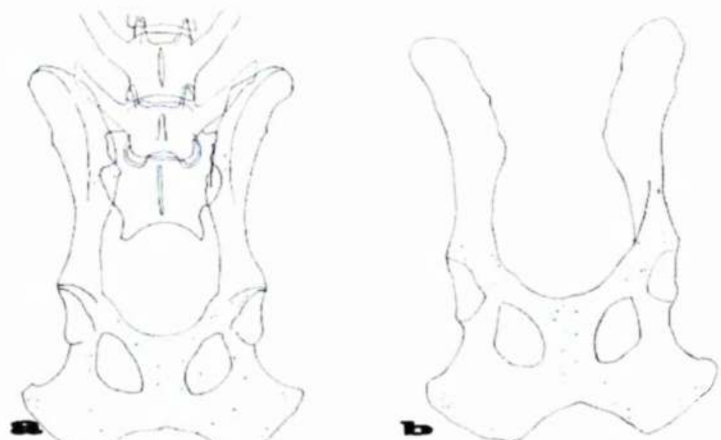


Figure 4.26. Dorsal view (a) and ventral view (b) of nutrient foramina of macerated pelvis 24.

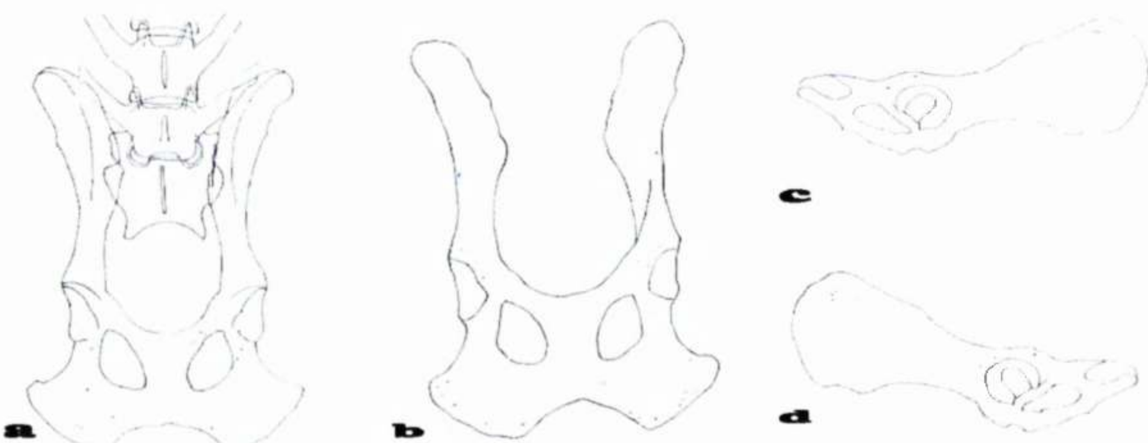


Figure 4.27. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 25.

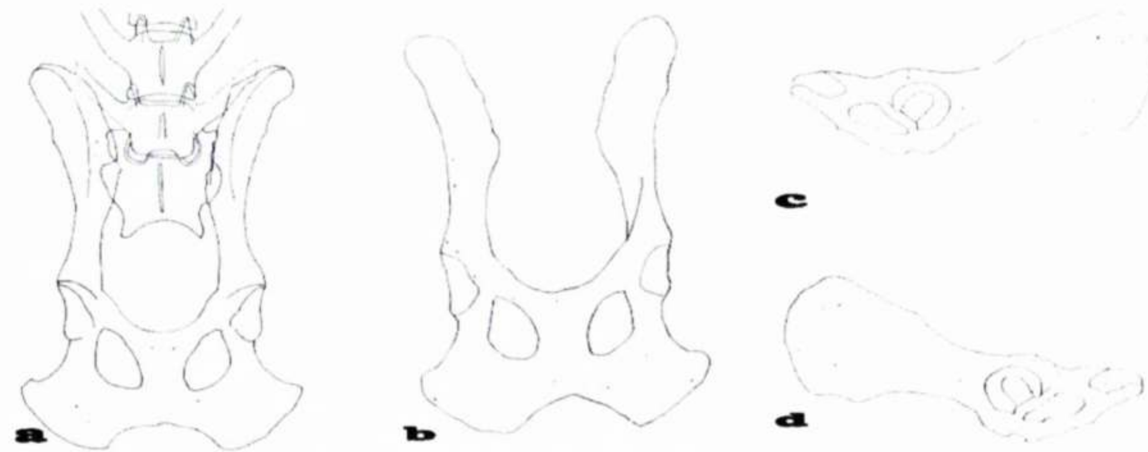


Figure 4.28. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 26.

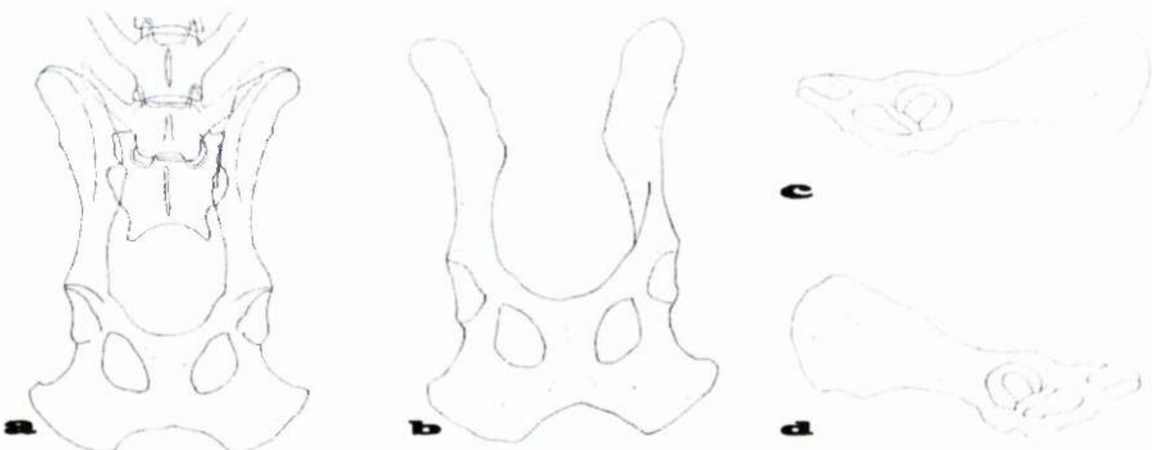


Figure 4.29. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 27.

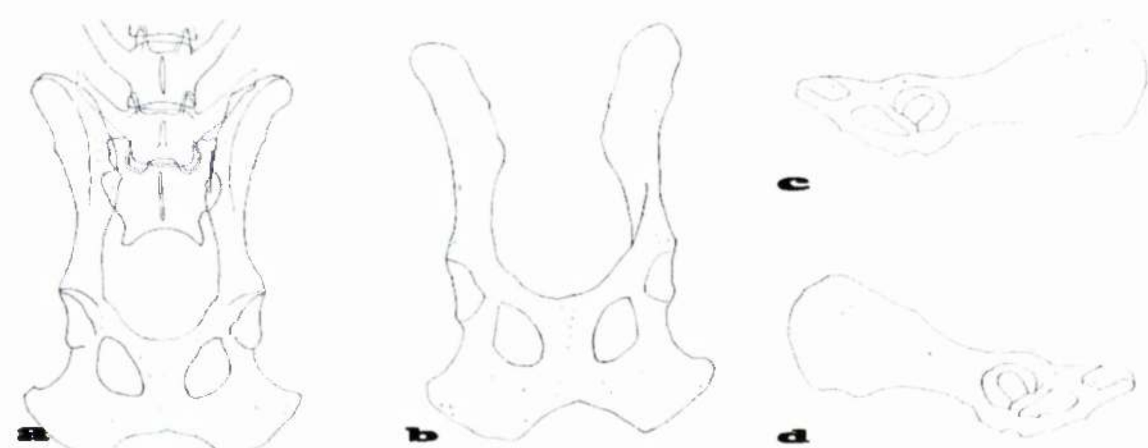


Figure 4.30. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 28.

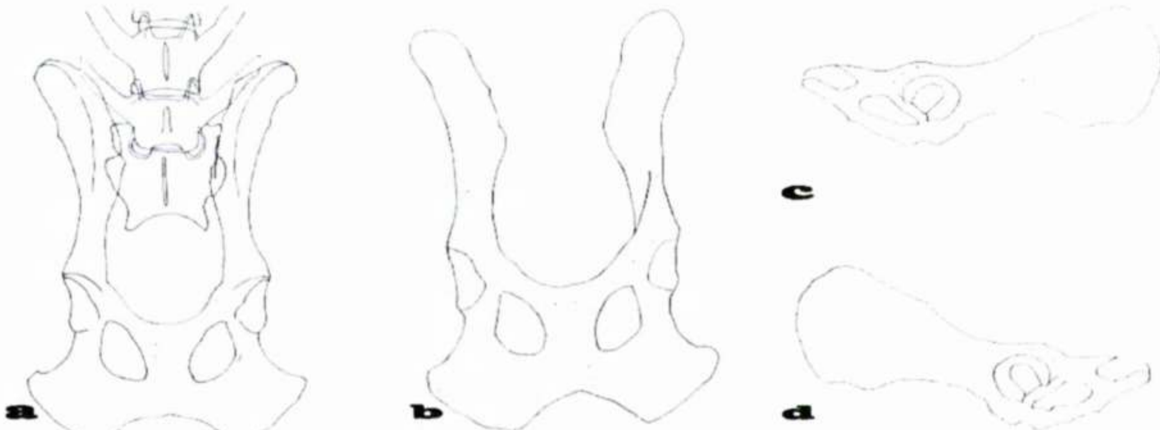


Figure 4.31. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 29.

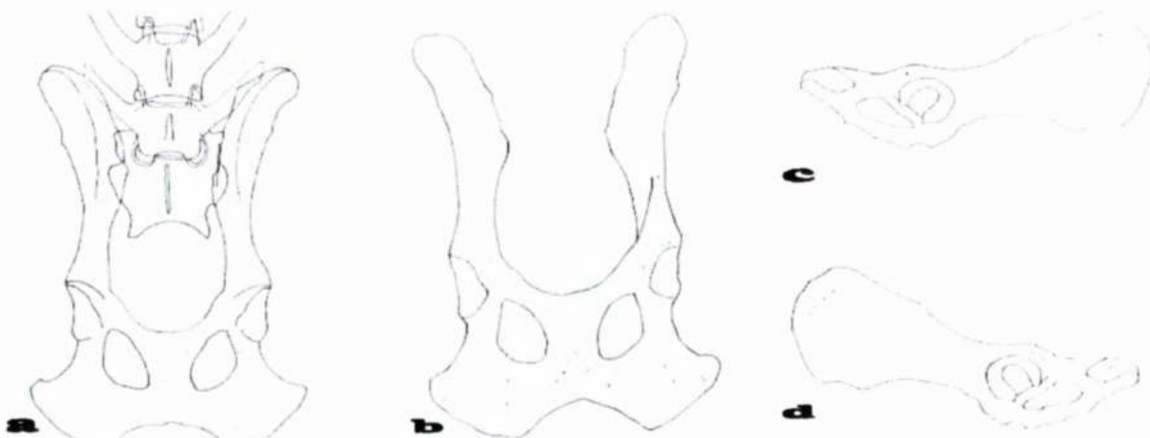


Figure 4.32. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 30.

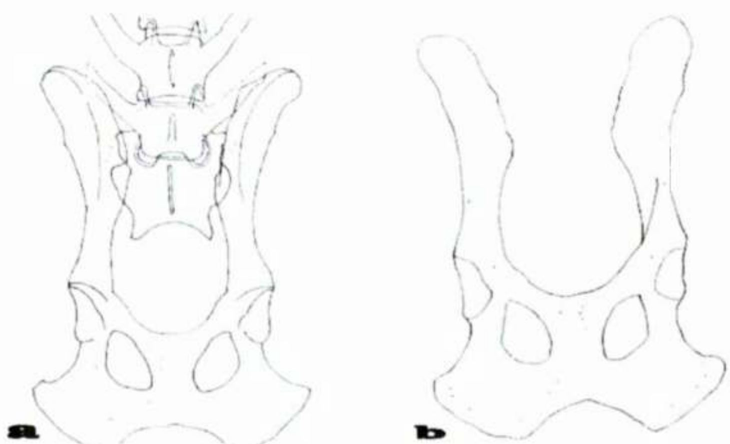


Figure 4.33. Dorsal view (a) and ventral view (b) of nutrient foramina of macerated pelvis 31.

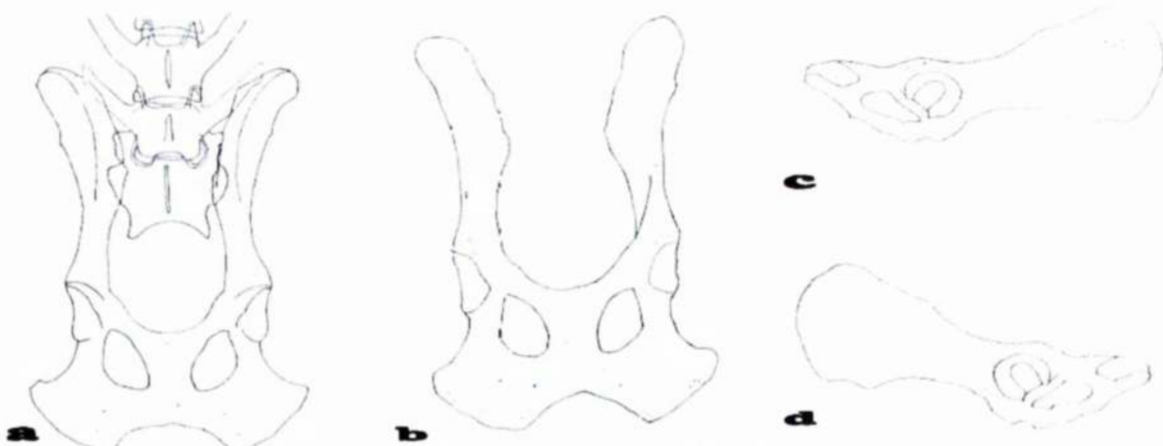


Figure 4.34. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 32.

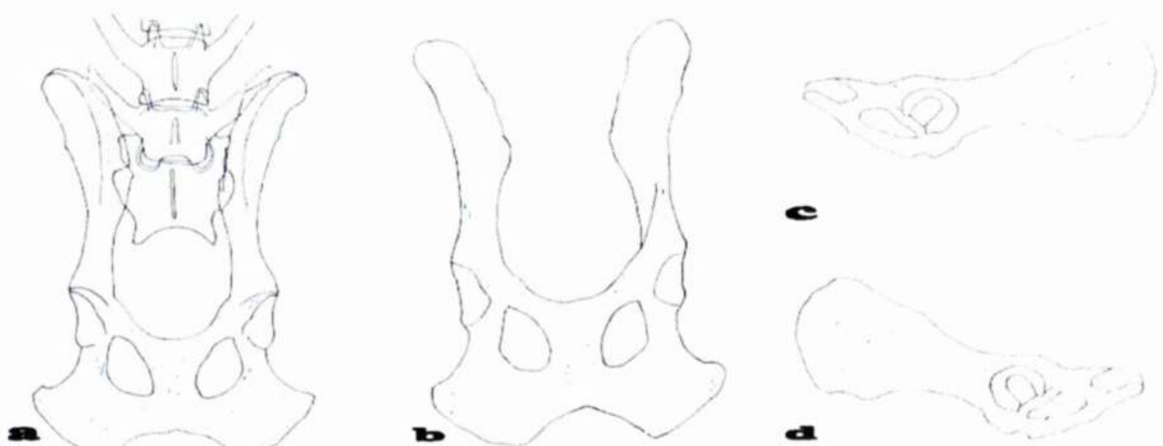


Figure 4.35. Dorsal view (a), ventral view (b), left lateral view (c) and right lateral view (d) of nutrient foramina of macerated pelvis 33.

4.3. DISCUSSION

Bone is a living material. To be kept alive it must have an adequate blood supply. All the physiologic processes within bone are dependant upon this blood supply. This is particularly striking in bone's response to injury (Rhinelander & Wilson, 1982). Many studies have taken place documenting the importance of blood supply to the normal physiological functions of bone (Brinker *et al*, 1990). It is also well known that an adequate blood supply is required to ensure bone healing after fracture (Brooks, 1971). Most authors agree that after fracture, the blood supply may be supplemented further by an extraosseous supply to the fracture site (1999, URL-3; Franch *et al*, 1998; Court-Brown, 1985; Brookes, 1971), which starts to develop immediately after injury (Rhinelander & Wilson, 1982). It is known that the increased stability provided by rigid plating decreases callus formation, allows the direct crossing of capillaries from one fragment to another and enhances the medullary arterial supply permitting a rapid recovery of the medullary circulation (Sumner-Smith, 1982). However a closely applied plate blocks the venous outflow through the cortex, thereby interfering with bone blood flow (Brinker *et al*, 1990; Court-Brown, 1985). Unfortunately, plate application also requires complete exposure of the fracture site and greatly disrupts the soft tissue attachments and blood supply to the fractured bone (McLaughlin & Roush, 1999). Plates and screws also produce large areas where circulation is damaged (Sumner-Smith, 1982) possibly because normal cortical blood supply comes from periosteal vessels, which the plate would block (Rhinelander & Wilson, 1982). It has been seen that cartilage forms in callus when the blood supply is diminished (Brooks, 1971).

This study was carried out in order to verify that the proposed insertion sites for external skeletal fixation (Chapter 7) did not interfere with principal nutrient vessels or foramina. With external fixation the local blood flow at the fracture site has been found to be higher than that in fractures treated with rigid compression plating. In this respect also, the use of external fixators appears to be beneficial (Wu *et al*, 1964).

4.3.1. Nutrient Foramina

Numerous nutrient foramina are found on all bones and facilitate vascularisation of interior regions of the bone by allowing entry and exit of blood vessels (Jojić, 1982).The blood supply and foramina of long bones has been extensively researched (Morris & Kelly, 1980; Kato *et al*, 1970; Rhinelander, 1968; Brookes & Harrison, 1957). Rhinelander & Wilson in 1982 stated that blood supply to irregular bones occurs at multiple sites rather than at major nutrient foramina, a finding that the current study confirms in part. Although this research noted that the majority of pelvic foramina were small and in multiple sites, a few major foramina were also present. However available information is scarce regarding the blood supply to the pelvis. A total of 33 macerated pelves were studied in this investigation. The dorsal, ventral, lateral and medial surfaces of each bone were carefully examined.

4.3.1.1. Ilial wing

It was found that the lateral aspect of the ilial wing displayed a large number of foramina in all cases. Many canals were present on the gluteal fossa where the bone is thinnest and few were present on the thickest part of the iliac crest. Apart from these 2 zones the foramina were scattered arbitrarily. The size of the canals on the ilial wing was random. The medial ilial wing was perforated uniformly in all cases with a slight predomination towards the crest. Over a third were densely perforated and just under a third were sparsely perforated. 21.2% had large openings adjacent to the articular surface. Jojić in 1982 documented foramina on the ilial wing but only on the periphery.

4.3.1.2. Ilial body

The ilial body displayed the most constant pattern of foramina. 84.9% of cases displayed a principal nutrient artery in this zone. It was suggested in 1982 by Kaderley *et al* that this foramen contained the iliolumbar artery and was the nutrient artery of the ilium. Rhinelander & Wilson in 1982 stated that a large nutrient artery pierces the ilium but did not mention where. The large majority were bilateral. Jojić in 1982 documented the presence of this foramen in 80% of cases. Most animals also had another principal foramen or scattering of small foramina on the lateral ilial body. Jojic (1982) found this foramen in 20% of specimens but he stated that it was present instead of the ventral one. He also documented the presence of a principal medial foramen, which this study did not find in any specimen. The ilial body does not display the consistent all over perforations present in the ilial wing. The lack of mention of the ventral ilial principal nutrient artery in surgical textbooks may predispose this structure to damage and consequent haemorrhage. To date only one textbook of small animal surgical approaches (Piermattei & Greeley, 1979) and one paper on surgical treatment of acetabular fractures (Wheaton *et al*, 1973) documented this. This nutrient artery is especially vulnerable during a lateral surgical approach to the ilium, an approach frequently used when applying a bone plate or lag screw to an ilial body fracture. Iatrogenic damage to this vessel coupled with damage to the periosteal circulation, due to subperiosteal elevation of the gluteal muscles, may result in considerable compromise of the blood supply to the fracture site.

4.3.1.3. Acetabulum

A principal nutrient foramen was found on the dorsal mid acetabulum in over 60% of cases. The remainder had a scattering of small foramina in the equivalent location. This is an area, which could be potentially damaged during application of an acetabular plate. No reference has been found to the dorsal acetabular principal foramen or small foramina. Jojić (1982) illustrated the presence of a principal cranial acetabular foramen on the cranial acetabular rim. This study did not find this on any specimen. Occasionally there was a scattering of small foramina in this zone. A quarter of the sample had small foramina on the lateral acetabular wall adjacent to the lunate surface. To date no mention has been found of these acetabular foramina. Rhinelander & Wilson in 1982 said that smaller foramina can be found near the acetabulum and iliac crest but did not mention where.

4.3.1.4. Symphysis

The pelvic symphysis displayed a diffuse scattering of foramina in all cases. The dorsal side had either bilateral principal foramina, present in random positions, in isolation or with a scattering of secondary foramina. The ventral aspect tended to contain a large number of small foramina.

4.3.1.5. Pubis

No consistent pattern was found on the pubic rami. Often either a single foramen or cluster of small foramina was present at the iliopubic eminence. This could be either on the dorsal or ventral side. Contrary to these findings, Jojić (1982) found a uniform pattern of small foramina on both aspects.

4.3.1.6. Ischium

4.3.1.6.1. Ischiatic Table

The prevalence of dorsal ischiatic tables had one or two principal nutrient foramina placed centrally. The majority was accompanied by numerous secondary foramina. Ventrally there were abundant small foramina. In over half of the specimens they were restricted to the caudal edge. There has been no information found regarding the ventral ischium, however contrary to these findings, Jojić (1982) found numerous small foramina dorsally.

4.3.1.6.2. Ischiatic Tuberosity

Over half of the specimens in this study had an abundance of large and small secondary foramina on the ischiatic tuberosity. It was noted that the larger breeds had significantly larger foramina.

4.3.1.6.3. Lesser Sciatic Notch

The majority of specimens in this investigation had a large secondary foramina, frequently coupled with a few small secondary foramina on the ventrolateral edge of the lesser sciatic notch. They could be unilateral or bilateral. Jojić in 1982 illustrated two principal foramina in this area. This study found no principal foramina present here.

4.3.1.7. Obturator foramen

In accordance with the findings of Jojić in 1982, nearly every specimen displayed one, two or three large secondary foramina on the medial wall ventral to the lesser ischiatic notch, adjacent to the obturator foramen.

4.4. CONCLUSIONS

The canine pelvis has abundant nutrient foramina. Certain areas have distinct sizes of canals, which occur in a regular pattern or patterns. Others have a more random distribution and have foramina that are present in varying frequencies. No two specimens had exactly the same patterns of foramina. This may explain the variations and differences between the findings of this study and the limited reports of other authors. The proposed external skeletal fixation insertion sites do not appear to interfere with any principal nutrient vessels. They may however compromise individual secondary vessels in the iliac crest, lesser sciatic notch and ischiatic tuberosity. These locations have numerous quantities of other similar foramina, indicating rich vascularisation, which would undoubtedly be able to compensate. It is possible, that by the nature of their design and application, bone plates attached to the ilial body may damage the blood supply to the fracture site, thus impeding healing and union.

2. METHYL METHACRYLATE CASTING OF THE PELVIC ARTERIES

The earliest recorded examples of casts being made of an anatomical cavity are those of the cerebral ventricles by Leonardo da Vinci (1452 – 1519). Leonardo da Vinci used molten wax for this work. He understood the physical problems involved sufficiently clearly to provide an escape hole for the fluid or air displaced by the wax (Tompsett, 1970). Polyester resin castings were not documented in Great Britain until 1948 (Tompsett, 1970). This procedure revolutionized the art of anatomical casting as it became possible to produce rigid, strong and colored casts with minimal shrinkage and an indefinite lifespan.

This part of the study was made to obtain a clear and concise description of the normal vascular supply to the pelvic region of the dog.

4.5. MATERIALS AND METHODS

4.5.1. Preparation

A fresh male greyhound type canine cadaver was used for this procedure. The animal was placed in dorsal recumbency on a dissecting table. The legs were tied with string to the corresponding corner of the table in order to stabilise it in the required position. The abdominal aorta and caudal vena cava were located using sharp and then blunt dissection. They were both ligated, the aorta being ligated just cranial to the bifurcation of the aorta into the external and internal iliac arteries. A cannula was inserted into the lumen of the aorta (afferent cannula) and the vena cava (efferent cannula) and secured with string. The aortic cannula was flushed through with a continuous flow of physiological saline at room temperature, using a large syringe and manual pressure. The efferent cannula was left open. Flushing was sustained until the returning flow out of the efferent cannula was non-sanguineous.

4.5.2. Casting

Before casting took place string was tied tightly around each stifle to prevent the passage of resin in to the distal hindlimbs. Casting of the arterial system was carried out using methyl methacrylate mixed with a red dye. The methyl methacrylate was administered via the aortic cannula, again using a large syringe and manual pressure. When resistance to injection became extreme, the injection was ended. This signified filling of the capillary beds. A sample of resin was kept in a spare cannula and set aside. This was used as a guide as to when the resin was set on the assumption that when this resin was set, the resin within the whole animal would be set. This took approximately 36 hours.

4.5.3. Maceration

Once the animal was set it was skinned using a Swann Morton No.4 scalpel handle with a size 22 blade. The whole animal was then transected at the thoraco – lumbar junction using the scalpel and blade previously specified for the soft tissue and long handled bone cutters on the vertebral column. At all times care was taken to ensure that there was minimal movement of the animal and that no external pressure was applied to the pelvic region.

The hindquarters were then placed on to a stainless steel tray with a grid base and lifting handles. This was lowered in to a saturated solution of potassium hydroxide (KOH). This was monitored daily and the rate of maceration was checked. Twice weekly the specimen was removed from the KOH by lifting the tray out, and washing with running tap water to dislodge any waste material. The specimen was then replaced in the solution by carefully lowering the tray back in. This was continued until all the hard and soft tissue was removed.

4.6. RESULTS

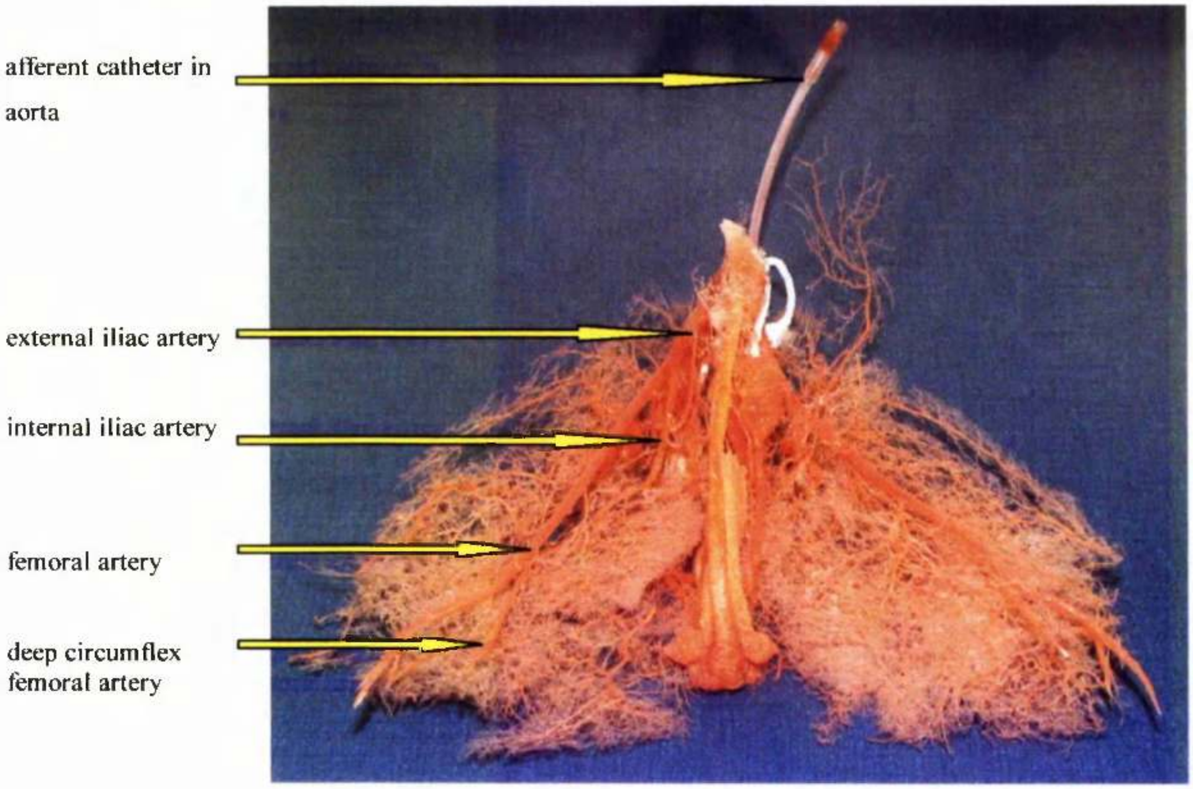


Figure 4.36. Casting of the pelvic arterial vasculature.

The methylmethacrylate casting accurately demonstrated the pelvic vasculature. However in this cast the vessels were more apparent on the left. Figures 4.37 and 4.38 demonstrate flow charts of the pelvic arterial and venous system respectively, using information derived from anatomy textbooks.

4.7. DISCUSSION

Blood supply to the pelvis is well described and diagrammatically illustrated in anatomical textbooks (Evans & DeLahunta, 2000; Dyce *et al*, 1996; Evans, 1993; Adams, 1986), although small differences are present between authors descriptions of the smaller vessels. Only the main arteries are documented in these textbooks and it is difficult to visualize the extent of the minor arteries, normally lying between or within the musculature. This study was carried out to obtain a clearer overall picture of the pelvic vascular tree. Blood supply to the pelvis is vast, as seen in the pelvic casting. This extensive supply will undoubtedly assist the rapid healing of pelvic fractures. In most cases the blood supply would not be compromised by surgical interference except in the case of ilial body fractures.

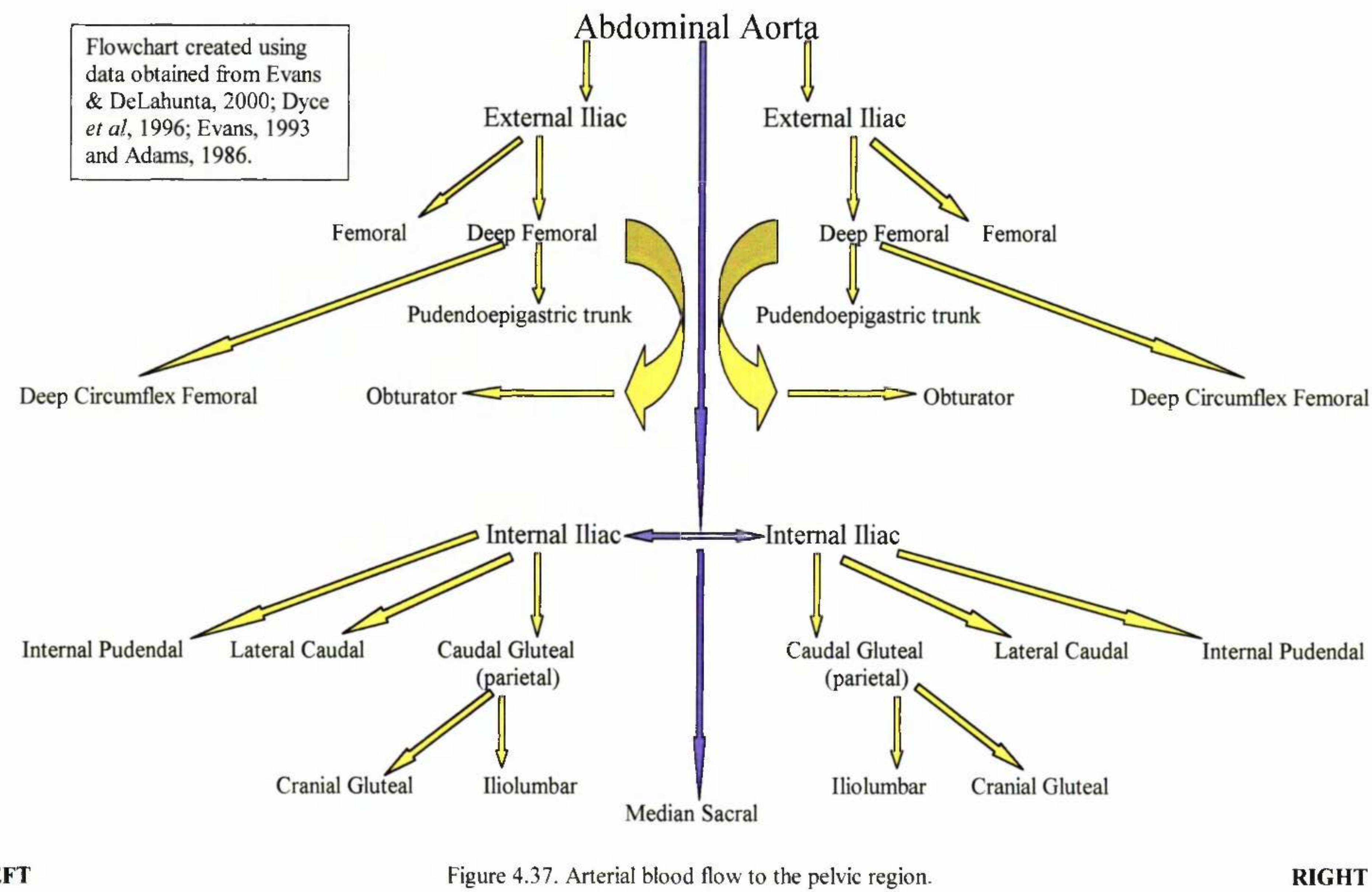


Figure 4.37. Arterial blood flow to the pelvic region.

