ACTA ORTHOPAEDICA SCANDINAVICA
SUPPLEMENTUM NO. 179

From the Department of Orthopaedic Surgery (Head: Prof. Tor Hierton),
University Hospital, Uppsala, Sweden.

Popliteal cysts and their relation to the gastrocnemio-semimembranosus bursa

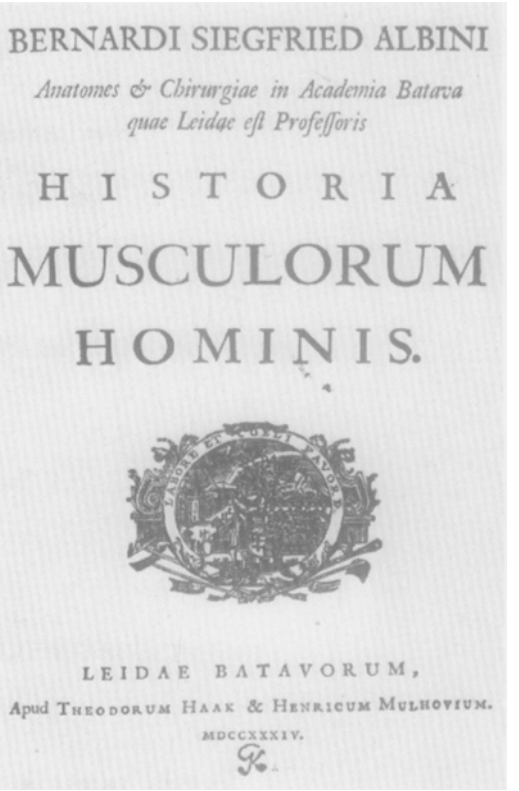
Studies on the surgical and functional anatomy

BY

WOLFGANG RAUSCHNING

MUNKSGAARD. COPENHAGEN 1979

ISBN 87-16-08563-9
ISSN 0300-8827
Upplands Grafiska AB, Uppsala, Sweden 1979



BERNARDI SIEGFRIED ALBINI

Anatomes & Chirurgiae in Academia Batava quae Leidae eſt Profeſſoris

HISTORIA

MUSCULORUM

HOMINIS.

LEIDAE BATAVORUM,

Apud THEODORUM HAAK & HENRICUM MULHOVIUM.

MDCCXXXIV.

De semimembranoso —

. . . Qua denique eadem illa cauda pone caput superius tibiae incedit, ibi inter eam & capsam genu bursa parva.

De gemello —

. . . Capiti ejus interiori subjacet bursa magna, accreta firmiter tendineae parti illius capitis, extremoque Semitendinosi, & capsae genu juxta condylum interiorem.

ALBINUS, 1734 (see page 12)

To Helga and Carl Carlson

CONTENTS

DEFINITION

The author defines a popliteal cyst as a communicating gastrocnemio-semimembranosus bursa which is constantly or temporarily distended by synovial fluid, and *not* as a cyst originating from the tendon sheath of the popliteus muscle.

ABBREVIATIONS

g-s bursa = gastrocnemio-semimembranosus bursa
I.A.N.C. = International Anatomical Nomenclature Committee, third edition, 1966
B.N.A. = Basle Nomina Anatomica, 1895
J.N.A. = Jena Nomina Anatomica, 1935
P.N.A. = Paris Nomina Anatomica, i.e. the first edition of the Nomina Anatomica I.A.N.C., 1955.

KEY WORDS

Popliteal cyst
Baker's cyst
popliteal bursa
surgical anatomy
functional anatomy

INTRODUCTION

EARLY CLINICAL OBSERVATIONS CONCERNING POPLITEAL CYSTS

The first mention of a cystic swelling in the popliteal region was made by *Dupuytren*, who in 1829 reported on a patient with an enormous hydrops in the knee joint. In 1840 *Adams* described in detail a chronic inflammatory knee disease which he was the first to designate "chronic rheumatoid arthritis". He believed that the first link in the morbid chain was the disease of the synovial membrane, contradicting Cruveilhier, among others, who considered that the disease started in the cartilage ("usure des cartilages"). He also stated that the affection was very chronic and impossible to cure although it was sometimes benefited by rest. In a comprehensive review concerning abnormal conditions of the knee joint (1839—1847), Adams reported that in the majority of such cases he had palpated a cystic tumour in the medial part of the popliteal region, in fact so often that he considered this to be a reliable symptom of the rheumatic joint affection. On inspection it took the shape of a very well defined ovoid projection adjacent to the inner hamstring muscles, which was felt to be very tense in the extended position. He stated: "If we feel this bursa and then cause the patient's limb to be flexed, we can follow the fluid with our fingers into the articulation". Through his own dissections he established that this cyst mainly consisted of an enlargement and "dropsical condition" of the bursa which naturally exists at the decussation of the semimembranosus tendon with the tendon of the internal head of the gastrocnemius. Adams found that in some cases this enlarged bursa communicated with the joint by "a species of valvular opening". In other cases small round apertures into the joint were observed.

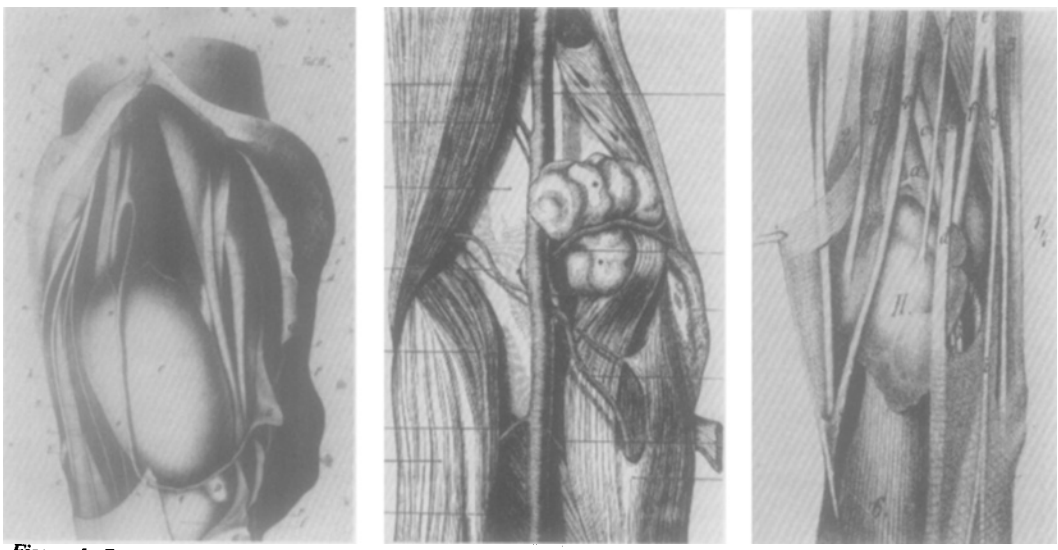


Figure 1. Post-mortem dissection studies of popliteal cysts performed by W. Gruber.
Left: *Specimen from a young man who died of septicaemia following puncture of a popliteal cyst (1846)*
Middle: *Hernial outpouching in an autopsy preparation (1865)*
Right: *"Large bursal hygroma" detected by chance at post-mortem examination (1885).*

In a large number of knee dissection studies *Gruber* examined the posterior synovial recesses, protrusions and communicating bursae (1845, 1846, 1857, 1865, 1869, 1885). He formulated the concept of synovial herniation which was subsequently adopted by many authors. Gruber published several papers concerning "hygromas of enormous size" which he had observed by chance at routine post-mortem examinations (Figure 1). Regarding the clinical implications he concluded that in below-knee amputations the risk of an ascending knee joint arthritis via a communicating hernia had to be taken into account and suggested aspiration of the knee effusion through the bursa to minimise this hazard. This was done by Pitha (1846) in a young man, but a fulminant arthritis rapidly developed and the patient died of septicaemia. Gruber also dissected several amputation specimens and reported a popliteal fistula arising from a bursal perforation in a case of gonococcal arthritis and a large fistular system extending down to the tendon of Achilles in another case.

In contrast to Gruber, *Foucher* (1856) found in post-mortem studies that all cysts arose from a bursa and none from synovial herniation (". . . et ne comme un diverticulum, un hernie de la synoviale articulaire"). Foucher also referred to clinical reports on his own patients and those of contemporary physicians and noted that popliteal cysts could be emptied into the joint cavity by manual compression if the joint was in the flexed position, whereas this was never possible with the knee extended. This phenomenon has since been confirmed by other authors and has been referred to as the "sign of Foucher" (Heineke 1868, Goldscheider 1898).

Several doctoral theses have been devoted to the clinical aspects, pathogenesis and therapy of popliteal cysts, especially in the early French literature (Nélaton 1851, Longy 1852, Burguet 1854, Ollivier 1855, Baudouin 1855, Garnier 1890, Hémet 1900, Ciolina 1904).

In his two classic papers of 1877 and 1885, *Baker* reviewed two patients of his own and eight patients treated by contemporary physicians who had cystic tumours in the popliteal region. He drew attention to the formation of synovial cysts in the leg in connection with disease of the knee joint and to the fact that most often the knee disease had begun some time before the appearance of the (secondary) cyst. Commonly the joints were affected by what Baker called osteoarthritis. He was not particularly specific about the pathogenesis of the cysts. He considered that their formation was due to the fact that synovial fluid makes its way out of the knee, and for most cases he held the hernial concept of Gruber, Billroth and others, whereas for some he conceded that rupture of a communicating bursa or of a synovial hernia had allowed the cyst to form. Five of Baker's patients eventually underwent amputation through the thigh.

Power (1885, 1887), on examination of these amputation specimens, found severe destruction due to articular tuberculosis. He exhibited some specimens at the Pathological Society of London and outlined the extension of the cysts and their communication with the joint cavity (Figure 2). In our day Maudsley and Arden (1961) have reviewed the clinical findings in Baker's patients and come to the conclusion that most of them suffered from tuberculosis of the joint and two from rheumatoid arthritis. A histopathological re-examination of Baker's knee specimens which have been preserved at St. Bartholomew's Hospital Museum was undertaken by Gask and Wilson, who found that they displayed signs of typical synovial tuberculosis.

During the "days of laudable pus" conservative treatment with counter-irritation, compression and vesication with collodion and pressure and the application of a plaster-of-Paris bandage was common practice (Kirmisson 1892). More invasive methods of treatment did occur, however, such as puncture and tapping, the injection of Morton's fluid, caustics or iodine and still more aggressive procedures with the aim of producing

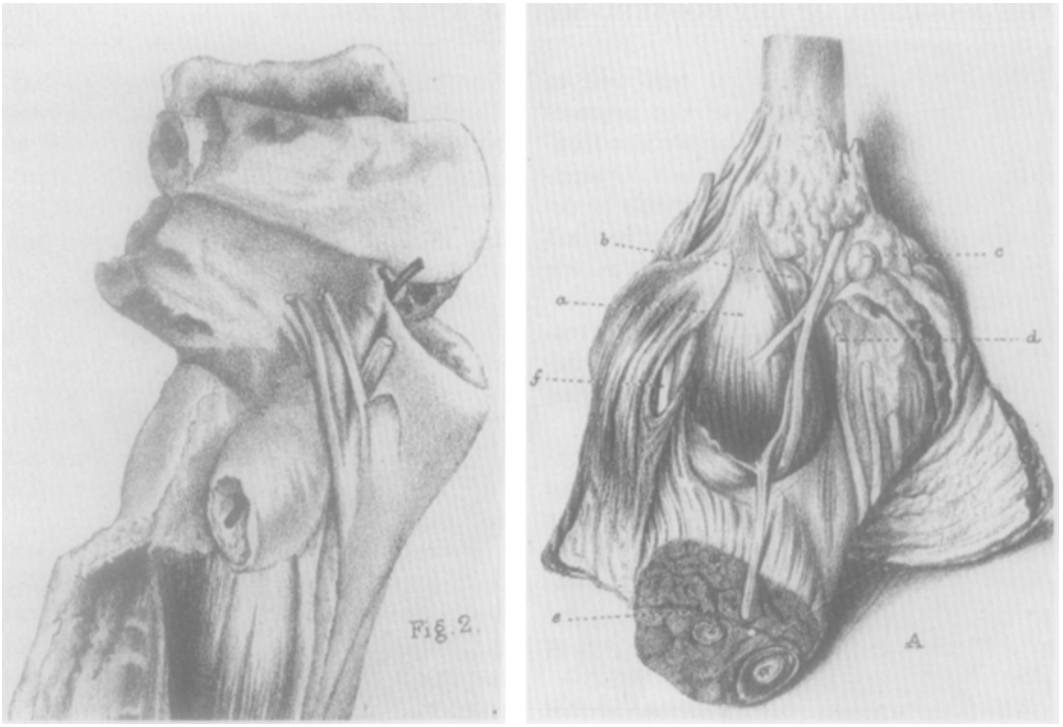


Figure 2. "Intermuscular synovial cysts" in knee joints amputated because of tuberculous arthritis and dissected by Powers (1885, 1887).

purulent inflammation, such as subcutaneous discission, opening and stuffing or packing, or the insertion of setons. Numerous fatal complications were reported as a result of such treatment (Gruber 1846, Heineke 1868, Baker 1877, Gribbon 1885). Surgical removal seems to have been performed for the first time by Malgaigne, in the early 1850's—one of his two patients died of septicaemia. Only few excisions are reported from the antiseptic era, as disastrous complications were common. Since the introduction of asepsis several reports of uncomplicated surgical interventions in popliteal cysts have been made (Bond 1890, Hutton 1895, Sheild 1898, Hawkes 1899).

