J. Anat. (1982), **134**, 3, pp. 563–572
With 4 *figures*
Printed in Great Britain

The primary articular nerves to the dog knee

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(*Accepted* 21 *May* 1981)

INTRODUCTION

'Hilton's Law' states that the same nerve trunks that supply motor branches to muscles crossing a joint likewise provide branches to the skin overlying the insertions of the same muscles, and to the periarticular tissues of the joint proper (Hilton, 1863). The nerves innervating the periarticular tissues – somewhat misleadingly called 'articular nerves' – are composed of both postganglionic autonomic (sympathetic) and sensory axons, the latter of which end peripherally as encapsulated or free sensory receptors (Hromada & Polacek, 1958; Polacek, 1961, 1965, 1966; Freeman & Wyke, 1967; Dee, 1969; O'Connor & Gonzalez, 1979). Traditional thought holds that articular nerves serve as the initial segments of pathways by which the central nervous system is apprised of joint position and movement (Cohen, 1958; Browne, Lee & Ring, 1954; Carli, Farabollini, Fontani & Meucci, 1979). Indeed, a number of studies of articular nerve activity (cat hip joint, Carli *et al.* (1979) and knee joint, Andrew & Dodt (1953) and Andrew (1954)) indicated that slowly adapting, tension-sensitive receptors are present in periarticular tissues, and that specific rates of movement and specific static joint positions are each characterized by specific discharge frequencies of receptors (Boyd & Roberts, 1953; Boyd, 1954; Carli *et al.* 1979; Skoglund, 1956).

However appealing it is from a teleological perspective, the traditional view has recently come under question. Thus, recent work on cat knee receptors suggests that slowly adapting endings are virtually silent at (static) joint positions other than those of the very extremes of motion (Burgess & Clark, 1969; Clark, 1975; Clark & Burgess, 1975; Grigg, 1976). Such a lack of activity at mid-range positions is clearly at odds with earlier work, and just as clearly is inconsistent with the notion that knee joint periarticular receptors are capable of signalling (at least static) joint position (Horch, Clark & Burgess, 1975; Clark & Burgess, 1975). Although the evidence that mechanoreceptors signal joint movement remains strong, it is clear that much is still to be learned about the function of periarticular receptors and articular nerves.

For example, recent – albeit preliminary – evidence suggests that periarticular innervation (*sensu lato*) may function in roles related to the well-being of the joint, in addition to (or as opposed to) playing a role in the perception of position or movement. Thus, sectioning of the posterior and medial articular nerves to dog knee joints may result in macromolecular disruption of articular cartilage that is discernible as early as 9 weeks after surgery and which resembles changes characteristic of the earliest stages of osteoarthritis (Palmoski, O'Connor & Brandt, 1979).

Clearly, the first step towards establishing a level of reproducibility, a mechanism, or the clinical significance (if any) of cartilage alterations produced by articular nerve neurotomy (or any other manipulation of articular nerves) lies in accurately characterizing the major articular nerves to an animal joint that is a proven model for studying joint pathologies. Accordingly, the present investigation was undertaken to establish the origin, course, degree of variability, and approximate destination of each of the major (largest) articular nerves of the dog knee joint.

MATERIALS AND METHODS

Both hind limbs from each of 10 recently killed adult mongrel dogs were removed at the hip joint, and of these a total of 10 right and 8 left limbs proved suitable for study. Dissections were made on the fresh chilled extremities with the aid of a Zeiss surgical microscope, and great care was taken to identify branches of the saphenous, obturator, tibial, and common peroneal nerves that were destined for the knee joint. These branches were traced, using microdissection techniques, to the point where their divisions could not with assurance be distinguished from surrounding connective tissue. In many instances, it was possible to trace branches to their apparent intracapsular destinations.

Tissue samples were removed from what appeared to be the capsular and intracapsular destinations of articular nerve filaments from each of six additional dog knees to verify that such tissues did, in fact, contain lengths of nerve fibres and their terminations. This tissue was stained according to a special modification of the gold chloride technique (O'Connor & McConnaughey, 1978; O'Connor & Gonzalez, 1979).