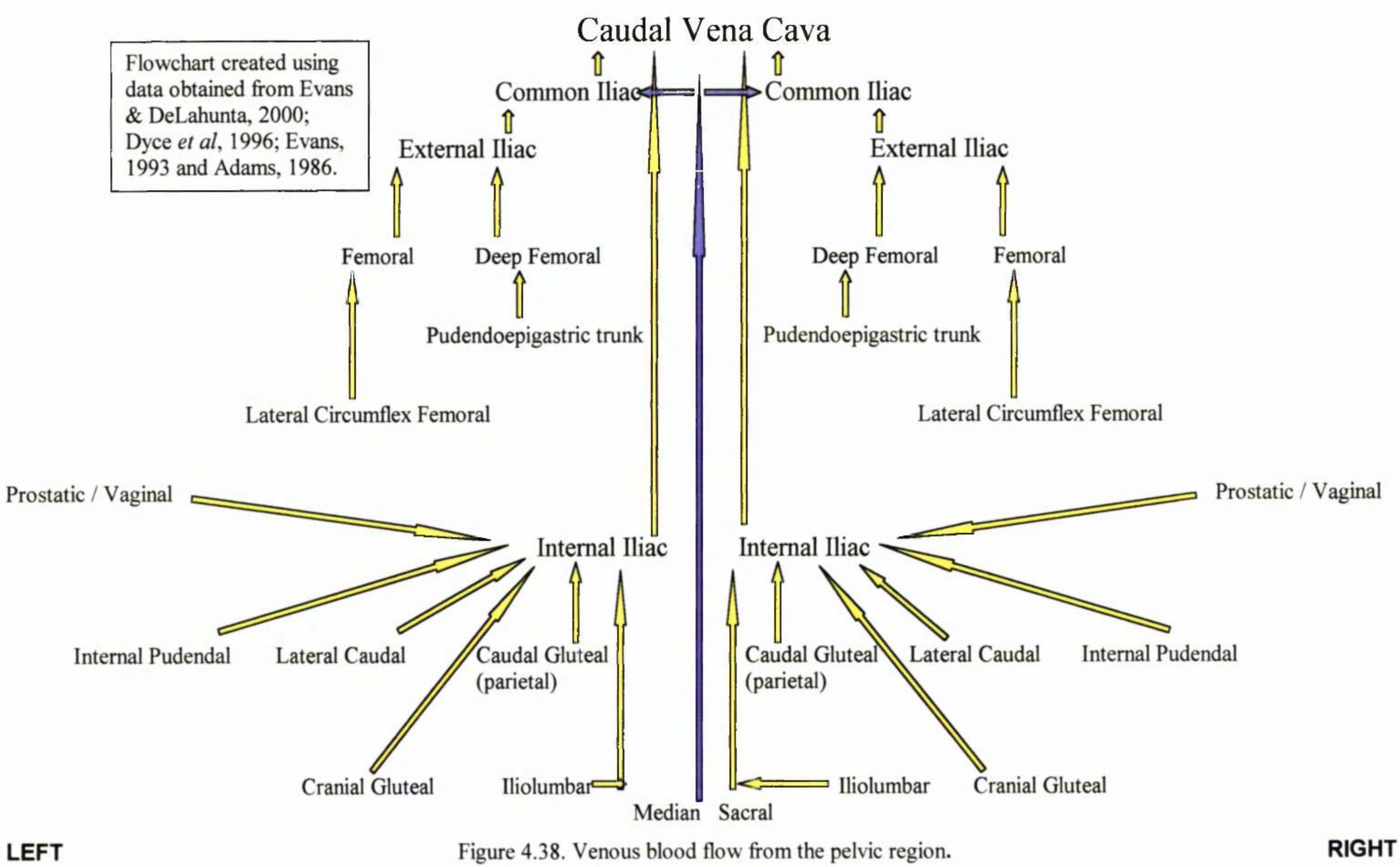


Figure 4.38. Venous blood flow from the pelvic region.

PELVIC FRACTURES OF THE DOG AND CAT – A RETROSPECTIVE RADIOGRAPHIC STUDY

Despite pelvic fractures being one of the most common fractures seen in veterinary practice there is surprisingly little information available in the literature regarding specific fracture locations, types and the overall severity of the pelvic disruptions. To date we have found no commonly used classification systems for small animal pelvic fractures. A retrospective radiographic investigation was carried out using data obtained from animals referred to Glasgow University Veterinary School (GUVS) and The Royal Veterinary College, London (RVC) over a period of 6 years. A simple but effective classification system was created based primarily on the anatomical location of each fracture site with a secondary emphasis on fracture type. The areas of the pelvis, which displayed the highest incidence of fracture, were deduced and the most common combinations were isolated. The sample included canine and feline patients. The data was initially studied while amalgamated to give general small animal results, and then separated to illustrate possible interspecies variations.

We chose not to include the direction of force as frequently it is unknown and almost always it proves to be random and multidirectional.

5.1. MATERIALS & METHODS

The sample comprised of a total of 225 cases (161 from GUVS and 64 from RVC). This consisted if 157 dogs (109 from GUVS and 48 from RVC) and 68 cats (52 from GUVS and 16 from RVC).

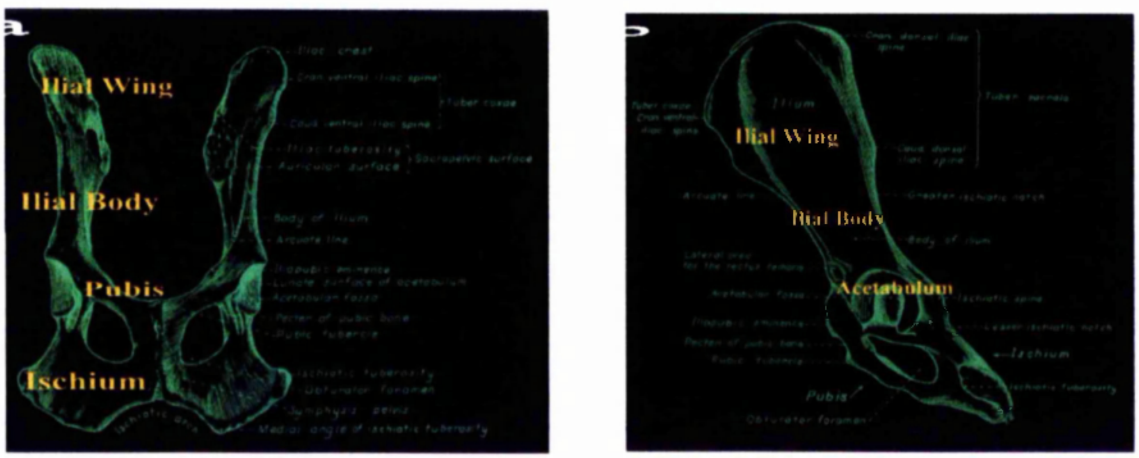
A pro-forma master data sheet was designed and produced to allow the accurate recording of each animal's detailed information in a standard format. The case notes and radiographs for each animal were studied. The data recorded for this study from the case notes included owner and referring veterinary practice information, the animal's age, sex, breed, treatment, cause or suspected cause of fracture, concomitant injuries, time window between injury and surgery (when applicable) and complications when they occurred.

Information on cause of fracture, sex and concomitant injuries was not available with the RVC cases. In all patients both ventrodorsal and lateral radiographs were available.

5.1.1. Anatomical locations

The pelvis was divided into specific anatomical locations for use in the classification of fracture location (Figures 5.1a & 5.1b). These were 1. ilial wing, 2. ilial body, 3. acetabulum (subdivided into cranial, mid, caudal and comminuted), 4. ischium, 5. pubis, 6. symphyseal separation, 7. sacroiliac fracture / luxation and 8. sacral fracture. The acetabular fractures were defined as cranial when the fracture line passed through the cranial articular margin adjacent to the ilial body, mid when the fracture line passed through the mid portion of the articular region and caudal when it passed through the caudal articular margin adjacent to the ischium.

The exact anatomical location of each fracture was recorded.



Figures 5.1a & b. Anatomical locations of fracture sites.

5.1.2. Sites

The number of fracture sites presented by each animal was recorded diagrammatically.

5.1.3. Types

Ilial wing and body fractures were subdivided in to transverse, oblique, greenstick, comminuted, chip and longitudinal fractures. Fractures of the acetabulum and ischium were not so easy to classify into actual type as often the direction of the fracture line or lines were irregular. Subsequently it was decided to classify the fractures, which were not comminuted, chip or greenstick according to the number of pieces they were broken into i.e. 2 piece and 3 piece. Thus a 2 piece was classified as being where there was one fracture line and the bone was broken clearly in to 2 parts and a 3 piece as being where there were 2 clear fracture lines and the bone was broken in to 3 parts. Symphyseal fracture separations were divided into separation of the whole symphysis, cranial symphysis or caudal symphysis.

5.1.4. Distribution

Distribution of fractures is defined as whether the anatomical locations are unilateral or bilateral. Data from both canine and feline cases was separated out into either fracture configuration and recorded.

5.1.5. Concomitant injuries

Concomitant extrapelvic injuries from all cases were recorded and separated in to hard and soft tissue.

5.1.6. Combinations

The common fracture location combinations for canine and feline data were deduced.

Initially all data from GUVS and RVC was amalgamated to get an overall small animal picture (Table 5.1). This was divided into amalgamated canine and feline for GUVS (Table 5.2) and RVC (Table 5.3) independently to give a small animal overview while highlighting any geographical differences. This was then subdivided into canine data from amalgamated (Table 5.4) and independent GUVS (Table 5.5) and RVC (Table 5.6) and feline data from amalgamated (Table 5.7) and independent GUVS (Table 5.8) and RVC (Table 5.9). This was to illustrate both species and geographical differences.

5.1.7. Imaging

Although radiography is the traditional imaging modality in orthopaedics, ultrasound can be used to image the continuity and integrity of the periosteal surface of certain bones. In the pelvis the ilium and hip joint were scanned using a Siemens Elegra scanner with extended field of view technology and the images acquired digitally. In addition the hip joint was imaged using 3-dimensional b-mode ultrasound. A male greyhound was used for this experiment. To avoid clipping of the coat, the hair was soaked in alcohol and combed in the direction of the proposed scan.

5.1.7.1. Imaging of the ilium with extended field of view ultrasound

The greyhound was placed in lateral recumbency. Images were taken in long axis from three aspects: dorsal, lateral and ventral. In all cases the transducer was run in a cranial to caudal direction. For the dorsal scans the transducer was placed on the dorsal border of the ilium, a few millimetres caudal to the cranial dorsal iliac spine, and run to the lateral aspect of the ischiatic tuberosity. It was not placed on the actual cranial dorsal iliac spine as the bony protuberance caused a loss of skin contact. For the lateral view the transducer was placed a few millimetres ventral to the cranial dorsal iliac spine and run to the lateral aspect of the ischiatic tuberosity. For the ventral scans the transducer was placed on the ventral border of the ilium, on the approximate level of the cranial ventral iliac spine, and run to the lateral aspect of the ischiatic tuberosity.

5.1.7.2. Imaging of the hip with extended field of view ultrasound

The greyhound was placed in dorsal recumbency. Images were taken in short axis. The transducer was placed on the pelvic symphysis and swept laterally to the approximate level of the hip joint.

5.1.7.3. Imaging of the hip with 3-dimensional b-mode ultrasound

The greyhound was placed in lateral recumbency. The transducer was placed over the hip joint in a dorsal plane and "rocked" once so that the aperture travelled from a dorsal to ventral direction. This allows a 3-d volume to be acquired. A wedge image plus images in the transverse, dorsal and para-sagittal plane are illustrated in summarised quadrants as well as in the enlarged form.

5.2. RESULTS

5.2.1. Normal canine and feline pelves

The dog pelvis illustrated in Figure 5.2 is well positioned. The pelvis looks completely symmetrical. The caudal vertebrae lie on the pelvic symphysis. The cat pelves (Figures 5.3 & 5.4) however illustrate bad positioning. The pelves are rotated and although no fractures are present look as though there is a sacroiliac separation on the left (Figure 5.3) and right (Figure 5.4) and possibly pubic disruptions. This highlights how good radiographs are essential. However this study is retrospective and there was no control over the taking of the radiographs or the positioning of the animals. A small number of the radiographs were of insufficient quality and were not included in the results. In most cases the lateral views were also available.

Figure 5.2. Normal canine pelvis

Figure 5.3. Normal feline pelvis.

Figure 5.4. Normal feline pelvis.

Essentially canine and feline pelvic anatomy is the same but the feline pelvis is proportionately longer and narrower than the canine pelvis.

5.2.2. Anatomical locations

Out of a total of 784 fractures from the amalgamated canine and feline data from both GUVS and RVC, 235 occurred on the right of the animal, 235 on the left, 133 were bilateral and 48 were unspecified. The most common amalgamated small animal fracture location (Table 5.1 & Figure 5.5) was that of the pubis constituting 28.1% of all fractures. This was closely followed by the ischium (23%). Sacroiliac luxations displayed the next highest number (13.9%) followed by ilial body fractures (11.1%). Mid acetabular and ilial wing fractures displayed almost similar quantities (5.9% and 5.5% respectively). At the other end of the scale the least common locations were symphyseal separations (3.6%), caudal acetabulum (3.3%), comminuted acetabulum (2.6%), sacrum (2.1%) with cranial acetabulum being the rarest (1%).

	Right	Left	Bilateral	Not Specified	Number of Fractures	% of Fractures
Sacroiliac Luxation	35	40	17		109	13.9
Ilial Wing	15	20	4		43	5.5
Ilial Body	43	30	7		87	11.1
Cranial Acetabulum	3	5			8	1.0
Mid Acetabulum	21	19	3		46	5.9
Caudal Acetabulum	14	12			26	3.3
Comminuted Acetabulum	9	11			20	2.6
Pubis	45	53	60	1	220	28.1
Ischium	50	45	42	2	180	23.0
Sacrum				17	17	2.1
Symphyseal Separation				28	28	3.6
Total	**235**	**235**	**133**	**48**	**784**	

Table 5.1. Amalgamated canine and feline data from GUVS and RVC.

	Right	Left	Bilateral	Not Specified	Number of Fractures	% of Fractures
Sacroiliac Luxation	27	27	13		80	15.8
Ilial Wing	9	14	3		29	5.7
Ilial Body	22	15	6		49	9.7
Cranial Acetabulum	2	3			5	1.0
Mid Acetabulum	12	13	2		29	5.7
Caudal Acetabulum	12	9			21	4.1
Comminuted Acetabulum	6	7			13	2.6
Pubis	29	36	35	2	137	27.0
Ischium	30	30	24	1	109	21.5
Sacrum				14	14	2.8
Symphyseal Separation				21	21	4.1
Total	**149**	**154**	**83**	**38**	**507**	

Table 5.2. Amalgamated canine and feline data from GUVS.

The amalgamated canine and feline data from GUVS showed a similar picture (Table 5.2 & Figure 5.6) with fractures of the pubis (27%) and ischium (21.5%) and sacroiliac luxations (15.8%) being the most common. Fractures of the sacrum (2.8%) and comminuted acetabulum (2.6%) were again the least common. In this data set however the ilial wing and mid acetabulum displayed the same incidence of fracture (5.7%) as did the caudal acetabulum and symphysis (4.1%). The combined data from RVC showed a different pattern (Table 5.3 & Figure 5.7). In accordance with the GUVS result the most common fracture locations were the pubis (30%) and ischium (25.6%). However the third most common was the ilial body (13.7%) followed by sacroiliac luxation (10.5%). In this data set both the ilial wing and mid acetabulum (6.1%) and the symphysis and comminuted acetabulum (2.5%) displayed the same value. Fractures of the caudal acetabulum (1.8%) and cranial acetabulum and sacrum (1.1%) were the least common.

	Right	**Left**	**Bilateral**	**Not Specified**	**Number of Fractures**	**% of Fractures**
Sacroiliac Luxation	8	13	4		29	10.5
Ilial Wing	6	6	1		14	6.1
Ilial Body	21	15	1		38	13.7
Cranial Acetabulum	1	2			3	1.1
Mid Acetabulum	9	6	1		17	6.1
Caudal Acetabulum	2	3			5	1.8
Comm. Acetabulum	3	4			7	2.5
Pubis	16	17	25		83	30.0
Ischium	20	15	18		71	25.6
Sacrum				3	3	1.1
Symphyseal Separation				7	7	2.5
Total	**86**	**81**	**50**	**10**	**277**	

Table 5.3. Amalgamated canine and feline data from RVC.

Pubic (29%) and ischial (25.4%) fractures from GUVS and RVC canine data were again the most common. This was followed by a substantially lesser value for ilial body fractures (12%) and less again for sacroiliac luxations (10.7%). The mid acetabulum and ilial wing had similar values of 5.8% and 5.1% respectively. The least common locations were the caudal acetabulum (3.6%), symphysis (3.3%) and comminuted acetabulum (2.9%); the rarest being sacrum (1.6%) and cranial acetabulum (1%).

	Right	**Left**	**Bilateral**	**Not Specified**	**Number of Fractures**	**% of Fractures**
Sacroiliac Luxation	20	21	9		59	10.7
Ilial Wing	9	11	4		28	5.1
Ilial Body	29	25	6		66	12.0
Cranial Acetabulum		4			4	1.0
Mid Acetabulum	14	14	2		32	5.8
Caudal Acetabulum	10	10			20	3.6
Comminuted Acetabulum	9	7			16	2.9
Pubis	27	36	48	1	160	29.0
Ischium	37	30	36	1	140	25.4
Sacrum				9	9	1.6
Symphyseal Separation				18	18	3.3
Total	**155**	**158**	**105**	**29**	**552**	

Table 5.4. Canine data from GUVS and RVC.

The canine data from GUVS (Table 5.5 & Figure 5.9) showed a slightly different picture. Again pubic (27.4%) and ischial (24.2%) fractures were by far the most common. However in this data set sacroiliac luxations were the third most common (13.1%) and ilial body fractures (10.5%) the fourth which was opposite to the canine data from GUVS/RVC. The mid acetabulum displayed the next result (5.5%), followed by symphyseal separations (4.7%). Ilial wing fractures and caudal acetabular fractures had identical values of 4.4% followed by comminuted acetabulum (3.2%). The rarest locations again were the sacrum (2%) and cranial acetabulum (0.6%).

	Right	Left	Bilateral	Not Specified	Number of Fractures	% of Fractures
Sacroiliac Luxation	16	15	7		45	13.1
Ilial Wing	3	6	3		15	4.4
Ilial Body	13	13	5		36	10.5
Cranial Acetabulum		2			2	0.6
Mid Acetabulum	8	9	1		19	5.5
Caudal Acetabulum	8	7			15	4.4
Comminuted Acetabulum	6	5			11	3.2
Pubis	16	27	25	1	94	27.4
Ischium	21	21	20	1	83	24.2
Sacrum				7	7	2.0
Symphyseal Separation				16	16	4.7
Total	**91**	**105**	**61**	**25**	**343**	

Table 5.5. Canine data from GUVS.

	Right	Left	Bilateral	Not Specified	Number of Fractures	% of Fractures
Sacroiliac Luxation	4	6	2		14	6.7
Ilial Wing	6	5	1		13	6.2
Ilial Body	16	12	1		30	14.4
Cranial Acetabulum		2			2	1.0
Mid Acetabulum	6	5	1		13	6.2
Caudal Acetabulum	2	3			5	2.4
Comminuted Acetabulum	3	2			5	2.4
Pubis	11	9	23		66	31.6
Ischium	16	9	16		57	27.3
Sacrum				2	2	1.0
Symphyseal Separation				2	2	1.0
Total	**64**	**53**	**44**	**4**	**209**	

Table 5.6. Canine data from RVC.

The canine data from RVC (Table 5.6 & Figure 5.10) showed a different pattern from the canine GUVS records. In accordance with it pubic (31.6%) and ischial (27.3%) fractures were the most frequently seen. This was followed by fractures of the ilial body (14.4%)

and sacroiliac luxations (6.7%). The next most common fractures were paired in frequency. For example ilial wing and mid acetabulum (6.2%), caudal and comminuted acetabulum (2.4%) and the rarest, sacrum, cranial acetabulum and, unusually, symphyseal separation, all at 1%.

	Right	Left	Bilateral	Not Specified	Number of Fractures	% of Fractures
Sacroiliac Luxation	15	19	8		50	21.6
Ilial Wing	6	9			15	6.5
Ilial Body	14	5	1		21	9.1
Cranial Acetabulum	3	1			4	1.7
Mid Acetabulum	7	5	1		14	6.0
Caudal Acetabulum	4	2			6	2.6
Comminuted Acetabulum		4			4	1.7
Pubis	18	17	12	1	60	25.9
Ischium	9	15	6		40	17.2
Sacrum				8	8	3.4
Symphyseal Separation				10	10	4.3
Total	**80**	**77**	**28**	**19**	**232**	

Table 5.7. Feline data from GUVS and RVC.

The feline data from GUVS and RVC (Table 5.7 and Figure 5.11) showed that the most common fracture location was the pubis (25.9%) closely followed by sacroiliac luxations (21.6%) and ischial fractures (17.2%). Fractures of the ilium featured next with ilial body presenting 9.1% and ilial wing 6.5%. Fractures of the mid acetabulum (6%), symphysis (4.3%) and sacrum (3.4%) were the next most common. Whereas fractures of the caudal acetabulum were slightly rarer (2.6%) caudal and comminuted acetabulum shared the lowest percentage (1.7%).

	Right	Left	Bilateral	Not Specified	Number of Fractures	% of Fractures
Sacroiliac Luxation	11	12	6		35	21.3
Ilial Wing	6	8			14	8.5
Ilial Body	9	2	1		13	7.9
Cranial Acetabulum	2	1			3	1.8
Mid Acetabulum	4	4	1		10	6.1
Caudal Acetabulum	4	2			6	3.7
Comminuted Acetabulum		2			2	1.2
Pubis	13	9	10	1	43	26.2
Ischium	9	9	4		26	15.9
Sacrum				7	7	4.3
Symphyseal Separation				5	5	3.0
Total	**58**	**49**	**22**	**13**	**164**	

Table 5.8. Feline data from GUVS.

The GUVS records (Table 5.8 & Figure 5.12) showed that again the most common three locations were pubis (26.2%), sacroiliac (21.3%) and ischial (15.9%). The ilium features next with ilial wing representing 8.5% and ilial body 7.9%. Mid acetabulum, sacrum and caudal acetabulum were the next most common, with values of 6.1%, 4.3% and 3.7% respectively. The three rarest locations were the symphysis (3%), cranial (1.8%) and comminuted acetabulum (1.2%).

	Right	Left	Bilateral	Not Specified	Number of Fractures	% of Fractures
Sacroiliac Luxation	4	7	2		15	22.1
Ilial Wing		1			1	1.5
Ilial Body	5	3			8	11.8
Cranial Acetabulum	1				1	1.5
Mid Acetabulum	3	1			4	5.9
Caudal Acetabulum						
Comminuted Acetabulum		2			2	2.9
Pubis	5	8	2		17	25.0
Ischium	4	6	2		14	20.6
Sacrum				1	1	1.5
Symphyseal Separation				5	5	7.4
Total	**22**	**28**	**6**	**6**	**68**	

Table 5.9. Feline data from RVC.

The RVC feline data showed a dissimilar picture (Table 5.9 and Figure 5.13). In keeping with the GUVS files fractures of the pubis (25%), sacroiliac luxations (22.1%) and fractures of the ischium (20.6%) were the most numerous. Apart from these, the data was unalike. The next most frequently seen locations were the ilial body (11.8%), symphysis (7.4%) and mid acetabulum (5.9%). Comminuted acetabulum (2.9%) was next with ilial wing, cranial acetabulum and sacrum being the rarest, but with identical values of 1.5%

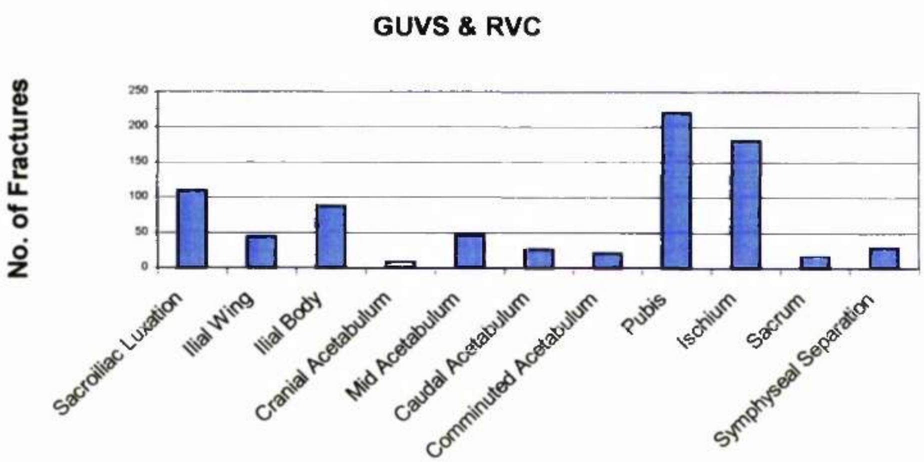


Figure 5.5. Fracture locations from amalgamated canine and feline GUVS and RVC cases.

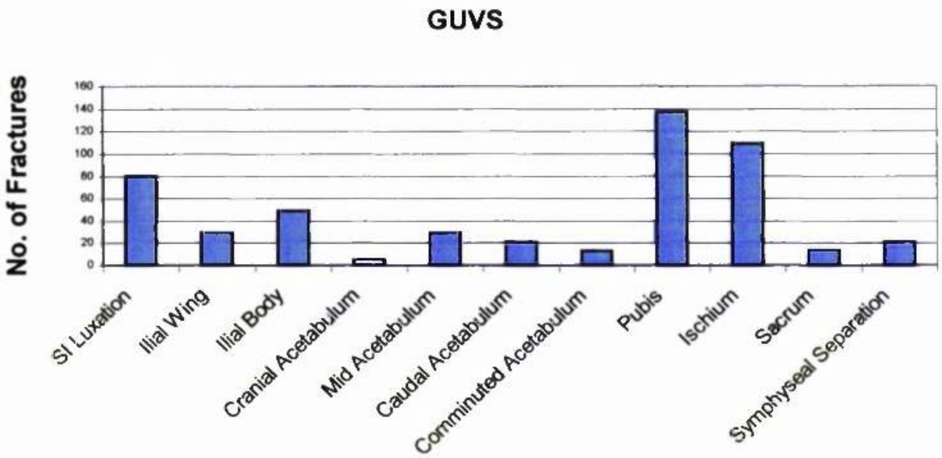


Figure 5.6. Fracture locations from amalgamated canine and feline GUVS cases.

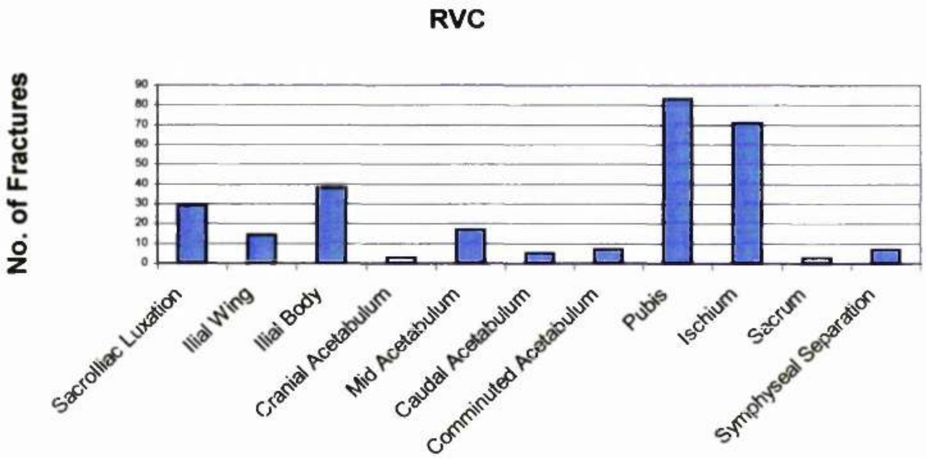


Figure 5.7. Fracture locations from amalgamated canine and feline RVC cases.

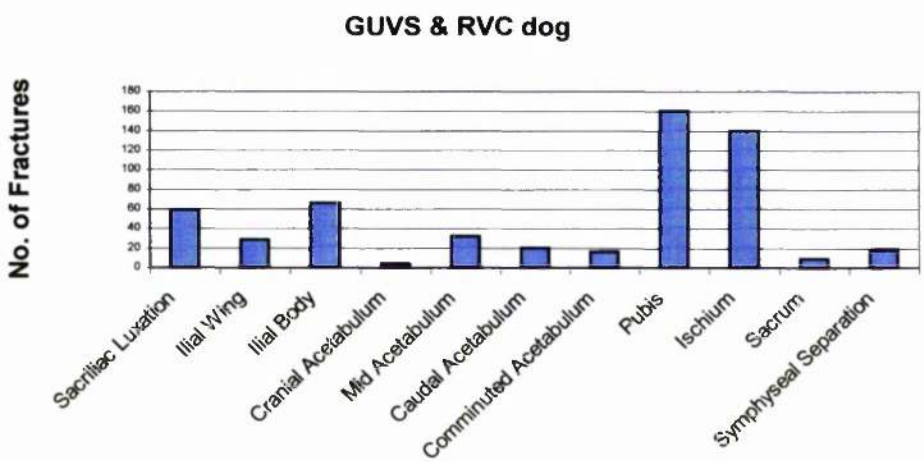


Figure 5.8. Fracture locations from canine GUVS and RVC cases.

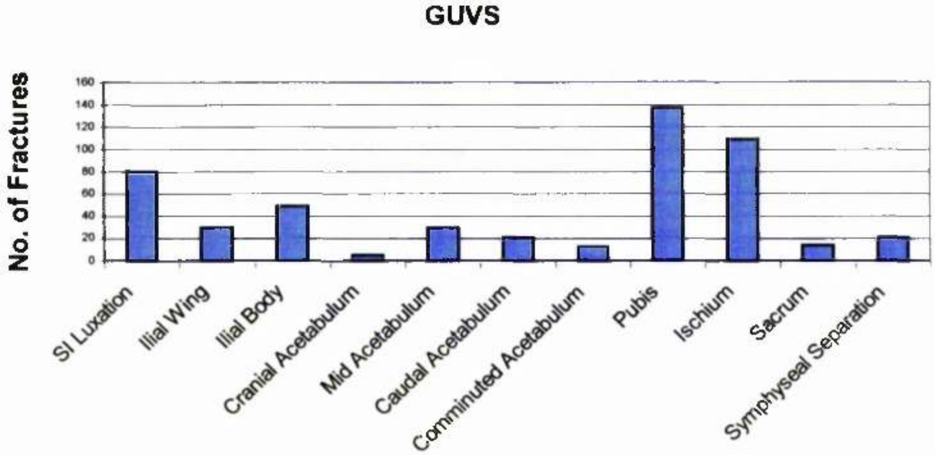


Figure 5.9. Fracture locations from canine GUVS cases.

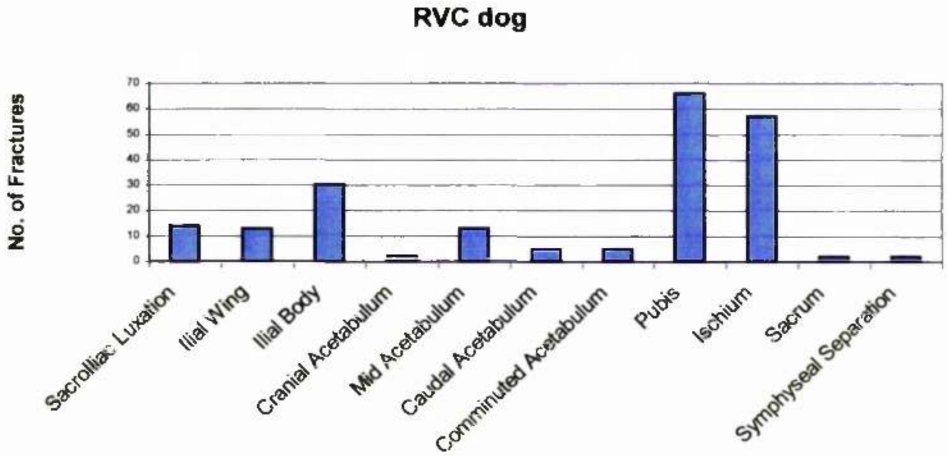


Figure 5.10. Fracture locations from canine RVC cases.

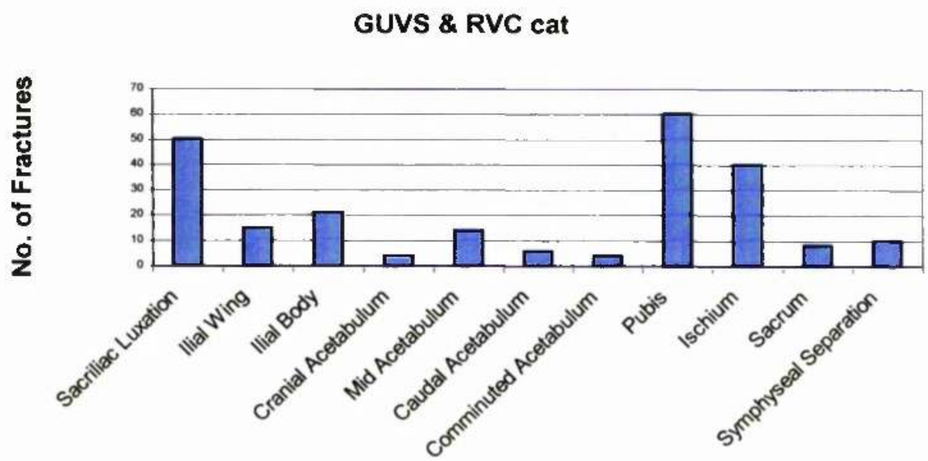


Figure 5.11. Fracture locations from feline GUVS and RVC cases.