THE ANATOMY OF THE POSTERO-MEDIAL KNEE BURSAE

Albinus (1734) was the first anatomist to make mention of bursae at the postero-medial aspect of the knee joint (see also frontispiece). The one situated between the semimembranosus tendon and the capsule he denominated "bursa parva", and that beneath the medial head of the gastrocnemius muscle he called the "bursa magna". The latter bursa he found to be firmly adherent to the tendinous part of the gastrocnemius and semitendinosus muscles and the capsule overlying the medial femoral condyle.

Monro (1788) (Alexander Monro secundus) published a beautifully illustrated monograph of all the bursae mucosae of the human body. One postero-medial bursa he called the "bursa vesicularis postica ad latus genus". This opus was considerably enlarged by *Rosenmüller* for the German edition of 1799.

The pathologist *Gruber* performed several series of meticulous dissection studies on at least 700 knees (1845, 1846, 1856, 1857, 1865, 1869, 1885). He gave a correct description of the gastrocnemio-semimembranosus (g-s) bursa although he did not name it, and stated that it communicated with the joint in about 50% and more commonly in robust persons and especially in men. He filled the communicating bursa by insufflating air into the joint through a patellar drill hole. In a large number of dissections in children he never found a communication, even though the bursa was constantly observed not only in newborn infants but also in foetuses. In monkeys, on the other hand, he never saw this bursa. He also described a separate, hitherto unknown bursa beneath the uppermost part of the gastrocnemius located above the femoral condyle, which he named the "bursa supracondyloidea (interna)". In his classic monograph "Die Knieschleimbeutel (bursae mucosae genuales)" he gave a detailed description of this bursa, which did not communicate with the joint.

Gruber considered that most of the communicating cavities were formed by synovial outpouching (Ausstülpung), whereas only one-third were communicating bursae. He also described and illustrated greatly varying and bizarre synovial protrusions through gaps in the gastrocnemius tendon and also the constriction of the neck which these protuberances sustained from such gaps. Two of these illustrations are reproduced in Figure 3. Regarding the aforementioned giant cysts, he claimed that some did not communicate with the joint cavity and thus constituted bursal hygromas. Gruber's concept of synovial protrusion has since been widely adopted in both the clinical and anatomical literature.

Heineke (1868) wrote a monograph concerning knee bursae and *Synnestvedt* (1869) presented a doctoral thesis on bursae mucosae, for which he received an award, based on a limited number of his own dissections and a survey of the contemporary literature. Synnestvedt carefully differentiates between the "bursa semimembranoso-gastrocnemialis" and "bursa musculi gastronemii interni" and is the last author to mention the bursa supracondyloidea (interna) described by Gruber.

Poirier (1886) defended the concept of two separate bursae around the medial belly of the gastrocnemius even though they often coalesce. He recognised that only this bursa could transform into a clinically manifest popliteal cyst and therefore designated it "bourse des kystes poplités". By injecting warm coloured suet he obtained casts of these bursae. At their upper pole he discovered small processes ("procès synoviaux sous-condyliens"). He also pointed out the intimate connection between the bursal wall and the tendons and questioned whether even the most skilful surgeon could enucleate a popliteal cyst in its entirety.

The anatomist *Henle* (1872) gave the most detailed description of the communication to be found in the literature. He stated, however, that the opening was very wide when the knee was extended and that on flexion of

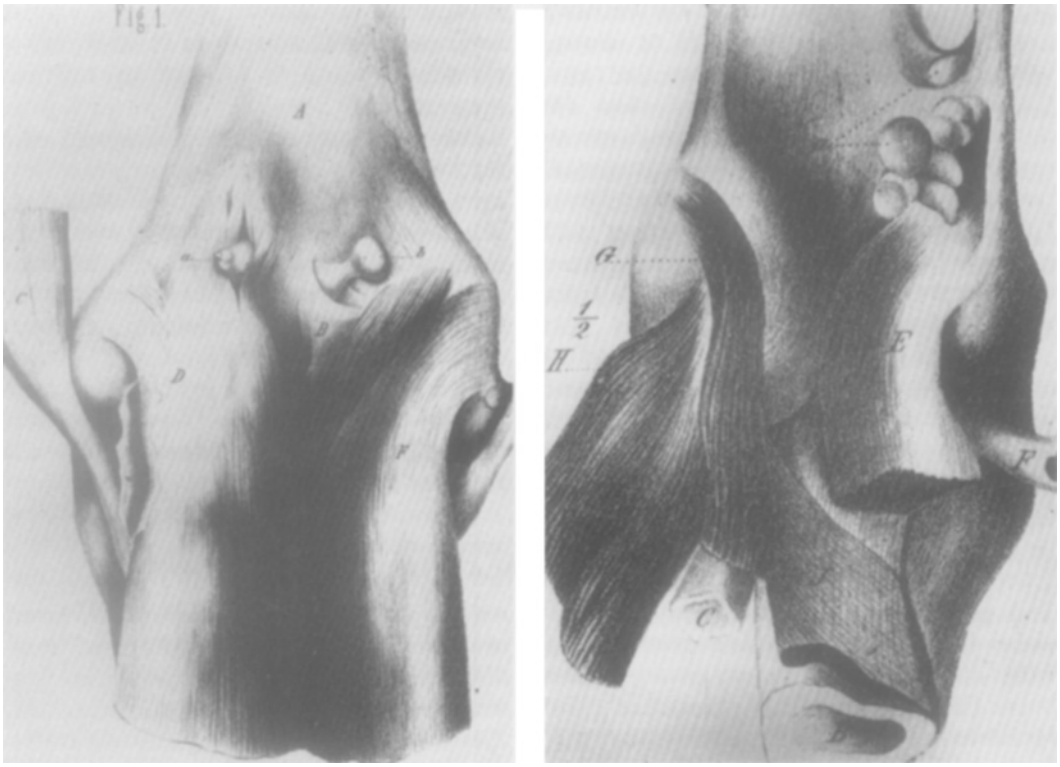


Figure 3. Illustrations from Gruber's classical monograph "Die Knieschleimbeutel (bursae mucosae synoviales)" from 1857, showing synovial outpouchings through the tendon of the gastrocnemius muscle.

the knee there was only a narrow slit. Several authors, including Brösicke (1899), Bardeleben-Haeckel (1901), Fick (1904), Merkel (1907), Sonntag (1916—17) and Lewin (1952), have since agreed with this view.

Most anatomists have reported an approximately 50% frequency of communication between the g-s bursa and the joint, but few have given consistent details, e.g. age, sex and state of the joint of the subjects from whom the specimens were obtained.

In the present century few basic investigations concerning the anatomy of popliteal bursae have been performed.

Wilson et al. (1938), emphasizing the bursal origin of the popliteal cysts, undertook a dissection study of the postero-medial knee region in 30 adult cadavers and distinguished six primary bursae which it seemed could coalesce with one another or be subdivided. Like many earlier anatomists they differentiated between the bursa lying beneath the medial gastrocnemius tendon and that between the gastrocnemius and semimembranosus tendons, which in 26 cases had fused to form one composite bursa. These investigators were also the first to point out that the communication is situated beneath the origin of the inner head of the gastrocnemius and that the bursa has no neck or stalk leading into the joint, as this innermost portion consists only of a synovial lining of the capsule. Although this study has been widely quoted by contemporary surgeons (Burleson et al. 1956, Childress 1970, Justis 1971), the idea of a narrow neck still predominates. Wilson and co-workers also prepared casts of the bursa by injecting paraffin mixed with radiopaque lipoidol, which enabled them to locate the bursa at post-mortem radiography and to study the casts for the impressions which the bursa had sustained from the capsular opening and from the surrounding tendons.

Lindgren (1977) examined the radiogra-

phic morphology of the communicating gastrocnemio-semimembranosus bursa, using plaster-of-Paris to prepare the casts. Corresponding radiographs and casts obtained during knee flexion and extension allowed an investigation of the functional radiographic anatomy of the bursa. *Moser* (1950) undertook dissection studies and concluded that the communication between the joint cavity and bursa can result from violent hyperextension.

Recently Lindgren & Willén (1977) performed post-mortem arthrography, dissections, light microscopic and scanning electron microscopic investigations of postero-medial knee capsule specimens from subjects of different age groups. They demonstrated that the opening between the joint and the bursa constantly had the shape of a cranially oriented transverse slit in the joint capsule and that the gastrocnemio-semimembranosus bursa more frequently communicated with the joint cavity with increasing age. In older age groups they found degenerative changes in the capsular wall and also in the broad layer of fibroelastic tissue which in most young persons separates the joint from the bursa. No essential morphological differences were noted between the synovial lining of the bursa and that of the joint, but the degenerative changes in the bursa were more pronounced when it was in communication with the joint.

RECENT INVESTIGATIONS ON POPLITEAL CYSTS (20th CENTURY)

Though the current opinion today tends towards the view that popliteal cysts develop from distension of a communicating knee bursa (Wilson et al. 1938, Morscher 1957, Hoffman 1963, Gristina & Wilson 1964, Bryan et al. 1967, Perri et al. 1968, Goldstein & Dickerson 1974, Smillie 1974), the concept of a hernial origin still widely prevails (Cravener 1932, Haggart 1938 and 1943, Edmunds & Hebble 1939, Meyerding & van Demark 1943, Kuhn & Hemphill 1944, Sachs & Rubinstein 1946, Wiles 1949, Lewin 1952, Kirpilä & Ripatti 1958, Beatty 1959, Colombo 1965, Wieser et al. 1967, Solomon & Berman 1972, Pinder 1973, Aegerter & Kirkpatrick 1975).

Other clinicians consider both modes of cyst formation possible (Burleson et al. 1956, Ackerman 1959, Hoffman 1963, Justis 1971). The following is a list of some clinical synonyms of popliteal cysts, which also provide an indication of the assumption concerning their mode of development:

Baker's cyst, Popliteal hernia, Posterior herniation of the knee joint, Kyste synovial herniaire, Popliteal ganglion, Arthrozele, Popliteal synovial herniation, Gastrocnemio-semimembranosus bursa, Medial gastrocnemius bursitis, Semimembranosus bursa, Semimembranosus bursitis, Bursitis semimembranacea, Semimembranaceuszysten, Popliteal bursitis, Intrapopliteal bursitis, Zystische Bursitis, Synoviazyste, Popliteazyste, Poplitealzyste, Popliteogene Unterschenkelzyste, Bursal cysts, Hygroma, Zystisches bursales Hygrom, Synoviales Kystom, Cystic bursal hygromas, Intermuscular synovial cysts.

Lately comprehensive *arthrographic studies* of the posterior recesses of the knee and of the communicating popliteal cavities have been performed with the use of positive contrast medium, and strong evidence in favour of the development of popliteal cysts from the communicating postero-medial bursa has been produced, (Ficat 1957, Kessler & Silberman 1960, Doppman 1965, Fischedick 1969, Lapayowker et al. 1970, Fischedick 1971, Pallardy et al. 1971, Reinhardt 1972, Solomon & Berman 1972, Wolfe & Coloff 1972, Pulich 1975, Étienne et al. 1976, Lindgren 1977, Matthias 1977, Lindgren 1978). Many investigators point out the discrepancy between the radiographically high incidence of communicating bursae—which should not be called Baker's cysts as they are artificially distended (Rauschning & Lindgren 1979) —and the relative infrequency of clinically palpable popliteal cysts. Arthrography has also proven of value for the diagnosis of intrinsic disorders of the knee, which are frequently found in

association with popliteal cysts. Not least, it is interesting to note that a diligent survey of these papers and the illustrations given in them does not reveal any true hernial protrusion. On the contrary, all cases can be identified as originating from the communicating gastrocnemio-semimembranosus bursa with the site of communication high up beneath the gastrocnemius tendon (Lindgren 1979), which is in agreement with the findings in a recent prospective arthrographic investigation of 41 popliteal cysts (Lindgren & Rauschning 1979). Regardless of whether popliteal cysts are considered to be synovial protrusions or distended bursae, most surgeons state that the cyst has an attachment to the postero-medial aspect of the knee joint capsule. Occasional cases of communication with the joint in the central portion of the popliteal space and even communications situated beneath the posterior oblique ligament have been reported, however (Haggart 1938).