RESULTS

The terminology used by other investigators to describe the innervation of the cat knee joint (Freeman & Wyke, 1967) will be used in this study for the sake of simplicity and to facilitate comparisons. Thus, Freeman & Wyke described three 'primary' articular nerves serving the cat knee: the posterior articular nerve, the medial articular nerve and the lateral articular nerve.

The medial articular nerve

The medial articular nerve of the dog knee was usually the first branch of the saphenous nerve, and by gross examination was approximately two thirds the diameter of the saphenous nerve. Its course from the saphenous nerve to the knee (stifle) joint was in the connective tissue interval between the anterior aspect of the (fused) adductor magnus and brevis muscle and the posterior surface of vastus medialis. It ran deep to the separation between the cranial and caudal portions of the sartorius muscle (when sartorius consisted of two parts) in company with the descending genicular artery and vein. At about the level of the proximal attachment of the medial collateral ligament the medial articular nerve branched towards its various destinations. With the aid of the surgical microscope it was possible to trace branches into and deep to the medial collateral ligament. Other branches could be traced to the capsular tissue of the anterior, medial, and posterior aspects of the joint, while some of these branches could be further traced to their apparent terminations within the capsule proper, the infrapatellar fat pad, or their apparent destinations in the attachments of the cruciate ligaments or meniscal horns.

The medial articular nerve was invariably present, although its origin was quite variable. Thus, in 11 out of 18 dissections it originated as a single branch of the saphenous nerve, while in 6 out of 18 dissections it was represented as two distinct

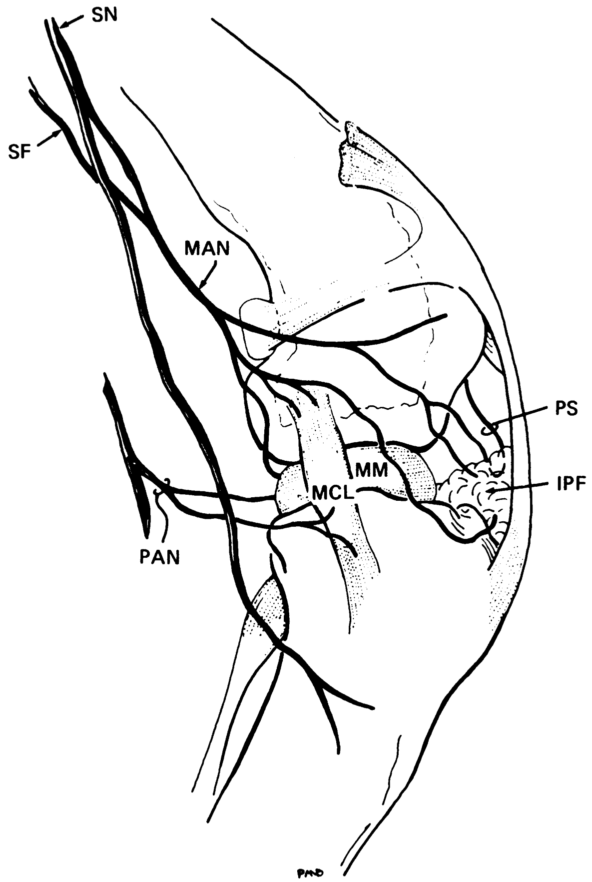

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Fig. 1. Distribution of the medial articular nerve (MAN) and posterior articular nerve (PAN) to the dog knee. The former branches from the saphenous nerve (SN) at about mid-thigh. Occasionally, it will receive supplementary fibres (SF) from the obturator and/or femoral nerves. It supplies the medial, posterior, and anterior aspects of the joint, and may even send branches, by way of the plica synovalis (PS), to the anterior attachment of the posterior cruciate ligament. The posterior articular nerve, when present, supplies mainly the posterior and posteromedial aspects of the joint. MCL, medial collateral ligament; MM, medial meniscus; IPF, infrapatellar fat pad.

branches that remained separated throughout their course. In 1 out of 18 dissections it consisted of three distinct branches (interconnections existed throughout the course of these three branches). In addition, in each of 2 out of 18 dissections, a medial articular nerve originating from the saphenous nerve received contributions from a muscular branch of the femoral nerve, and in each of 2 out of 18 other specimens, a medial articular nerve originating from the saphenous nerve received a contribution from the obturator nerve.