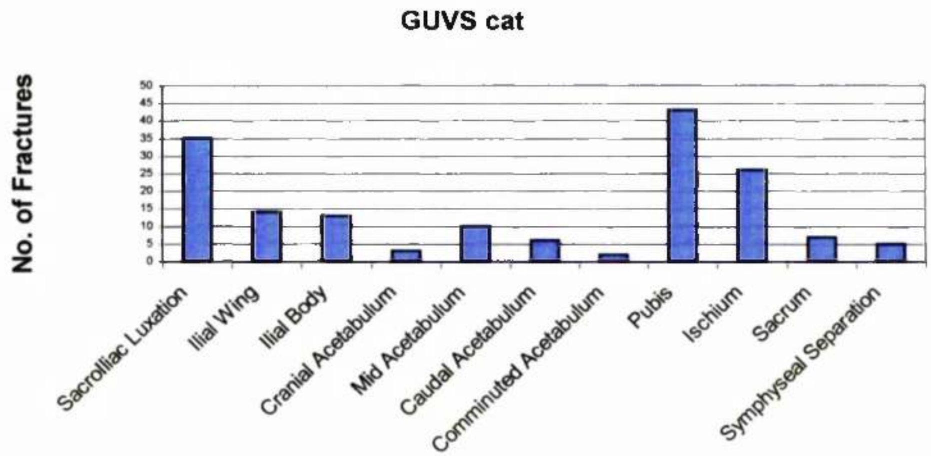


Figure 5.12. Fracture locations from feline GUVS cases.

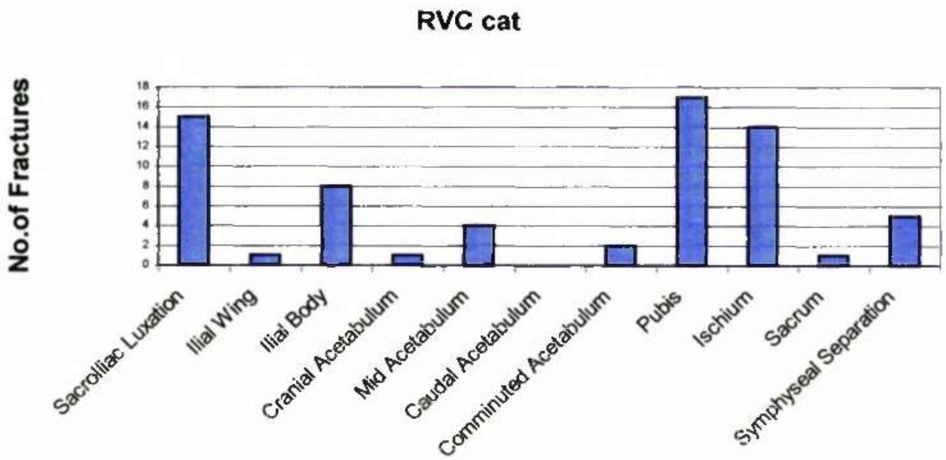


Figure 5.13. Fracture locations from feline RVC cases.

5.2.3. Sites

Small animal pelvic disruptions were frequently found to be multiple and bilateral with considerable displacement of the bone fragments (Figures 5.14, 5.15, 5.16, 5.18, 5.19). Often there was disruption of the weight bearing axis (Figure 5.16) or axes (Figures 5.14, 5.15, 5.17, 5.18) and compromise of the pelvic canal (Figure 5.16).

Figure 5.14 demonstrates a case with 4 fracture sites. These were a right sacroiliac luxation, a left comminuted acetabulum and bilateral pubic and ischial fractures. Figure 5.15 presents 6 fracture sites. These were bilateral ilial body fractures combined with bilateral pubic and ischial lesions. Figure 5.16 and 5.17 are two views of the same pelvis. This figure had 4 fracture sites. These were a left sacroiliac luxation, right ilial body fracture, right caudal acetabular fracture and right pubic fracture. Figure 5.18 had 6 sites. These were bilateral ilial body, pubic and ischial fractures. Figure 5.19 displayed 5 sites, these were bilateral ilial body and pubis and left ischium.

The common number of lesions varied between species (Tables 5.10 & 5.11, Figures 5.20 & 5.21). In dogs 4 sites (25%) were the most common and 8 sites (1%) the least frequent whereas in cats 3 sites (33%) were the most common and 7 sites (2%) the least frequent. The largest number of fracture sites present in dogs was 8 whereas in the cat it was 7. In dogs both 4 and 5 sites displayed the same value of 16%, but in the cat 4 sites (21%) were considerably more common than 5 (15%).

RIGHT ***LEFT***

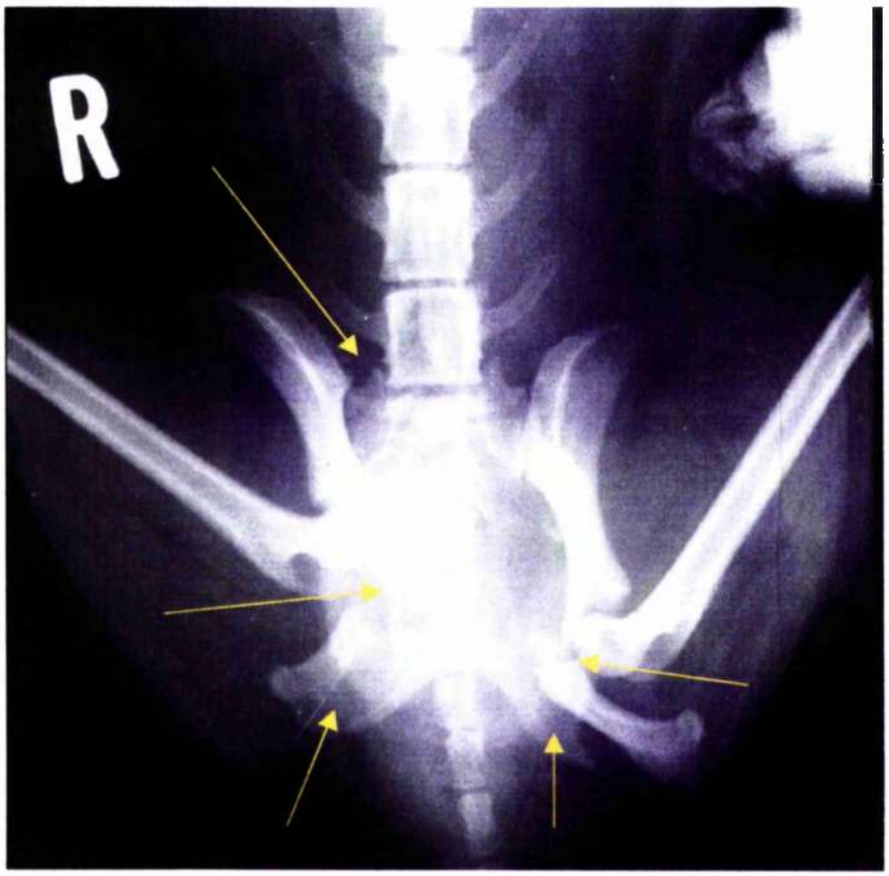


Figure 5.14. Multiple pelvic fractures (ventrodorsal view).

RIGHT ***LEFT***

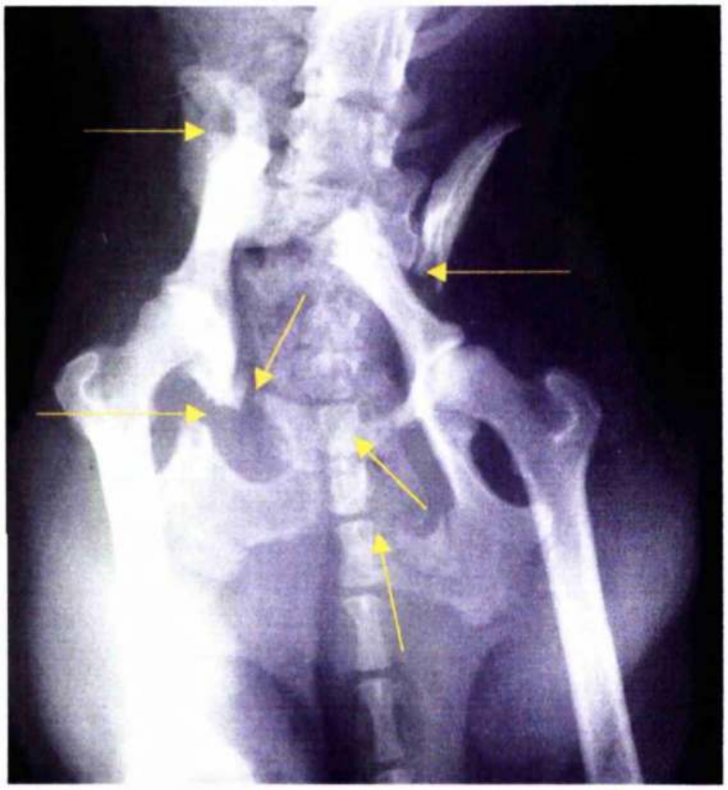


Figure 5.15. Multiple pelvic fractures (ventrodorsal view)

LEFT ***RIGHT***

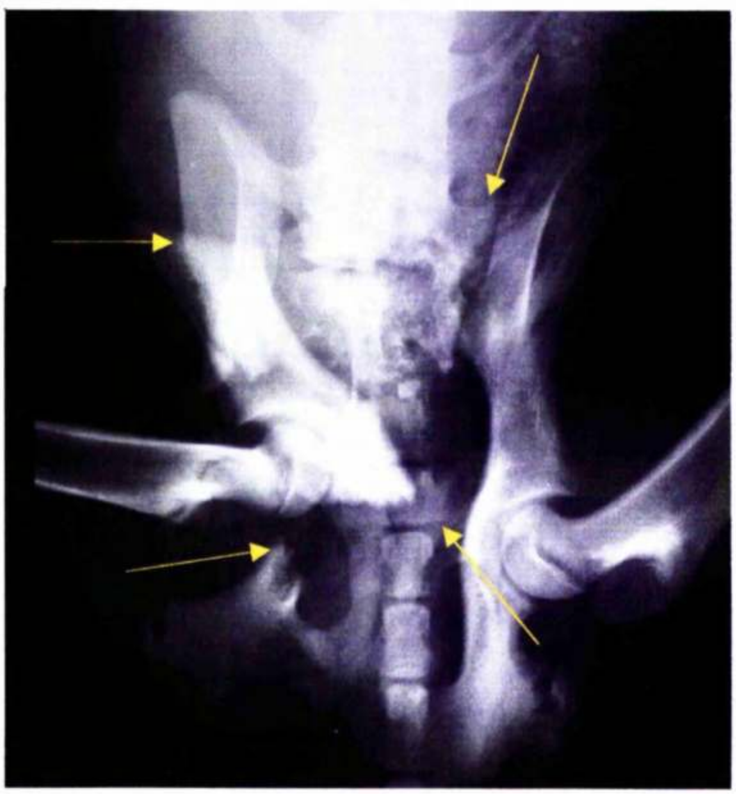


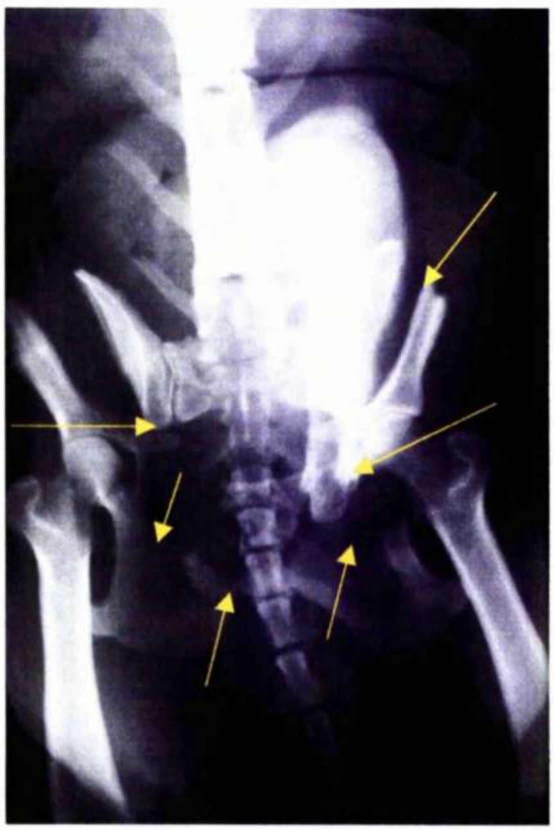
Figure 5.16. Multiple pelvic fractures (ventrodorsal view).

CRANIAL

CAUDAL

Figure 5.17. Multiple pelvic fractures (lateral view).

RIGHT



LEFT

Figure 5.18. Multiple pelvic fractures (ventrodorsal view).

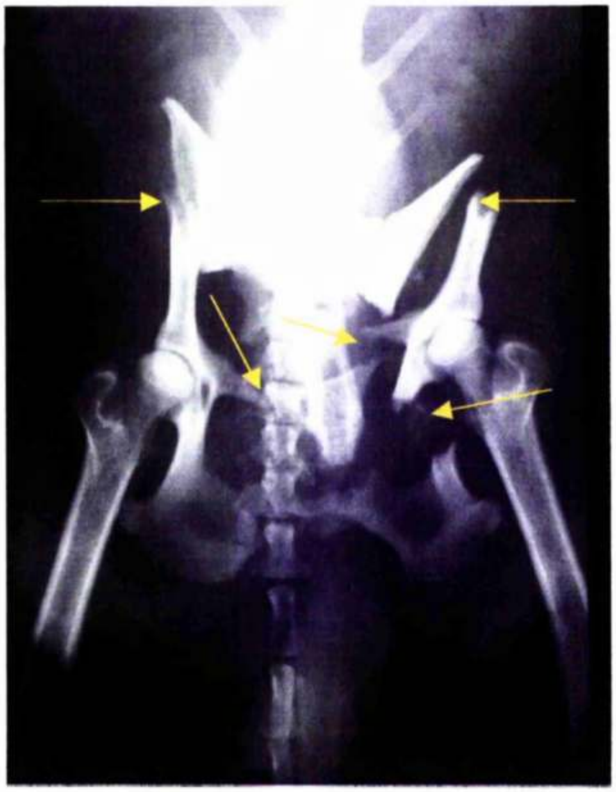


Figure 5.19. Multiple pelvic fractures (ventrodorsal view).

Dogs	Sites	Number of Animals	%
140 usable	1	13	9
17 unusable	2	16	11
	3	24	17
	4	35	25
	5	23	16
	6	23	16
	7	4	3
	8	2	1

Table 5.10. Number of fracture sites in dogs.

Cats	Sites	Number of Animals	%
66 usable	1	5	8
2 unusable	2	10	15
	3	22	33
	4	14	21
	5	10	15
	6	4	6
	7	1	2

Table 5.11. Number of fracture sites in cats.

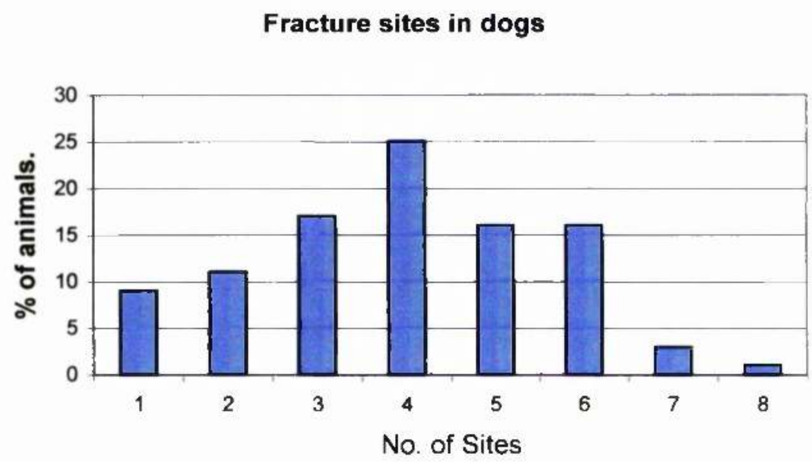


Figure 5.20. Number of fracture sites in dogs.

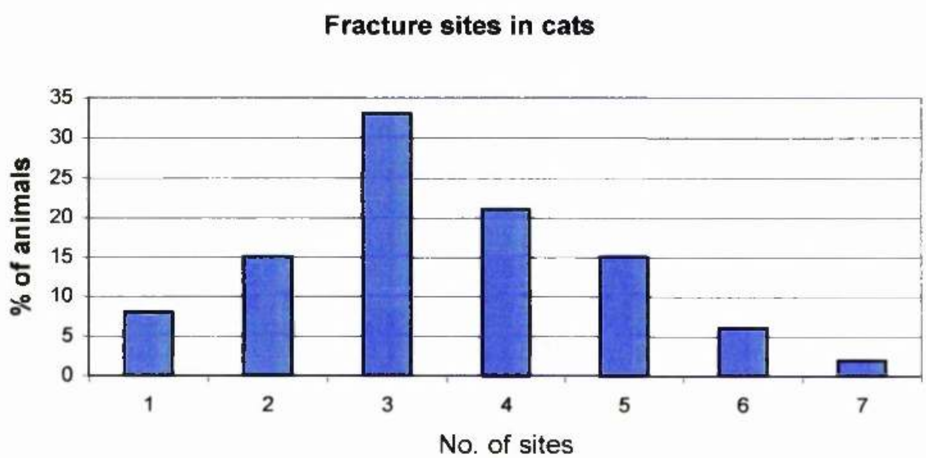


Figure 5.21. Number of fracture sites in cats.

In the dog (Table 5.12) it was found that in both the ilial body and ilial wing the most frequently encountered fracture type was oblique, represented by 5.1% in the ilial wing and 11.5% in the ilial body (Figures 5.22 & 5.24). This was closely followed in the ilial body by transverse (7%) then comminuted (3.2%). Chip and longitudinal fractures were the least common with 0.6%. No greenstick fractures were found in this region. In the ilial wing transverse, greenstick and comminuted fractures all contributed 0.6%. No chip fractures were found. In the ischium and acetabulum the most common type was 2 piece, then comminuted, represented by 16.6% and 7.6% respectively in the acetabulum with 24.2% and 12.7% respectively in the ischium (Figures 5.26 & 5.28). This was following in the acetabulum by greenstick (1.3%), 3 piece (1.3%) and the rarest, chip fracture (0.6%).

In the ischium 3 piece was the next most common (8.9%) then greenstick (2.5%), again with chip fractures (0.6%) being the rarest. It was found that 7% or dogs had a fracture separation of the whole symphysis (Figure 5.30), followed by 1.3% with a fracture separation of the cranial symphysis. No caudal symphyseal lesions were seen.

5.2.4. Fracture types

Dog	Types	No. of animals	% of animals	Cat	Types	No. of animals	% of animals
Ilial Wing	Transverse	1	0.6	Ilial Wing	Transverse	1	1.5
	Oblique	8	5.1		Oblique	5	7.4
	Greenstick	1	0.6		Greenstick	0	0
	Comminuted	1	0.6		Comminuted	0	0
	Chip	0	0		Chip	1	1.5
	Longitudinal	1	0.6		Longitudinal	0	0
Ilial Body	Transverse	11	7.0	Ilial Body	Transverse	10	14.7
	Oblique	18	11.5		Oblique	4	2.5
	Greenstick	0	0		Greenstick	0	0
	Comminuted	5	3.2		Comminuted	4	2.5
	Chip	1	0.6		Chip	0	0
	Longitudinal	1	0.6		Longitudinal	0	0
Acetabulum	2 Piece	26	16.6	Acetabulum	2 Piece	13	8.3
	3 Piece	2	1.3		3 Piece	0	0
	Comminuted	12	7.6		Comminuted	2	2.9
	Chip	1	0.6		Chip	0	0
	Greenstick	2	1.3		Greenstick	1	1.5
Ischium	2 Piece	38	24.2	Ischium	2 Piece	18	11.5
	3 Piece	14	8.9		3 Piece	1	1.5
	Comminuted	20	12.7		Comminuted	3	4.4
	Chip	1	0.6		Chip	0	0
	Greenstick	4	2.5		Greenstick	0	0
Symphysis	Whole Symphysis	11	7.0	Symphysis	Whole Symphysis	3	4.4
	Cranial Symphysis	2	1.3		Cranial Symphysis	0	0
	Caudal Symphysis	0	0		Caudal Symphysis	1	1.5

Table 5.12. Canine and feline fracture types

The cat however showed a slightly different picture. In accordance with the dog, the oblique fracture was the most common type in the ilial wing (Figure 5.23), presented in 7.4% of all cases. However in the ilial body (Figure 5.25) transverse was the most usual (14.7%). In the ilial wing, there were no recorded cases of greenstick, comminuted or longitudinal fractures, but transverse and chip fractures appeared in equal amounts (1.5%). In the ilial body there were no greenstick, chip or longitudinal fractures, but comminuted and oblique lesions were present in equal quantities (2.5%). As in the dog 2 piece fractures were the most common type in the acetabulum and ischium, represented by 8.3% and 11.5% respectively (Figures 5.27 & 5.29). This was followed by comminuted (2.9%) and greenstick (1.5%) fractures. In this location there were no 3 piece or chip fractures. The second most common ischial fracture type was comminuted (4.4%) then 3 piece (1.5%). No chip or greenstick fractures were found. Cats presenting with a symphyseal lesion (Figure 5.31) had a skew towards a fracture separation of the entire symphysis (4.4%), 1.5% having damage to the caudal symphysis only. In opposition to the dog, no cranial symphyseal lesions were seen.

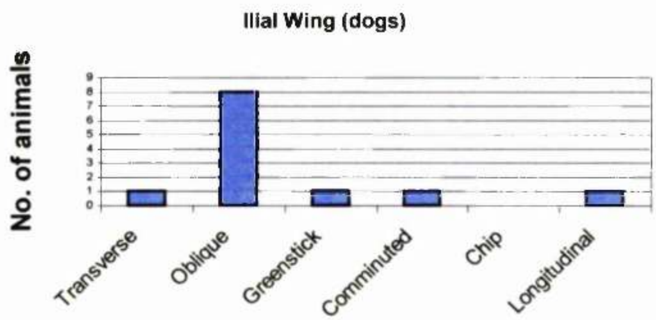


Figure 5.22. Ilial wing fracture types in the dog.

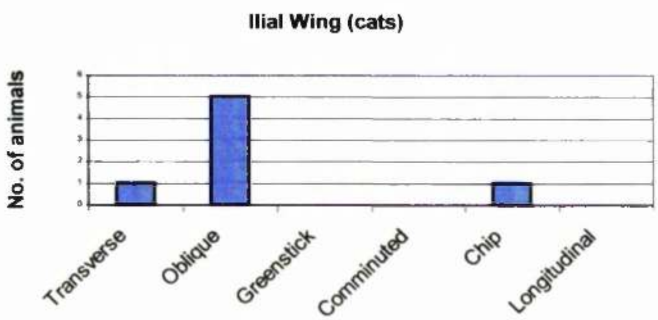


Figure 5.23. Ilial wing fracture types in the cat.

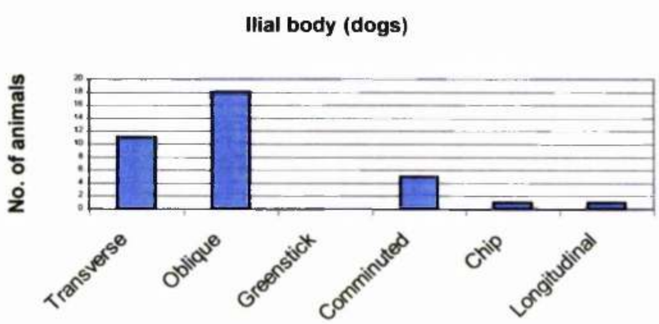


Figure 5.24. Ilial body fracture types in the dog.

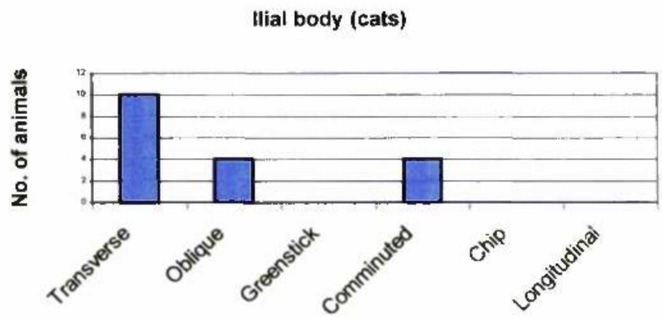


Figure 5.25. Ilial body fracture types in the cat.

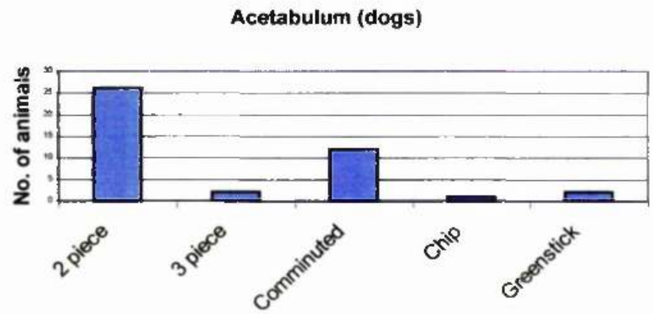


Figure 5.26. Acetabular fracture types in the dog.

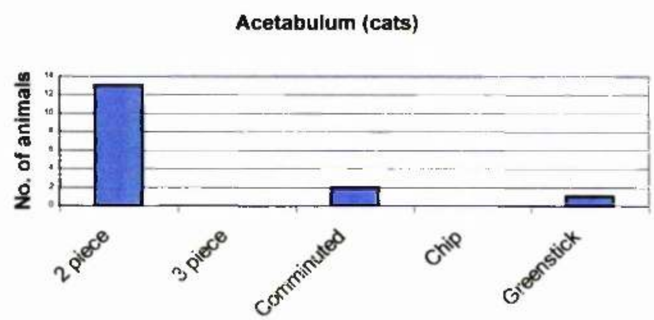


Figure 5.27. Acetabular fracture types in the cat.

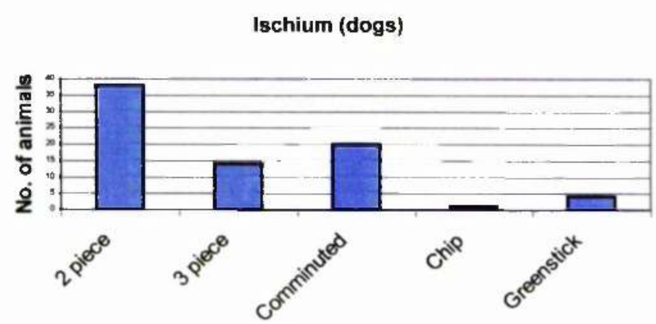


Figure 5.28. Ischial fracture types in the dog.

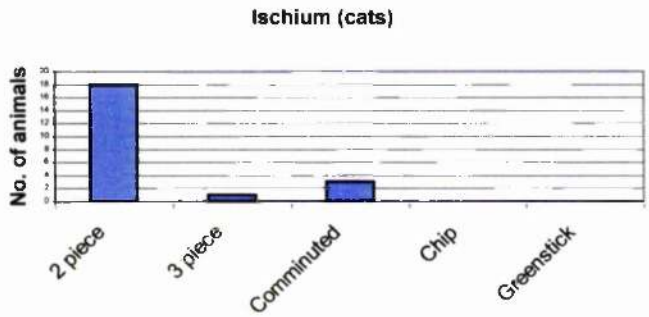


Figure 5.29. Ischial fracture types in the cat.

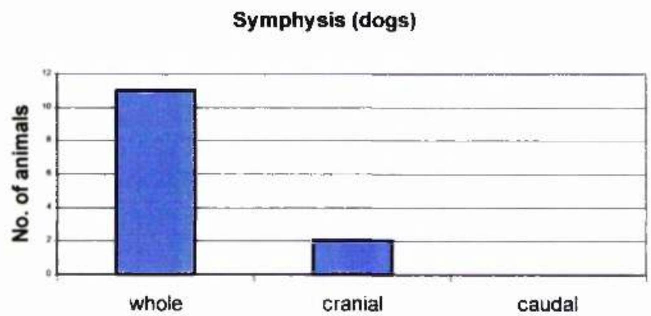


Figure 5.30. Symphyseal fracture types in the dog.

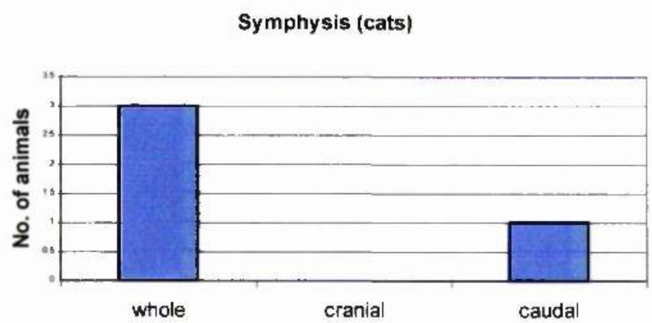


Figure 5.31. Symphyseal fracture types in the cat.

CAUDAL

CRANIAL

Figure 5.32. Pelvic disruption (lateral view)

RIGHT

LEFT

Figure 5.33. Pelvic disruption
(ventrodorsal view)

Figure 5.32 illustrates a lateral view of a disrupted canine pelvis. Here there is a left oblique ilial body fracture, a right-sided 3 piece ischial fracture and a left 2 piece caudal acetabular fracture. There are also bilateral pubic fractures present. Figure 5.33 shows a canine pelvis in ventrodorsal view. Here there is a right oblique ilial wing fracture, bilateral 2 piece ischial fractures, right 2 piece mid acetabular fracture and bilateral pubic disruptions.

RIGHT ***LEFT***

Figure 5.34. Pelvic disruption (ventrodorsal view)

RIGHT ***LEFT***

Figure 5.35. Pelvic disruption (ventrodorsal view)

Figure 5.34 illustrates a canine pelvis and shows a right 2-piece fracture of the right ischium and fractured right pubis. Figure 5.35 is a feline pelvis, displaying a right comminuted ilial body lesion, bilateral comminuted ischial fractures and a left caudal 2-piece acetabular fracture.

RIGHT *LEFT*

Figure 5.36. Pelvic disruption (ventrodorsal view)

RIGHT *LEFT*

Figure 5.37. Pelvic disruption (ventrodorsal)

Figure 5.36 shows a disrupted cat pelvis. It displays a left oblique ilial wing lesion, a left 2 piece ischial fracture and a left pubic fracture. Figure 5.37 is a canine pelvis. In this case there is a left oblique ilial body fracture, a left sided 2 piece ischial fracture and bilateral pubic fractures. This fracture pattern is known as the "floating hip" where the weight bearing segment is completely detached from the axial skeleton.

RIGHT *LEFT*

Figure 5.38. Pelvic disruption (ventrodorsal)

RIGHT *LEFT*

Figure 5.39. Pelvic disruption (ventrodorsal view)

Figure 5.38 illustrates a right comminuted ischial fracture and right pubic disruption combined with a left sacroiliac luxation. The only fractures that it was not possible to classify by type were those of the pubis. It was found that on a ventrodorsal view, mainly due to bad positioning, the pubic region was often occluded by the bowel or coccygeal vertebrae. However it was possible to distinguish symphyseal separations. A lateral view illustrates the presence of a fracture but offers little help in demonstrating type.

RIGHT ***LEFT***

Figure 5.40. Pelvic disruption (ventrodorsal view)

Figure 5.39 is a radiograph of a cat pelvis, which clearly shows a right cranial 2-piece acetabular disruption and right sacroiliac separation. There is a left pubic fracture but it is impossible to classify the type due to superimposition of the coccygeal vertebrae. Figures 5.40 and 5.41 are different views of the same cat pelvis. There is a right-sided sacroiliac luxation, a right 2 piece caudal acetabular fracture, a right 2 piece ischial fracture and bilateral pubic fractures. All fractures other than the pubic are easily seen on the ventrodorsal view (Figure 5.40). Once more the pubis in concealed by the overlying coccygeal vertebrae. The lateral view (Figure 5.41) helps illustrate the presence of the pubic fractures but does not assist in classifying by type.

CRANIAL *CAUDAL*

Figure 5.41. Pelvic disruption (lateral view)

5.2.5 Distribution of fractures

The distribution of fractures in dogs and cats was proportionately very similar (Table 5.13, Figures 5.42 & 5.43). Records showed that 32% of dogs and 37% of cats presented with a unilateral fracture configuration while 57% of dogs and 61% of cats had bilateral fractures. In this data set 12% of dogs and 2% of cats had unusable files.

Dogs	No. of animals	Cats	No. of Animals	Total	No. of animals
Unilateral	50	Unilateral	25	Unilateral	75
Bilateral	90	Bilateral	41	Bilateral	131
Old	3	Old	1	Old	4
Unknown	14	Unknown	1	Unknown	15
Total	**157**	**Total**	**68**	**Total**	**225**

Table 5.13. Distribution of fractures

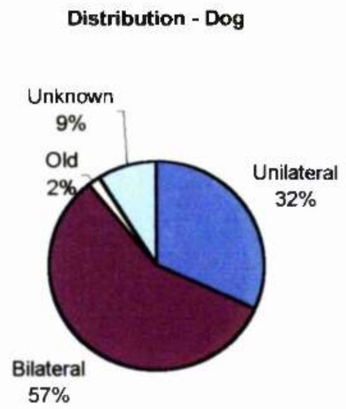


Figure 5.42. Distribution of fractures in the dog.

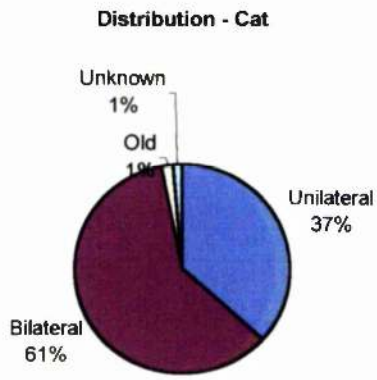


Figure 5.43. Distribution of fractures in the cat.

5.2.6. Concomitant injuries

A wide variety of concomitant extrapelvic damage was documented. This was divided into hard and soft tissue damage. The majority of animals presented with soft tissue damage of varying degrees of severity, ranging from mild abrasions and lacerations to degloving injuries and full thickness abrasions. Neurological complications were also common especially in cats. There was no apparent correlation between the pelvic fracture locations and types and any present extrapelvic injury.

Hard tissue damage		Soft tissue damage
Fracture of:	femoral neck, shaft, condyles	pneumothorax
	tibia	diaphragmatic hernia
	metatarsals	pulmonary haemorrhage
	tail	bowel rupture
	tooth	nerve damage (primarily n. ischiadicus)
	humerus	Ligg. cruciata genus rupture
	occipital condyles	lacerations / abrasions
	L3, L7	brachial plexus avulsions
	scapula	bladder rupture
	ribs	urethral transection
	thoracic vertebrae	abdominal haemorrhage
	maxilla	ruptured m. gastrocnemius
	mandible	abortion
	talus	
Luxation of:	hip or hips	
	hock	
	stifle	
	patella	
	proximal interphalangeal joint	
Separation of:	distal femoral epiphysis	
	proximal femoral epiphysis	
	sacro-caudal joint	

Table 5.14. Concomitant extrapelvic damage.