Descriptions of the surgical anatomy are unspecific about the location and shape of the communication with the joint, as well as about the topographic relationship to adjacent anatomical structures, and opinions are greatly divided concerning the optimum surgical approach for exposure of the opening (Holmes 1870, Billroth 1876, Fullerton 1916, Davis 1918, Piersol 1919, Clark 1949, Wiles 1949, Anson & Maddock 1952, Lewin 1952, Apley 1968, Aegerter & Kirkpatrick 1975).

Reports have varied considerably concerning the *frequency of communication* as observed at operation. In adults a frequency of more than 50% and up to 100% has been reported by surgeons who have published large materials (Hoffman 1963: 58%, Gristina & Wilson 1964: 66%, Bryan 1967: 74% when a pathological condition of the joint was present, 30% when it was absent, Wilson et al. 1938: 98%, Meyerding & van Demark 1943: 100%, Burleson et al. 1956: 65%, Childress 1970: 73%, Vahvanen 1973: 86%). Infantile popliteal cysts are commonly claimed to lack a communication with the joint (Morscher 1957, Malloch 1970, Borellini et al. 1971). However, Touloukian (1971) and Gristina & Wilson (1964) each found 11 communicating cysts at 20 and 23 operations, respectively.

In the opinion of some surgeons *closure of the communication* is unnecessary or not possible owing to the size of the opening (Moser 1950, Burleson et al. 1956, Crasselt 1966, Justis 1971, Smillie 1974, Hort 1975). Most authors, however, apart from a radical excision of the cyst, advocate closure of the communication (Bond 1890, Kirmisson 1892, Hawkes 1899, Hémet 1900, Wilson et al. 1938, Edmunds & Hebble 1939, Meyerding & van Demark 1943, Haggart 1943, Kuhn & Hemphill 1944, Sachs & Rubinstein 1946, Orr 1951, Saegesser 1956, Kirpilä & Ripatti 1958, Beatty 1959, Harvey & Corcos 1960, Colombo 1965, Bryan et al. 1967, Borellini et al. 1971, Justis 1971, Solomon & Berman 1972, Goldstein & Dickerson 1974). Plastic aponeurotic procedures using free tendon grafts to close the opening in the capsule have been performed by Haggart (1938) and Childress (1954, 1970).

In some larger reviews the results of *histopathological examination* of excised popliteal cysts have been reported (Hammer 1920, Haggart 1938, Wilson et al. 1938, Buck et al. 1943, Kuhn & Hemphill 1944, Burleson et al. 1956, Kirpilä & Ripatti 1958, Harvey & Corcos 1960, Hoffman 1963, Myles 1971, Reinhardt 1972), but no consistent histological features have been described upon which a clinically relevant classification could be based or conclusions drawn regarding their pathogenesis.

In the literature numerous accounts bear witness to the propensity of popliteal cysts to recur following surgical excision (Lewin 1952, Burleson et al. 1956, Beatty 1959, Harvey & Corcos 1960, Hoffman 1963, Bryan et al. 1967, Hooper & Brookler 1971, Myles 1971, Pinder 1973, Vahvanen 1973, Meire et al. 1974), particularly after their removal in children (Malloch 1970, Dinham 1975). In a recent clinical and arthrographic follow-up study Rauschning & Lindgren (1979) found 40 recurrences and 15 postoperative complications following 41 routine operations on such cysts.

AIMS OF THE PRESENT INVESTIGATION

Concerning the surgical anatomy of popliteal cysts the reader both of papers dealing with this subject and of recognised textbooks of anatomy and orthopaedic surgery meets with information that is inconsistent in several respects. The aim of the present investigation was therefore to study

1. the origin of popliteal cysts, in order to establish whether they are capsular herniations or fluid-distended bursae,
2. the optimum surgical approach to the cyst, particularly its communication with the joint,
3. the topographic anatomy of the deep portion of the cyst, commonly referred to as its neck, pedicle or stalk,
4. the possibility and necessity of isolating the whole cyst,
5. the possibility and necessity of radical removal of all cyst tissue,
6. the detailed anatomy of the communication with respect to its location, shape and width,
7. the frequency of communication of popliteal cysts as observed during operation,
8. the presence of any weak portions in the postero-medial knee joint capsule,
9. the implications of the joint movement, of tendon pull and of possible capsular tearing forces for the surgical technique,
10. the anatomical prerequisites for achieving a firm and durable closure of the communication.

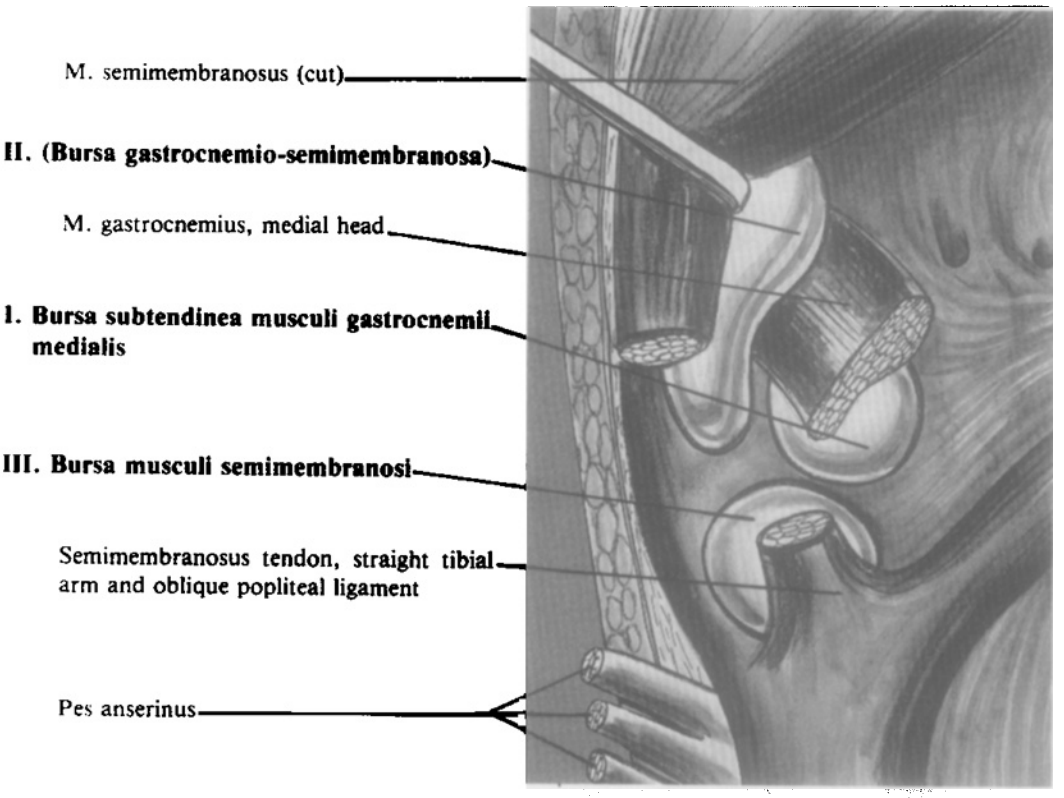


Figure 4. The location of the three knee bursae under study ***and their current denomination according to the International*** *Anatomical Nomenclature Committee (1966).*

ANATOMICAL NOMENCLATURE AND SELECTED SYNONYMS

I. Bursa subtendinea musculi gastrocnemii medialis (I.A.N.C.)

= Bursa musculi gastrocnemii medialis (B.N.A.)
= Bursa capitis tibialis musculi gastrocnemii (J.N.A.)
= Bursa subtendinea musculi gastrocnemii medialis (P.N.A.)

= Bursa mucosa supracondyloidea (interna) (GRUBER, 1857)
= Bursa mucosa capitis interni gastrocnemii (HEINEKE, 1868)
= Bourse séreuse rétro-condylienne superieure ou du jumeau interne (POIRIER, 1886)
= Bourse séreuse de muscle jumeau interne (TILLAUX, 1892)
= Bursa gastrocnemia medialis (FICK, 1904)
= Bourse du jumeau interne (TESTUT, 1909)

II. (Bursa gastrocnemio-semimembranosa, not designated in **I.A.N.C.)**

= Bursa gastrocnemio-semimembranosa (B.N.A.)
= Bursa gastrocnemio-semimembranacea (J.N.A.)
= Bursa gastrocnemiosemimembranosa (P.N.A.)

= Bursa mucosa retro-condyloidea interna sive semimembranoso-gastrocnemialis (GRUBER, 1857)
= Bursa mucosa semimembranoso-gastrocnemialis (SYNNESTVEDT, 1869)
= Bursa synovialis semimembranosa (HENLE, 1871)
= Bourse rétro-condylienne inferieure ou bourse commune au jumeau interne et au demimembraneux (POIRIER, 1886)
= Bourse des kystes poplités (POIRIER, 1886)
= Bursa gastrocnemio-semimembranosa retrocondylica medialis (FICK, 1904)

III. Bursa musculi semimembranosi (I.A.N.C.)

= Bursa musculi semimembranosi (B.N.A.)
= Bursa musculi semimembranacei (J.N.A.)
= Bursa musculi semimembranosi (P.N.A.)

= Bursa parva (ALBINUS, 1734)
= Bursa mucosa infra-condyloidea interna sive semimembranosa (GRUBER, 1857)
= Bourse séreuse sous-condylienne (POIRIER, 1886)
= Bourse séreuse du tendon direct du muscle demimembraneux (TILLAUX, 1892)
= Bursa semimembranosa (FICK, 1904)
= Bursa semimembranosa propria sive tibio-semimembranosa (MERKEL, 1907)
= Bourse propre du démi-membraneux (TESTUT, 1909)

The bursa around the medial head of the gastrocnemius (II) has also been referred to as the "bursa magna" (ALBINUS, 1734), "bursa vesicularis postica ad latus genu" (MONRO, 1788) and "bursa genualis posterior" (ROSENMÜLLER, 1799). These investigators did not mention the bursa beneath the medial head of the gastrocnemius muscle (I).

ANATOMICAL DISSECTION STUDY

Conventional knife dissections were conducted on human cadavers to clarify the detailed anatomy of the g-s bursa and the location of its communication with the joint. During these dissections observations were also made concerning capsular tearing forces that might be transmitted to the capsular opening. The surgical approach was studied with particular reference to the access to the communication and to the avoidance of damage to cutaneous nerves.

MATERIAL

The material was obtained from autopsies at the Department of Pathology, University of Uppsala, in the years 1977 and 1978. The knees of 200 cadavers were examined by palpation, and in no case was a cystic swelling palpable in the popliteal space. Among these 200 cases, 54 were chosen for whom a study of the medical records and physical examination revealed no history or signs of rheumatoid arthritis affecting the knee, effusion into the knee joint, or previous knee operations. Cardiovascular disorders were the most common cause of death. The material thus consisted of 108 non-diseased joints. Eight subjects were 40—50 years of age at the time of death, and 46 were 51 years of age or older. Thirty-five knees were from men and 19 from women.

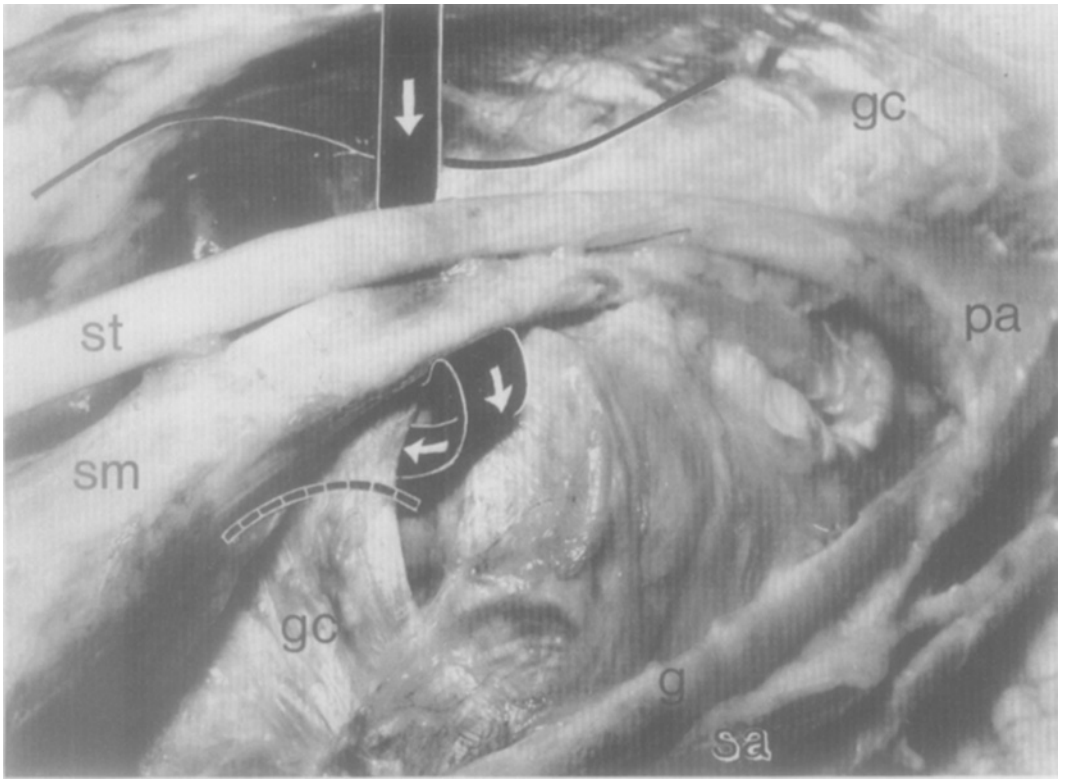


Figure 5. Oblique medial view of a right knee in an autopsy case in the prone position. Thigh to the left, lower leg to the right. After resection of the bursa a plastic band was inserted from the site of the commonly used incision centred over the swelling to demonstrate the conventional path of surgical approach to the communication. The decussation of the tendons obstructs the access to the opening in the capsule beneath the gastrocnemius (gs) (interrupted line). sm = semimembranosus, st = semitendinosus, g = gracilis, sa = sartorius, pa = pes anserinus.