Occasionally, a muscular branch of the femoral nerve (1 out of 18) or obturator nerve (3 out of 18) supplied a nerve branch that travelled with the medial articular nerve, but was separated from it, to about the level of the proximal attachment of the medial collateral ligament. At that point, each of these four accessory medial articular nerves coursed posteriorly and laterally to the posterior aspect of the joint. Some of the larger filaments of each such nerve could be traced through the posterior

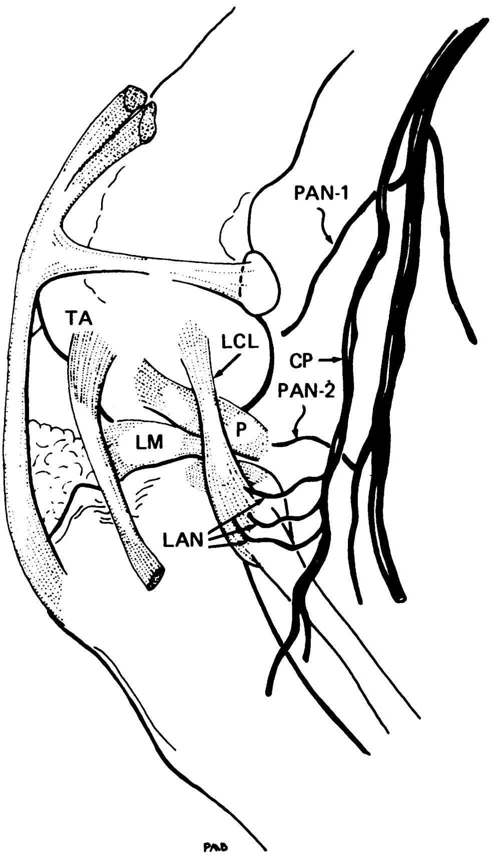

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Fig. 2. Distribution of the lateral articular nerve (LAN) to the dog knee joint. Its branches arise from the common peroneal nerve (CP) at about the point where the latter is related to the head of the fibula, deep to the biceps femoris muscle. It serves the lateral collateral ligament (LCL) and the lateral portion of the joint capsule. In this illustration, the posterior articular nerve arises by two separate branches: PAN-1 arises directly from the tibial nerve, while PAN-2 arises from a muscular branch of the tibial nerve. Other structures are: lateral meniscus (LM); tendon of tibialis anterior (TA); tendon of popliteus (P).

aspect of the capsule into a cruciate ligament or the posterior horn of the lateral meniscus.

The medial articular nerve branched extensively at the level of the proximal attachment of the medial collateral ligament. With the aid of a surgical microscope, branches could be traced into and deep to the medial collateral ligament, the medial, anteromedial, and posteromedial aspects of the joint capsule, through the infrapatellar fat pad to the anterior and posterior cruciate ligaments, and to the posterior horn of the lateral meniscus (= the meniscofemoral ligament).

The medial articular nerve may easily be approached surgically. Thus, the groove-like depression immediately posterior to the firm belly of vastus medialis may be identified by firmly sliding one's finger posteriorly on the medial aspect of the thigh, beginning anteriorly. A 2–3 cm long incision may be made in the middle third of the thigh along the anterior edge of this depression to expose vastus medialis. The surface of the muscle may be followed posterior and deep until the descending geniculate artery and vein are identified, at which depth the medial articular nerve may easily be found. No muscle, large artery, vein or nerve is endangered using this approach.

The posterior articular nerve

Somewhat surprisingly, the posterior articular nerve was absent in 8 out of 18 specimens. In each of the remaining 10 limbs it was smaller than the corresponding medial articular nerve, and as a group the posterior articular nerves varied greatly both with regard to the number of roots from which they were formed and their point of origin.