5.2.7. Combinations

In this sample there were no actual "common" fracture location combinations. A total of 54 possible fracture combinations were found. 25 were exclusive to dogs, 16 exclusive to cats and 13 that the whole sample had in common. It was found that 5 fracture combinations were relatively common in the dog (Table 5.15) and only one in the cat (Table 5.21).

	Combination		No. of animals	% of animals
1	3 fracture sites	Ilial Body / Pubis / Ischium	15	10%
2	2 fracture sites	Pubis / Ischium	7	5%
3	3 fracture sites	Sacroiliac Luxation / Pubis / Ischium	7	5%
4	3 fracture sites	Ilial Wing / Pubis / Ischium	6	4%
5	4 fracture sites	Sacroiliac Luxation / Comminuted Acetabulum / Pubis / Ischium	6	4%

Table 5.15 Common fracture site combinations in the dog.

The most common fracture combination in the dog was an ilial body fracture or fractures combined with pubic and ischial fractures (Table 5.16). This combination was present in 15 dogs, constituting 10% of the total sample. There were 9 permutations of this fracture combination alone. This pattern can be unilaterally or bilaterally configured showing a slight skew towards the bilateral group. However it was found that if a pubic fracture was present there was always an ipsilateral ischial fracture. The next most common fracture combination in the dog was that of combined pubic and ischial fractures (Table 5.17). This was found in 7 dogs, constituting 5% of the entire sample. There were 5 permutations of this fracture combination. The pubic and ischial fractures tended to be ipsilateral or both bilateral.

Ilial Body / Pubis / Ischium

Combination no.	Ilial Body	Pubis	Ischium	No. of dogs	% of dogs
1	right	bilateral	bilateral	2	1
2	bilateral	left	left	1	1
3	left	left	left	4	3
4	right	right	right	2	1
5	left	bilateral	left	2	1
6	right	left	left	1	1
7	right	right	bilateral	1	1
8	right	bilateral	right	1	1
9	bilateral	bilateral	bilateral	1	1
				Total = 15	**10%**

Table 5.16 Most common fracture site combination in the dog.

Pubis / Ischium

Combination no.	Pubis	Ischium	No. of dogs	% of dogs
10	bilateral	bilateral	2	1
11	right	right	1	1
12	left	left	2	1
13	bilateral	left	1	1
14	bilateral	right	1	1
			Total = 7	**5%**

Table 5.17 Second most common fracture site combination in the dog.

The second equal most frequently seen combination was that of a sacroiliac luxation or luxations combined with pubic and ischial fractures (Table 5.18). This was again found in 7 dogs, representing 5% of the total sample, subdivided into 4 permutations. Here the pubic and ischial fractures were always ipsilateral to each other or both bilateral. If the pubic and ischial fractures were unilateral and ipsilateral then the sacroiliac luxation was always contralateral.

Sacroiliac Luxation / Pubis / Ischium

Combination no.	Sacroiliac Luxation	Pubis	Ischium	No. of dogs	% of dogs
15	right	left	left	3	2
16	right	bilateral	bilateral	2	1
17	left	right	right	1	1
18	bilateral	bilateral	bilateral	1	1
				Total = 7	5%

Table 5.18 Second equal most common fracture site combination in the dog.

Ilial Wing / Pubis / Ischium

Combination no.	Ilial Wing	Pubis	Ischium	No. of dogs	% of dogs
19	bilateral	bilateral	bilateral	1	1
20	bilateral	left	right	1	1
21	left	bilateral	right	1	1
22	bilateral	bilateral	right	1	1
23	right	bilateral	bilateral	1	1
24	right	right	right	1	1
				Total = 6	4%

Table 5.19 Third most common fracture site combination in the dog.

The third most common fracture combination is shown in Table 5.19. This was a grouping of ilial wing, pubic and ischial fractures which was found in 6 dogs, constituting 4% of the total sample. It comprised of 6 permutations. This pattern could be unilaterally or bilaterally configured with a bias towards a bilateral organization.

Sacroiliac Luxation / Comminuted Acetabulum / Pubis / Ischium

Combination no.	Sacroiliac Luxation	Comminuted Acetabulum	Pubis	Ischium	No. of dogs	% of dogs
25	left	left	left	right	1	1
26	right	left	bilateral	bilateral	1	1
27	left	right	left	right	1	1
28	bilateral	left	bilateral	right	1	1
29	right	right	right	right	1	1
30	left	right	right	right	1	1
					Total = 6	4%

Table 5.20 Third equal most common fracture site combination in the dog.

The third equal most frequently encountered fracture location combination (Table 5.20) in the dog is the combination of sacroiliac luxation, comminuted acetabulum, pubic and ischial fractures. There were 6 permutation of this combination, seen in 6 dogs (4% of the total sample). This combination was always bilaterally configured.

Sacroiliac Luxation / Pubis / Ischium

	Combination		No. of animals	% of animals
1	3 fracture sites	Sacroiliac Luxation / Pubis / Ischium	10	15
			Total = 10	**15%**

Table 5.21. Common fracture site combination in the cat.

Sacroiliac Luxation / Pubis / Ischium

Combination no.	Sacroiliac Luxation	Pubis	Ischium	No. of animals	% of animals
1	right	bilateral	bilateral	1	1
2	right	right	right	2	3
3	bilateral	bilateral	right	1	1
4	right	left	left	2	3
5	left	right	right	2	3
6	bilateral	bilateral	bilateral	2	3
				Total = 10	**15%**

Table 5.22. Common fracture site combination in the cat.

In the cat the only common fracture location combination was that of sacroiliac luxation, pubis and ischium (Table 5.22). This combination had a total of 6 permutations. It was found in 10 animals representing 15% of the entire sample compared with 7 dogs (5%). In accordance with findings in the dog, the pubic and ischial fractures were always ipsilateral to each other or both bilateral. If the pubic and ischial fractures are unilateral and ipsilateral then the sacroiliac luxation was always contralateral.

5.2.8. Imaging

5.2.8.1. Imaging of the ilium

Figure 5.44 shows an ultrasound scan of the canine ilial body, imaged dorsally. The gluteal muscle mass overlying the ilium can be seen. Figure 5.45 shows an ultrasound scan of the canine ilial body, imaged laterally. The gluteal muscle mass lying in the gluteal fossa of the ilium can be seen. There is a small divergence created at the transducer passes over the ilium-acetabular junction. This corresponds to a small "v" shaped formation on the bone surface. Figure 5.46 shows an ultrasound scan of the canine ilial body, imaged ventrally. M. iliopsoas can be seen underlying the ilium.

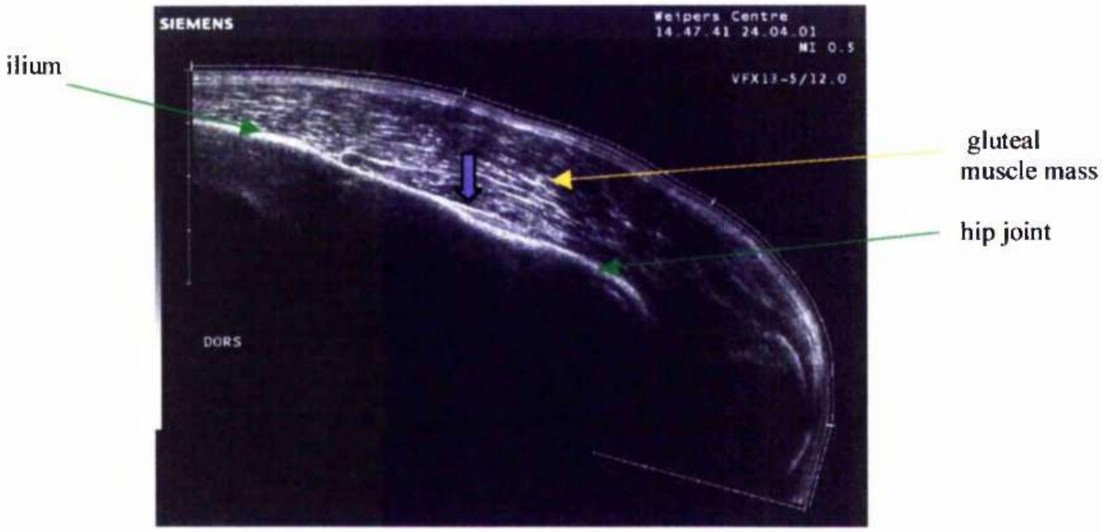


Figure 5.44. Ilial body imaged dorsally.

Figure 5.45. Ilial body imaged ventrally.

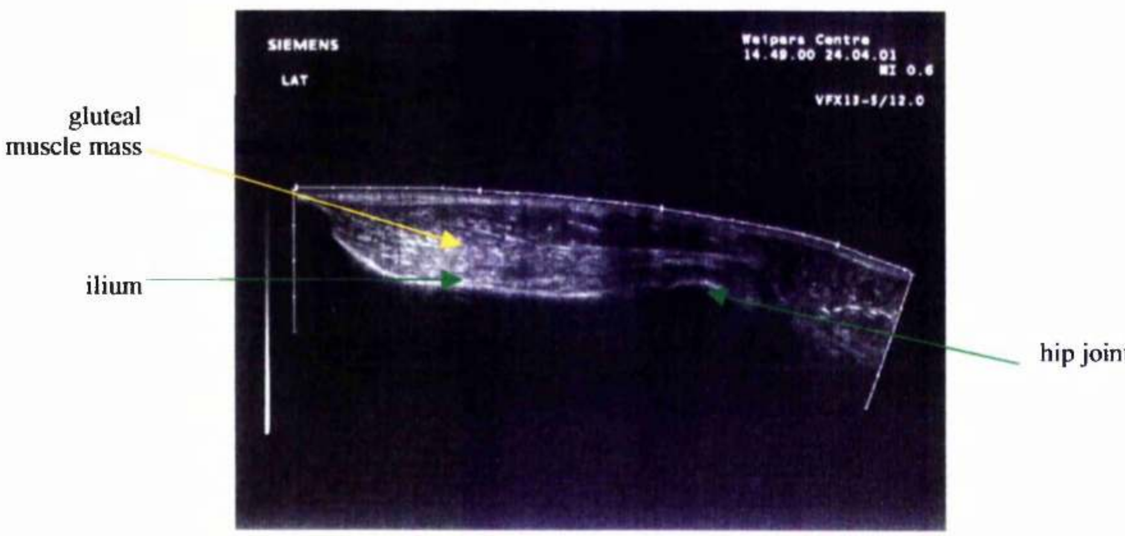


Figure 5.46. Ilial body imaged laterally.

5.2.8.2. Imaging of the hip

The extended field of view scan in Figure 5.47 shows the acetabular leg of the ischium and the hip joint. The adductor group can be seen in short axis overlying the external obturator.

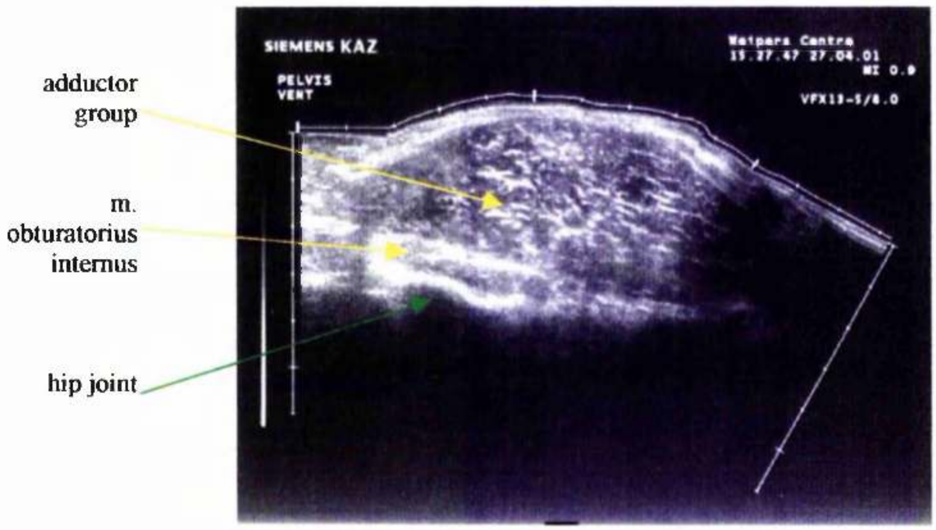


Figure 5.47. Ventral view of the hip joint.

Figures 5.48 to 5.52 illustrate the hip joint scanned using 3-dimensional b-mode ultrasound. In Figure 5.49 demonstrated the multiple images in a quadrant. a. is in the dorsal plane, b is a wedge, c. is in the para-sagittal plane and d. is in the transverse plane. These images are then enlarged. Figure 5.48 is an enlargement of b. Figure 5.50 is an enlargement of c. Figure 5.51 is an enlargement of a. Figure 5.52 is an enlargement of d.

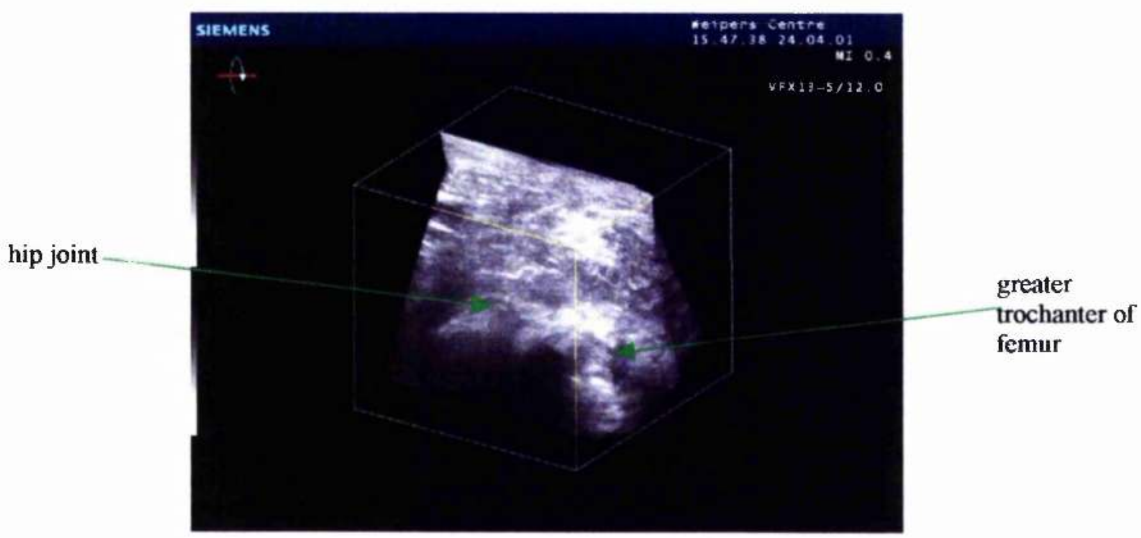


Figure 5.48. 3-dimensional wedge over hip joint.

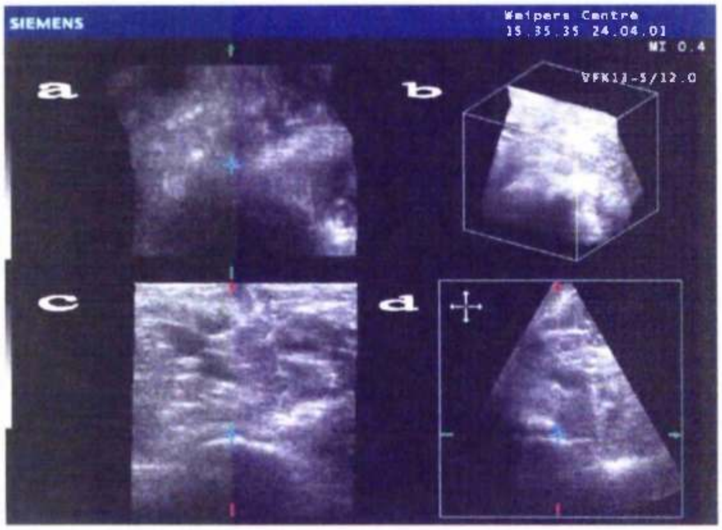


Figure 5.49. Quadrants displaying all planes of section.

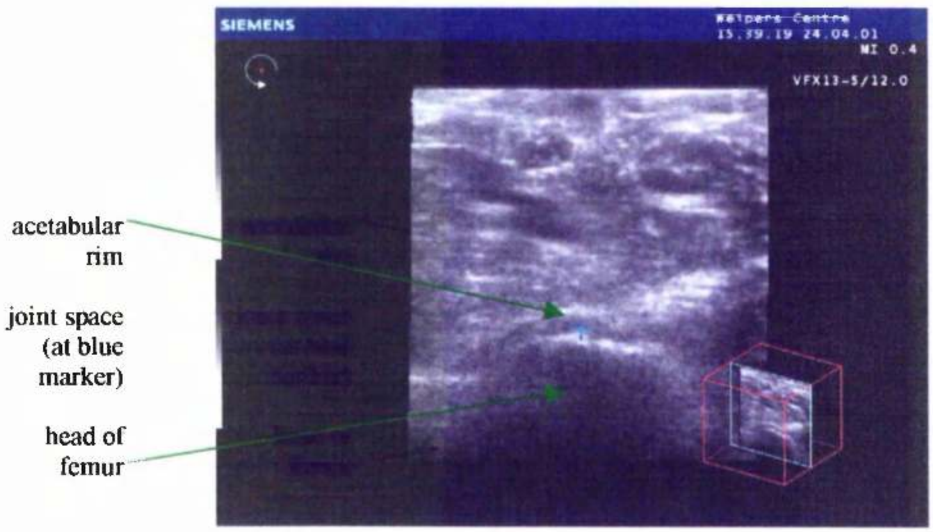


Figure 5.50. 3-dimensional scan in para-sagittal plane.

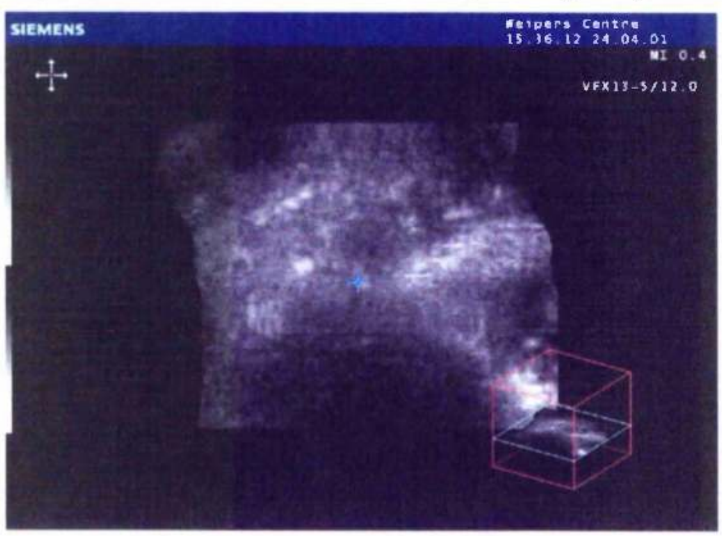


Figure 5.51. 3-dimensional scan in dorsal plane.

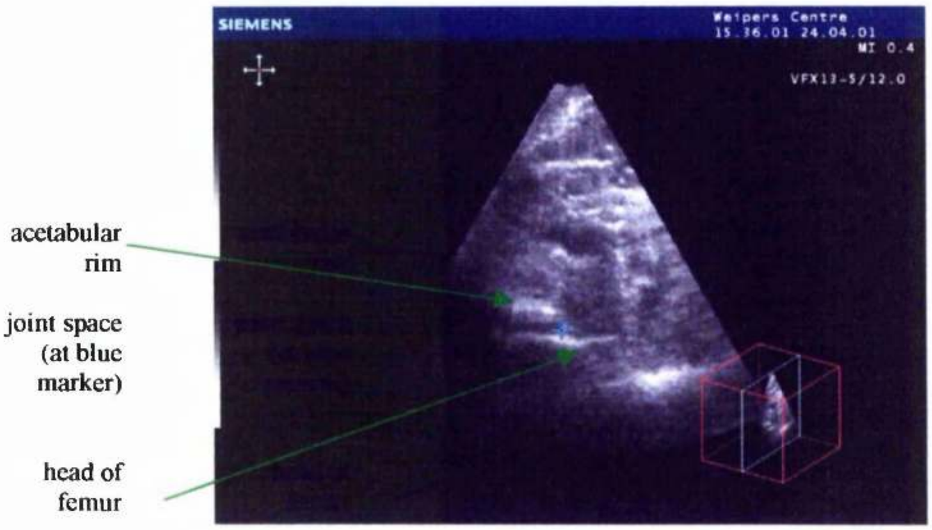


Figure 5.52. 3-dimensional scan in transverse plane.

In Figure 5.48 the hip joint and the greater trochanter of the femur can be seen. Figure 5.49 demonstrates the gluteal muscle mass, the acetabular rim, the coxofemoral joint space and the femoral head. The acetabular rim, coxofemoral joint space and the femoral head are also apparent on Figures 5.50 and 5.52. Figure 5.51 shows the joint but is not as clear as the others.

5.3. DISCUSSION

A number of studies have been carried out in which fractures in both humans (Dakin *et al* 1999; Brandser & Marsh, 1998) and animals (Anderson & Coughlan, 1997; Prieur *et al*, 1990) have been classified into distinct patterns and incorporate data such as the percentage of the bone length which is disrupted (Prieur *et al*, 1990) and the accompanying neurological damage (Gibbons *et al*, 1990).

There are several classification systems for human pelvic fractures available (Poka, 1989; Tile, 1984; Lowell, 1979; Judet *et al*, 1964). These range from simple, where the pelvis is classified into being stable or unstable (Peltier, 1965; Dunn & Morns, 1968; Holdsworth, 1972; Thaggard *et al*, 1978; Young & Resnik, 1990; Edwards, 1993), to highly complex and multifactorial where the location, direction of impact and stability are all taken in to account (Burgess *et al*, 1990). In veterinary orthopaedics, Denny in 1978, Alexander & Carb in 1979 and Eaton-Wells *et al* in 1990 postulated pelvic fracture classification systems. Denny attempted to categorize pelvic fractures in the dog according to their anatomical position.

Alexander devised a system where the fractures were classified into either surgical or non-surgical. Eaton-Wells *et al* postulated a highly complex system that took stability, displacement, joint involvement and pelvic canal stenosis into account.

In this research a simple but effective classification system was created based primarily on the anatomical location of each fracture site with a secondary emphasis on fracture type. The areas of the pelvis, which displayed the highest incidence of fracture, were deduced and their distribution recorded. The most common fracture combinations were isolated and any concomitant hard and soft tissue damage was tabulated. An attempt was made to demonstrate the continuity and integrity of the periosteal surface of selected pelvic bones and to image the hip joint, using diagnostic ultrasound.

There is little information available in the literature regarding anatomical fracture locations and fracture types, number of fracture sites and fracture distribution in small animals. Most of this information is sparse, is relevant only to dogs and focuses on certain bones such as the ilium and acetabulum rather than the complete pelvis. Marginally more information is obtainable on concomitant extrapelvic injuries and fracture combinations.

5.3.1. Anatomical locations

Trauma is haphazard in its effects and extent and this is reflected in the great variety in the position and number of pelvic fracture locations recorded (Denny, 1978). The vector forces applied to the pelvis during a road traffic accident are random, indiscriminate, multifactorial and multidirectional. There is also a wide plethora of fracture types, concomitant extrapelvic injuries and fracture combinations.

In the current study the pelvis was divided into specific anatomical locations for use in the classification of fracture location. These were 1. ilial wing, 2. ilial body, 3. acetabulum (subdivided into cranial, mid, caudal and comminuted), 4. ischium, 5. pubis, 6. symphyseal separation, 7. sacroiliac fracture / luxation and 8. sacral fracture. The acetabular fractures were classified in accordance with the groups suggested by Robins in 1992, which were cranial, central, caudal and comminuted.

The amalgamated data for canine and feline cases from GUVS and RVC displayed an overall small animal picture (Table 5.23). The most common pelvic fracture by far in this amalgamated group was that of the ischium, closely followed by the pubis. The third most common location was the sacroiliac joint followed closely by fracture of the ilial body. Mid acetabular and ilial wing fractures presented with similar amounts. The seventh, eighth and ninth most common locations were the pelvic symphysis, caudal acetabulum, and comminuted acetabulum respectively. The rarest fracture locations were the sacrum and cranial acetabulum. Pelvic fractures were found to occur with equal incidence on the left and right of the pelvis in both dogs and cats.

1 Most Common	Pubis	7	Symphyseal Separation
2	Ischium	8	Comminuted Acetabulum
3	Sacroiliac Luxation	9	Caudal Acetabulum
4	Ilial Body	10	Sacrum
5	Mid Acetabulum	11 Least Common	Cranial Acetabulum
6	Ilial Wing		

Table 5.23. Amalgamated canine and feline data from GUVS and RVC

5.3.1.1. Geographical differences

The reason for which geographical differences were investigated was because the data was obtained from 2 different sources.

Geographical differences were noted between fracture locations. Many factors may play a part in this disparity. As nearly all pelvic fractures are caused by road traffic accidents it is possible that the geographical differences in fracture locations may be due to factors such as proximity to urban or rural areas or distance from major roads. Both locations had large catchment areas, which encompass diverse and varied districts. Genetic factors such as the breeds of animal present in the different geographical locations may also play a part. Both GUVS and the RVC are referral centres so the differences may be explained by the availability of other small animal specialist practices nearby who may be more equipped to deal with complex polytrauma cases and not feel the need to refer. The differences may also be a reflection on CPD status of the referring practices, as some may be able to carry out more difficult orthopaedic surgical procedures.

5.3.1.1.1. Amalgamated canine and feline data

The amalgamated data for canine and feline cases from GUVS was compared to that from RVC. In both geographical locations, fractures of the pubis and ilium occurred the most frequently by far. However in GUVS the sacroiliac joint was the next most common location followed by the ilial body. The reverse was true for the RVC. Ilial wing and mid acetabular fractures were the fifth equal most common for both geographical locations. In both geographical locations symphyseal separations were sixth equal but presented with the same frequency as caudal acetabular fractures in GUVS and comminuted acetabular fractures in RVC. The next most frequently seen fracture locations in GUVS was that of the sacrum, comminuted acetabulum then cranial acetabulum compared to the caudal acetabulum then cranial acetabulum and sacrum in the RVC.

1 Most Common	Pubis	7=	Symphyseal Separation
2	Ischium	7=	Caudal Acetabulum
3	Sacroiliac Luxation	9	Sacrum
4	Ilial Body	10	Comminuted acetabulum
5=	Mid Acetabulum	11 Least Common	Cranial Acetabulum
5=	Ilial Wing		

Table 5.24. Amalgamated canine and feline data from GUVS.

1 Most Common	Pubis	7=	Symphyseal Separation
2	Ischium	7=	Comminuted Acetabulum
3	Ilial Body	9	Caudal Acetabulum
4	Sacroiliac Luxation	10=	Sacrum
5=	Mid Acetabulum	10= Least Common	Cranial Acetabulum
5=	Ilial Wing		

Table 5.25. Amalgamated canine and feline data from RVC.

5.3.1.1.2. Canine data

The GUVS canine data (Table 5.26) showed that the pubis and ischium were the most frequent areas of the pelvis to be fractured. This was followed by sacroiliac luxations and disruptions of the ilial body. The next most common were mid acetabular fractures and symphyseal separations. Ilial wing and caudal acetabular fractures appeared in equal quantities, followed by comminuted acetabular, sacral and cranial acetabular fractures.

1 Most Common	Pubis	7=	Ilial Wing
2	Ischium	7=	Caudal Acetabulum
3	Sacroiliac Luxation	9	Comminuted Acetabulum
4	Ilial Body	10	Sacrum
5	Mid Acetabulum	11 Least Common	Cranial Acetabulum
6	Symphyseal Separation		

Table 5.26. Canine data from GUVS.

The RVC canine data (Table 5.27) showed that again the pubis and ischium were the most frequent areas to be fractured. This was followed by fractures of the ilial body and sacroiliac luxations. The next most common, presenting with equal quantities were mid acetabular and ilial wing fractures. Comminuted and caudal acetabular fractures also appeared in equal quantities, followed by equal quantities of symphyseal separations, sacral and cranial acetabular fractures.

1 Most Common	Pubis	7=	Caudal Acetabulum
2	Ischium	7=	Comminuted Acetabulum
3	Ilial Body	9= Least Common	Symphyseal Separation
4	Sacroiliac Luxation	9= Least Common	Sacrum
5=	Mid Acetabulum	9= Least Common	Cranial Acetabulum
5=	Ilial Wing		

Table 5.27. Canine data from RVC.

5.3.1.1.3. Feline data

The GUVS feline data (Table 5.28) shows that the most common fracture locations were that of the pubis and sacroiliac joint. This was followed by the ischium, ilial wing and ilial body. The mid acetabulum presented with the next in frequency, followed in decreasing incidence by fractures of the sacrum, caudal acetabulum and pelvic symphysis. The least common locations were the cranial and comminuted acetabulum.

1 Most Common	Pubis	7	Sacrum
2	Sacroiliac Luxation	8	Caudal Acetabulum
3	Ischium	9	Symphyseal Separation
4	Ilial Wing	10	Cranial Acetabulum
5	Ilial Body	11 Least Common	Comminuted Acetabulum
6	Mid Acetabulum		

Table 5.28. Feline data from GUVS.

The RVC feline data bears little resemblance to the GUVS data. The most common fracture locations were that of the pubis and sacroiliac joint. This was followed by the ischium, ilial body, symphyseal separation, mid and comminuted acetabulum in decreasing order of frequency. The next in line are ilial wing, cranial acetabulum and sacrum, which presented with equal frequency. There were no caudal acetabular fractures.

1 Most Common	Pubis	7	Comminuted Acetabulum
2	Sacroiliac Luxation	8=	Ilial Wing
3	Ischium	8=	Cranial Acetabulum
4	Ilial Body	8= Least Common	Sacrum
5	Symphyseal Separation	Not present	Caudal Acetabulum
6	Mid Acetabulum		

Table 5.29. Feline data from RVC.

This data (Tables 5.24, 5.25, 5.26, 5.27, 5.28 & 5.29) shows that there are geographical differences in the incidence of both canine and feline anatomical fracture locations. The locations that are present in different amounts are highlighted in grey.

5.3.1.2. Species differences

Canine and feline data were compared because until relatively recently, although canine fractures were moderately well studied, little research was carried out to investigate feline orthopaedic trauma. As a consequence of this, cats were often treated like small dogs.

Species differences were noted in this study. The difference in actual pelvic anatomy, proportions of the bones, trabecular patterns, cortical thickness, bone density and size and body weight of the animals possibly contributed to this difference. Cats are all of similar sizes and morphologies compared to dogs, which span a vast range of sizes, weights and shapes. The nutritional status of the animals could also play a role.

In both the dog and cat (Tables 5.30 & 5.31) the area presenting with the highest number of fractures was the pubis. In the dog this was closely followed by the ischium then sacroiliac joint. In the cat the opposite is true with sacroiliac luxations being the second most common and the ischium the third. In both species the fourth most frequently fractured location was the ilial body. In the dog this is followed by the mid acetabulum and ilial wing. Again in the cat the opposite is true. The seventh, eighth and ninth most common fractures display distinct species differences. In the dog these were the caudal acetabulum, pelvic symphysis and comminuted acetabulum respectively. In the cat they were the pelvic symphysis, sacrum then caudal acetabulum. In the canine sample the fracture locations presenting with the lowest frequency were the sacrum and cranial acetabulum. In the feline sample they were the comminuted and cranial acetabulum, which were present in equal quantities.

1 Most Common	Pubis	7	Caudal Acetabulum
2	Ischium	8	Symphyseal Separation
3	Sacroiliac Luxation	9	Comminuted Acetabulum
4	Ilial Body	10	Sacrum
5	Mid Acetabulum	11 Least Common	Cranial Acetabulum
6	Ilial Wing		

Table 5.30. Canine data from GUVS and RVC

1 Most Common	Pubis	7	Symphyseal Separation
2	Sacroiliac Luxation	8	Sacrum
3	Ischium	9	Caudal Acetabulum
4	Ilial Body	10= Least Common	Comminuted Acetabulum
5	Ilial Wing	10= Least Common	Cranial Acetabulum
6	Mid Acetabulum		

Table 5.31. Feline data from GUVS and RVC

These findings were in accordance with Scott in 2001 who stated that fracture of the ilium is the commonest fracture of the weight-bearing region of the feline pelvis, although he did not include the sacroiliac joint in his findings. He also mentioned that fracture usually involves the iliac shaft caudal to the sacroiliac joint, which these results substantiate. A study by Denny in 1978 revealed that 6 out of his sample of 123 dogs had sacroiliac separations. This represents 4.9% and is nearer to the RVC result of 6.7% than the GUVS result of 13.1%. Betts in 1993 mentioned that an iliac fracture is one of the more commonly encountered pelvic fractures. Other authors have encountered ilial fractures with a greater frequency than in these findings. For example Chambers & Darnell in 1972 found that 9 out of 10 pelvic fractures involve the ilium.

5.3.2. Sites

Many authors mention that trauma tends to fracture multiple pelvic bones but to date only one author has attempted to document the actual number of fracture sites (Denny, 1984).

Pelvic fractures differ considerably in the degree of damage sustained (Betts, 1993). As a result of the box-like anatomy of the pelvis and the short musculotendinous support of the bones most fractures are multiple (Robins, 1973; Betts, 1993; Houlton & Dyce, 1994) and involve at least three or more bones (Brinker *et al*, 1990). However a study by Denny in 1978 revealed that 30 out of 123 dogs (24.4%) had solitary fractures of the pelvis (shaft of the ilium in 6, acetabulum in 20, ischium in 2 and pubis in 2). 90 out of 123 dogs (73.2%) had more than 1 fracture site. Denny's sample displayed a higher incidence of solitary fractures than in this study. These results showed that 13 out of 140 dogs (9%) and 5 out of 66 cats (8%) had 1 solitary fracture site. The largest percentage of dogs had 4 sites and cats had 3 sites. The next most frequent number of sites was 3 in dogs and 4 in cats. Equal numbers of animals had 5 and 6 sites in dogs and 2 and 5 sites in cats. Dogs displayed a maximum of 8 fracture sites and cats displayed a maximum of 7 fracture sites.