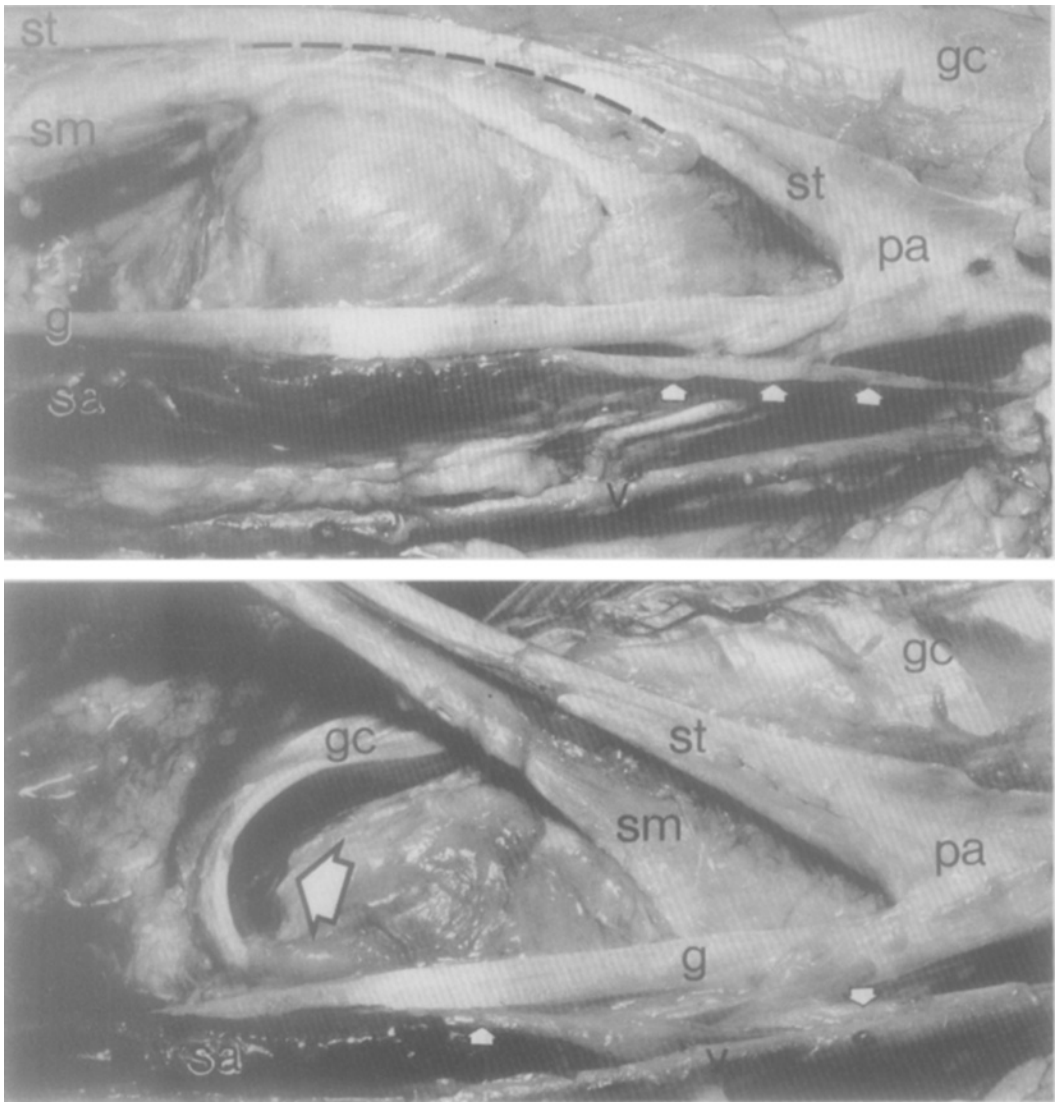


Figure 6. Medial view of a right knee in an autopsy case in the prone position. For abbreviations see Figure 5. The saphenous nerve (small arrows) conjoints with the great saphenous vein (v).

Upper: *The dashed line indicates the incision suggested by the author (extended knee). The semitendinosus serves as a landmark.*

Lower: *Upon knee flexion the tendons are easily retracted dorsally, providing good access to the opening in the capsule (large arrow).*

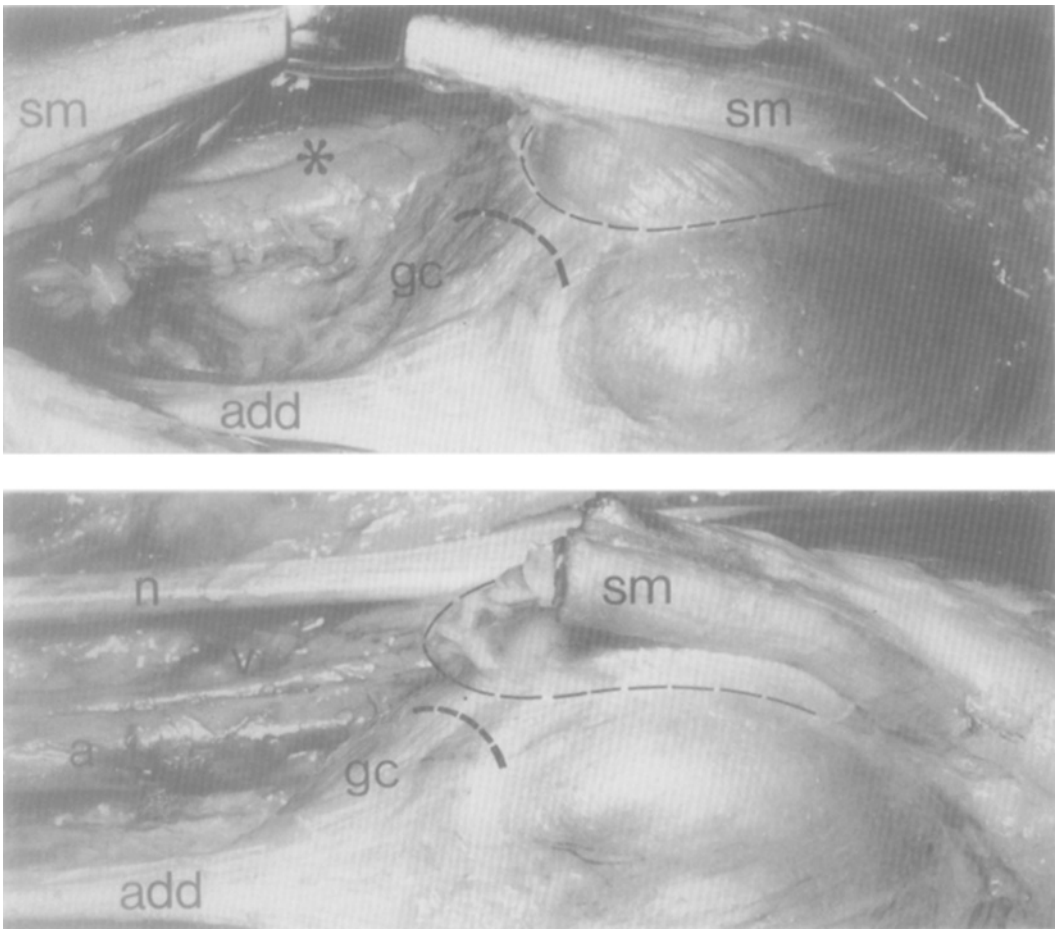


Figure 7. Medial view of a right knee in an autopsy case in the prone position. The pes anserinus tendons have been removed. The g-s bursa bulges beneath the semimembranosus (sm). There is no anatomical obstacle between the bursa and the neurovascular structures (*). The adductor magnus (add) and gastrocnemius (gc) are intimately interwoven. Resection of the semimembranosus (lower figure) gives a free view of the popliteal artery (a), vein (v) and nerve (n). The thick dashed line indicates the site of the communication between the joint and the bursa beneath the gastrocnemius tendon.

SELECTION OF SPECIMENS AND COURSE OF DISSECTION

All 108 knees were filled with 60—80 ml of saline tinted with methylene blue. With the body in the prone position the popliteal fascia was exposed and incised longitudinally along the lateral border of the semitendinosus tendon. Upon repeated gentle flexion communicating cysts filled in 58 knees (13 right, 9 left and 18 bilateral), on several occasions with an audible and palpable bruit. These were submitted to detailed dissection. In all 108 knees the entire posteromedial capsule was transilluminated with fibreoptic light in search for any weak areas.

The subcutaneous nerves at the posteromedial aspect of the knee were dissected, the course of the major saphenous nerve in particular. The bursae artificially distended with fluid were dissected to clarify the extent of the bursa, its gross anatomy and its topographic relationship to the structures of this region. The site of the communication was determined in relation to the origin of the

gastrocnemius tendon. The size and shape of the opening was recorded and the deformation of the opening caused by passive movement of the knee, as well as by pull on inserting tendons simulating active flexion, was examined. Finally, the thickness of the gastrocnemius tendon overlying the capsular aperture was measured at three levels.

CUTANEOUS NERVES

The *saphenous nerve,* after passing through the subsartorial canal, was invariably found to emerge between the sartorius muscle and the gracilis tendon. It entered the subcutaneous space by perforating the crural fascia above or at the level of the joint. As a rule the nerve joined the great saphenous vein within a few centimetres (Figures 5 and 6). Accessory branches were present in two cases, and in one further specimen an extrafascial anatomosis with the cutaneous nerve ending of the anterior division of the obturator nerve was observed. The average distance between the saphenous nerve and the medial border of the gastrocnemius tendon at the level of the femoral condyle was 4 cm (range 3—6 cm). The centre of the popliteal region was supplied by terminal branches of the *posterior femoral cutaneous nerve.* The number and distribution of nerve endings varied considerably, but the saphenous nerve and its branches were oriented in the longitudinal axis of the leg. Occasionally fibres from the posterior femoral cutaneous nerve crossed the cyst beneath the popliteal fascia without sending branches to its wall.

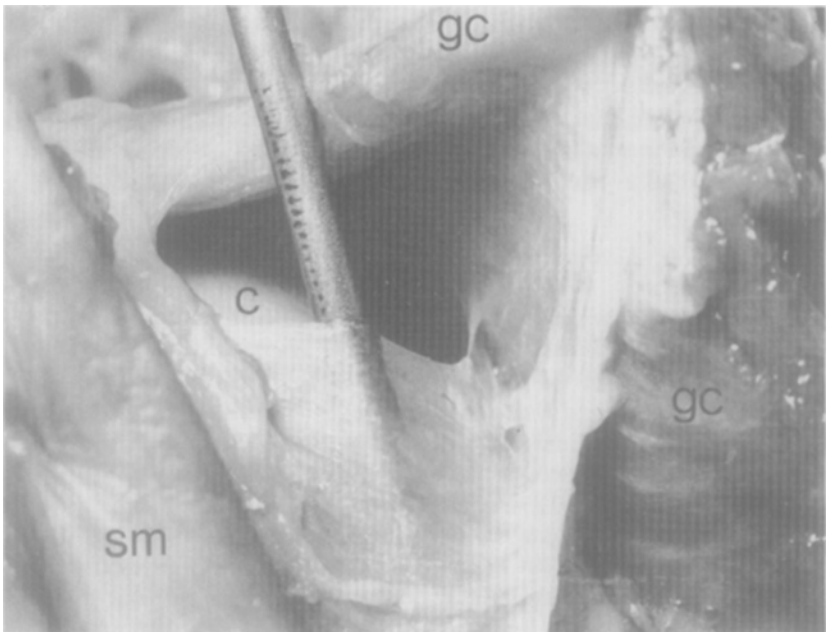


Figure 8. Extraarticular view of the communication in the right knee of an autopsy case in the prone position, seen from the medio-distal direction. The gastrocnemius (gc) is retracted dorsally. The loose part of the bursal wall has been resected, and the remainder adheres firmly to the capsule and the tendons. A probe is inserted beneath the lower capsular portion. Note the marked thinning of the capsule distal to the sharp upper margin. The femoral condyle (c) is visible through the gap. sm = semimembranosus tendon.