Thus, in only 4 out of 18 specimens did the posterior articular nerve arise as a single root from the deep surface of the tibial nerve from whence each travelled in company with a small artery and vein to the posterior aspect of the joint capsule. In 2 out of 18 legs it arose as two separate rootlets that merged and ran to the posterior aspect of the joint capsule, and in 4 out of 18 specimens a relatively large branch arose from a muscular branch to popliteus, which then ran to the posterior aspect of the joint capsule (Figs. 1, 2).

The posterior articular nerve(s) may be approached surgically as follows: With the animal lying prone, the depression marking the popliteal fossa is identified, and by palpation is traced cranially and laterally. This extension of the popliteal fossa represents the division between the biceps femoris laterally and the semimembranosus and semitendinosus medially. An incision is made from approximately mid-thigh to the lowermost extent of the popliteal fossa, and the sciatic nerve is exposed cranially by retracting the biceps femoris laterally and the semimembranosus and semitendinosus medially. The bifurcation of the tibial and common peroneal nerves is identified, and the posterior articular nerve is sought as it departs from the deep surface of the tibial nerve. As with the surgical exposure of the medial articular nerve, no major blood vessels or nerves need be disturbed.

The lateral articular nerve

The lateral articular nerve arose as one or several branches from the common peroneal nerve about 2 cm before it wrapped around the neck of the fibula. Thus, in 3 out of 18 dissections it consisted of one branch, in 6 out of 18 dissections as two branches, in 6 out of 18 dissections as three branches, in 2 out of 18 dissections as four branches, and in 1 out of 18 dissections as five branches. Each such branch travelled superiorly to supply the superior tibiofibular joint, the lateral collateral ligament, or the lateral or posterolateral joint capsule. Occasional branches could be traced through the capsular tissue to the periphery of the lateral meniscus (Fig. 2).

The lateral articular nerve may be approached surgically, but only by damaging the most distal fibres of the biceps femoris muscle. Thus, the common peroneal nerve is identified by palpation as it wraps around the neck of the fibula, and an incision is made immediately over the nerve. The fibres of the biceps femoris muscle are then separated to expose the common peroneal nerve, and the articular nerves springing from it.

Histological findings

Examination of gold chloride-stained serial sections of joint capsules, fat pads, ligaments, and meniscal horns suspected of being destinations of articular nerve filaments indicated that each such tissue type was traversed by both individual

Fig. 3. Type II encapsulated nerve ending. Although the axis cylinder is clearly visible, the individual lamellae composing the capsule are apparent only at the 'L' arrows. Gold chloride, oil immersion.

4

Fig. 4. Two unmyelinated axons closely associated with several fat cells. Gold chloride, oil immersion.

axons and bundles of axons. Both myelinated and unmyelinated axons were identified, and the myelinated fibres were in several instances observed to end as encapsulated nerve endings corresponding morphologically to Type I and Type II endings known to populate cat periarticular tissues (Freeman & Wyke, 1967; O'Connor & Gonzalez, 1979). Thus, Type I endings consisted of a dense aborization of neurites, embedded in a matrix of pale staining cells, and surrounded by a thin capsule of 4–6 lamellae. Each such end organ was typically oval in shape, and the parent axon entered through one pole.

The Type II endings were elongated corpuscles consisting of a central axial neurite surrounded by a loosely arranged group of dark-staining cells. Surrounding this was an acellular, amorphous matrix which itself was enclosed by its own capsule of some 5–6 lamellae (Fig. 3). Occasionally, an accessory neurite, surrounded by its own set of loosely arranged, dark-staining cells, was observed to run within the acellular matrix of a Type II ending.

Free nerve endings were also observed in each of these tissues. The parent axons of such endings could be either myelinated or unmyelinated, and those endings associated with myelinated axons tended to be coarser than those derived from unmyelinated axons. Plexuses of unmyelinated fibres were consistently identified on the smooth muscle of arteries and arterioles, while single unmyelinated fibres were occasionally observed to pass immediately adjacent to fat cells (Fig. 4).