5.3.3. Types

The actual type of fracture often dictates the prognosis, type and methodology of treatment. Despite this there is minimal information available regarding specific types of fracture. With the exception of one author (Scott, 2001) nobody had attempted to document feline pelvic fracture types.

In the current study ilial wing and body fractures were subdivided in to 6 types; transverse, oblique, greenstick, comminuted, chip and longitudinal. Acetabular and ischial fractures were subdivided in to 5 types; 2 piece, 3 piece, comminuted, chip and greenstick. Fracture separations of the symphysis were subdivided in to 3 types; fracture separations of the whole, cranial or caudal symphysis.

5.3.3.1. Ilium

It is a commonly held belief that most fractures of the ilium are oblique (Houlton & Dyce, 1994; Robins, 1992; Brinker *et al*, 1990; Brinker *et al*, 1984). The results of this research indicated that this was true for ilial wing fractures in the dog and cat and ilial body fractures in the dog. The cat however displayed a greater frequency of transverse fractures in the ilial body. In the dog, ilial wing fractures that were transverse, greenstick, comminuted or longitudinal presented with the same frequency. Cats however had the same frequency of transverse and chip ilial wing fractures but had no greenstick or comminuted disruptions. In the dog, transverse ilial body fractures were the second most frequently seen followed by comminuted then 2 individual cases of chip and greenstick. Scott in 2001 stated that the configuration of an ilial shaft (body) fracture in cats may be transverse, oblique or occasionally comminuted. These results show that ilial body fractures were certainly transverse and oblique but that comminuted fractures were not occasional as they occurred with the same frequency as oblique fractures. No cats had greenstick, chip or longitudinal ilial body fractures. Ilial wing fractures were more common in the cat than the dog. The reverse was true for ilial body fractures.

5.3.3.2. Acetabulum

Fractures of the acetabulum are often complex (Dunbar, 1984) and the incidence of acetabular fractures is high (Olmstead, 1990) however the incidence is considerably higher in the dog than the cat. Acetabular fractures can be located anywhere in the acetabulum and consist of everything from simple two-piece fractures to complex multifragment fractures (Olmstead, 1990). The fracture planes may be transverse, oblique or comminuted (Houlton & Dyce, 1994). In this study acetabular fractures were classified primarily by the number of individual fracture fragments than by the discrete fracture lines. It is often difficult to interpret the actual lines of fracture due to superimposition of the pubis and bad positioning during radiography. It was thought that acetabular fractures could be classified more accurately by using the number of fracture fragments. The majority of both canine and feline acetabular fractures were 2 piece followed by comminuted. A small number of dogs had a 3 piece or greenstick fracture and 1 individual presented with a chip fracture. One individual cat had a greenstick acetabular fracture; no cats had 3 piece or chip acetabular fractures.

5.3.3.3. Ischium

Fractures of the ischium appear in the present study substantially more often in dogs than cats. However the most frequently occurring pattern in both species is 2 piece followed by comminuted. Dogs displayed a significant number of 3 piece patterns with a lesser number of greenstick fractures and only 1 individual with a chip fracture. The feline group had 1 individual with a 3 piece fracture and no cases with either chip or greenstick fractures.

5.3.3.4. Symphysis

A species difference in symphyseal fracture separations was apparent in this research. Although a significant percentage of animals from each group presented with a fracture separation of the whole symphysis, no dog had a fracture separation of the caudal symphysis whereas no cat had a fracture separation of the cranial symphysis.

5.3.3.5. Pubis

In this study the only fractures that were not possible to classify by type were those of the pubis. It was found that on a ventrodorsal view, mainly due to bad positioning, the bowel or caudal vertebrae often occluded the pubic region.

5.3.4. Distribution

There is a lack of information in the literature regarding fracture distribution. The only details available are those pertaining to the sacroiliac joint. This was written by Betts in 1993 who said that unilateral separation of the sacroiliac joint is much more common than bilateral luxation. This investigation revealed that distribution of fractures in dogs and cats was proportionately very similar. Records showed that 32% of dogs and 37% of cats presented with a unilateral fracture configuration while 57% of dogs and 61% of cats had bilateral fractures.

5.3.5. Concomitant injuries

Associated damage reported is extensive and varied in its severity and includes injury to the bladder, rupture of the urethra, ureteral avulsion, rectal compression (Betts, 1993; Denny, 1993), peripheral nerve injury (Denny, 1993; Tarvin & Lenehan, 1990; Betts, 1993) especially lumbo-sacral nerve damage (Eaton-Wells *et al*, 1990), pulmonary contusions, rib fractures (Tarvin & Lenehan, 1990), pneumothorax (Brinker *et al*, 1990), pleural effusion, spinal fractures, intestinal adhesions, vascular injuries (Houlton & Dyce, 1994; Poka, 1989) muscular and ligamentous injury (Eaton-Wells *et al*, 1990) and hip luxation (Denny, 1993). This research discovered a larger range of soft and hard tissue damage than reported in the literature. These include long, short and flat bone fractures, tooth fractures, joint luxations, epiphyseal separations, hernias, bladder rupture and abortion.

5.3.6. Combinations

The anatomy of the pelvis is complex and there are numerous combinations of fracture (Scott, 2001). In 1978 Denny recorded that there was a great variety in the position and number of pelvic fracture sites and 66 combinations were found. This study revealed a total of 54 possible fracture combinations. 25 were exclusive to dogs, 16 exclusive to cats and 13 that the whole sample had in common.

In this study the most common fracture combination in the dog was an ilial body fracture or fractures combined with pubic and ischial fractures. This combination was present in 10% of the total sample. There were 9 permutations of this fracture combination alone.

This pattern can be unilaterally or bilaterally configured showing a slight bias towards the bilateral group. However it was found that if a pubic fracture was present there was always an ipsilateral ischial fracture. This concurs with Denny who in 1978 observed that certain combinations of fracture site were observed more frequently than others e.g. fracture of the ipsilateral ilium, pubis and ischium. This fact was subsequently mentioned by Robins, 1992; Roush & Manley, 1992; Brinker *et al*, 1990 and Brinker *et al*, 1984 who found that fractures of the ilium are invariably accompanied by fractures of the pubis and ischium. This is also true for the third most common combination of ilial wing, pubis and ischium.

The next most common fracture combination in the dog was that of combined pubic and ischial fractures. This was found in 5% of the entire sample. There were 5 permutations of this fracture combination. The pubic and ischial fractures tended to be ipsilateral or both bilateral.

The second equal most frequently seen combination was that of a sacroiliac luxation or luxations combined with pubic and ischial fractures (Table 5.18). This was again found in 5% of the total sample, subdivided into 4 permutations. Here the pubic and ischial fractures were always ipsilateral to each other or both bilateral. If the pubic and ischial fractures were unilateral and ipsilateral then the sacroiliac luxation was always contralateral. These results concur with Houlton & Dyce, 1994 who state that unilateral sacroiliac luxations are generally associated with fractures of the opposite hemipelvis.

The third most common fracture combination was a grouping of ilial wing, pubic and ischial fractures which was found in 4% of the total sample. It comprised of 6 permutations. This pattern could be unilaterally or bilaterally configured with a bias towards a bilateral organization.

The third equal most frequently encountered fracture location combination in the dog was the combination of sacroiliac luxation, comminuted acetabulum, pubic and ischial fractures.

There were 6 permutation of this combination, seen in 4% of the total sample. This combination was always bilaterally configured. This was first mentioned in 1992 by Roush & Manley who stated that acetabular fractures often are accompanied by fractures of the pubis or ischia. A commonly held opinion is that because of the geometry of the pelvis, unilateral sacroiliac displacement cannot occur without associated fractures or a pelvic symphyseal separation (Brinker *et al*, 1990; Betts, 1993; Houlton & Dyce, 1994), which was substantiated by this research.

In the cat the only common fracture location combination was that of sacroiliac luxation, pubis and ischium. This combination had a total of 10 permutations. It was found in 10 animals representing 15% of the entire sample compared with 7 dogs (5%). In accordance with findings in the dog, the pubic and ischial fractures were always ipsilateral to each other or both bilateral. If the pubic and ischial fractures are unilateral and ipsilateral then the sacroiliac luxation was always contralateral.

All these fracture combinations concur with Betts, 1993 and Brinker *et al*, 1990 who state that most fractures of the ischium are accompanied by other fractures e.g. of the ilium, acetabulum or sacroiliac joint (Brinker *et al*, 1984). Also that pubic fractures commonly accompany other pelvic fractures (Betts, 1993).

Brinker *et al* in 1984 stated that fracture-separation of the sacroiliac joint is always accompanied by other fractures (usually of the ischium and pubis), which allow the displacement and give rise to instability of one half of the pelvis. The condition may be unilateral or bilateral. To the contrary Dunbar in 1984 wrote that separation (luxation) of the sacroiliac joint is almost always accompanied by fractures of the ischium or pubis unless the luxation is bilateral. This research correlates with the findings of Brinker *et al* 1984. Dunbar also stated that with bilateral sacroiliac luxations, fractures may or may not occur.

5.3.7. Imaging

Ultrasound imaging of orthopaedic injuries has been undervalued. Because the traditional way of investigating fractures is by radiography, many clinicians believe that it is the best or only way despite evidence to the contrary (Ricciardi *et al*, 1993; Steiner & Sprigg, 1992; Broker & Burbach, 1990; Dias *et al*, 1988; Graif *et al*, 1988). There is a reluctance by orthopaedic surgeons to accept the use of ultrasound in trauma cases. Radiography can only provide evidence of bony disruption whereas ultrasound can successfully image fractures, any concomitant soft tissue damage and provide a clear visualisation of the soft tissue – bone interface. It is not dangerous to either the sonographer or animal, is highly repeatable and can be applied to a conscious unsedated animal. Other imaging modalities such as computed tomography (CT) or magnetic resonance imaging (MRI) also provide good and comparable quality diagnostic imaging but are highly expensive and non-repeatable due to economic and safety reasons. Is also not possible to follow up a fracture case using MRI after application of an orthopaedic implant. Ultrasound may be used to monitor fracture healing and callus formation over a long period or time.

5.3.7.1. Ilium

The ilium was imaged using extended field of view ultrasound. The continuity and integrity of the periosteal surface of the ilium was demonstrated successfully. Both the dorsal and lateral views showed the overlying gluteal muscle mass clearly, the ventral view showed m. iliopsoas.

5.3.7.2. Hip joint

The hip joint was imaged with extended field of view and 3-dimensional b-mode ultrasound. Extended field of view ultrasound revealed the outline of the hip joint but it was not with as much clarity as the ilium. The adjacent adductor group and m. obturatorius internus were apparent. 3-dimensional b-mode ultrasound demonstrated the hip joint with great lucidity. The 3-dimensional wedge clearly revealed the hip joint and the greater trochanter of the femur. The transverse plane and para-sagittal plane both showed the acetabular rim, joint space and femoral head. The dorsal plane was not quite as obvious.

TREATMENT OF PELVIC FRACTURES IN DOGS AND CATS – A RETROSPECTIVE STUDY

As a follow on from the previous chapter in which a classification system for small animal pelvic fractures was devised, resultant treatments used and arising complications were investigated. A large number of pelvic fracture cases are treated conservatively with a varying degree of success reported in the literature. There are twelve commonly documented indications for surgical fixation. If an animal displays one or more of these criteria it is seen as a possible candidate for surgery. Using our findings we attempted to update the specific criteria for surgery and deduce which specific fracture sites respond most positively to a particular treatment protocol.

6.1. MATERIALS & METHODS

The data was obtained from animals referred to Glasgow University Veterinary School (GUVS) and the Royal Veterinary College, London (RVC) over a period of eight years plus those presented to the Peoples Dispensary for Sick Animals (PDSA), Glasgow in 1999 and 2000. The sample comprised of a total of 235 cases (166 from GUVS, 64 from RVC, 5 from PDSA). This consisted if 162 dogs (112 from GUVS, 48 from RVC, 2 from PDSA) and 73 cats (54 from GUVS, 16 from RVC, 3 from PDSA).

6.1.1. Criteria for surgery

There are twelve commonly documented indications for surgical fixation. These can be categorised as follows:

1. Decrease in size of the pelvic canal (Alexander *et al*, 1962; Denny, 1978; Dunbar, 1984; Brinker *et al*, 1990; Eaton-Wells *et al*, 1990; Betts, 1993; Houlton & Dyce, 1994) especially where a fragment can potentially impinge on viscera contained within the pelvic canal (Alexander & Carb, 1979).
2. Age, breed, sex and bodyweight of the animal are to be carefully evaluated (Houlton & Dyce, 1994).
3. Fracture of the acetabulum (displacement of the articular surfaces) (Denny, 1978; Alexander & Carb, 1979; Dunbar, 1984; Brinker *et al*, 1990; Tarvin & Lenehan, 1990; Betts, 1993; Houlton & Dyce, 1994).

4. Instability of the hip (fracture of the ilium, ischium and pubis on same side; segmental or Malgaigne fracture) (Denny, 1978; Dunbar, 1984; Brinker *et al*, 1990; Tarvin & Lenehan, 1990; VanGundy, 1990; Betts, 1993).
5. Unilateral or bilateral instability (Eaton-Wells *et al*, 1990; Tarvin & Lenehan, 1990; Betts, 1993) particularly if accompanied by coxofemoral dislocation or other limb fractures (Denny, 1978; Brinker *et al*, 1990).
6. Sacro-iliac luxation or fracture luxation (Eaton-Wells *et al*, 1990; Tarvin & Lenehan, 1990).
7. Ilial shaft fractures with craniomedial displacement compromising the pelvic canal, especially in intact bitches (Tarvin & Lenehan, 1990).
8. Gross fragment displacement (Dunbar, 1984; Tarvin & Lenehan, 1990; Houlton & Dyce, 1994).
9. Multiple bilateral pelvic fractures (Denny, 1978; Eaton-Wells *et al*, 1990).
10. Cases in which the owner's (Houlton & Dyce, 1994) or animal's attitude will render conservative treatment ineffective (Eaton-Wells *et al*, 1990).
11. Patients in which postoperative appearance and as near normal gait are important (Eaton-Wells *et al*, 1990).
12. Ability of the owner to pay (Houlton & Dyce, 1994).

Other factors, which should be taken into consideration, are the facilities available and the experience of the surgeon (Houlton & Dyce, 1994).

If an animal fulfils one or more of these criteria then it is seen as a possible candidate for surgery.

6.2. RESULTS

Out of this sample (Table 6.1), 44 dogs (27.2%) (41 from GUVS, 1 from RVC, 2 from PDSA) and 33 cats (45.2%) (29 from GUVS, 1 from RVC, 3 from PDSA) were conservatively managed. Out of this sample 98 dogs (60.4%) (51 from GUVS, 47 from RVC, zero from PDSA) and 37 cats (50.7%) (22 from GUVS, 15 from RVC, zero from PDSA) were surgically treated (Table 6.1). 5 dogs (3.1%) and 1 cat (1.4%) had fractures diagnosed too late to treat surgically, 1 dog (0.6%) and 1 cat (1.4%) were euthanased pre treatment, 1 dog (0.6%) died prior to treatment. The treatment of 13 dogs (8.0%) and 1 cat (1.4%) was undocumented (Figures 6.1, 6.2, 6.3, 6.4, 6.5 & 6.6).

From this sample, 50 surgically (51.0%) and 3 non-surgically managed (6.8%) dogs (21 from GUVS, 32 from RVC) and 25 (73.5%) surgically and 5 (15.2%) non-surgically managed cats (17 from GUVS, 13 from RVC) developed complications. In the canine sample which displayed complications, 1 (1.0%) dog was euthanased, 1 (1.0%) died and 1 (1.0%) had problems arising from an old fracture. In the feline sample 1 (1.0%) had problems arising from an old fracture.

Dogs	**GUVS**	**PDSA**	**Cats**	**GUVS**	**PDSA**
Conservative	41	2	Conservative	29	3
Surgical	51		Surgical	22	
Old	5		Old	1	
Euthanased	1		Euthanased	1	
Unknown	13		Unknown	1	
Died	1		Died	0	
Total	**112**	**2**	**Total**	**54**	**3**
	RVC			**RVC**	
Conservative	1		Conservative	1	
Surgical	47		Surgical	15	
Total	**48**		**Total**	**16**	
Dogs	**SUMMARY**		**Cats**	**SUMMARY**	
Conservative	44		Conservative	33	
Surgical	98		Surgical	37	
Old	5		Old	1	
Euthanased	1		Euthanased	1	
Unknown	13		Unknown	1	
Died	1		Died	0	
Total	**162**		**Total**	**73**	

Table 6.1. Treatment summary for GUVS, RVC and PDSA data.

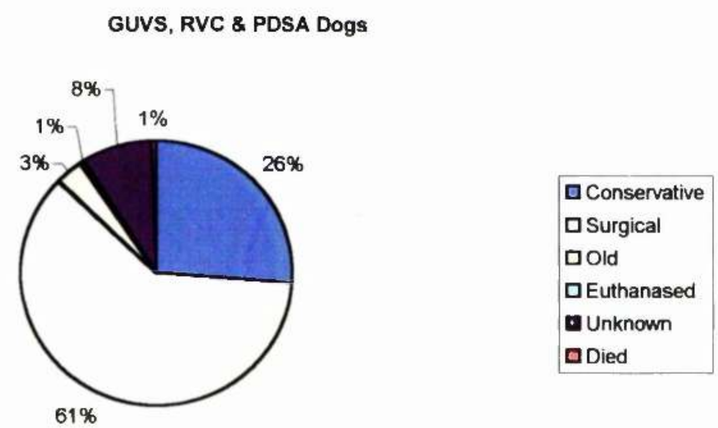


Figure 6.1. Treatment of amalgamated GUVS, RVC and PDSA canine data.

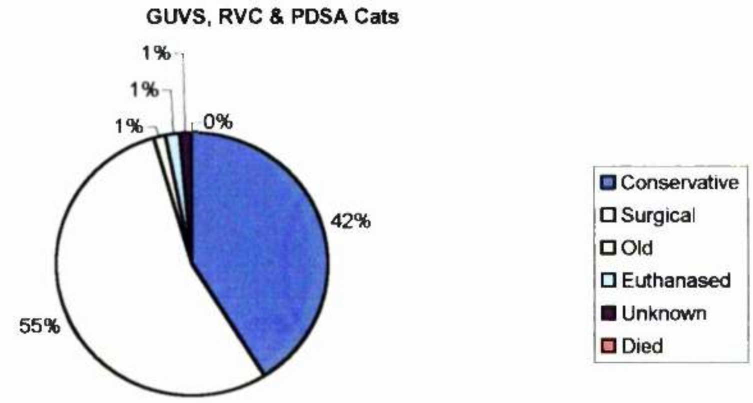


Figure 6.2. Treatment of amalgamated GUVS, RVC and PDSA feline data.

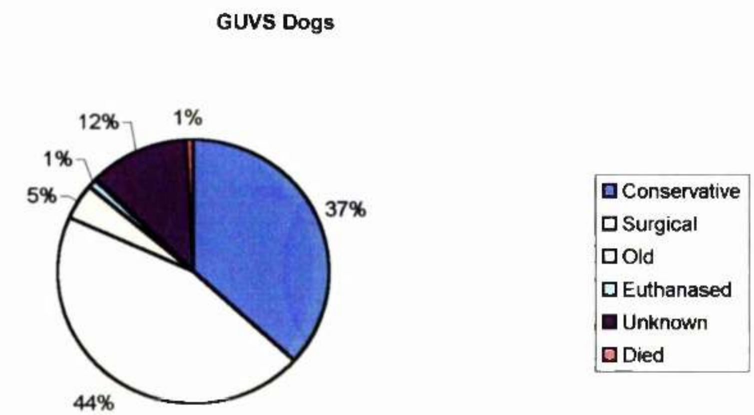


Figure 6.3. Treatment of GUVS canine data.

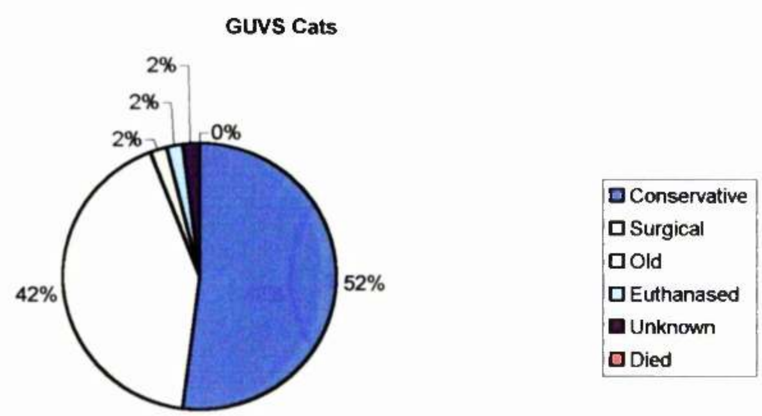


Figure 6.4. Treatment of GUVS feline data.

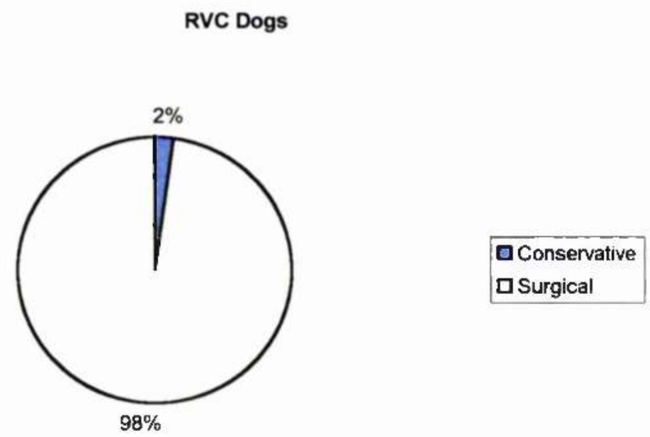


Figure 6.5. Treatment of RVC canine data.

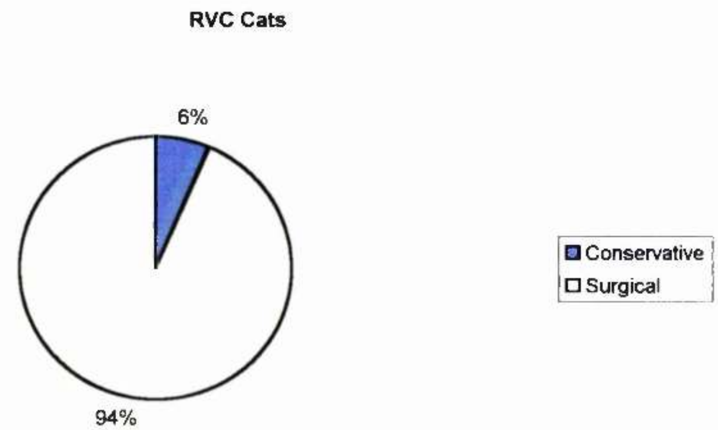


Figure 6.6. Treatment of RVC feline data.

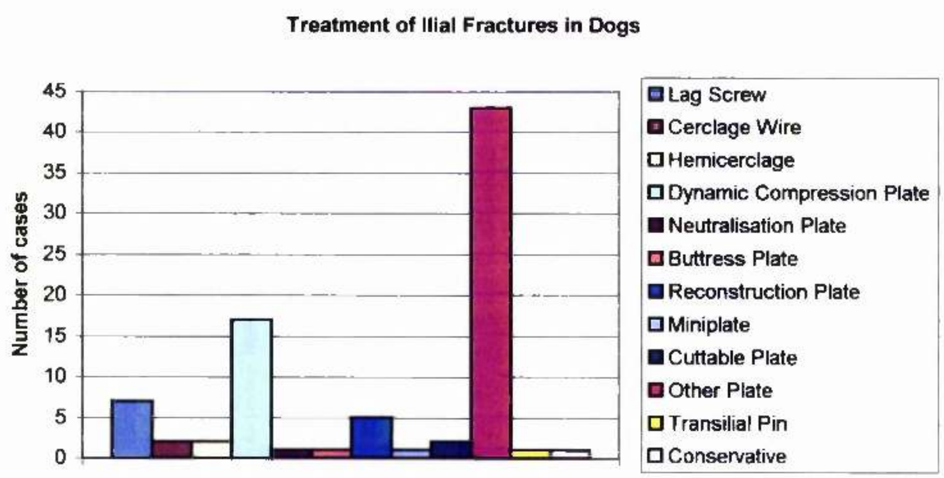


Figure 6.7. Treatment of ilial fractures in dogs.

Out of a total of 94 ilial fractures, 28 (29.8%) were of the ilial wing and 66 (70.2%) were of the ilial body. There were 9 (32.1%) conservatively treated ilial wing fractures and 19 were surgically managed (67.9%). There were 3 conservatively treated ilial body fractures (4.5%) and 63 were surgically managed (95.5%). The amalgamated surgical group was managed via 11 different methods. 7 animals were treated by lag screw fixation (8.5%), 2 by cerclage (2.4%), 2 by hemicerclage (2.4%). 17 animals (20.7%) had application of a dynamic compression plate, applied in dynamic mode. A neutralisation plate was used in 1 animal (1.2%), and 1 animal (1.2%) had a buttress plate applied. A reconstruction plate was used to treat 5 dogs (6.1%), 1 (1.2%) by a miniplate and 3 (2.4%) by a cuttable plate. Fracture management in 43 animals (52.4%) was achieved by application of an unspecified plate (labelled "other plate" in Figure 6.7). A transilial pin was applied in 1 animal (1.2%)

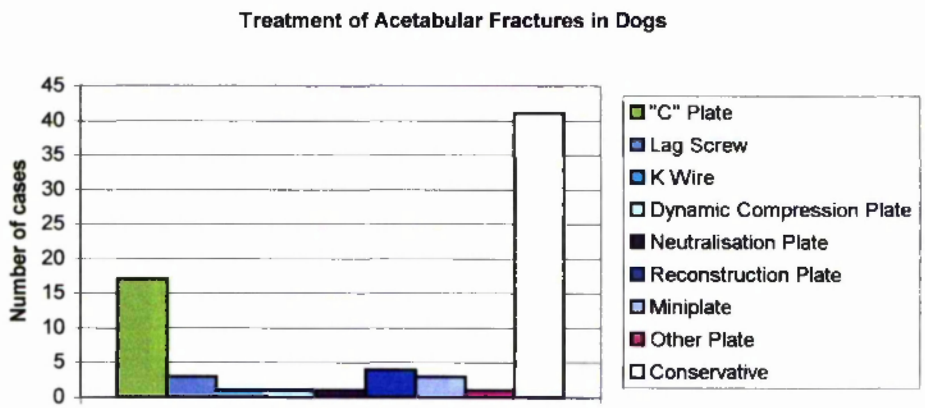


Figure 6.8. Treatment of acetabular fractures in dogs.

Out of a total of 72 acetabular fractures, 4 (5.5%) were of the cranial acetabulum, 32 (44.4%) were of the mid acetabulum, 20 (27.8%) were of the caudal acetabulum and 16 (22.2%) were comminuted acetabulum. There were 41 (56.9%) conservatively treated acetabular fractures and 31 were surgically managed (43.1%). There were 3 conservatively treated cranial acetabular fractures (75.0%) and 1 was surgically managed (25.0%). There were 9 conservatively treated mid acetabular fractures (28.1%) and 23 were surgically managed (71.9%). There were 17 conservatively treated caudal acetabular fractures (85.0%) and 3 were surgically managed (15.0%). There were 12 conservatively treated comminuted acetabular fractures (75.0%) and 4 were surgically managed (25.0%). The amalgamated surgical group was managed via 8 different methods. Treatment of 17 animals was achieved by use of an acetabular "c" plate (54.8%) while 3 animals were treated by lag screw fixation (9.7%), 1 by Kirschner wire (3.2%) and 1 animal (3.2%) had an application of a dynamic compression plate, applied in dynamic mode plus 1 animal (3.2%) with a neutralisation plate. Another 4 dogs (12.9%) were treated by a reconstruction plate and 3 (9.7%) by a miniplate. Finally 1 animal (3.2%) was managed by application of an unspecified plate (labelled "other plate" in Figure 6.8).

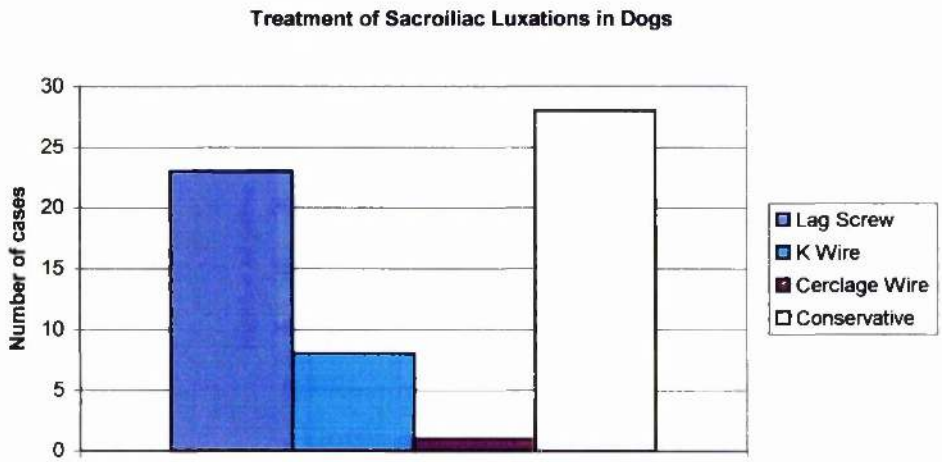


Figure 6.9. Treatment of sacroiliac luxations in dogs.

There were a total of 60 sacroiliac luxations (Figure 6.9). 28 (46.7%) conservatively treated and 32 were surgically managed (53.3%). The surgical group was managed via 3 different method, comprising of 23 animals treated by lag screw fixation (71.9%), 8 by Kirschner wire (25.0%) and 1 animal by cerclage wire (3.1%).

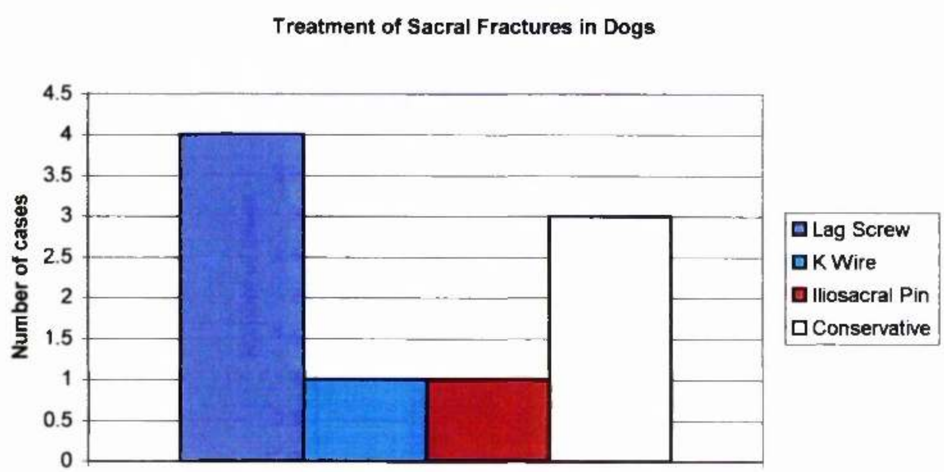


Figure 6.10. Treatment of sacral fractures in dogs.

There were a total of 9 sacral fractures (Figure 6.10), broken down as 3 (33.3%) conservatively treated and 6 surgically managed (66.7%). The surgical group was managed via 3 different methods; 4 animals were treated by lag screw fixation (66.7%), 1 by Kirschner wire (16.7%) and 1 animal by an iliosacral pin (16.7%).

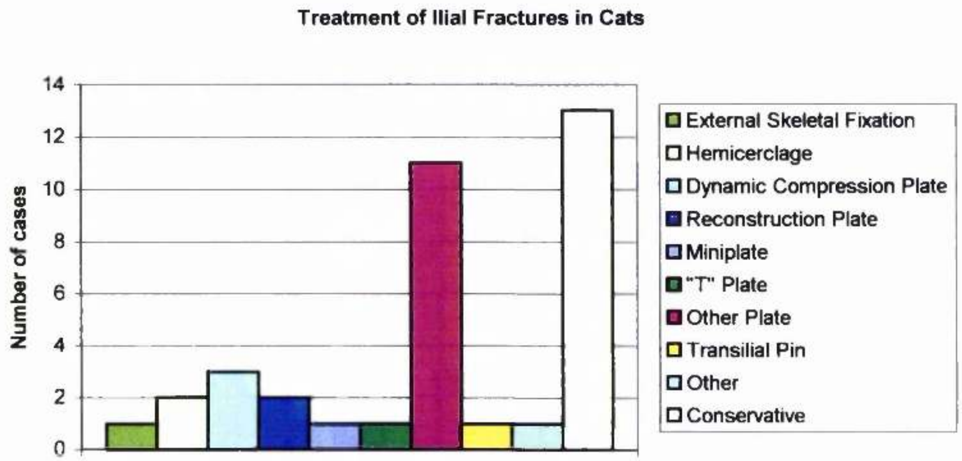


Figure 6.11.Treatment of ilial fractures in cats.

Out of a total of 36 ilial fractures, 15 (41.7%) were of the ilial wing and 21 (58.3%) were of the ilial body. There were 10 (66.7%) conservatively treated ilial wing fractures and 5 surgically managed (33.3%). There were 3 conservatively treated ilial body fractures (14.3%) and 18 surgically managed (85.7%). The amalgamated surgical group was managed via 9 different methods. The result of this was that 1 animal was treated by external skeletal fixation (4.3%), 2 by hemicerclage (8.7%), 3 animals (13.0%) by application of a dynamic compression plate, applied in dynamic mode, 2 cats (8.7%) by a reconstruction plate, 1 (4.3%) by a miniplate and 1 (4.3%) by a "T" plate, 11 animals (47.8%) by application of an unspecified plate (labelled "other plate" in Figure 6.11). To complete the group 1 animal had a transilial pin applied (4.3%) and one (4.3%) had an unspecified type of fixation applied that was not a plate (labelled "other" in Figure 6.11).