THE COMMUNICATING BURSA

Of the six primary bursae at the postero-medial aspect of the knee (Wilson et al. 1938), only the g-s bursa was found to communicate with the knee joint. After division of the unyielding popliteal fascia this bursa was invariably found in the sulcus formed by the muscle bellies of the semimembranosus and medial head of the gastrocnemius, the so-called sulcus popliteus medialis. It was oblong or ovoid, 1—2 cm wide and 3—6 cm long (Figure 7). Its posterior wall was usually slightly lobulated and surrounded by loose areolar tissue. No communication with the semitendinosus tendon sheath was seen. The lower pole was usually firmly attached to the medial border of the gastrocnemius by a fibrous cord. Once this was divided, the bursa could easily be dissected free. Towards the decussation of the gastrocnemius and semimembranosus tendons the bursal wall became increasingly adherent. As, during knee extension, these tendons were forcefully pressed against each other, flexion of the knee and retraction of the muscles was required to obtain access to the anterior compartments of the bursa (Figures 5 and 6). One constant process of the bursa was situated between the joint capsule and the straight tibial arm of the semimembranosus tendon and occasionally protruded medially (Figure 7). Another compartment of the compound g-s bursa consisted of the constant bursa beneath the tendon of the gastrocnemius muscle. In 54 cases this bursa had coalesced with the above-mentioned bursa between the gastrocnemius and semimembranosus tendons (Figure 8). In four specimens only the small subgastrocnemius bursa filled with fluid from within the joint, while the bursa between the tendons of the gastrocnemius and semimembranosus was empty.

Membranes were frequently found within the g-s bursa. They formed incomplete septa, usually oriented in the sagittal plane. Some of the larger g-s bursae extended in the cranial direction beneath the semimembranosus tendon, and this portion in particular frequently displayed diverticulae. Small branches of the medial superior genicular artery entered the bursa at its upper pole. The inner surface of the bursa was often covered with soft synovial ridges. Sometimes diverticulae or meshwork of tiny synovial bands were seen especially in the anterior portion. Fibrin or mucin clots, as well as cartilage debris and a few rice bodies were contained in some of the bursae.

THE COMMUNICATION

In all specimens transillumination disclosed a thin area in the postero-medial capsule immediately distal to the 2.5—3 cm broad gastrocnemius tendon insertion (Figures 8 and 9). No such thinning was seen around the oblique popliteal ligament. When the bursa communicated with the joint cavity the opening presented as a transverse slit at the uppermost rim of the capsule, separating the capsule from the gastrocnemius tendon opposing the upper lateral circumference of the femoral condyle. Its width was 4—24 mm (mean 1.8 mm). The margin was sharply defined and occasionally slightly frayed. The slit was situated 2.0—5.5 cm (mean 3.4 cm) distal to the origin of the gastrocnemius tendon. From the inside of the joint it resembled the pouch of a kangaroo (Figure 9). The slit invariably lay over the postero-lateral circumference of the medial femoral condyle, thus facing the centre of the popliteal fossa (Figure 7, interrupted line) and was separated from the popliteal nerve and vessels by the broad gastrocnemius muscle belly (Figure 8).

The entire capsular opening was covered by the tendon of the gastrocnemius muscle. Opposite the medial edge of the slit it was

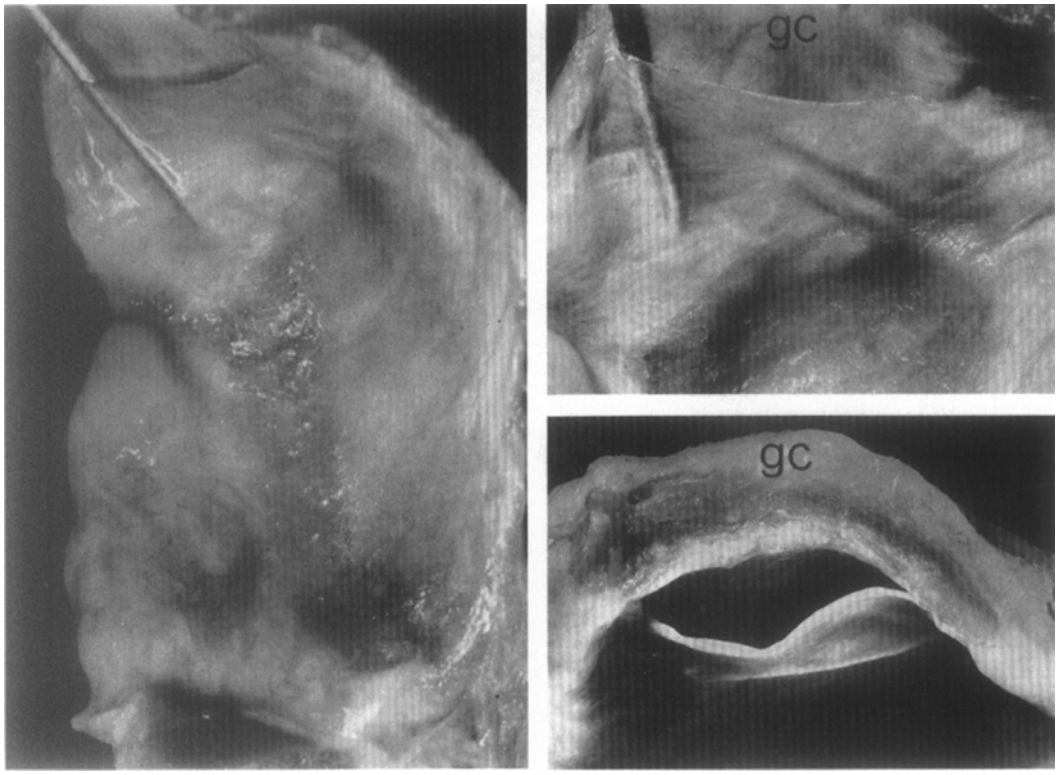


Figure 9. Preparation of the postero-medial capsule removed in a frozen state from the left knee of an autopsy specimen.

Left: *Intraarticular view showing the meniscus at the bottom and the slit-shaped communication between the joint cavity and the bursa at the top.*

Upper right: *Detail of the communication. Behind the broad gap the gastrocnemius tendon (gc) is seen.*

Lower right: *The opening viewed from above after horizontal section of the gastrocnemius tendon.*

3—7 mm thick (mean 4.8 mm), opposite the mid-point of the slit 3—7 mm (mean 4.6 mm) and at the the lateral edge 3—6 mm (mean 3.9 mm) (Figure 9). In three cases a tiny synovial ridge was detected on the articular surface of the gastrocnemius tendon, whereas no counterpart for the sharp upper rim of the capsule was seen in the remainder of specimens.

When the tibia was rotated at various degrees of knee flexion, the slit was deformed diagonally. Pulling on the semimembranosus tendon, particularly with the knee flexed, markedly widened the opening cranio-caudally. On several occasions the slit widened owing to further tearing at its edges. Simulated hyperextension did not widen the gap, as the capsule was pulled cranially by the semimembranosus tendon, which then acted as a tension band protecting the capsular opening.

SERIAL CRYOSECTIONING OF UNDECALCIFIED SPECIMENS

A substantial drawback of conventional knife dissection is the increasing difficulty in orientation encountered in the preparative procedure. Thus, when the fascia is split the popliteal space pressure decreases, and the collapse of the cyst after escape of its fluid content, together with the distortion resulting from retraction and division of tendons and muscles, make determination of the topography and the dimensions of the cyst difficult. The rather complex pluricompartmental extensions of the bursa, and its relationship to the tendons which it covers, are difficult to visualize. Moreover, the displacement and compression of popliteal structures caused by a distended cyst are relieved once the fluid-filled cavity is emptied.

Ullberg and co-workers (1954, 1977) developed a procedure of cryosectioning of whole animals for autoradiographic and toxicological studies. As serial sectioning of the fluid-filled frozen joint would permit a detailed study of the synovial extension of the articular cavity and the bursa, the technique of cryosectioning of large animal specimens was modified. A description and discussion of the technique is also given elsewhere (Rauschning 1979).

Figure 10. Sagittal cryosection through the medial posterior portion of an amputation knee specimen frozen in slight flexion. The g-s bursa does not communicate with the joint cavity. It is seen as a thick dark line between the tendons of the gastrocnemius (gc) and the semimembranosus (sm), which are twisted around each other in the same sagittal plane. The arrow indicates the junction between the capsule and the gastrocnemius tendon.

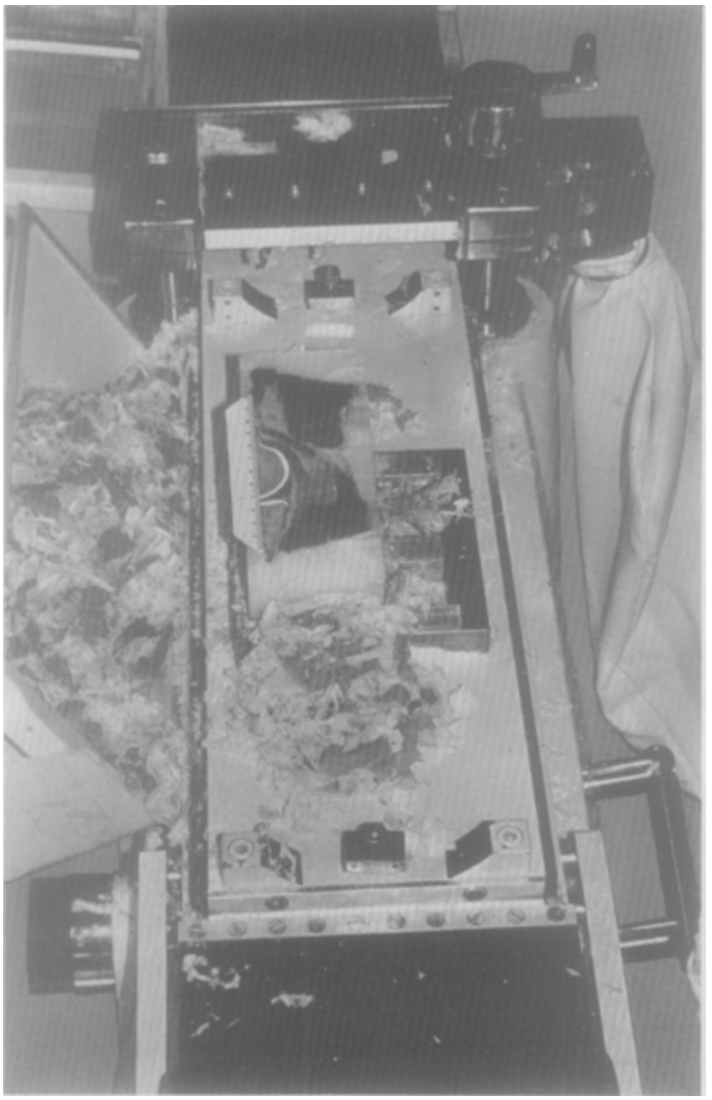
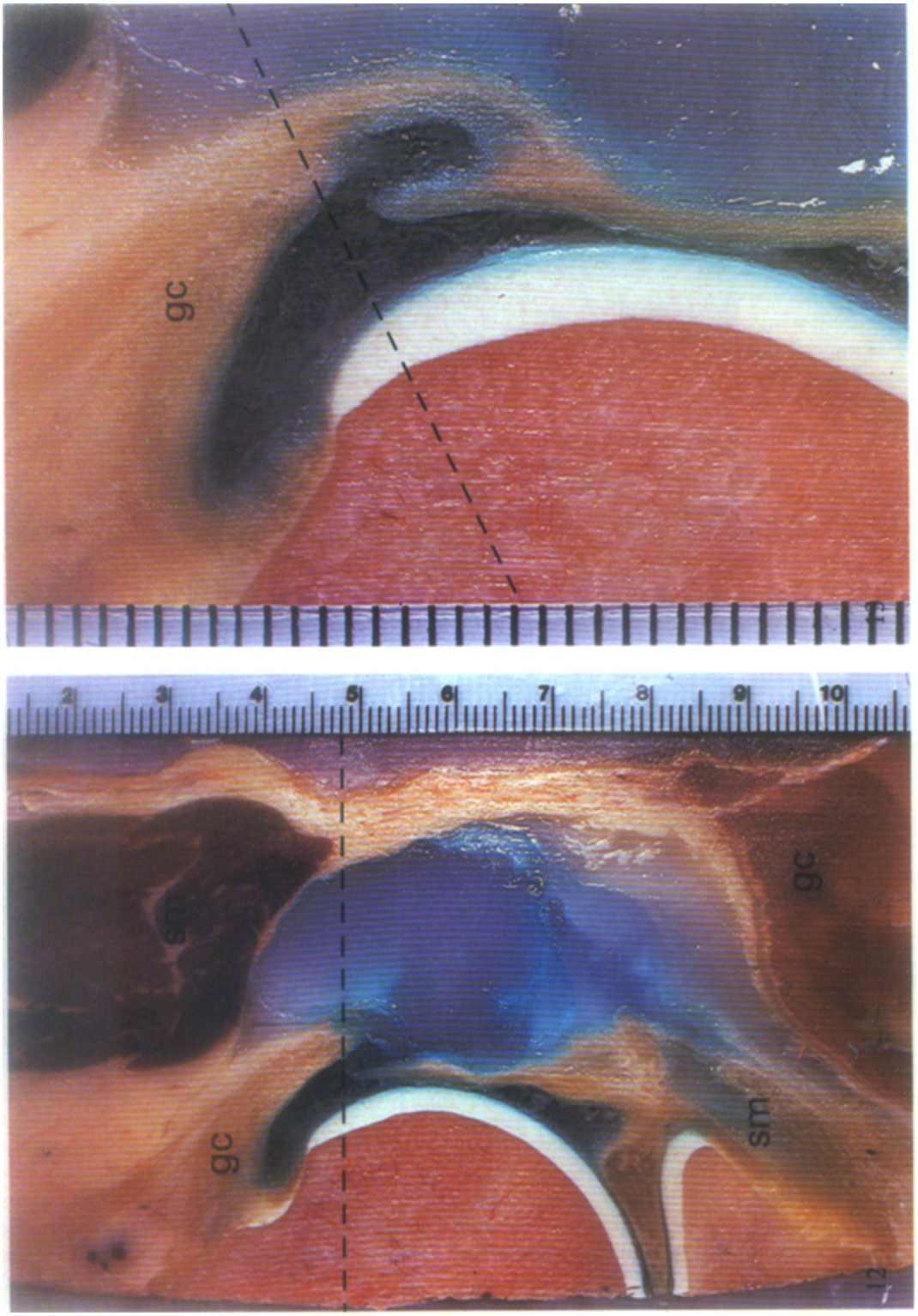


