Heterotopic bone can form at four kinds of sites. First, heterotopic bone may arise in nonskeletal soft tissues of animals. Examples include ossification of the spinal dura of dogs, bony pneumoliths in alveolar walls of the lungs, metaplastic bone in the mammary glands of cows and bitches, metaplastic bone in the walls of urinary bladders affected by chronic cystitis or carcinoma, and bone formed in the capsules of chronically inflamed salivary glands. Second, heterotopic bone may arise in nonosseous musculoskeletal tissues. Examples include ossifying myositis of quarter horses, localized myositis ossificans of dogs and cats, and generalized myositis ossificans of domestic cats and pigs. Third, heterotopic bone is commonly formed in entheses, which are bony sites of insertion of tendons, ligaments, and joint capsules. Examples include animals with chronic degeneration of synovial and amphiarthrodial joints and cats chronically exposed to toxic levels of vitamin A. Fourth, heterotopic bone is formed by paraskeletal tissues, which are tissues with osteogenic potential that lie adjacent to bone surfaces. Bony responses seen in hypertrophic osteodystrophy of dogs and in the organizing stages of subperiosteal hematomas are examples in this group.

Three disorders of animals in which heterotopic bone may be produced in muscle organs are discussed in greater detail in the following sections. They include fibrotic and ossifying myopathy of the horse, localized myositis ossificans of the dog and cat, and generalized myositis ossificans of the domestic cat and pig.

Fibrotic and Ossifying Myopathy of the Horse

Classification

Fibrotic myopathy is a condition caused by postinflammatory fibrosis of the caudal thigh muscles and the intervening intramuscular fascia.[11,12] The term *ossifying myopathy* is used to describe those cases in which metaplastic bone is formed in the fibrous tissue response.[11] Common initiating factors include work related trauma, especially in working quarter horses, external trauma,[11,12] and intramuscular injections.[12] A characteristic lameness develops following the organization of edema, both in muscle tissues and intramuscular fascia, into fibrous tissue, resulting in restrictive adhesions between affected muscle groups.

Incidence, Age, Breed, and Sex

Equine clinics will see one to several cases per year. The only large study of this condition[12] indicated that affected horses ranged from 3 to 15 years of age and involved primarily the quarter horse breed. There is no apparent sex predilection.

Clinical Characteristics

Restrictive adhesions produce a characteristic hindlimb gait abnormality sometimes referred to as *goose-stepping*. There is an abrupt shortening of the cranial phase of the stride, with the distal limb being jerked caudally just before the foot touches the ground. Often, the skin is adhered to the affected muscle group, resulting in a depression in the normal contour of the caudal thigh region. Affected muscle tissue and fascia are firm to hard on palpation. Surgical removal of the affected tissue usually produces some improvement in the gait.[12]

Sites

Caudal thigh muscles affected in this condition are primarily the semitendinosus muscle, less frequently the semimembranosus and biceps femoris muscles,[11,12] and rarely the gracilis muscle.[12,13]

Gross Morphology

The appearance of the affected tissue is related to the duration of the condition. In relatively early lesions there is edema separating fascicles in the muscle and in the adjacent fascia. Gradually, as the edema is organized by fibrous tissue, the connective tissue septa within the muscle organs become thicker, pale, and firm. Muscle fibers are replaced by fibrous tissue. The formerly loose tissue of the fasciae becomes filled with hard, white, dense connective tissue (fig. 4.17 A).

Histological Features

Within chronically affected muscle organs, muscle fibers atrophy and disappear, temporarily leaving behind adipose tissue and linearly oriented perimyseal tissue that formerly separated fascicles of muscle fibers (fig. 4.17 B). Gradually, the septa of perimyseal tissue thicken and obliterate the intervening adipose tissue (fig. 4.17 C). Epimyseum also undergoes a similar fibrotic change and merges with irregular dense fibrous tissue that has formed in the intermuscular fascia (fig. 4.17 D). There may be islands of metaplastic bone.

Growth and Metastasis

The lesion is a type of scar tissue that forms in and around muscle organs following aseptic inflammation resulting from mechanical trauma of work or repeated needle trauma from injections. The lesions may increase in size over a period of months. No progression to neoplasia is expected, although heterotopic bone may develop in the scar tissue as a result of metaplasia.