Out of a total of 29 acetabular fractures (Figure 6.12), 4 (13.8%) were of the cranial acetabulum, 15 (51.7%) were of the mid acetabulum, 6 (20.9%) were of the caudal acetabulum and 4 (13.8%) were comminuted acetabulum. There were 24 (82.8%) conservatively treated acetabular fractures and 5 were surgically managed (17.2%). There were 3 conservatively treated cranial acetabular fractures (75.0%) and 1 was surgically managed (25.0%). There were 13 conservatively treated mid acetabular fractures

(86.7%) and 2 were surgically managed (13.3%). There were 5 conservatively treated caudal acetabular fractures (83.3%) and 1 was surgically managed (16.7%). There were 3 conservatively treated comminuted acetabular fractures (75.0%) and 1 was surgically managed (25.0%). The amalgamated surgical group was managed via 4 different methods resulting in 2 animals treated by an acetabular "c" plate (40.0%). 1 animal (20.0%) by application of a dynamic compression plate, applied in dynamic mode and 1 animal (20.0%) with a neutralisation plate plus 1 cat (20.0%) treated by a miniplate.

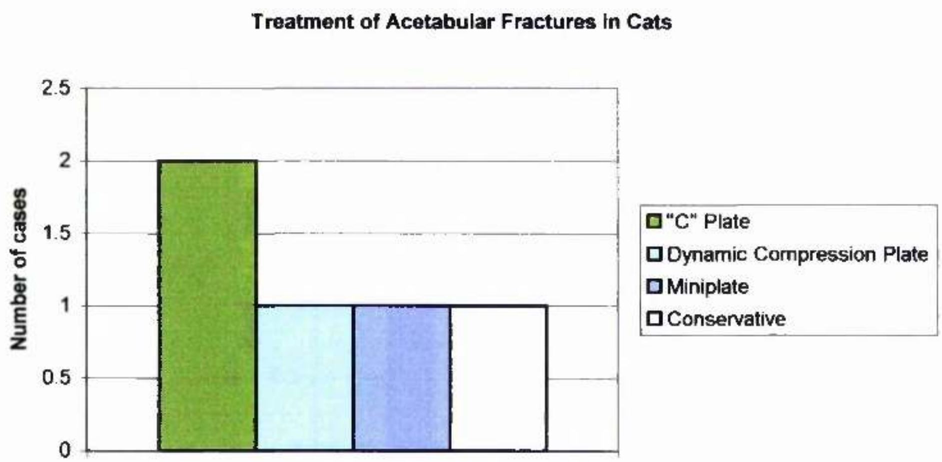


Figure 6.12. Treatment of acetabular fractures in cats.

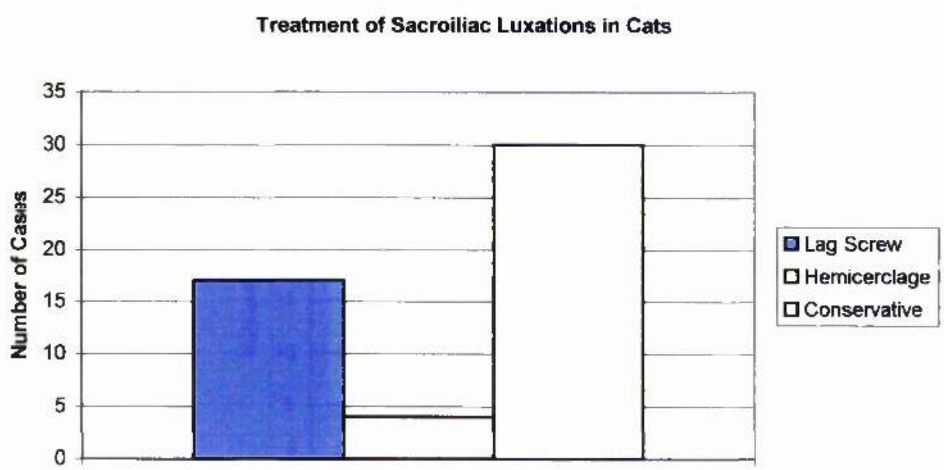


Figure 6.13. Treatment of sacroiliac luxations in cats.

There were a total of 51 sacroiliac luxations (Figure 6.13) of which 30 (58.8%) were conservatively treated and 21 were surgically managed (41.2%). The surgical group was managed via 2 different methods so that 17 animals were treated by lag screw fixation (81.0%) and 4 by Kirschner wire (19.0%).

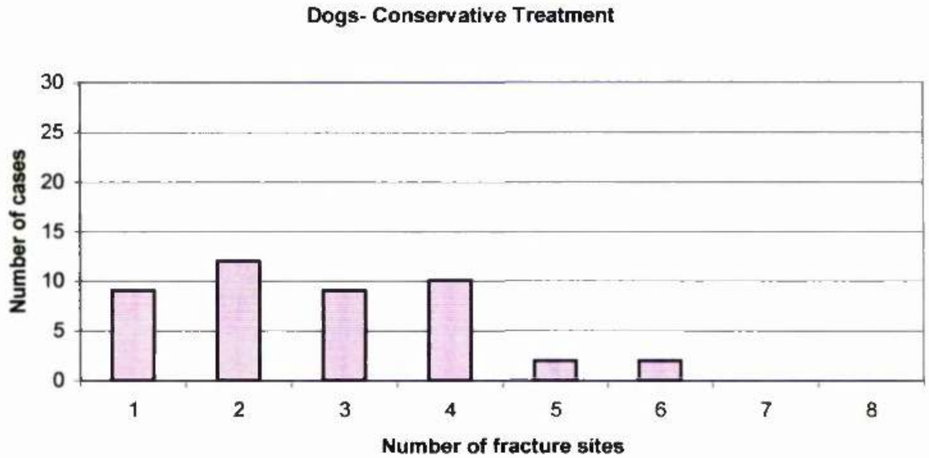


Figure 6.14. Number of fracture sites in conservatively treated dogs.

Out of the 44 conservatively treated dogs (Figure 6.14) 9 (20.5%) presented with fractures in 1 anatomical site, 12 (27.3%) had fractures in 2 anatomical sites, 9 (20.5%) had fractures in 3 sites, 10 animals (22.7%) had 4 fracture sites, 2 animals (4.5%) had 5 fracture sites and another 2 animals (4.5%) had 6 sites. No animals with more than 6 sites were conservatively managed.

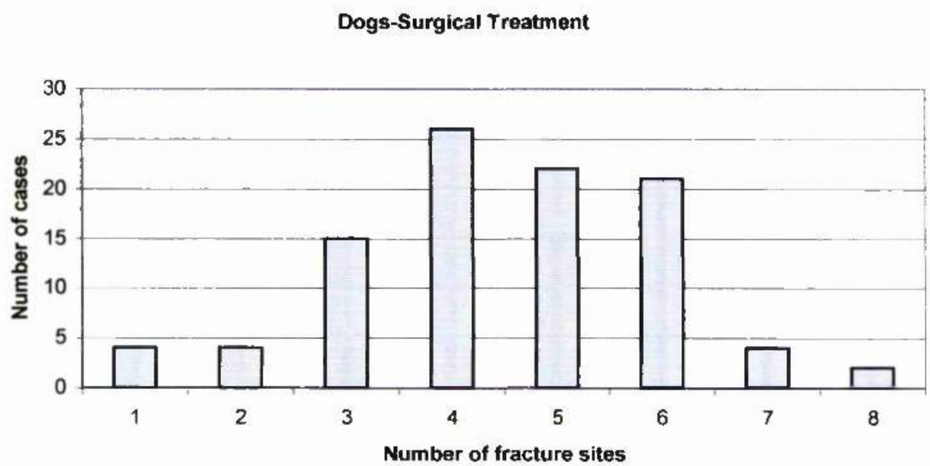


Figure 6.15. Number of fracture sites in surgically treated dogs.

Out of the 98 surgically treated dogs (Figure 6.15) 4 (9.1%) presented with fractures in 1 anatomical site, 4 (9.1%) had fractures in 2 anatomical sites, 15 (15.3%) had fractures in 3 sites, 26 animals (26.5%) had 4 fracture sites, 22 animals (22.4%) had 5 fracture sites and 21 animals (21.4%) had 6 sites. Unlike the conservatively managed group (Figure 6.14), 4 animals (9.1%) had 7 fracture sites and 2 animals (2.0%) had 8 fracture sites.

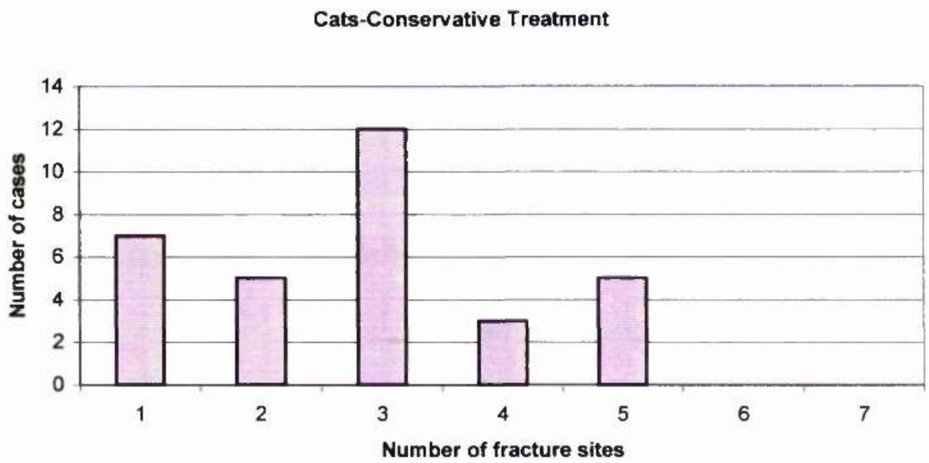


Figure 6.16. Number of fracture sites in conservatively treated cats.

Out of the 33 conservatively treated cats (Figure 6.16) 7 (21.2%) presented with fractures in 1 anatomical site, 5 (15.2%) had fractures in 2 anatomical sites, 12 (36.4%) had fractures in 3 sites, 3 animals (9.1%) had 4 fracture sites and 5 animals (15.2%) had 5 fracture sites. No animals with more than 5 sites were conservatively managed.

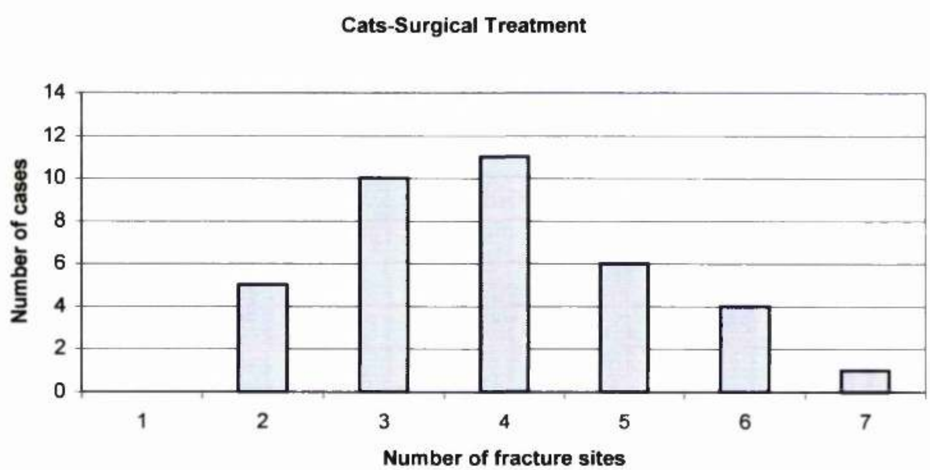


Figure 6.17. Number of fracture sites in surgically treated cats.

Out of the 37 surgically treated cats (Figure 6.17) no cases presented with fractures in 1 anatomical site, 5 (13.5%) had fractures in 2 anatomical sites, 10 (27.0%) had fractures in 3 sites, 11 animals (29.7%) had 4 fracture sites and 6 animals (16.2%) had 5 fracture sites. Unlike the conservatively managed group (Figure 6.16), 4 animals (10.8%) had 6 sites and 1 animal (2.7%) had 7 fracture sites.

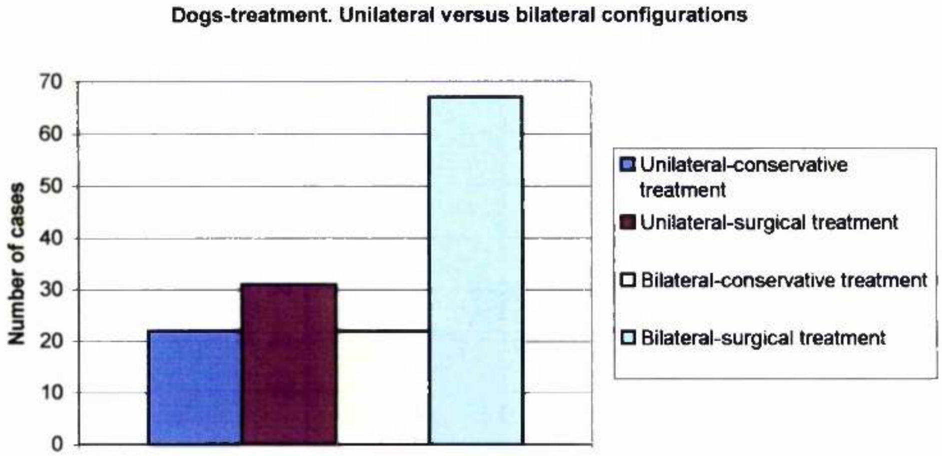


Figure 6.18. Treatment of dogs - unilateral versus bilateral fracture configurations.

Out of the canine sample, 53 animals had fractures, which were unilaterally configured, and 88 were bilaterally configured. Of these 22 (41.5%) of the unilateral fractures were conservatively managed and 31 (58.5%) were treated surgically while 22 (25.0%) of the bilateral fractures were conservatively managed and 67 (76.1%) were treated surgically (Figure 6.18).

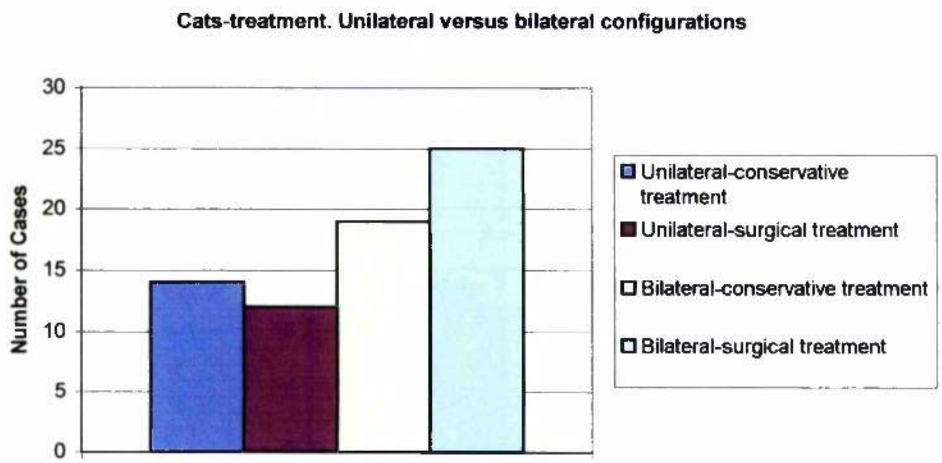


Figure 6.19. Treatment of cats - unilateral versus bilateral fracture configurations.

Out of the feline sample 26 animals had fractures, which were unilaterally configured, and 43 were bilaterally configured. Of these 12 (46.2%) of the unilateral fractures were conservatively managed and 14 (53.8%) were treated surgically while 25 (58.1%) of the bilateral fractures were surgically managed and 19 (44.2%) were treated conservatively (Figure 6.19).

	Complication		Complication
1	Pelvic canal stenosis	7	Malunion
2	Loosening of implant	8	Delayed union
3	Malpositioning of implant	9	Nonunion
4	Complete implant failure	10	Osteoarthritis
5	Partial disruption of bony alignment	11	Osteomyelitis
6	Complete disruption of bony alignment	12	

Table 6.2. List of complications

The post surgical complications listed in Table 6.2 were those found in this sample.

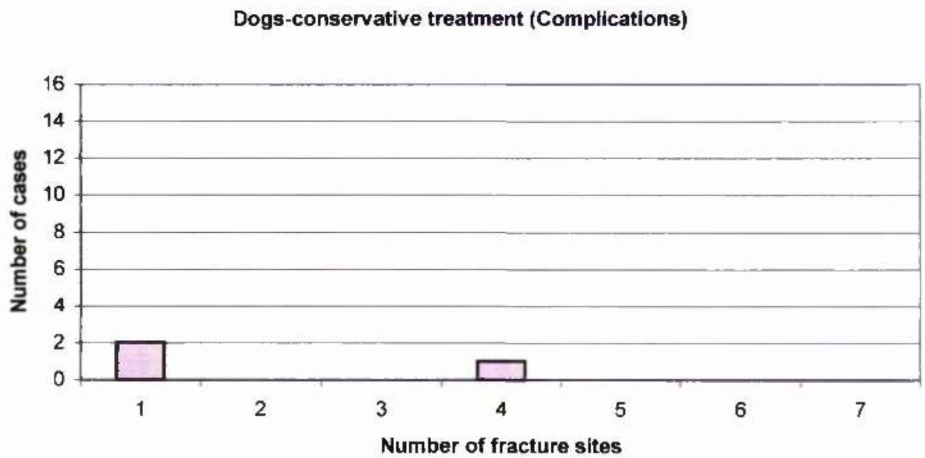


Figure 6.20. Number of fracture sites of conservatively managed dogs displaying complications.

Of the 3 (5.7%) of the 53 dogs, which displayed complications and were conservatively treated (Figure 6.20) 2 animals (3.8%) had a single fracture site and 1 animal (1.9%) had 4 fracture sites.

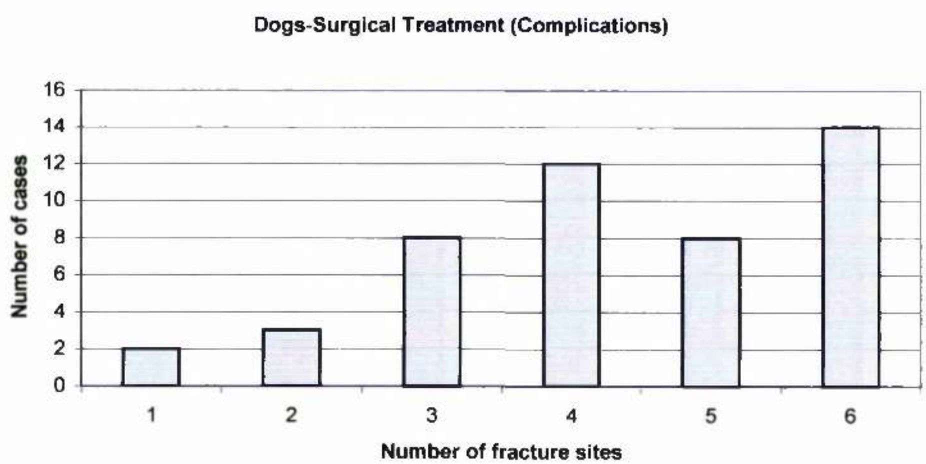


Figure 6.21 Number of fracture sites of surgically managed dogs displaying complications.

Of the 50 (94.3%) of the 53 dogs which displayed complications and were surgically treated (Figure 6.21). 2 animals (3.8%) had a single fracture site, 3 animals (5.7%) had 2 fracture sites, 8 animals (15.1%) had 3 fracture sites, 12 animal (22.6%) had 4 fracture sites, 8 animals (5.7%) had 5 fracture sites and 14 animals (26.4%) had 6 fracture sites. No animals in this group had more than 6 anatomical fracture sites.

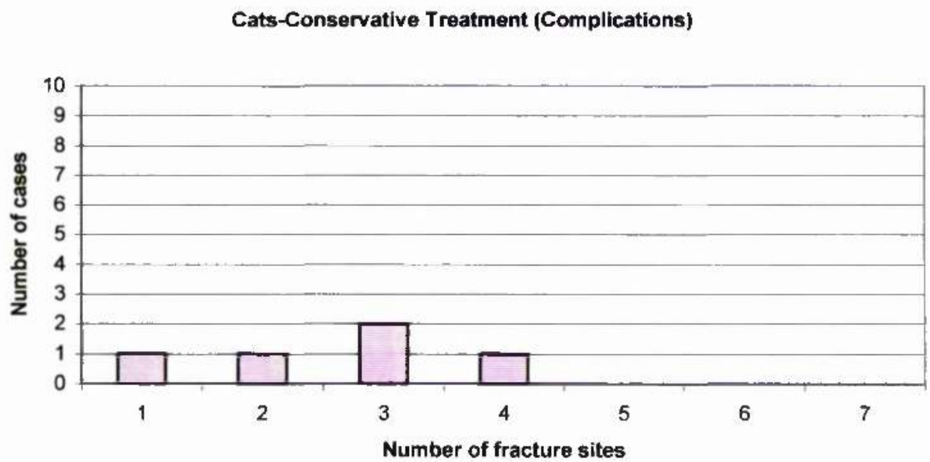


Figure 6.22. Number of fracture sites of conservatively managed cats displaying complications.

Of the 5 (15.2%) of the 33 cats which displayed complications and were conservatively treated (Figure 6.22), 1 animal (3.0%) had 1 fracture site, 1 animal (3.0%) had 2 fracture sites, 2 animals (6.1%) had 3 fracture sites and 1 animal (3.0%) had 4 fracture sites. No animal in this group had more than 4 fracture sites.

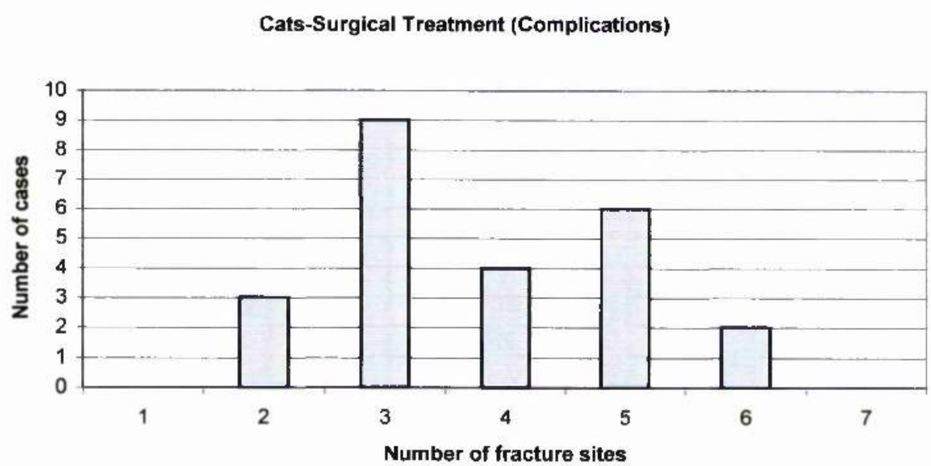


Figure 6.23. Number of fracture sites of surgically managed cats displaying complications.

Of the 24 (64.9%) of the 37 cats which displayed complications and were surgically treated (Figure 6.23), 3 animals (8.1%) had 2 fracture sites, 9 animals (24.3%) had 2 fracture sites, 4 animals (10.8%) had 4 fracture sites, 6 animals (16.2%) had 4 fracture sites and 2 animals (5.4%) had 5 fracture sites. No animals in this group had a single site or more than 6 anatomical fracture sites.

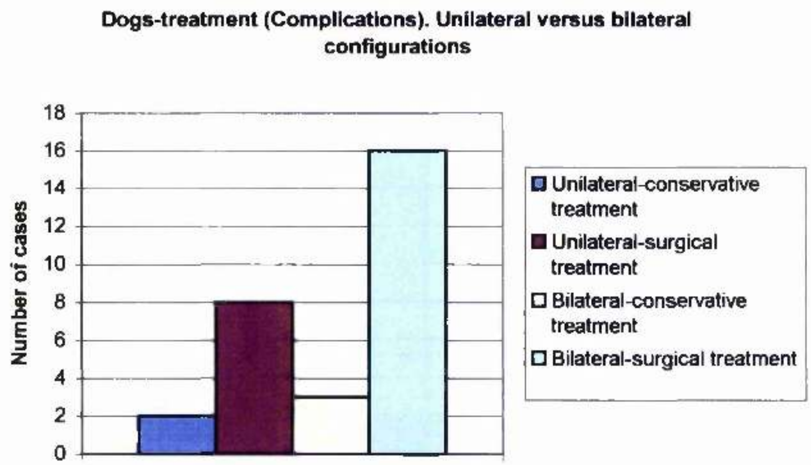


Figure 6.24. Treatment of dogs displaying complications - unilateral versus bilateral fracture configurations.

Out of the canine sample displaying complications 19 animals had fractures, which were unilaterally configured, and 31 were bilaterally configured. Of these 19, 2 (3.8%) of the unilateral fractures were conservatively managed and 17 (32.1%) were treated surgically. Of the 31 cases, 1 (1.9%) of the bilateral fractures was conservatively managed and 30 (56.6%) were treated surgically (Figure 6.24).

Out of the feline sample displaying complications 10 animals had fractures, which were unilaterally configured, and 19 were bilaterally configured. Of these 10, 2 (6.7%) of the unilateral fractures were conservatively managed and 8 (26.7%) were treated surgically. Of the 19 cases, 3 (10.0%) of the bilateral fractures were conservatively managed and 16 (53.3%) were treated surgically (Figure 6.25).

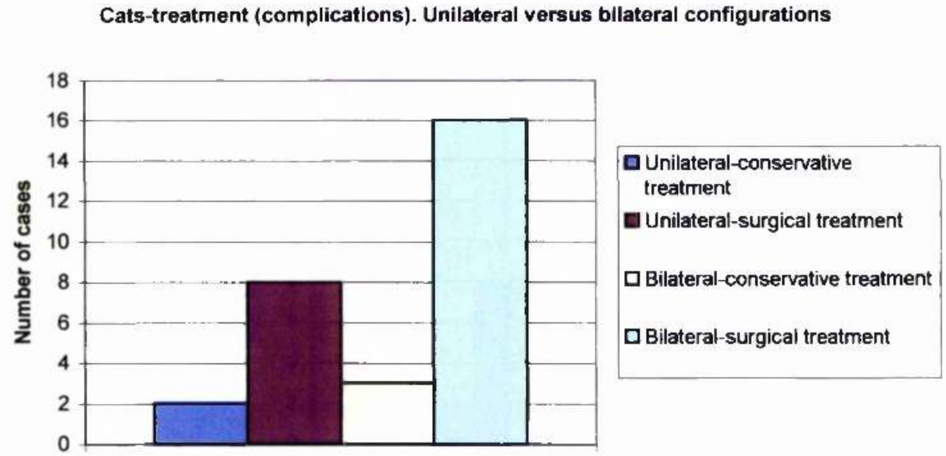


Figure 6.25. Treatment of cats displaying complications - unilateral versus bilateral fracture configurations.

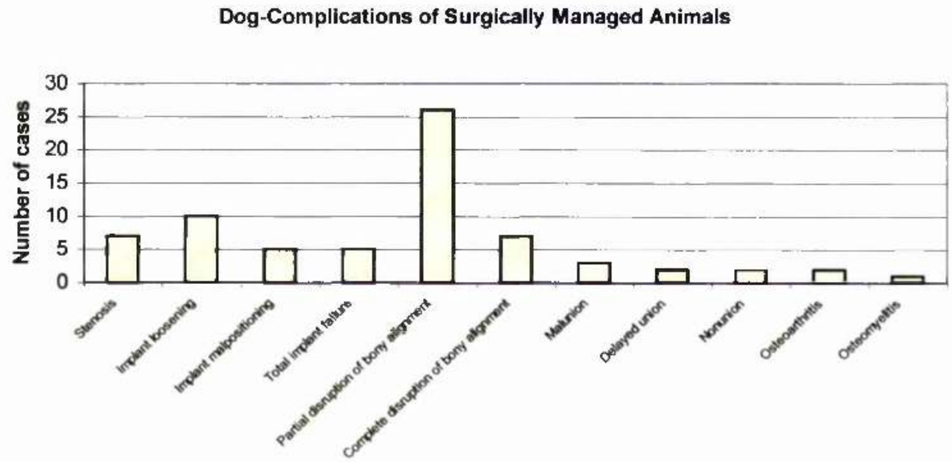


Figure 6.26. Complications of surgically managed dogs.

There were 7 cases of pelvic canal stenosis (13.2%) (Figure 6.26), 10 cases of implant loosening (18.9%), 5 cases of implant malpositioning (9.4%), 5 cases if total implant failure (9.4%), 26 cases of partial disruption of bony alignment (49.0%) and 7 cases of complete disruption of bony alignment (13.2%); all in surgically treated animals. There was a total of 3 incidences of malunion (5.7%), 1 in a surgically treated dog and 2 in conservatively treated dogs. There were 2 cases of delayed union (3.8%), 1 in a surgically treated dog and 1 in a conservatively treated dog. There were 2 cases each of non-union and osteoarthritis (3.8%) and 1 case of osteomyelitis (1.9%) in the surgical group. Also 1 case had a complication, which was unspecified (1.9%).

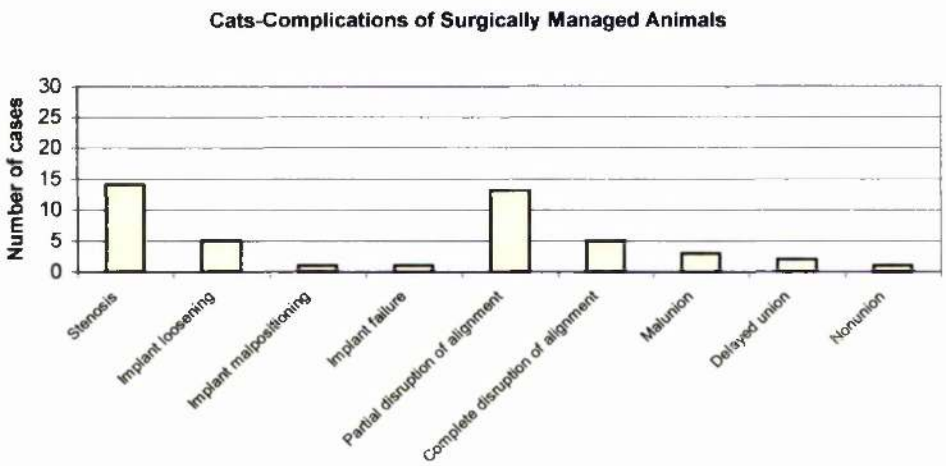


Figure 6.27. Complications of surgically managed cats.

There were 14 cases of pelvic canal stenosis (46.7%) (Figure 6.27), 11 from the surgical group and 3 from the conservative group. Also reported were 5 cases of implant loosening (16.7%), 1 case of implant malpositioning (3.3%) and 1 case if total implant failure (3.3%) all being found in the surgical group. There were 13 cases of partial disruption of bony alignment (43.3%), 12 from the surgical group and 1 from the conservative group. Complete disruption of bony alignment (16.7%) was present in 5 cases, all in surgically treated animals. There was a total of 3 incidences of malunion (10.0%), 2 in surgically treated cats and 1 in a conservatively treated cat. There were 2 cases of delayed union (6.7%) and 1 case of non-union (3.3%) in the surgical group. There was no incidence of osteoarthritis or osteomyelitis in cats.

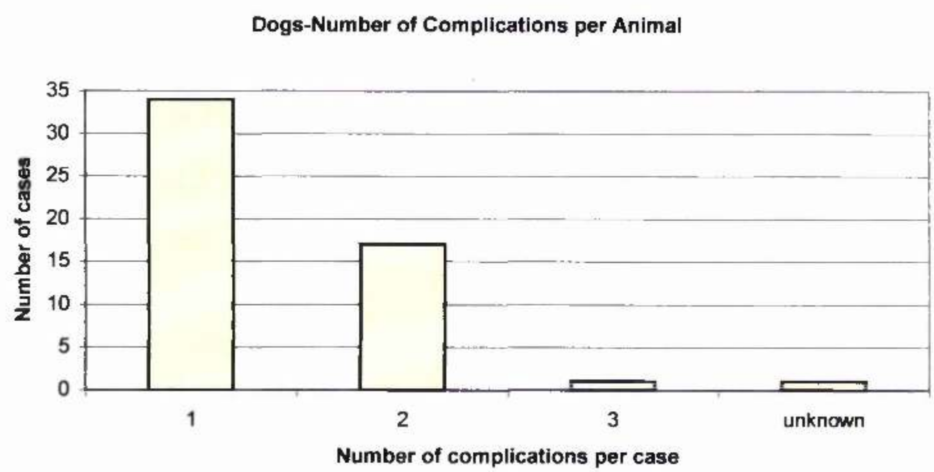


Figure 6.28. Number of complications present per dog.

The majority of canine cases (34) presented with complications had only a single complication (64.2%) but 17 cases (34.1%) had a combination of 2 complications, 1 case (1.9%) had a combination of 3 complications and 1 case (1.9%) was unknown. No dog had more than 3 different complications (Figure 6.28).

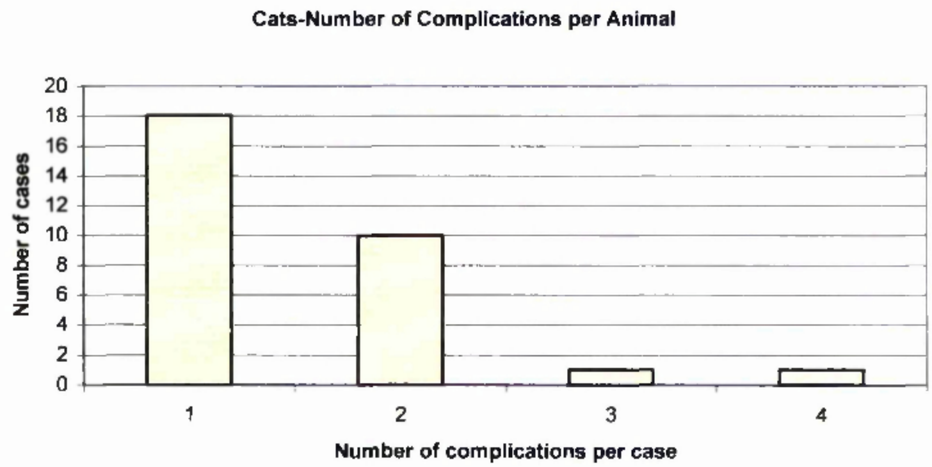


Figure 6.29. Number of complications present per cat.