Figure 11. Serial cryosectioning with a heavy duty cryomicrotome built into a cryostat (LKB 2250 PMW). A human knee joint specimen with a communicating popliteal bursa is sectioned in the sagittal plane at —20°C. The block is mounted on the horizontally moving sledge and the knife is fed downwards to cut sections 5—200 μm thick. The debris can be removed by a vacuum cleaner during automatic trimming.

MATERIAL AND METHODS

The material consisted of 14 fresh human knee joints. Two knees were obtained from above-knee amputations for arteriosclerotic gangrene. These two amputated knees had no communicating g-s bursa; one was sectioned in the horizontal and the other in the sagittal plane (Figure 10). The remaining specimens were obtained at autopsies. The subjects were over 50 years of age and all knees were healthy and had not been operated upon. The presence of a communicating bursa in the autopsy cases was ascertained as follows: With the body in a prone position 60—80 ml of methylene-blue-stained water was instilled into the joint and the popliteal fascia was exposed by raising a large rectangular skin flap. When at gentle


gc
2
3
4
5
6
7
8
9
10
sm
gc
gc
sm
12

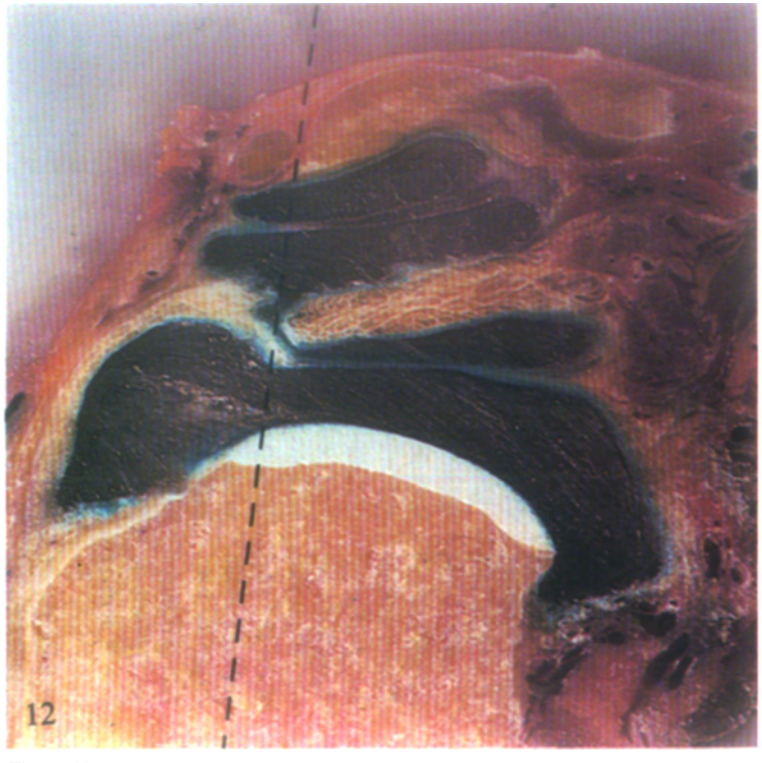


Figure 12. (×1.5. The knee specimens were frozen at moderate flexion, the dashed line in the upper figure indicates the plane of sectioning in the lower figure and **vice versa.**

Upper: *Sagittal cryosection at the medial border of the communication. A large communicating g-s bursa displaces the gastrocnemius (gc) laterally and the semimembranosus (sm) medially, i.e. towards the viewer. Note the broad insertion of the semimembranosus in the tibia.*

Lower: *Horizontal cryosection at the level of the thin upper rim of the capsule. The thick gastrocnemius tendon covers the capsular slit. Note the septa in the bursa.*

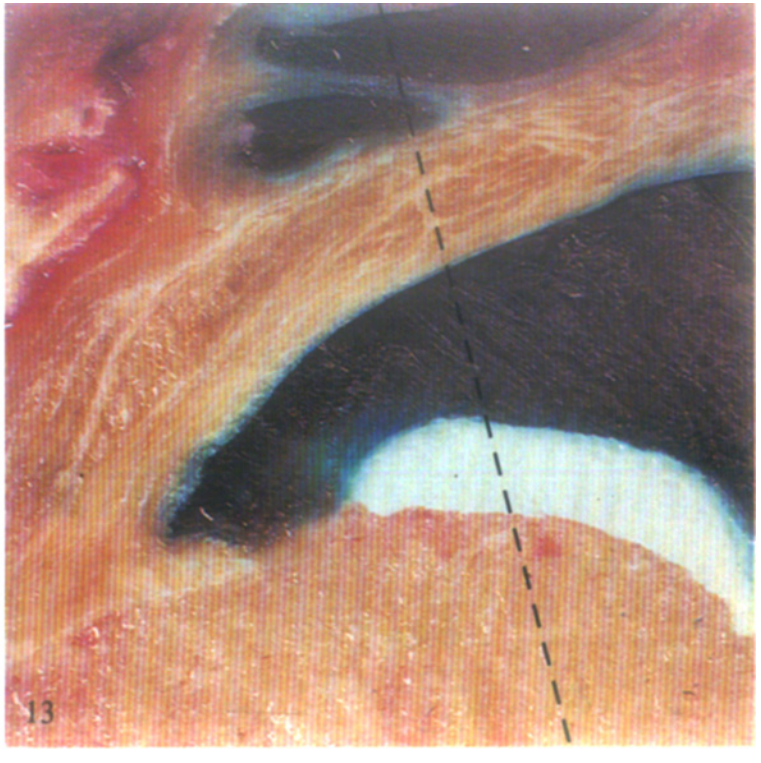


Figure 13. (×4. Same specimens as in Figure 12).

Upper: *Detail from a sagittal cryosection some mms medial to the slit-formed communication. A synovial fold conjoins the capsule with the gastrocnemius tendon (gc).*

Lower: *Detail from a horizontal cryosection through the upper postero-medial recess of the knee. The origin of the gastrocnemius forms a broad tendinous cupole; no separate fibrous capsule is seen.*

flexion a communicating cyst could be seen through the fascia, carbon dioxide snow was repeatedly applied between the skin flap and the fascia. It took approximately six hours for the knee to become frozen. Thus 12 cadaver knees with communicating g-s bursae were obtained. In one case with bilateral communicating bursae one knee was frozen at maximal extension and the other at about 40° of flexion. The remaining 10 knees were frozen at various angles of flexion. A block was then cut comprising either the whole popliteal space, including the posterior halves of the femoral condyles and the tibial plateau, or—for sagittal plane sectioning—the postero-medial quadrant of the joint containing a larger portion of the medial femoral and tibial condyles.

Specimens with a maximum height of about 7 cm were mounted on a large stage, in a semiliquid solution of carboxymethyl cellulose (CMC gel) and then frozen in a container filled with hexane cooled with dry ice to a temperature of about —75°C. The freezing time was 20—30 minutes.

The block was placed in a plastic bag and stored in a freezer (—25°C). Prior to sectioning the block was left in the microtome cryostat for some hours for thermal equilibration (—20°C). Cracking of the surface was observed if the block was not allowed to accommodate.

The specimen was mounted on the sledge of a heavy duty microtome (LKB 2250 PMV Cryo-Microtome). The whole frozen specimen was sectioned through and the surface of the block was photographed by the author at consecutive levels (Figure 11).

It was not necessary to collect sections on tape, since the anatomical details were well outlined by their natural colours on the surface of the block. Also, the methylene-blue-stained ice contained in the articular cavities showed up with good contrast. The brilliance of the picture was improved if the surface of the block was thawed by rubbing it with a cloth soaked in ethylene glycol.

As the control panel of the cryomicrotome could be programmed to cut a predetermined number of sections (1—20) of selected thickness, equidistant intervals for documentation were ensured. The maximum microtome knife excursion of 50 mm was increased to approximately 65 mm by intermounting an additional bottom plate. More than 1,000 sections were cut from every specimen. Ten specimens were sectioned in the transverse plane and four in the sagittal plane.

For photography a 35 mm SLR camera equipped with a 50 mm macro lens and an automatic flash was used and photographs were taken on 25 ASA colour film with a gauge placed on the block. The magnification on the film could be read directly on the scale of the lens. As a rule, photographs were taken at 2 mm intervals. The films were studied at intermediate magnification in a light microscope or by projection onto a screen.

RESULTS

The tendon of the medial head of the gastrocnemius took the shape of a broad plate and originated from the supracondyloid tubercle and along a crest extending towards the insertion of the adductor magnus tendon. Here both tendons were intimately interwoven. The muscular portion arose from an area of roughened bone on the popliteal aspect of the femoral shaft. The ratio of the muscular to the tendinous portions varied greatly. The gastrocnemius tendon covered the lateral half of the posterior curvature of the medial femoral condyle, forming a 4—8 mm thick dome. The tendon alone constituted the upper part of the fibrous capsule. All fibres were oriented longitudinally and no separate layer of capsular fibres was detected (Figures 12—15). Towards the centre of the popliteal space the muscular portion increased. The slit-shaped opening into the joint was always completely covered by the tendon (Figures 12 and 15). No sesamoid bone or cartilage was found. The neurovascular supply to the muscle was seen on the lateral aspect of the muscle belly below the level of the joint.

The straight tibial arm of the semimembranosus tendon had a very broad insertion in the tibia (Figure 12). In both sagittal and horizontal sections the oblique popliteal ligament presented as a diffuse thickening of the fibrous capsule (Figures 12 and 14). Neither above nor below this posterior oblique ligament was any weakening of the capsule detected. The posterior horn of the medial meniscus was not firmly attached to this particular portion of the capsule, whereas its postero-medial and medial segments were closely interwoven with the capsule, the attachment increasing in the medial direction (Figures 12 and 14).

The thick capsular portion above the oblique popliteal ligament consisted of transversally and diagonally oriented fibrous strands. Towards the junction with the gastrocnemius its thickness decreased almost abruptly, and this thin area in the frontal plane was always narrower than the overlying tendon. The medial and lateral borders of this "capsular window" consisted of longitudinally oriented fibrous columns. No fibrous margin corresponding to the sharply defined rim of the capsule was seen on the articular surface of the gastrocnemius tendon, and in no specimen could the former line of attachment be identified. Some thin synovial bands, but no membranes, partially bridged the orifice (Figure 12).