Localized Myositis Ossificans of the Dog and Cat

Classification

Localized myositis ossificans is a reactive lesion of dogs, cats, and humans occurring in soft tissues usually located adjacent to bones.[1,14-16] Some authors believe that the lesion in humans is initiated by trauma to paraskeletal

tissues, including muscle. The traumatized area contains a hematoma, disrupted fascia, and damaged muscle tissue. This area undergoes a unique pattern of organization and repair having a zonal arrangement in which metaplastic bone tissue forms at the periphery of the lesion. The name of this disorder was poorly chosen since muscle tissue is not always involved, no inflammation may be present, and bone formation is a late event in the development of the lesion.[1,6] The pathologist should be aware of this disorder since a biopsy specimen containing tissue from the center of a forming lesion may be confused with osteosarcoma.

Incidence, Age, Breed, and Sex

This condition is thought to be uncommon based on the paucity of reports in the veterinary medical literature; however, since it is not a life threatening disease and resolves eventually into a firm mass, few animals would be euthanized and submitted for postmortem examination because of the lesion. Localized myositis ossificans has been reported in a 2-year-old female Siamese cat,[14] two male German shepherd dogs 7 and 8 years of age,[15] and a 5-year-old male doberman.[16]

Clinical Characteristics

The affected animals had progressive weakness, muscle atrophy, pain, and loss of range of movement in the joints of the affected limbs. One of the dogs had a history of trauma to the affected leg about 2 months prior to presentation for this disorder.[15] Surgical removal was successful in one case where it was attempted.[16] The cat had firm bilateral nodular swellings in the common tendon of the triceps brachii muscle just proximal to its insertion onto the olecranon process of the ulna. Neither lesion recurred following surgical removal.[14]

Sites

The affected dogs had unilateral lesions involving the gluteal muscles, just caudal to the femoral neck of the right hind leg.[15,16] The cat developed bilateral nodular swellings involving the soft tissues surrounding the common tendon of the triceps brachii muscle proximal to its insertion onto the olecranon process of the ulna.[14]

Gross Morphology

The partially ossified masses removed from the gluteal muscles of the right hind legs of two dogs measured $4.5 \times 3.2 \times 2.9$ cm and $24 \times 6.9 \times 10.8$ cm, respectively.[15] The larger mass had a huge central hematoma. Adjacent muscle tissue was pale and fibrotic.

In the cat, the ossified masses in both forelegs measured about 1.4×2.5 cm and were centered on the soft tissues investing the common tendon of the triceps brachii muscle proximal to its insertion line on the olecranon of the ulna.[14]

Radiographic Features

A para-articular soft tissue radiodensity was located just caudal to the femoral neck of the right femur of each dog.[15,16] Radiographs of a necropsy specimen showed zonation in the mass with maximum radiodensity occurring at the periphery.

Radiographic studies of the cat showed radiodense masses located in the soft tissues proximal to the olecranon processes of both ulnas. Also present was a mild periosteal bony response on the left proximal ulna and a marked periosteal bony reaction on the distal humerus and proximal ulna of the right leg.[14] No cortical destruction of adjacent bones was observed in any of the affected animals.

Histological Features

A zonal pattern was evident histologically in the lesions of the dogs[15,16] and the cat.[14] An organizing hematoma is commonly found in the center of a lesion of localized myositis ossificans. The hematoma is bordered by a highly cellular and rapidly proliferating population of mesenchymal cells. Some cells have bizarre nuclei and may be found in areas where osteoid and cartilage matrix are being produced. Biopsy specimens taken from this area share many histological features with osteosarcoma. The proliferative zone is covered by a more mature fibrovascular response within which the osteoid is more abundant and orderly. In the maturing lesion the mass is covered by a thin bony shell formed by anastomotic trabeculae of woven bone. Peripheral to the shell of metaplastic bone, the soft tissues are fibrotic and may contain atrophic muscle fibers.