The majority of feline cases (18) presented with complications had only a single complication (60.0%) but 10 cases (33.3%) had a combination of 2 complications, 1 case (3.3%) had a combination of 3 complications and 1 case (3.3%) had a combination of 4 complications. No cat had more than 4 different complications.

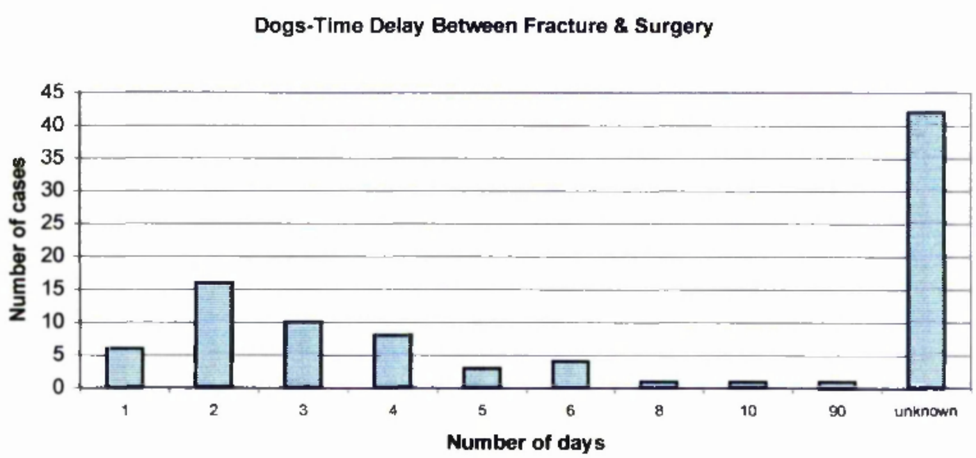


Figure 6.30. Time delay between fracture and surgery in dogs.

In managing the surgery cases 6 animals (6.1%) had a time delay of 1 day between onset of trauma and surgery, 16 animals (16.3%) had 2 days, 10 animals (10.2%) had 3 days, 8 animals (8.2%) had 4 days, 3 animals (3.1%) had 5 days, 4 dogs (4.1%) had a time delay of 6 days, 3 individuals (1.0%) each had a delay of 8, 10 and 11 days. 1 animal (1.0%) had a delay of 90 days and 64 cases (65.3%) had an unknown delay.

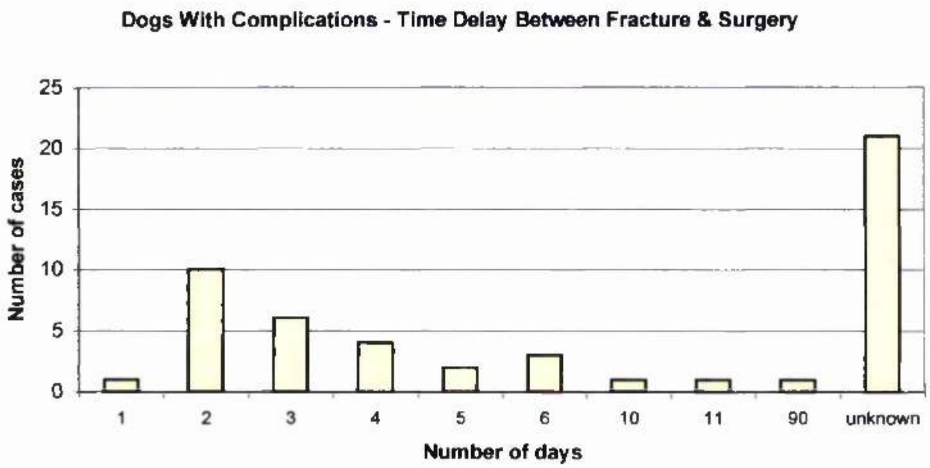


Figure 6.31. Time delay between fracture and surgery in dogs displaying complications.

In the surgical group displaying complications 1 animal (2.0%) had a time delay of 1 day between onset of trauma and surgery, 10 animals (20.0%) had 2 days, 6 animals (12.0%) had 3 days, 4 animals (8.0%) had 4 days, 2 animals (4.0%) had 5 days, 3 animals (6.0%) had a time delay of 6 days, 2 individuals (1.0%) each had a delay of 10 and 11 days, 1 animal (2.0%) had a delay of 90 days and 21 cases (42.0%) had an unknown delay.

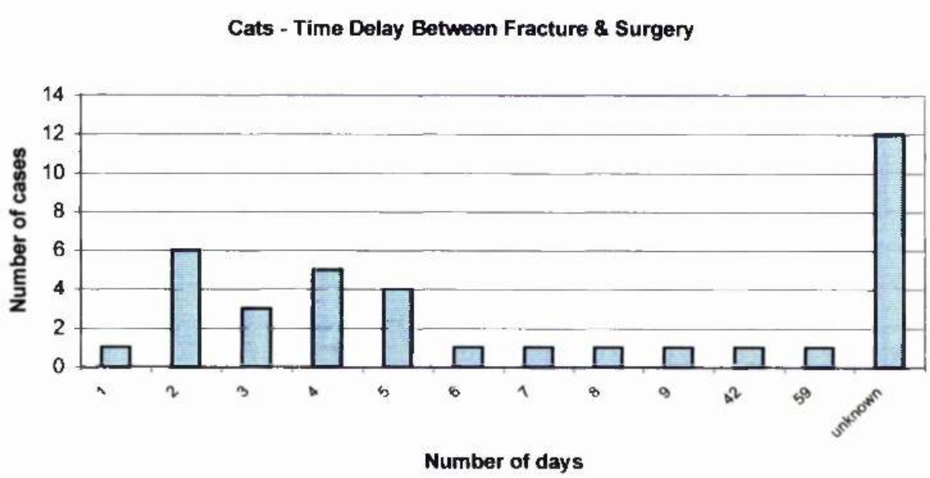


Figure 6.32. Time delay between fracture and surgery in cats.

Of the surgical group of cats 1 animal (2.7%) had a time delay of 1 day between onset of trauma and surgery, 6 animals (16.2%) had 2 days, 3 animals (8.1%) had 3 days, 5 animals (13.5%) had 4 days, 4 animals (10.8%) had 5 days, 4 individuals (2.7%) each had a delay of 6, 7, 8, and 9 days. 2 individuals each (2.7%) had a delay of 42 and 59 days and 12 cases (65.3%) had an unknown delay.

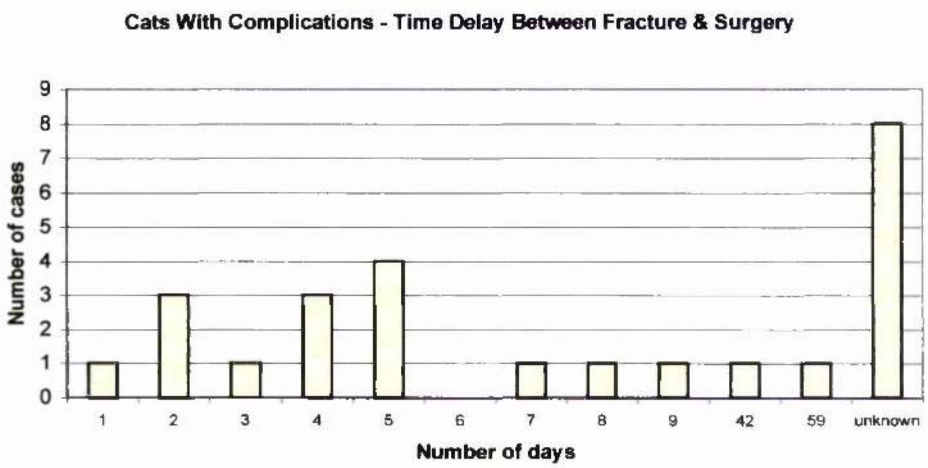


Figure 6.33. Time delay between fracture and surgery in cats displaying complications.

In the surgical group of cats displaying complications 1 animal (4.0%) had a time delay of 1 day between onset of trauma and surgery, 3 animals (12.0%) had 2 days, 1 animal (4.0%) had 3 days, 3 animals (12.0%) had 4 days, 4 animals (16.0%) had a time delay of 5 days, 3 individuals (4.0%) each had a delay of 7, 8 and 9 days, 2 individuals each (4.0%) had a delay of 42 and 59 days and 8 cases (32.0%) had an unknown delay.

6.3. DISCUSSION

Due to the wide variety of anatomical locations and types of fracture of the pelvis, no single treatment protocol can be deemed appropriate for every case. Each trauma case must be judged on its own merits as certain fractures are more suitable than others for conservative management while others respond more favourably to surgical intervention. This study investigated the commonly used treatments for each of the anatomical fracture locations and explored the treatment methodologies, which resulted in, follow up complications.

Many types of internal fixation instrumentation are used in the treatment of pelvic fractures. These include intramedullary pins (Simonian *et al*, 1997; Dunbar, 1984; Alexander *et al* 1962), lag screws (VanGundy, 1990; Dunbar, 1984), cancellous screws, cortical screws (McLaughlin & Roush, 1999; Simonian *et al*, 1997), Steinmann pins, bone plates (McLaughlin & Roush, 1999; Robins, 1992; Dunbar, 1984; Brown & Biggart, 1975; Wheaton, 1973) such as dynamic compression plates (Allgöwer *et al*, 1973), plastic plates (Dunbar, 1984), cuttable plates (McLaughlin & Roush, 1999), "T" plates (McLaughlin & Roush, 1999), "L" plates, acetabular "C" plates and miniplates (Roush & Manley, 1992).

The aim of internal fixation should be the attainment of adequate alignment and stability (Allgöwer *et al*, 1973; Robins *et al*, 1973) so that secondary and lesser injuries can be managed conservatively (Dunbar, 1984). In many cases it is within the power of the surgeon to carry out fairly precise anatomic alignment of the broken bones and thus reconstruct the pelvis (Alexander *et al*, 1962).

There are twelve commonly documented indications for surgical fixation. If an animal fulfils one or more of these criteria then it is seen as a possible candidate for surgery. These can be categorised as follows:

1. Decrease in size of the pelvic canal (Alexander *et al*, 1962; Denny, 1978; Dunbar, 1984; Brinker *et al*, 1990; Eaton-Wells *et al*, 1990; Betts, 1993; Houlton & Dyce, 1994) especially where a fragment can potentially impinge on viscera contained within the pelvic canal (Alexander & Carb, 1979).
2. Age, breed, sex and bodyweight of the animal (Houlton & Dyce, 1994).
3. Fracture of the acetabulum (displacement of the articular surfaces) (Denny, 1978; Alexander & Carb, 1979; Dunbar, 1984; Brinker *et al*, 1990; Tarvin & Lenehan, 1990; Betts, 1993; Houlton & Dyce, 1994).
4. Instability of the hip (fracture of the ilium, ischium and pubis on same side; segmental or Malgaigne fracture) (Denny, 1978; Dunbar, 1984; Brinker *et al*, 1990; Tarvin & Lenehan, 1990; VanGundy, 1990; Betts, 1993).
5. Unilateral or bilateral instability (Eaton-Wells *et al*, 1990; Tarvin & Lenehan, 1990; Betts, 1993) particularly if accompanied by coxofemoral dislocation or other limb fractures (Denny, 1978; Brinker *et al*, 1990).

6. Sacro-iliac luxation or fracture luxation (1996, URL-2; Eaton-Wells *et al*, 1990; Tarvin & Lenehan, 1990).
7. Ilial shaft fractures with craniomedial displacement compromising the pelvic canal, especially in intact bitches (Tarvin & Lenehan, 1990).
8. Gross fragment displacement (Dunbar, 1984; Tarvin & Lenehan, 1990; Houlton & Dyce, 1994).
9. Multiple bilateral pelvic fractures (Denny, 1978; Eaton-Wells *et al*, 1990).
10. Cases in which the owner's (Houlton & Dyce, 1994) or animal's attitude will render conservative treatment ineffective (Eaton-Wells *et al*, 1990).
11. Patients in which postoperative appearance and as near normal gait are important (Eaton-Wells *et al*, 1990).
12. Ability of the owner to pay (Houlton & Dyce, 1994).

Other factors, which should be taken into consideration, are the facilities available and the experience of the surgeon (Houlton & Dyce, 1994).

This study revealed that these indications were not always adhered to which may explain the high post surgical complication rate.

Out of this sample 27.2% of dogs and 45.2% of cats were conservatively managed, and 60.4 % of dogs and 50.7% of cats were surgically treated. This may not be a good overall reflection on average national treatment protocols as most of the cases were from GUVS and RVC, which are specialist referral centres with orthopaedic departments. It is possible that a higher percentage of pelvic fractures managed by private practices are treated conservatively.

6.3.1. Ilial fractures

In both dogs and cats, ilial body fractures were more common than ilial wing fractures. In dogs the majority of ilial fractures were treated surgically; 87.2% compared to 12.8% managed conservatively. There were 12 methods of treatment for ilial fractures in the canine group. These comprised of conservative management, 7 different types of plating, lag screw fixation, cerclage and hemicerclage wiring and application of a transilial pin. The majority of the surgically treated fractures were plated, predominantly using a plate of unspecified type and mode. The feline set had a similar pattern with 63.9% of ilial fractures being treated surgically and 36.1% conservatively. In this group there were 10 methods of treatment. These comprised of conservative management, 5 different types of plating, hemicerclage wiring, external skeletal fixation, application of a transilial pin and another unspecified surgical treatment. Again the majority of these fractures were plated, principally using a plate of unspecified type and mode. Bone plating of ilial body fractures was suggested by Brinker *et al* in 1984; Dunbar, 1984; Brown & Biggart, 1975; Robins *et al*, 1973. Whereas Alexander *et al* in 1962 suggested the application of an intramedullary pin, Brown & Biggart, 1975 stated that oblique ilial shaft fractures may require supplemental pins to prevent overriding. Roush & Manley in 1972 found that plate fixation of ilial fractures resulted in the highest percentage of success.

6.3.2. Acetabular fractures

Surgical repair of acetabular fractures is aimed at restoring integrity to the joint (Kahler & Zura, 1997; Dunbar, 1984). With acetabular fractures, anatomic realignment of the articular surface and rigid fixation are primary factors in restoration of normal function to the limb (Wheaton *et al*, 1973). If the fracture goes untreated, abnormal wear leads to denuding of the articular cartilage, osteoarthrosis and pain (Kahler & Zura, 1997; Brinker *et al*, 1984). Usually an attempt is made to re-establish a functional articular surface. In the present study, the majority of acetabular fractures were of the weight-bearing portion of the acetabulum. A substantial percentage of these were comminuted. Most canine acetabular fractures were treated conservatively; 56.9% compared to 43.1% treated surgically. Dogs were managed by 9 different methods of treatment. This comprised of conservative management, 6 different forms of plating, lag screw fixation and application of a K-wire. The majority of these fractures were plated, chiefly using a plate of unspecified type and mode. A smaller percentage of cats had fracture of the acetabulum. The smaller number of treatment types applied reflects this. Most feline acetabular fractures were treated conservatively; 82.8% compared to 17.2% treated surgically. Cats were managed by 4 different methods of treatment. These comprised of conservative management and 3 different forms of plating. The majority of these fractures were treated by an acetabular "C" plate. It is important to manage acetabular fractures properly to reduce the probability of undesirable sequelae such as degenerative joint disease. Brinker *et al* 1984 recommend the application of an acetabular "C" plate or contoured bone plate whereas Wheaton *et al* in 1973 suggested the use of either bone plates or 2 Steinmann pins with a figure-of-eight tension band wire. Lanz *et al* in 1998 and then in 1999 recommended a screw / wire / polymethylmethacrylate composite fixation for acetabular fractures.

6.3.3. Sacroiliac luxations

Sacroiliac luxations were considerably more common in cats than dogs. However less than half of these in either species were surgically treated. Dogs were managed by 4 different methods of treatment. These comprised of conservative management, lag screw fixation or application of a Kirschner or cerclage wire. The majority of surgically treated dogs had application of a lag screw. Cats however were managed by 3 treatment methods: conservative, by application of a lag screw or hemicerclage. The majority of this surgical group also had the application of a lag screw. Lag screw fixation for sacroiliac luxations was recommended by Dunbar in 1984. Because the sacroiliac joint is part of the weight-bearing axis where force is transmitted from the appendicular to axial skeleton, it is subject to considerable forces during locomotion. Care has to be taken to ensure that the implant selected is of sufficient size and strength to withstand this.

6.3.4. Sacral fractures

Two thirds of sacral fractures in dogs were treated surgically and one third conservatively, compared to the feline group where all sacral fractures were conservatively managed. In dogs 4 treatment methodologies were used. These were conservative, application of a lag screw, Kirschner wire or iliosacral pin. Lag screw fixation was the most common surgical method.

6.3.5. Pubic and ischial fractures

In both the canine and feline groups all fractures of the pubis and ischium were treated conservatively. Some authors suggest that certain pubic fractures warrant surgical intervention such as hemicerclage wiring (Alexander *et al*, 1962). Brinker *et al* in 1984 stated that ischial fractures may be reduced using a small bone plate or hemicerclage wire possibly in conjunction with a Steinmann pin. The general opinion is, however that pubic fractures should not be fixed as the results rarely outweigh the trauma of the operation.

In 1992, Roush & Manley indicated that ischial fractures need not be surgically treated unless the fragments impinge on the sciatic nerve or are attached to the acetabulum. Specific reduction and stabilization of these fractures is very rare (Robins, 1992). Occasionally a distracted fracture of the ischiatic tuberosity may require fixation using lag screws or a tension band wire (Robins, 1992).

6.3.6. Number of fracture sites

A species difference exists in the number of fracture sites present. In general individual cats present with fewer fracture sites than dogs.

6.3.6.1. Non-surgical group

This group comprised of dogs with up to 6 fracture sites and cats with up to five sites. The majority of dogs had 2 or 4 sites and the majority of cats had 1 or 3 sites.

6.3.6.2. Surgical group

The canine surgical group contained animals with up to 8 fracture sites whereas the feline group had animals with 2 to 7 sites.

6.3.7. Distribution

The majority of cases in both the canine and feline group had surgically treated bilateral fractures. This was followed in dogs in decreasing order by surgically treated unilateral fractures, conservatively treated unilateral fractures then surgically treated bilateral fractures. The feline group showed a different pattern. The second most common category was conservatively treated bilateral fractures. The third, in accordance with the canine sample was conservatively treated unilateral fractures and lastly, surgically treated unilateral fractures.

6.4. CONCLUSIONS

Treatment of ilial fractures in dogs and cats tends to correspond to the surgical guidelines. By definition, any ilial body fracture disrupts the weight-bearing arc on the side with the fracture and therefore should be treated surgically in order for early ambulation to occur. Frequently ilial body fractures are displaced and compromise the pelvic canal. They nearly always are accompanied by other fractures and an isolated ilial body fracture is extremely rare. It was found that 29.8% of ilial fractures in dogs and 58.3% in cats were of the ilial body, the weight-transmitting portion of the ilium. A total of 95.5% of these in dogs and 85.7% in cats were surgically managed.

Certain surgical techniques suggested for acetabular fractures do not have the rigid stabilization of a plate or the combination of compression plus axial stability provided by Steinmann pins plus a figure-of-eight wire or a composite (screw / wire/ polymethylmethacrylate) fixator. The surgical guidelines indicate that all acetabular fractures should be managed surgically (Denny, 1978; Alexander & Carb, 1979; Dunbar, 1984; Brinker *et al*, 1990; Tarvin & Lenehan, 1990; Betts, 1993; Houlton & Dyce, 1994). However Robins in 1992 stated that conservative treatment is appropriate in undisplaced fractures, particularly if they involve the caudal third of the articular surface. In accordance with this, most cases in this sample were surgically treated only if the fracture involved the cranial two thirds of the acetabulum, corresponding to the weight-bearing portion. The caudal acetabulum does not contribute to the weight-bearing portion of the pelvis, therefore was only surgically managed if there was gross displacement of the bone fragments.

Again by definition, a sacroiliac fracture luxation disrupts the weight-bearing arc. Sacroiliac luxations occur with other fractures, frequently bilaterally and therefore produce considerable instability, often with displacement. This fracture location fulfils the criteria for at least three of the surgical guidelines but despite this, fewer than half were managed surgically.

6.4.1. Complications

Internal fixation is not without its hazards and complications and it is essential that these should be recognised and understood (Vaughan, 1975). The incidence of complications related to the surgical repair of fractures in dogs is not accurately known although it was mentioned by Kahler & Zura in 1997 that the composite complication rate for open reduction of acetabular fractures may be as high as 70%. The factors are often interrelated (DeAngelis, 1975). Complications of pin or plate fixation are usually due to technical errors, although the margin for error can be small (Brown & Biggart, 1975). In this study dogs were found to have 11 different types of post surgical complication, cats had 9 types, all in common with the dog.

Except in the treatment of acetabular fractures, perfect reduction is not essential for a satisfactory outcome (Alexander & Carb, 1979; Robins *et al*, 1973). However the definition of satisfactory is not well defined. Results that allow the return of function and mobility of the animal but have disruption of anatomical bony alignment may be satisfactory in household pets and but may be unacceptable in show, working or performance animals. The complications stated in this research, may in certain animals, be deemed acceptable.

6.4.2. Number of fracture sites

It would generally be assumed that multiple pelvic fractures, i.e. those with numerous fracture sites would present with a higher number of complications. Surprisingly this was not the case.

6.4.2.1. Canine non-surgical group

Only dogs with 1 and 4 fractures sites displayed complications, which comprised of 22.2% of dogs with 1 site and 11.1% of dogs with 4 sites. No conservatively treated cases with 2, 3,5 or 6 sites had any complications.

6.4.2.2. Canine surgical group

Dogs with 1 to 6 sites displayed post surgical complications. This comprised of 50.0% of dogs with 1 fracture site, 75.0% of dogs with 2 sites, 53.3% of dogs with 3 sites, 46.2% of dogs with 4 sites, 36.4% of dogs with 5 sites and 66.7% of dogs with 6 sites. No animal with 7 or 8 fractures sites displayed post surgical complications.

6.4.2.3. Feline non-surgical group

Cats with 1 to 5 fractures sites displayed complications. This comprised of 14.3% of cats with 1 site, 20.0% of cats with 2 sites, 16.7% of cats with 3 sites, 66.7% of cats with 5 sites, 20.0% of cats with 6 sites. No conservatively treated cases with 6 or 7 sites had any complications.

6.4.2.4. Feline surgical group

Cats with 2 to 6 sites displayed post surgical complications. This comprised of 60.0% of cats with 2 sites, 90.0% of cats with 3 sites, 36.4% of cats with 4 sites, 100% of cats with 5 sites and 50.5% of cats with 6 sites. No animal with 7 fractures sites displayed post surgical complications.

6.4.3. Number of complications per animal

Most cases in both the canine and feline group had only one complication per individual. However a substantial amount had 2 complications. A minor amount of dogs had three and a small number of cats had three or four complications per animal.

6.4.3.1. Stenosis

In some cases the fracture segments can be displaced to the point of reducing the size of the pelvic canal and interfering with normal defecation. Obstipation becomes a persistent problem (Brinker *et al*, 1984). A slight reduction in the diameter of the pelvic canal may be termed acceptable in all but breeding bitches or queens. In this research, stenosis was present with double the frequency in cats than dogs. Stenosis is considerably more frequent in the cat (46.7%) than the dog (13.2%). This is reflected in the amount of information available in the literature. It was found to be the most widespread complication in surgically treated cats. The feline pelvis is proportionately narrower than that of the dog; a fact which may explain the high incidence of this complication.

6.4.3.2. Implant loosening

Loosening of the implant (often as a result of osteomyelitis), with consequent loss of fracture immobilization is a common feature (Hosgood & Lewis, 1993;Vaughan, 1975). Improper placement of one or more screws is the most likely cause of loosening (Roush & Manley, 1992). This study revealed that implant loosening occurs with similar frequencies in dogs (18.9%) and cats (16.7%).

6.4.3.3. Implant malpositioning

The malpositioned implant is present as a technical error and occurs considerably more often, in the current study, in dogs (9.4%) than cats (3.3%).

6.4.3.4. Implant failure

The commonest error is using an implant of insufficient size adequately to immobilize and support the fracture (Emmerson & Muir, 1999; Vaughan, 1975). This complication occurred, in the current examination, in dogs with the same frequency as implant malpositioning. It was present in 9.4% of surgically treated dogs. It was found to be less common in cats (3.3%) and was present in the same proportions as implant malpositioning and nonunions.

6.4.3.5. "Unions"

Malunion is defined as a healed fracture but anatomically incorrectly aligned (Sumner-Smith & Bishop, 1982). Delayed union is defined as a healing fracture although healing very slowly (Sumner-Smith & Bishop, 1982) and a nonunion is a failure to unite (Sumner-Smith & Bishop, 1982). In this study two more categories were included. These were partial and complete disruption of alignment. The differentiation between these and malunited fractures are that malunions were fractures that healed in an incorrect alignment in spite of the implant. i.e. the implant was insufficient to hold the fracture ends in alignment. Partial and complete disruptions of alignment are where the fracture was stabilised in an anatomically incorrect position. i.e. the fracture healed out of alignment because of the implant.

6.4.3.6. Partial disruption of alignment

This complication was found in this study to be the most common by far. In dogs it was present in 49% of surgically treated cases. In cats it was second in frequency to stenosis and was present in 43.3% of the surgical group. This complication may, in certain cases be seen as acceptable except in acetabular fractures.

6.4.3.7. Complete disruption of alignment

In the current investigation, complete disruption of alignment was not as common as partial disruption. It was more common in cats. It was seen in 13.2% of dogs; present in the same amounts as stenosis. In the cat it was present in 16.7% of the surgical group, with the same frequency as implant loosening. The pelvis may become very asymmetrical and locomotion may be impaired.

6.4.3.8. Malunion

Many malunions do not interfere with function but are not acceptable to owners critical of breed conformation. The cause is usually insufficient or inappropriate fixation (Betts, 1995). Malunions were more common in the dog (5.7%) than the cat (3.3%).

6.4.3.9. Delayed union

Delayed union refers to a fracture that has not healed in the usual time (Brinker et al, 1990; DeAngelis, 1975). It is an intermediate stage in fracture healing that can proceed to union or nonunion (Betts, 1995). The most common cause of delayed union is inadequate fixation (Brinker et al, 1990) leading to motion at the fracture site (DeAngelis, 1975). However a delayed union can develop from an infection effect on bone healing (Betts, 1995). Delayed unions were more common in the cat (6.7%) than the dog (3.8%).

6.4.3.10. Nonunion

The distinction between delayed union and nonunion is often unclear (DeAngelis, 1975). Nonunion refers to a fracture in which all evidence of repair and osteogenic activity at the fracture site has ceased and movement is present at the fracture site (Betts, 1995; Brinker et al, 1990). Nonunions appeared slightly more frequently in the dog (3.8%) than the cat (3.3%).

6.4.3.11. Osteoarthritis

Osteoarthritis frequently forms in the coxofemoral joint following insufficient rigidity and stability of fixation. While 3.8% of dogs developed osteoarthritis no cats were seen with this sequelae.

6.4.3.12. Osteomyelitis

Infection arising in connection with the surgical repair of a fracture is the commonest cause of osteomyelitis in dogs. The pathological changes produced vary in degree and extent, so that slight and severe forms of the condition are encountered (Vaughan, 1975). The incidence of osteomyelitis, following orthopaedic surgery, is not truly known (Sumner-Smith, 1990). In the canine surgical group 1.9% developed osteomyelitis. No cases were seen in the feline group.

6.4.4.Time delay

The timing of the repair of pelvic fractures is an important factor (Alexander & Carb, 1979). Surgical repair should be attempted within 4 days of injury (Betts, 1993; Brinker *et al*, 1990; Slatter, 1985) but ideally within 48 hours of the injury (Robins, 1973). Reduction and fixation are accomplished much more easily and accurately if attempted within this time period (Brinker *et al*, 1990). Each additional day considerably increases the effort and iatrogenic trauma necessary for repair (Betts, 1993). After 5 days the surgical objectives are difficult to accomplish and they may be impossible to attain after 8 or 10 days (Scott, 2001; Alexander & Carb, 1979; Robins, 1973). Delay makes reduction more difficult because of spastic contraction of the muscles and inflammatory thickening of the soft tissue.

Unfortunately 65.3% of canine cases in the current research had an undocumented time delay. Out of the remaining cases 40.8% were presented for surgery on or before the recommended 4 days. The remainder were presented at 5, 6,8,10 and 11 days post trauma. One individual was surgically treated 90 days after fracture.

It was found that 32.5% of feline cases also had an undocumented time delay. Out of the remaining cases 40.5% were presented to surgery on or before the recommended 4 days. The remainder were presented at 5, 6 ,7 ,8 and 9 days post trauma. Two individuals were surgically treated 42 and 59 days after fracture.

Despite a large number of cases in both the canine and feline group having surgery soon after fracture, there was still a high rate of complication. With a time delay of 1 day, 16.7% of dogs and all cats developed complications. Of animals treated 2 days after surgery this changed to 62.5% of dogs and 50.0% of cats. After 3 days the figure was 60% of dogs and 33.3% of cats; after 4 days, 50% of dogs and 60% of cats all had complications. The percentage rose for time delays of more than 4 days to 100% in some cases.

EXTERNAL SKELETAL FIXATION OF PELVIC FRACTURES

External skeletal fixation has been used successfully in the treatment of pelvic fractures in the human for many years (Khalil, 1995; Dahners *et al*, 1984; Dahners *et al*, 1983; Guntenberg *et al*, 1978; Jones *et al*, 1974). It is gaining popularity in veterinary orthopaedics in the treatment of long bone and mandibular fractures. Surgically managed pelvic fractures in the dog and cat are traditionally treated using internal fixation. This includes intramedullary pins (Simonian *et al*, 1997; Dunbar, 1984; Alexander *et al* 1962), lag screws (VanGundy, 1990; Dunbar, 1984), cancellous screws, cortical screws (McLaughlin & Roush, 1999; Simonian *et al*, 1997), Steinmann pins, bone plates (McLaughlin & Roush, 1999; Robins, 1992; Dunbar, 1984; Brown & Biggart, 1975; Wheaton, 1973) such as dynamic compression plates (Allgöwer *et al*, 1973), plastic plates (Dunbar, 1984), cuttable plates (McLaughlin & Roush, 1999), "T" plates (McLaughlin & Roush, 1999), "L" plates, acetabular "C" plates and miniplates (Roush & Manley, 1992).

No adequate guidelines or protocols have been found for external skeletal fixation of pelvic fractures.

The purpose of this anatomical study was to determine whether pelvic fractures in the dog could potentially be stabilized using external skeletal fixation. We investigated safe, hazardous and unsafe areas for pin insertion in orthopaedic surgery. Safe corridors are defined as longitudinal regions through which pins can be inserted safely as they contain neither musculotendinous nor important neurovascular structures. Hazardous corridors contain musculotendinous units but no important neurovascular structures. Unsafe corridors contain both musculotendinous units and neurovascular structures (Marti, 1993).

7.1. MATERIALS & METHODS

Corridors were investigated using extensive dissection coupled with standard anatomical textbooks (Evans & DeLahunta, 2000; Evans, 1993) and an atlas of gross anatomy (Boyd & Paterson, 1991). Three safe and three hazardous corridors were located in each hemipelvis.

7.1.1. Cranial dorsal iliac spine (Figures 7.1 & 7.6).

This is a safe insertion site that is subcutaneous and easily palpable. There was good bone stock for pin holding along the iliac crest. If the pin is inserted through the trans cortex, due to the lateromedial concavity of the ilial wing, it will exit the bone just below the crest and re-enter above the ventral border. This may involve piercing a very small region of the m. gluteus profundus. The pin should be inserted at 90° to the dorsal plane for maximum accuracy.

7.1.2. Junction of ilial wing and body (Figure 7.2 & 7.7).

This position was hazardous due to gluteal muscle coverage. If the pin was inserted too caudally i.e. beyond the level of the sacro-iliac articulation it was in danger of damaging the ramus ventralis from the first nn. Sacrales spinales, truncus lumbosacralis or a. and n. gluteus cranialis. There was good pin holding at this site if full pins were used, that is pins that penetrate both bony cortices. The pins should be inserted 90° to the dorsal plane in order to miss the large nutrient foramina, which lie on the ventral cortex of the ilial body.

7.1.3. Junction of cranial acetabulum and ilial body (Figure 7.3, 7.8 & 7.9).

This position was hazardous, as the pin would have to pass through the mm. gluteus superficialis and gluteus profundus. In this location there was good bone stock but the pin would lie very close to the a. and n. gluteus caudalis. There was also danger of penetration of the joint space. Again the pin should be inserted 90° to the dorsal plane or angled a few degrees caudally.

7.1.4. Lesser ischiatic notch (Figure 7.4 & 7.10).

There was good bone stock in this site but the pin would lie very close to the lig. sacrotuberale, n. ischiadicus and a. gluteus caudalis. Insertion should be 90° to the dorsal plane.

7.1.5. Ischiatic tuberosity (Figure 7.5 & 7.11).

Two safe areas were identified on the ischiatic tuberosity. This area was subcutaneous and easily palpable. The first position (position a.) would involve the pin being inserted at the most lateral point of the ischiatic tuberosity, from a cranio-lateral position coursing in a caudo-medial direction towards the lateral edge of the ischiatic arch. The second position (position b.) would involve the pin being inserted at the most lateral point of the ischiatic tuberosity, from a caudo-lateral position, coursing cranio-medially towards the obturator foramen.

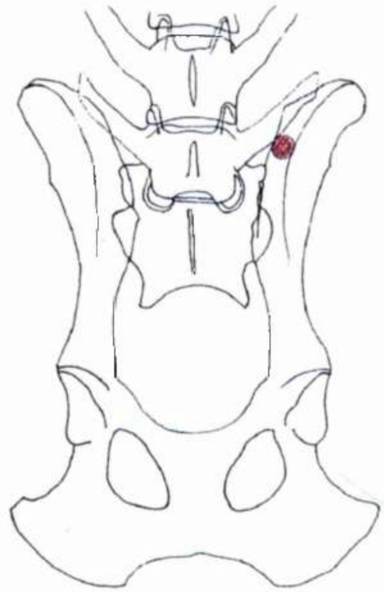


Figure 7.1. Pin insertion site 1.