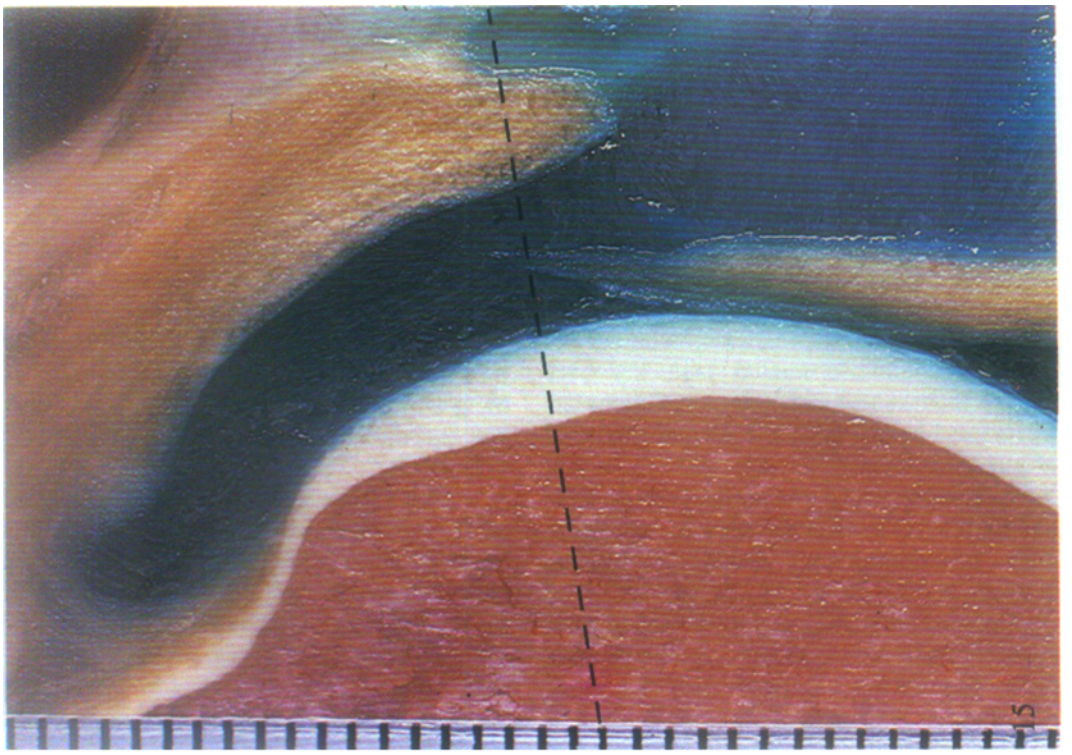
With the knee in extension the popliteal artery, vein and nerve lay close to the medial aspect of the lateral femoral condyle. During flexion the neurovascular structures retracted away from the capsule posteriorly. The broad medial belly of the gastrocnemius muscle was interposed between the site of the capsular opening and the blood vessels and nerves.

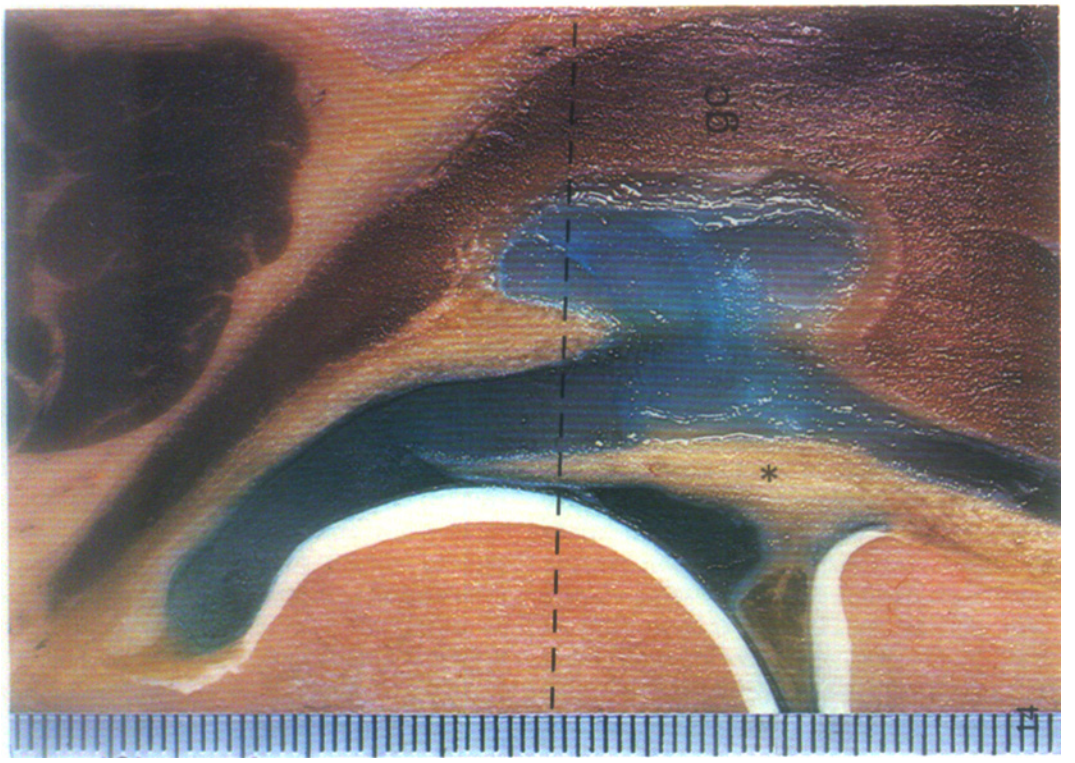
The communicating g-s bursa extended between the tendons of the gastrocnemius and the semimembranosus. In one case, however, only the subgastrocnemial bursa was filled with blue ice. When the bursa was distended it displaced the gastrocnemius tendon laterally and the semimembranosus tendon medially (Figure 12).

In knees frozen in flexion the posterior joint recesses and the anterior extensions of the g-s bursa were wide and filled with ice, and the capsular gap was open (Figures 14 and 15).

During knee extension both the posterior recesses and the subgastrocnemial portion of the bursa were completely emptied and were only discernible as thin blue lines. The gastrocnemius tendon was firmly stretched over the condyle, thus compressing the capsular slit. The tightly overlying semimembranosus tendon seemed to potentiate this effect (Figure 16). The posterior portion of the bursa bulged beneath the popliteal fascia.

Strikingly often the bursal cavities were subdivided by membranes and septa which were not oriented in any particular directions. As all compartments of the cyst were filled with methylene-blue-stained ice, however, they must have been incomplete or perforated (Figures 12—15). The wall of the posterior portion of the bursa was well defined. In the deep compartments no separate fibrous wall was seen. A synovial lining intimately followed the tendons, the aponeuroses of the muscles and the capsule, and no plane of cleavage was detected.


5


gc
*
H

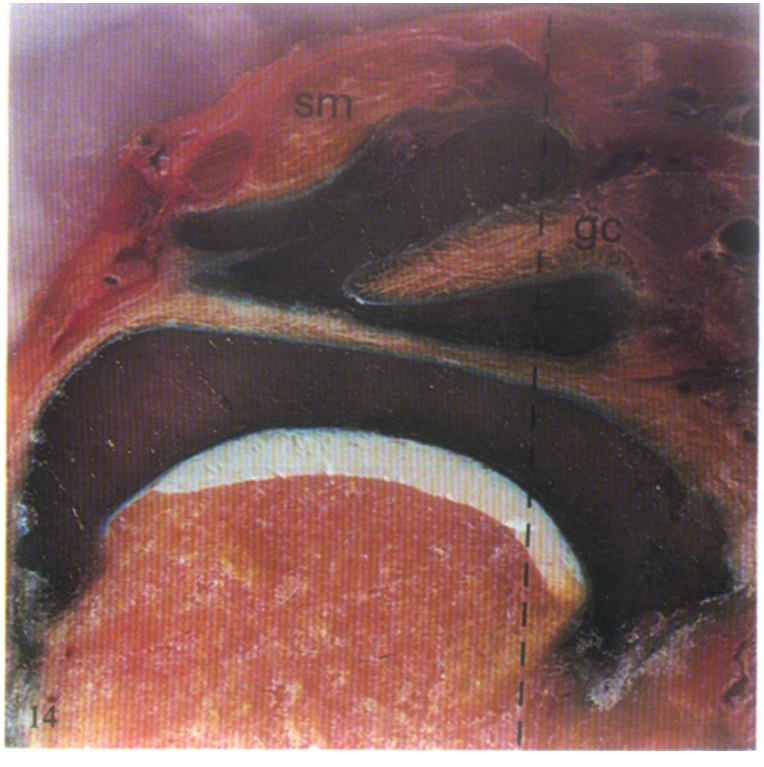


Figure 14. (×2. Same specimens as in Figure 12).
Upper: *Sagittal cryosection at the level of the lateral portion of the communication. The g-s bursa causes an impression in the gastrocnemius (gc), which at this level mainly consists of muscular tissue. Note the loose connection between the meniscus and the oblique popliteal ligament (*)*
Lower: *Horizontal cryosection about 1 cm distal to the upper margin of the capsule. The bursa is interposed between the capsule, the semimembranosus (sm) and the gastrocnemius tendon (gc).*

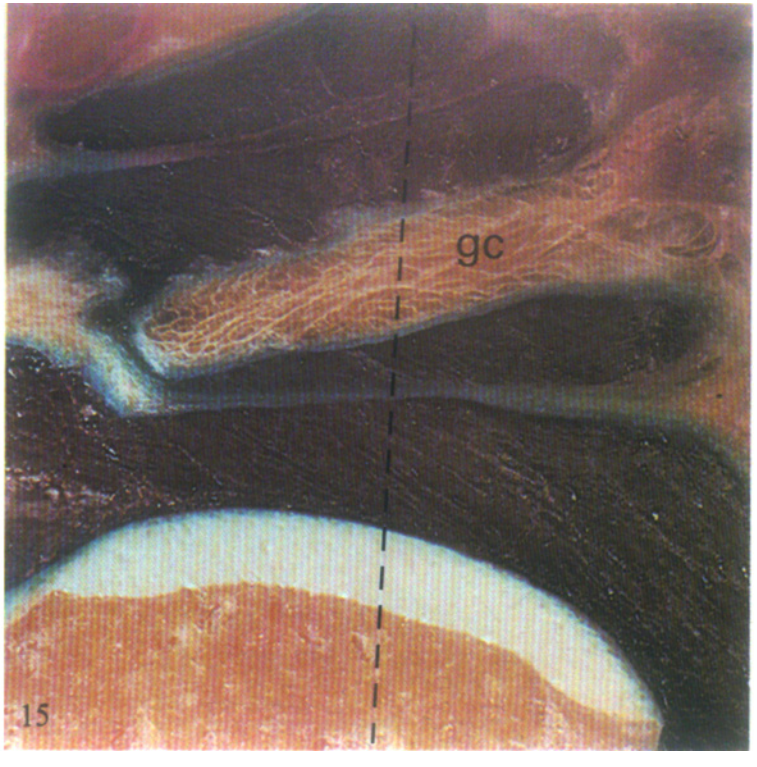


Figure 15. (×4. Same specimens as in Figure 12).
Upper: *Detail from a sagittal cryosection through the mid-portion of the slit.*
Lower: *Detail from a horizontal cryosection at the level of the sharp upper rim of the capsule (cf. Figure 12). The tendinous origin of the gastrocnemius (gc) covers the communication with some overlapping.*

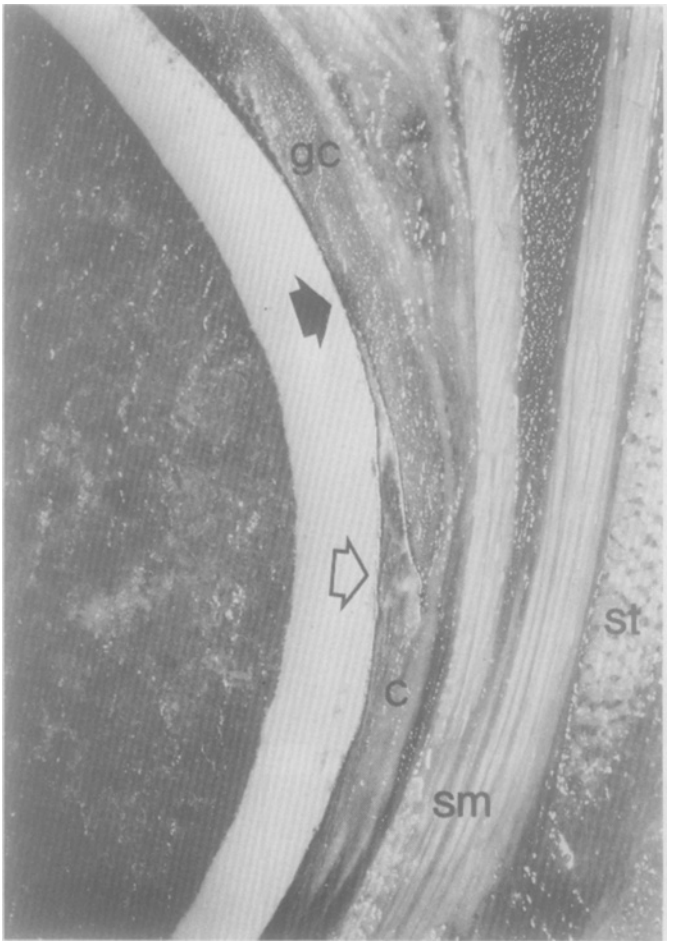


Figure 16. Sagittal cryosection through the postero-medial quadrant of an autopsy knee specimen at the level of the mid-portion of the slit; the knee was frozen at maximal extension (cf. Figure 3). The gastrocnemius tendon (gc) constitutes the upper fibrous capsule, the lower capsular portion (c) displays thinning at a length of 2 cm (indicated by arrows, the filled arrow indicating the upper margin of the capsule). The semimembranosus (sm) and semitendinosus (st) firmly compress the capsule, emptying all fluid from the joint recess and the anterior portions of the bursa.