Growth and Metastasis

This is a rare and unique reactive lesion occurring in traumatized paraskeletal tissues. The lesion is self-limiting in humans[1] and probably also in animals. Pathologists should be aware of this lesion and distinguish it from parosteal osteosarcoma and extraosseous osteosarcoma.

Generalized Myositis Ossificans of the Pig and Cat

Classification

This is a nonneoplastic disease of the supporting connective tissues of muscle organs, attachments, fasciae, and aponeuroses. It is characterized by an abnormal proliferation of primitive connective tissue elements that undergo metaplastic bone formation and produce secondary degenerative changes in muscle tissue.[17] Examples of this rare disorder of children have been reported in a group of related pigs[18] and in two domestic cats.[19,20]

The etiology of this disorder is unknown. In children there is evidence that the disease may be hereditary,[17] as it appears to be in swine.[18] When the disease in children is recognized in the early fibroproliferative stage before ossification has begun, it is sometimes called progressive myositis fibrosa or hereditary polyfibromatosis.[7]

Incidence, Age, Breed, and Sex

The disease is rare in children and animals. Age of onset varies in children from infancy to adolescence. The affected boar was 9 months of age, and its 34 affected offspring ranged from 2 to 6 months of age at the time of initial onset of signs.[18] The breed of swine was not reported. The diseases occurred in both male and female pigs sired by this boar.

The affected cats were 10 months[19] and 2 years of age[20] at the time the disease was diagnosed.

Clinical Characteristics

The pigs developed rapidly progressive hind-leg paresis and loss of condition. Stiffness and reluctance to move accompanied the appearance and rapid growth of firm swellings in the soft tissues and musculature along the spine, hind legs, neck, shoulders, and tarsal regions.[18] One affected cat had a history of stiffness, pain, and progressive posterior paresis. A firm lump removed at 4 months of age from the musculature over the thoracic vertebrae recurred 3 months later. At this time numerous masses were also recognized in the musculature of all legs and later in the musculature of the ventral abdomen and back. Popliteal lymph nodes were greatly enlarged, and there was a neutrophilia with a left shift.[19] The other cat had a stiff forelimb gait and reduced movement of the shoulder joints due to a firm, bilateral subcutaneous mass extending from the dorsal cranial cervical area to the scapula.[20]

Sites

Location of bony masses varied in different pigs, but major sites affected in decreasing order of frequency were the musculature overlying the caudal, thoracic, and lumbar vertebrae and the neck, shoulder, and tarsal regions.[18] In both cats, the lesions were extensive, involving the musculature of the back, ventral abdomen, shoulders, forelegs, and caudal thighs.[19,20]

Gross Morphology

Lesions described in the pigs and cat are basically similar.[18-20] There is widespread replacement of muscle tissue by masses of cancellous bone and fibrous connective tissue. It is not always possible to distinguish between an extraosseous bony mass and the adjacent bone organ since they appear to fuse at some sites.

Histological Features

In sites of soft tissue involvement, muscle tissue is replaced by fibrous tissue and bone. Fatty tissue and some fibrous tissue fill the marrow spaces. In sites of bone organ involvement, the masses of heterotopic bone are continuous with the bony elements of the skeleton without obvious intervening remnants of the original cortex of periosteum. The boundary can usually be recognized by the abrupt transition from hematopoietic marrow filling marrow spaces of the bone organ to fatty marrow filling the cancellous bone spaces of the heterotopic bone.[18] Union of the heterotopic bone formed in the soft tissues to the adjacent bones apparently is the result of remodeling activities. Along the borders of the developing bony masses, there are cells in the fibrous tissue response that undergo metaplasia to osteoblasts. Soft tissues adjacent to the bony masses are fibrotic and often contain degenerating[19] and atrophic[18,20] muscle fibers.

Growth and Metastasis

This is a progressive, nonneoplastic, and fatal disorder of the interstitial tissue of muscle organs. Late in the course of the human disorder the person becomes virtually immobile due to the union of bony masses in different muscle groups and the formation of periarticular bony bridges that prevent joint motion.[17] Eventually death results from progressive involvement of the musculature of the thoracic cage, leading to respiratory failure or fatal pneumonia. None of the animals in the two reports were permitted to live to the end stage described for humans.

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