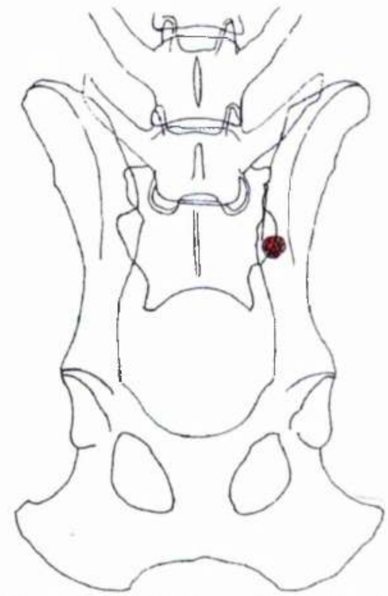


Figure 7.2. Pin insertion site 2.

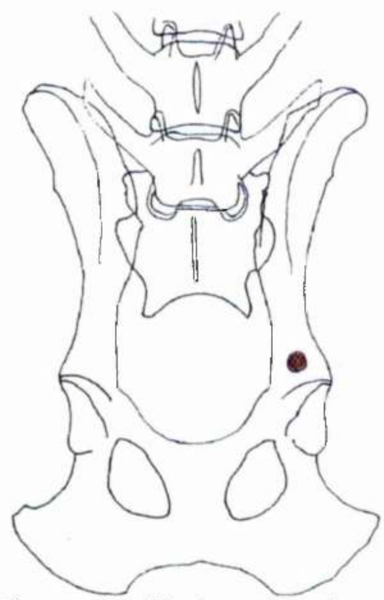


Figure 7.3. Pin insertion site 3.

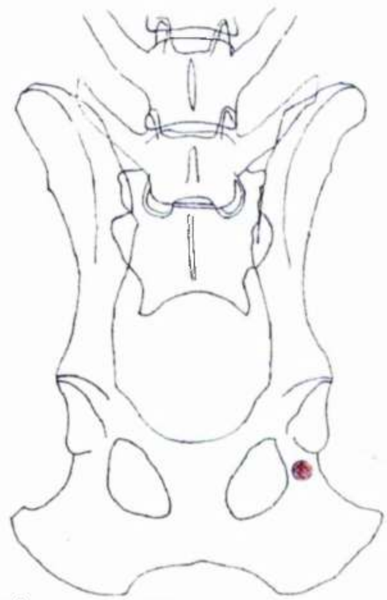


Figure 7.4. Pin insertion site 4.

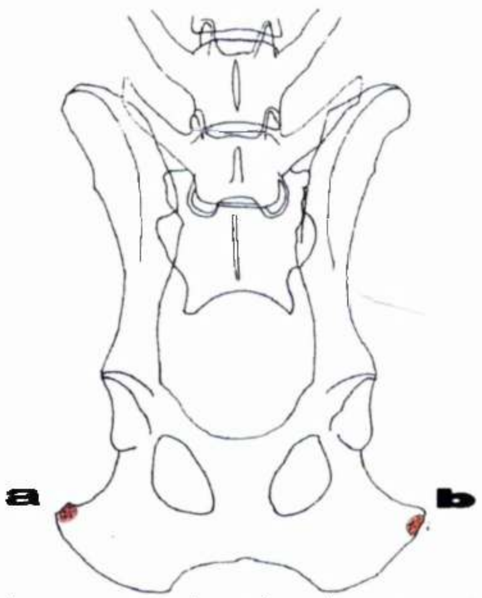


Figure 7.5. Pin insertion sites 5a and b.

In the following figures, numbered 7.6 to 7.10, the pins may be inserted through the trans-cortex to increases bone holding and stability.

Figure 7.6. Pin insertion site 1.

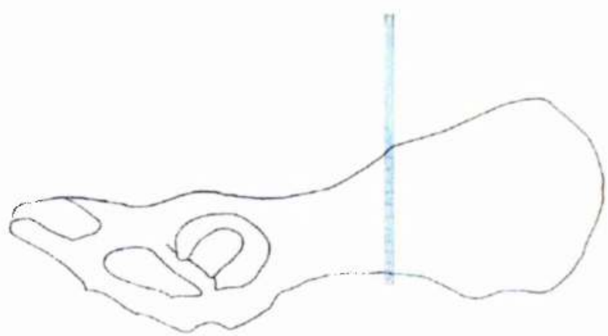


Figure 7.7. Pin insertion site 2.

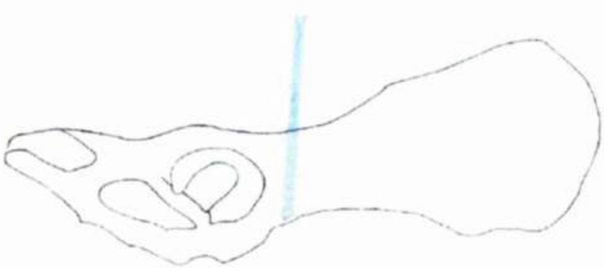


Figure 7.8. Pin insertion site 3a.

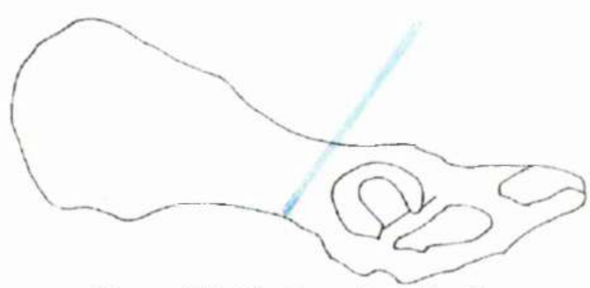


Figure 7.9. Pin insertion site 3b.

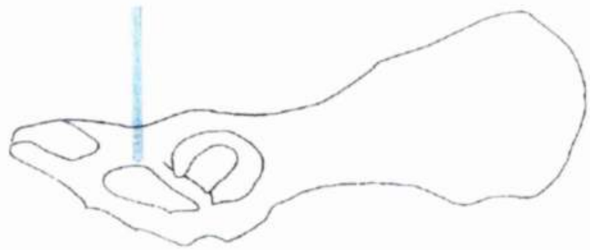


Figure 7.10. Pin insertion site 4.

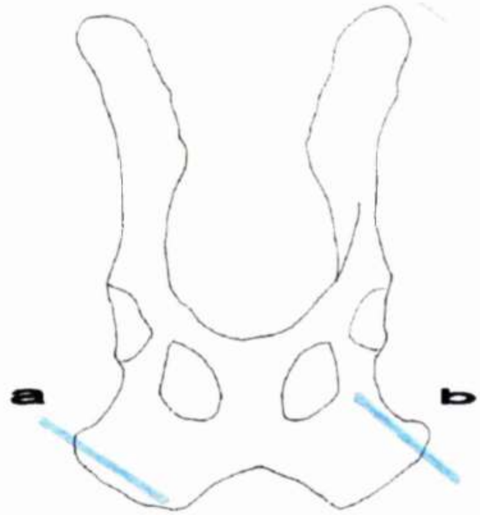


Figure 7.11. Pin insertion sites 5a and b.

7.1.6. Frame configurations

Using these insertion sites potential frame configurations were devised for some commonly found fracture sites and combinations.

7.1.6.1. Ipsilateral ilial body, pubic and ischial fractures (Figures 7.12, 7.16 & 7.17)

This is also known as a "floating hip". This fracture combination completely interrupts the weight bearing axis in essence, the hindlimb on the affected side being completely detached from the axial skeleton. It was postulated that pins should be located in the cranial dorsal iliac spine, ilial wing / body junction and both ischiatic tuberosities (in position b.). The connecting bars should be arranged in a triangular formation. This will reduce and compress the ilial body and ischiatic fractures, which in turn will bring the pubic fracture into correct alignment.

7.1.6.2. Ilial body fracture (Figures 7.13 & 7.18)

This fracture site interrupts the continuity of the weight-bearing axis and will endure considerable forces from weight bearing and muscle pull. It was proposed that a pin be positioned in the cranial dorsal iliac spine, ipsilateral ilial wing / body junction, lesser ischiatic notch and ischiatic tuberosity (in position a.). These should be joined by three linearly arranged connecting bars to provide stability and strong interfragmentary compression.

7.1.6.3. Symphyseal separation (small breed) (Figures 7.14 & 7.19)

A pin should be placed in position a. in each ischiatic tuberosity. These should be joined by a single connecting bar to provide trans pubic compression. This bar should be contoured dorsally to ensure sufficient skin clearance.

7.1.6.4. Symphyseal separation (large breed) (Figures 7.15 & 7.20)

A pin should be placed in the cranial acetabular / ilial body junction and ischiatic tuberosity in each hemipelvis. The pins are linked via a connecting bar at each side for stability with a third bar spanning the dorsum of the dog to increase trans pubic compression. Again this bar should be contoured to provide adequate skin clearance.

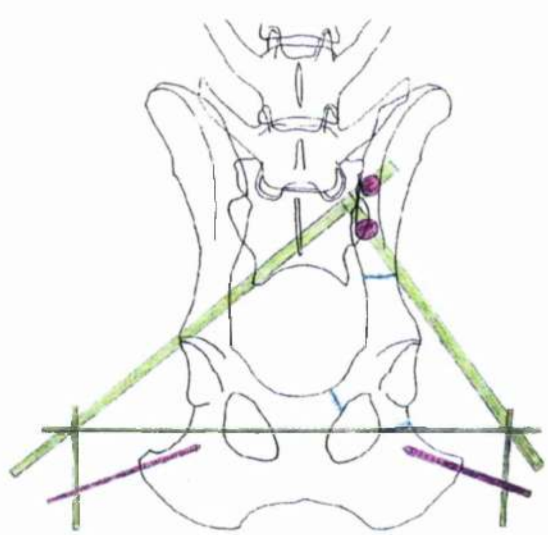


Figure 7.12. Frame configuration 1, dorsal view.

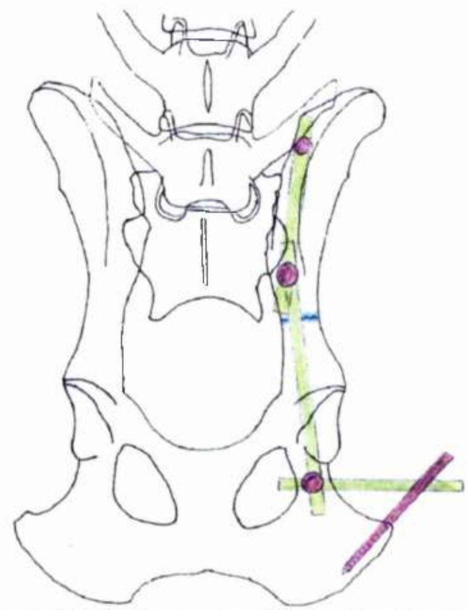


Figure 7.13. Frame configuration 2, dorsal view.

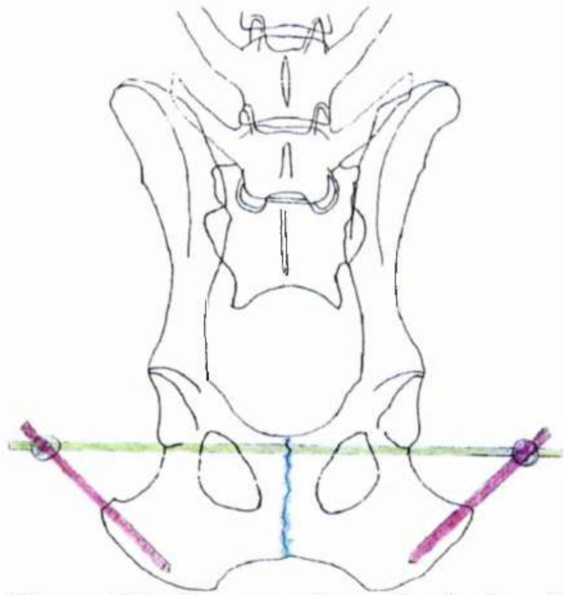


Figure 7.14. Frame configuration 3, dorsal view.

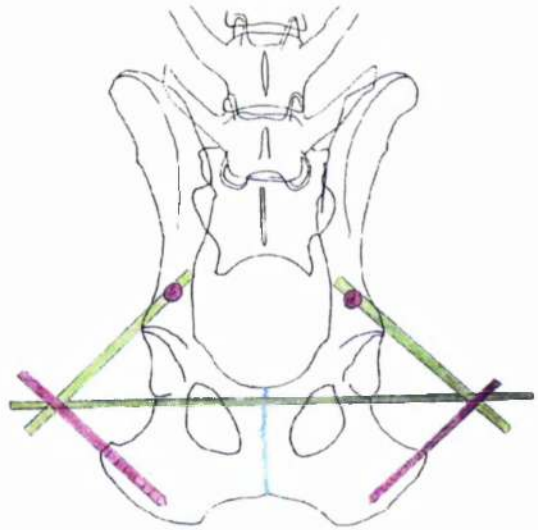


Figure 7.15. Frame configuration 4, dorsal view.

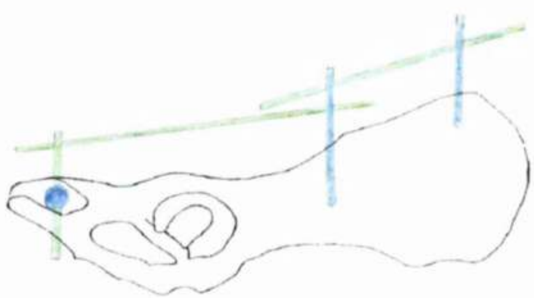


Figure 7.16. Frame configuration 1, lateral view 1.

Figure 7.17. Frame configuration 1, lateral view 2.

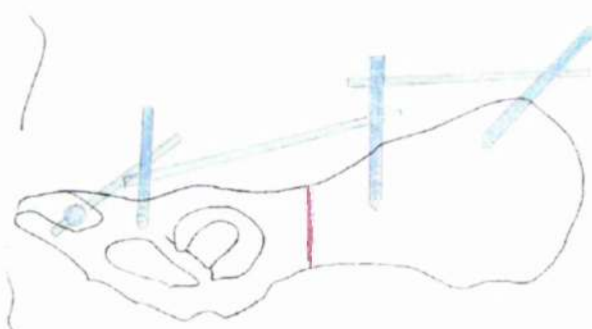


Figure 7.18. Frame configuration 2, lateral view 1.

Figure 7.19. Frame configuration 3, lateral view 2.

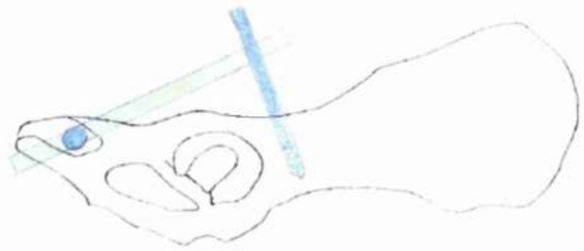


Figure 7.20. Frame configuration 4, lateral view.

7.2. DISCUSSION

External skeletal fixation has been used for many years in the treatment of human long bone (Gardner *et al*, 1996; Hessmann *et al*, 1994; Kershaw *et al*, 1993; Aalto *et al*, 1985; Cunningham *et al*, 1988), spinal (Vieweg *et al*, 1999) and pelvic (Khalil, 1995; Dahners *et al*, 1984; Dahners *et al*, 1983; Guntenberg *et al*, 1978; Jones *et al*, 1974) fractures. It has been implemented in veterinary orthopaedics (Foland & Egger, 1991; Fox, 1986) to treat fractures of long bones (Hyldahl *et al*, 1991) and the mandible (Renegar *et al*, 1982).

Extensive research has been carried out in the quest to find the optimum pin type and design (Marti & Roe, 1999; Anderson *et al*, 1997; Anderson *et al*, 1993; Evans *et al*, 1990; Kasman & Chao, 1984; Ansell & Scales, 1968), pin material (Collinge *et al*, 1994; DeCamp *et al*, 1988), pin insertion location (Kim *et al*, 1999), pin insertion mode and speed (Green & Matthews, 1981; Costich *et al*, 1964), connecting bar type and design (Lanz *et al*, 1999), clamp design (Aro *et al*, 1989) and frame configuration (Egger *et al*, 1985; Egger *et al*, 1983; Kempson & Campbell, 1977) in order to optimise the strength (Dewey *et al*, 1994; Bennett *et al*, 1987), stiffness (Behrens & Johnson, 1989; Brinker *et al*, 1985) stability (Egher *et al*, 1984) and performance (Huiskes & Chao, 1986; Briggs & Chao, 1982) of the fixation system while reducing or eliminating undesirable complications (Hyldahl *et al*, 1991; Behrens, 1981).

External skeletal fixation of pelvic fractures in small animals is not often implemented. It has the reputation for being subject to a high rate of complication, such as pin loosening and resultant fixation failure. Consequently some veterinary orthopaedic textbooks do not even mention it as a treatment option for pelvic fractures (Betts, 1993; Denny, 1993; Brinker *et al*, 1990; Tarvin & Lenehan, 1990). Conversely the same textbooks recommend and illustrate external fixator frame configurations for long bone fractures. There is no mechanical reason why external skeletal fixation should be successful in long bone and mandibular fractures but unsuccessful in pelvic fractures

The basic orthopaedic guidelines set for internal plate fixation state that for adequate fracture fixation, a minimum of four cortices (two screws) and ideally six to eight cortices (three to four screws) must be contacted in the bone segments on each side of the fracture (Brinker *et al*, 1990). However many authors do not adhere to this rule for external fixation. Eaton-Wells in 1990 advocated the use of, and illustrated an external fixator frame for an ilial body fracture. He used only two pins; one pin per fracture segment. Neither of these pins contacted the trans cortex, therefore only one cortex was contacted per bone fragment. It is possible that the high rate of pin loosening was due to the excess stresses placed on the pins if there were too few per fracture. This may also be an important factor in explaining the high rate of implant failure.

Three safe and three hazardous corridors were located in each hemipelvis. If all were utilised, then a maximum of twelve cortices could be engaged. Even if that were not realistic due to the location of the fracture, a stable and rigid fixator frame could be constructed using a careful selection of these. Increased pin holding could be attained by the use of threaded or part threaded pins, selected by using the largest diameter practical. These pins can in some instances be angled to reduce pullout. The anatomy of the pelvis does not allow the use of a single linear connecting bar, as the pins will not lie in a straight line. Either multiple short connecting bars or an acrylic connecting bar could be used. It is also possible to prebend the straight bars prior to application.

CONCLUSION

The pelvis was found to be a stable structure, comprising of paired hemipelves. The fused constituent bones in the mature adult are the ilium, ischium and pubis. In early life there is the addition of an acetabular bone, which helps form the acetabulum. This is incorporated with the ilium, ischium and pubis when they fuse: normally when the animal is approximately three months old. The acetabulum is the area of the pelvis that articulates with the head of the femur, forming the hip joint. The acetabulum is located at the junction of the three pelvic bones. No clear demarcation exists between the bones and the junctions between them can only be described subjectively. A thick layer of muscles covers the pelvis almost completely and only a few pelvic bony landmarks lie in a subcutaneous position, notably the iliac crests and ischiatic tuberosities. At dissection the musculature was present in accordance with standard anatomical textbooks. In order for this stable and well protected structure to be fractured, severe external violence must be applied. This trauma was, in the majority of cases, due to road traffic accidents, and in most of the remaining cases, caused by falling from a height. This trauma was haphazard in its effects, which was reflected in the large number of fracture combinations recorded. Fractures of the pelvis are exceedingly common and constitute 20 to 30% of all fractures seen in veterinary practice.

A review of the topographical canine musculature and cross sectional anatomy was carried out. An attempt was made to provide a correlation with image based registration extended field of view ultrasound. For the cross sectional study, greyhound type canine cadavers were sectioned transversely or radially. Lines, correlating to the lines of section on the cadavers were drawn on a live greyhound. These lines were used as markers for the ultrasound transducer to be scanned along. For the topographic study, extensive dissection was carried out in order to identify the pelvic musculature and to see if it was present in agreement with standard anatomical textbooks. The corresponding individual muscles were scanned on a live greyhound. It was found that although the ultrasonography demonstrated the cross sectional anatomy, it was difficult to identify individual muscles. Whereas, when the individual muscles and muscle groups were scanned a clearer picture was produced. It was hoped that as the normal pelvic anatomy was accurately displayed using this technology then it might have potential as a diagnostic tool for rapid exploration of clinical cases subjected to trauma.

The second part of the cross sectional study was carried out using both canine and feline cadavers, to try and deduce safe, hazardous, and unsafe corridors for external skeletal fixation pin insertion, a concept introduced by Marti in 1993. In each specimen, sections of the pelvis were prepared. One dog and both cats were sectioned perpendicular to the dorsal plane; the other dog was sectioned radially using the greater trochanter of the femur as a focal point, using an electric band saw at specific points. The number of sections made in the dog corresponds with the potential number of pins, which would be used in a uniplanar unilateral external skeletal fixation frame. In the cats, as many sections were taken as possible, as the feline pelvis is relatively unexplored and potential pin insertion sites were an unknown entity. Although this gave a clear indication of the complexity of the pelvic anatomy, it was difficult to deduce the exact external skeletal pin insertion site from these sections. The approach used in Chapter 8 gave clearer results and will be discussed later.

The blood supply to the pelvis was also investigated. This part of the study was divided in to two broad categories: observations of the nutrient foramina and arterial casting. It was found that there was a tremendous amount of variation of the positions and sizes of the pelvic nutrient foramina. Information published by other authors did not correspond entirely to the results found here. In the current study foramina were divided subjectively in to principal (the largest) and secondary, and this was further subdivided into large and small. All results were recorded diagrammatically. Only a few principal foramina were notably present in the majority of specimens. The most constant was that of the ventral ilial body. Apart from these foramina the ilial body is relatively avascular. It was subsequently realised that the standard lateral surgical approach to ilial body fractures could potentially damage the blood vessel as it enters the foramina, and only two authors made reference to it in their surgical approach protocols. As ilial body plating frequently causes iatrogenic damage to the periosteal vessels, this coupled with rupture of possibly the only nutrient vessel to this area of bone, could impair fracture union. Other areas of bone were noted to have principal or large secondary foramina that could potentially be damaged by bone plates, for example the dorsal acetabulum. However this area often has a scattering of small secondary foramina, which could also provide a compensatory blood supply.

Many authors maintain that pelvic fractures heal rapidly due to the abundant blood supply but to date no demonstration of this has been found. Methylmethacrylate casting of the pelvic arteries clearly demonstrated the extensive pelvic vascular tree. In conjunction to the major and well-documented arteries, there were also dense arborisations of small vessels that would have lain between or within the musculature of the pelvis and proximal hindlimb.

A retrospective radiographic study was carried out. The main goal of this study was to elucidate which pelvic fractures were the most common in small animals. There is a lack of information in the literature pertaining to this. It was hoped that the information gained would aid in the future in the design and production of treatment protocols, especially for those locations damaged most recurrently. A classification system was devised for all pelvic fractures. It was primarily based on the anatomical fracture location with a secondary emphasis on fracture type. The pre-existing human pelvic fracture classification systems are highly complex and include factors such as the direction of the injurious force or the presence of instability, or they may categorise the trauma in to distinct fracture patterns. These systems were impractical for use in small animals as more often than not the direction of force is either unknown or multidirectional and frequently there are no distinct fracture patterns. This newly devised classification system placed the fractures in to the following anatomical categories: ilial wing, ilial body, acetabulum (subdivided in to cranial, mid, caudal or comminuted), pubis and ischium. Once placed in an anatomical location they were then divided in to type. Ilial wing and body fractures were subdivided in to transverse, oblique, greenstick, comminuted, chip and longitudinal fractures. Fractures of the acetabulum and ischium were not so easy to classify into actual type as often the direction of the fracture line or lines were irregular. Subsequently it was decided to classify the fractures that were not comminuted, chip or greenstick according to the number of pieces they were broken into i.e. 2 piece and 3 piece. Thus a 2 piece was classified as being where there was one fracture line and the bone was broken clearly in to two parts and a 3 piece as being where there were two clear fracture lines and the bone was broken in to 3 parts. Symphyseal fracture separations were divided into separation of the whole symphysis, cranial symphysis or caudal symphysis. The only anatomical location, which was difficult to sub-classify by fracture type, was that of the pubis. Often the pubis was occluded by superimposition of the caudal vertebrae or by the overlying bowel.

A species difference was apparent in that fractures of specific anatomical locations were present in different frequencies in dogs and cats. As data was sourced from two different veterinary hospitals geographical differences in the relative amounts of specific anatomical fracture locations was also present.

For each animal the number of fracture sites, their distribution (i.e. unilateral or bilateral), and the presence of any concomitant extrapelvic injury was studied. An attempt was made to work out the most common fracture combinations. It was found that dogs and cats varied in both common numbers of fracture sites and their relative distribution. Extrapelvic damage often occurred in both species and included impairment to a wide plethora of hard and soft tissues. A vast number of potential fracture combinations were found which plainly manifests the random and haphazard forces of the trauma. There were no actual common fracture combinations. The combinations that were classed as the "most common" were actually only present in slightly elevated numbers. Once again there was a species difference present.

The pelvic osteology was also imaged using image-based registration extended field of view ultrasound to endeavour to demonstrate the integrity and the continuity of the individual pelvic bones. Three dimensional b-mode ultrasound was used to image the hip joint also. Again it was hoped that as the normal pelvic anatomy was accurately displayed using this technology then it might have potential as a diagnostic tool for rapid exploration of clinical cases subjected to trauma. The pelvic bones were clearly displayed using this technology. The ilium could be viewed from the dorsal, lateral and ventral aspects all with the same degree of clarity. The hip joint was shown with a high degree of success three dimensionally, although the transverse and para-sagittal planes were clearer then the dorsal plane.

The same retrospective cases were used in the next part of the investigation. The treatments used for each animal for each anatomical fracture location were recorded. Each case was evaluated and the fractures for each animal were compared to the standard criteria for surgery. It was subsequently deduced which animals were treated according to these criteria and which were not. The outcome was that many animals which fulfilled one or more surgical criteria were actually treated conservatively. It was found that there was an unacceptably high rate of complication, especially in the feline group. However some of these complications may be seen as acceptable in animals not used for showing, breeding or working. For example, in a companion animal a partial disruption of bony alignment may, except in acetabular fractures, be acceptable to the owner as the animal may be satisfactorily ambulatory. In a show animal, where cosmetic appearance is of greater importance this may not be the case. A bony misalignment may also affect gait which is again is assessed in show dogs. Breeding animals may develop dystocia if the pelvic canal is compromised by even a slightly malunited fracture. Other complications, unacceptable in any animal, included implant failure and implant loosening. These complications were due to the technical faults such as incorrect implant size selected for the size of the animal or incorrect application. It is also possible that those animals treated conservatively, which ideally should have been surgically managed, were subject to the financial limitations of the owner.

In summary: a large number of animals have their pelvic fractures surgically managed and an equally large number are conservatively managed. Veterinary orthopaedic textbooks lay down guidelines and criteria to evaluate the suitability of a particular animal for surgical management, however it was found that many animals conservatively treated, fulfilled one or more of these criteria.

A large number of the surgically treated animals developed post surgical complications. Some of these may be acceptable in certain circumstances, but an unacceptably high number are undesirable in all circumstances. Therefore it is possible that the selection of fixation for a particular fracture location and type should be modified, or that the size of implant, number of screws used or application technique should be revised.

The time delay between fracture and surgery was evaluated. Despite a large number of cases in both the canine and feline group having surgery soon after fracture, there was still a high rate of complication. With a time delay of 1 day, 16.7% of dogs and all cats developed complications. Of animals treated 2 days after surgery this changed to 62.5% of dogs and 50.0% of cats. After 3 days the figure was 60% of dogs and 33.3% of cats; after 4 days, 50% of dogs and 60% of cats all had complications. The percentage rose for time delays of more than 4 days to 100% in some cases. This result is surprising as most surgical guidelines state that surgery is its most successful if performed a maximum of 4 days after fracture. This result may have been due to a number of factors such as the severity of the disruption, lack of experience of the surgeon or incorrect selection of the appropriate method of fixation.

The final part of this study was the investigation of safe and hazardous corridors for the insertion of external skeletal fixation pins in the pelvis. This was attained through extensive dissection and the use of anatomy textbooks and an atlas. Three safe and three hazardous corridors were found in each hemipelvis. External fixation has achieved successful results in all aspects of human orthopaedics. Recently it has gained success and popularity in the treatment of small animal long bone and mandibular fractures. The instrumentation, insertion techniques and frame constructs have been extensively researched in order to achieve optimum frame stability, strength and performance. Although this part of the study is at present theoretical, it seems at this stage that external fixation of the pelvis is a plausible method of fracture fixation.

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9.2. URL REFERENCES

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OTHER PAPERS SUPPORTING THESIS

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PATRICK, F.E., BOYD, J.S., LI, A.

External skeletal fixation of pelvic fractures in dogs.

External skeletal fixation has been used in canine long bone and mandibular fractures for many years. It has however been frequently associated with postoperative problems such as pin loosening or pin tract infections. Current research and development has significantly reduced these problems due to an improvement in pin design, frame constructs and pin insertion techniques. Pelvic fractures are relatively common in dogs and constitute 20 to 30% of all fractures seen in veterinary practice. These fractures were traditionally treated conservatively but now there is an increasing trend towards surgical management. At present the preferred surgical treatment is via internal fixation. This is frequently unsuccessful with undesirable sequelae. The purpose of this anatomical study was to determine whether pelvic fractures could potentially be stabilized using external skeletal fixation. We investigated safe, unsafe and hazardous areas for external fixator pin insertion in orthopaedic surgery. Once these pin insertion corridors were postulated, potential external skeletal frame constructs were designed. In particular we assembled frames for use in the treatment of the most commonly found fracture combinations. We proposed which pin type, mode and angle of insertion and frame construct would provide maximum stability and the potential for dynamization with minimum soft tissue involvement. It is hoped that in future, external fixation will provide a suitable, safe and successful alternative to the more traditional treatment methodologies for pelvic fractures in the dog.

PATRICK, F.E., BOYD, J.S., LI, A.

Patterns of pelvic fracture in the dog and the consequences for treatment.

As a follow on from an earlier study in which we devised a classification system for small animal pelvic fractures, we investigated patterns of fracture in the dog, the incidence of certain fracture combinations and the consequences for the resultant treatment. Our data was obtained from animals referred to the RVC and GUVS over a period of nine years and presented to the PDSA, Glasgow in 1999 and 2000. Pelvic fractures are relatively common in the dog and constitute 20 to 30 % of all fractures seen in veterinary practice. They are frequently multiple and it is not unusual for animals to display lesions in up to six sites. These fractures are usually difficult to treat and are often further complicated by extensive extrapelvic damage. A large number of these cases are treated conservatively with a varying degree of success reported in the literature. There are four commonly documented indications for surgical fixation. If an animal displays one or more of these criteria it is seen as a possible candidate for surgery. Our results showed that the ten most common fracture pattern combinations in the dog satisfied at least one and sometimes up to all four of the surgical criteria. Despite this over 25% of these were successfully treated conservatively. Using our findings we attempted to update the specific criteria for surgery and deduce which specific fracture patterns respond most positively to a particular treatment protocol.

PATRICK, F.E., BOYD, J.S., LI, A..

A classification system for small animal pelvic fractures.

Fractures of the pelvic girdle in small animals are increasingly common and represent 20 - 30% of all traumatically induced fractures. The majority of these are multiple and are accompanied by extensive extrapelvic osseous and soft tissue damage. Despite this, little information is available in the literature regarding specific locations, types and overall severity of pelvic disruptions. As part of a study towards a protocol for the treatment of small animal pelvic fractures, we carried out a retrospective radiographic investigation using data obtained from animals referred to Glasgow University Veterinary School and The Royal Veterinary College over a period of 6 years. We attempted to create a simple but effective classification system based primarily on the anatomical location of each fracture site with a secondary emphasis on fracture type. We identified which areas of the pelvis display the highest incidence of fracture and isolated the most common combinations. Our sample included canine, feline and lagomorphic patients. The data was initially studied while amalgamated to give general small animal results, then separated to illustrate possible interspecies variations. It is hoped that this system of classification will be useful in the evaluation and selection of appropriate treatment for a particular grouping of fractures.

PATRICK, F.E., BOYD, J.S.

The canine pelvis - a morphometric study.

Trauma to the canine pelvis is relatively common often resulting in fracture of the ossa coxae and damage to the surrounding soft tissue and musculature. The majority of these fractures are successfully treated conservatively and it is only when there is comminution or substantial displacement of the bone fragments that surgical intervention is required. Usually the success of fracture union is determined using radiography or ultrasound, which inevitably involves general anaesthesia or clipping of the animal respectively. It is therefore hoped to devise a simple, inexpensive, easy to implement and non-invasive method, which will effectively detect any malunion or loss in anatomic alignment, without requiring deep sedation of the animal. Using easily palpable bony landmarks on the normal pelvis, lumbar spine and pelvic limb, we took a series of linear measurements from the left, the right and the dorsal aspect in 11 dogs. The angles between these linear measurements were calculated using trigonometry, and we were subsequently able to divide the pelvis morphometrically in to three triangles. The pelvic girdle was found to display near symmetry. On fractured pelvises the measurements were taken pre and six weeks post fixation, and any change in the values were noted. In the case of unilateral fractures, this near symmetry will hopefully allow us to use the unfractured side as the control. Although this study is still in its early stages, this method has shown potential. It is hoped that the success or otherwise of a particular methodology of fracture treatment could be determined this way.

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A comparison between the cross sectional and sonographic anatomy of the canine pelvic region.

Trauma to the pelvic girdle of the dog is relatively common often resulting in fracture of the ossa coxae and damage to the surrounding soft tissue and musculature. Traditionally osseous damage is evaluated radiographically but difficulty in investigating any concomitant soft tissue disruption exists. Ultrasonographic exploration of this region has previously proved unsatisfactory as the transducer aperture is small and there is limited continuity of the images. The innovation of extended field ultrasonography now allows for the integrated display of seamless real-time segments into one large composite image. This can cover a field of up to 60cms, thus eliminating the need to subjectively piece together a picture. The purpose of this project is to evaluate the potential use for this type of display in demonstrating the sonographic anatomy of this region in dogs. A series of dogs were scanned using a Siemens Elegra scanner with extended field of view technology and the images acquired digitally. These sonograms were compared to cross sectional anatomical preparations and an atlas constructed. The sonographic anatomy of the pelvis was found to be accurately displayed using the SieScape technology and demonstrated great potential as a diagnostic tool for rapid exploration of clinical cases subjected to trauma.