DISCUSSION

Gross observations

The present study is in general agreement with the casual observations of Gardner & Jacobs (1948). These workers, in a study that investigated the effects of electrical stimulation on respiration, observed that the medial and posterior articular nerves in each of six dog legs corresponded to similar nerves previously described by Gardner (1944) in cats. The medial articular nerve of the dog was also noted to be larger than the posterior, while, in the cat, the posterior articular nerve is the larger of the two. Our study confirms both the anatomical location of these two nerves in dogs, and the fact that the medial is typically larger than the posterior articular nerve. In addition, our observation that the medial nerve of 3 out of 18 specimens sent a branch to the posterior aspect of the joint is similar to Andrew's (1954) description of the medial articular nerve of the rabbit, which likewise may course to the posterior aspect of the knee joint, there to join the posterior articular nerve.

Our observation that the dog common peroneal nerve sends from one to five branches to the knee joint (which together constitute the lateral articular nerve) extends the observations of Gardner & Jacobs (1948) as does our finding that a separate posterior articular nerve may be lacking in a high percentage of specimens (8 out of 18). This last discovery is surprising and of interest because in the cat, the posterior articular nerve is the most constant, easily identifiable, and largest of the knee joint articular nerves, and much of what is known of the physiological properties of periarticular receptors is based on studies of this nerve (Skoglund, 1956; Burgess & Clark, 1969).

Histological observations

The histological observations demonstrate conclusively that the regions of the periarticular tissues into which articular nerve branches could be traced using microdissection procedures were populated with single axons, bundles of axons, and nerve endings. It seems reasonable to suppose that at least some of these receptors and axons were functionally associated with the dissected nerve branches, although direct physiological verification of this obviously was not obtained.

In this connection, it was of some interest that the point at which a given nerve fibre passed through the joint capsule did not necessarily correlate with the location of the apparent termination of the fibre. For example, some branches of the medial articular nerve that passed through the anterior and inferior aspects of the joint capsule could be traced within the plica synovalis superiorly and posteriorly to the heavily-innervated femoral attachment of the posterior cruciate ligament.

Significance

The present study represents the first formal description of the primary articular nerves to an animal joint that is a proven, popular model for the study of biochemical alterations accompanying certain joint pathologies (e.g. Palmoski, Colyer & Brandt, 1980*a*, *b*; Palmoski, Perricone & Brandt, 1979; Palmoski & Brandt, 1980). The consequence of cutting, stimulating, or otherwise manipulating articular nerves on articular cartilage, synovial tissue and fluid, ligaments, menisci, and fat pads may now be investigated against a large background of literature.

SUMMARY

This paper describes the course, size, surgical anatomical relationships, and general destinations of the medial, posterior and lateral articular nerves to the dog knee joint. Of these three 'primary' articular nerves, the medial was found to be the most constant, the largest, and the most easily accessible from a surgical point of view. It was always composed of at least one large branch from the saphenous nerve, and was observed on several occasions to receive fibre contributions from other branches of the femoral nerve as well as from the obturator nerve. It was easily accessible at about mid-thigh, at which point it lay in the connective tissue interval between the adductor muscle mass and the vastus medialis, immediately adjacent to the descending genicular artery and vein. It was distributed not only to medially located periarticular tissues, but also to the posterior and anterior aspects of the joint capsule, and to intra-articular structures.

The posterior articular nerve was remarkable in that it was frequently absent as a discrete branch from the tibial nerve. When present, it was of much smaller calibre than the medial articular nerve. It frequently arose as a number of tiny filaments from the tibial nerve, and appeared to be distributed mainly to the posterior aspect of the joint capsule.

The lateral articular nerve was invariably present, although it frequently arose from the common peroneal nerve as several small branches. It lay under cover of the biceps femoris muscle, and appeared to serve not only the lateral collateral ligament, but also the superior tibiofibular joint.

This study represents the first formal description of the articular nerves supplying an animal joint which is an established model for joint pathologies.

The authors would like to express their deep gratitude to Rosemarie Funkhouser for technical assistance, to Philip Blomgren for the excellent illustrations, and to Deborah Komlanc for typing the drafts of this manuscript. The work was supported by a grant from the National Institutes of Health (AM 26951).

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