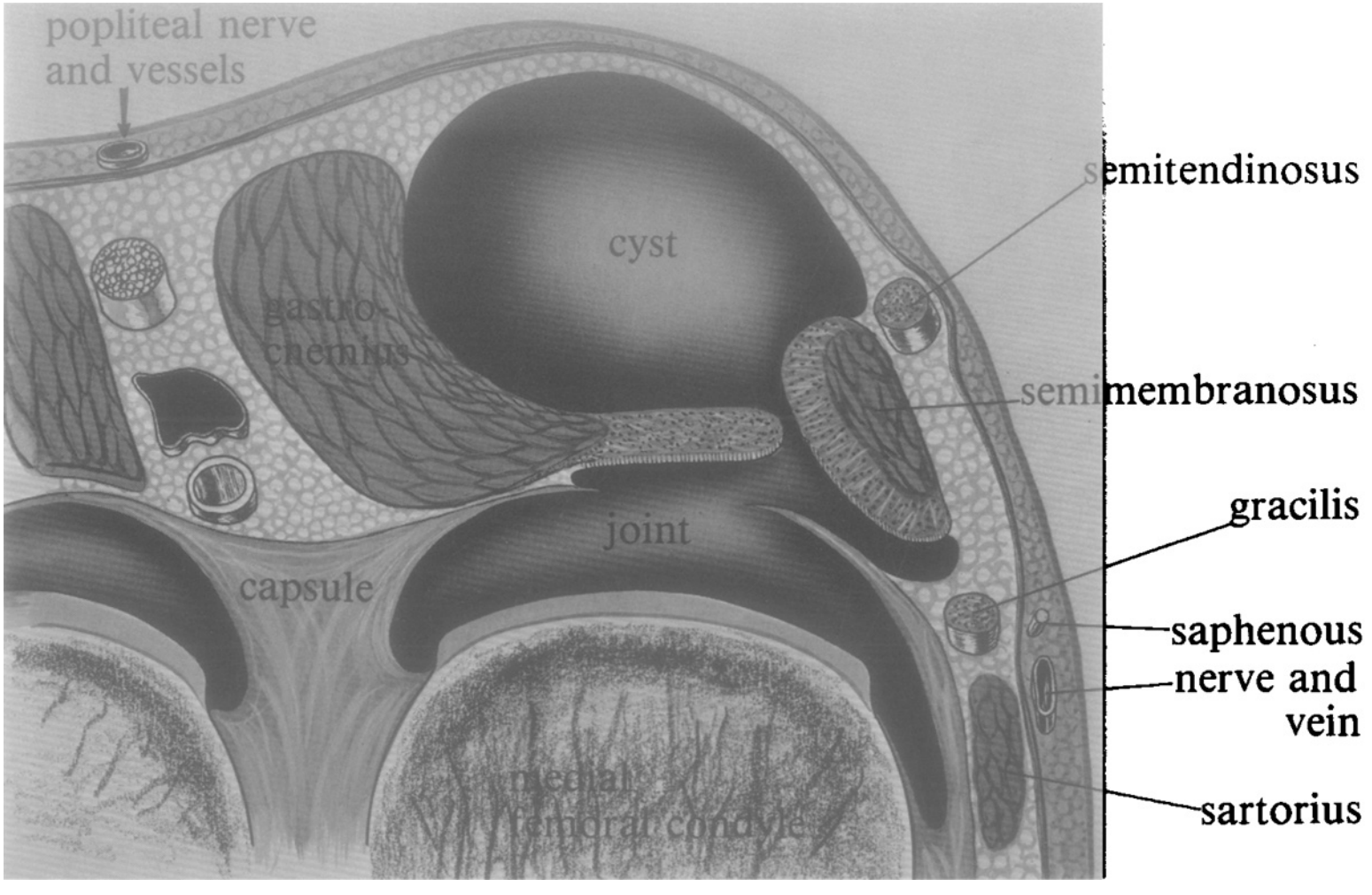


Figure 17. The surgical anatomy of popliteal cysts illustrated in a semi-schematic horizontal cross section of the postero-medial quadrant of the knee at the level of the communication with the popliteal cyst.

INTRAOPERATIVE MORPHOLOGY OF POPLITEAL CYSTS

PATIENTS AND METHODS

Observations made in the course of 26 operations on popliteal cysts, all performed by the author, were analysed. The mean age of the patients was 44.6 years (range 19—69 years). To diagnose suspected associated knee disorders, arthrotomy was performed in five knees and arthroscopy in 10 knees. One rupture of the medial semilunar cartilage, two cases of rheumatoid arthritis, one synovitis of uncertain origin, eight cases of advanced osteoarthritis and seven cases of chondromalacia of the patella or the femoral condyles were diagnosed. One meniscectomy, two synovectomies and two advancements of the tibial tuberosity had been performed at the same session as the operation on the cyst. Two of the operations were for recurrent cysts.

RESULTS

At operation all popliteal cysts were confined to the medial popliteal region and identified as g-s bursae from their location and their anatomical relationship to the joint capsule and the above-mentioned tendons, and from the site of communication between the cyst and the knee joint. Only the findings at operation which differed noteworthily from those made on the bursa at dissection described above will therefore be reported.

Five cysts were about the size of the normal g-s bursa, 13 were about as large as a hen's egg and seven were considerably larger; one (in a rheumatoid knee) was a giant popliteal cyst. In large cysts the posterior portion was flattened by the coarse popliteal fascia, forcing the cyst to extend craniolaterally towards the neurovascular structures posterior to the gastrocnemius muscle. No cyst bulged towards the centre of the popliteal space *beneath* the gastrocnemius muscle. Incision of the deep fascia obviously relieved the pressure in the popliteal space, as the cyst assumed a rounded shape and protruded through the fascial gap. In most cases the posterior portion of the cyst was easily isolated by blunt dissection, but some cysts with a thicker wall were firmly adherent to the surrounding tissues. Anteriorly all cysts firmly adhered to the tendinous portions of the muscles. It was not possible to dissect the cyst wall from these tendons or the capsule. In one case the cyst extended as far as the adductor magnus tendon.

Fifteen cysts contained synovial fluid of low viscosity, and the remainder more viscous fluid. In five cases the fluid had a gelatinous appearance. Osteocartilaginous loose bodies were found in two cysts. The inner surface of the cysts was covered by far thicker and coarser ridges, membranes and septa than in the normal bursa, and diverticulae were numerous.

The communication was invariably located beneath the tendon of the medial head of the gastrocnemius muscle. In Figure 17 the surgical anatomy is illustrated in a semischematic horizontal cross section.

The capsular opening in 13 cases had the same shape and size as those found in the anatomical dissection study. In five cases thin septa and synovial bands concealed the major part of the orifice and in eight cases no opening was found although saline instilled into the joint at flexion readily appeared at the site where the communication is usually located. As the operation proceeded it became apparent that membranes with marginal slit-shaped apertures covered the communication (Figure 18). Several membranes with openings at various sites were common. When these membranes were removed the usual bursal communication slit became visible. In one knee no communication was found even though a communicating g-s bursa had been demonstrated at preoperative arthrography. The opening was now completely obliterated by synovial bands and membranes.

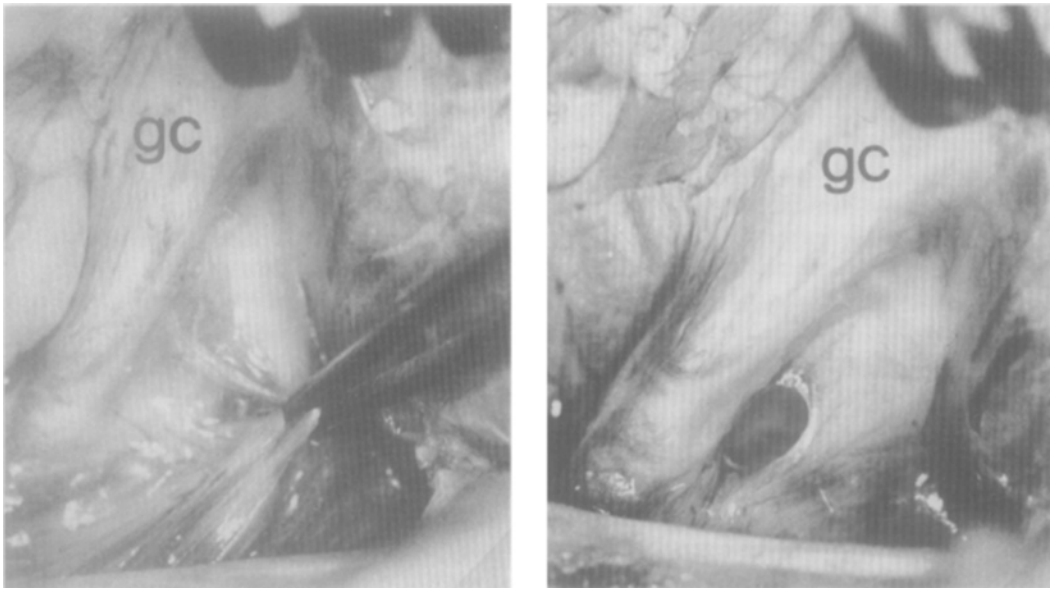


Figure 18. Intraoperative view of the communication between the joint and the popliteal cyst (medial view of the right knee with the patient lying supine and the gastrocnemius tendon (gc) dorsally retracted). Membranes are concealing the opening. After removal of one membrane (left), another septum with a round hole at its medial border appeared (right). At preoperative arthrography contrast medium had passed from the joint to the bursa but could not be manipulated back into the joint (valve mechanism).

DISCUSSION

Although the *aetiology and pathogenesis* of popliteal cyst formation are still a matter of debate, the present investigation has provided overwhelming evidence that at least in the great majority of instances they arise from the gastrocnemio-semimembranosus bursa. In the present study all clinically significant popliteal cysts consisted of distended bursae. Concerning the reports of early authors who from dissection studies of amputated limbs or from examination of cadavers with large popliteal cysts concluded that the cysts had formed by a hernial protrusion of the synovial membrane through gaps in the fibrous capsule, it should be pointed out that many of the knees were severely affected by tuberculosis with far advanced derangement of the joint capsule (Gruber 1846, 1869; Powers 1887). It may also be attributable to the virtual absence of joint tuberculosis that other investigators and I myself have failed to detect any popliteal cyst on palpation of a large number of cadavers, whereas quite a number of cysts have been reported in the early literature (see Introduction).

At operation on popliteal cysts of the present study *synovial membranes* were found in the upper subgastrocnemial portion of the cysts in 50% of the cases, concealing the communication but not impeding the flow of synovial fluid from the joint into the cyst. Once these were removed, the normal slit-shaped capsular opening of the g-s bursa came into view. These membranes presumably provide a plausible explanation for the numerous operative observations of seemingly non-communicating popliteal cysts which at preoperative arthrography had nevertheless filled with contrast medium from the joint (Burleson et al. 1956, Hoffman 1963, Gristina & Wilson 1964, Bryan 1967, Childress 1970).

The apparent discrepancy between the uniform shape of the communication in the present series of operations and the wide variety of shapes and sizes of the apertures as reported by many surgeons, may be due to the great diversity that is observed in the openings in the membranes. It is obvious that closure of the aperture in such membranes will hardly result in a tight seal when the concealed underlying capsular opening is left untouched.

In the clinical material of the present study a *valve mechanism* was demonstrated at the site of communication in 10 of the knees preoperatively by means of a specific arthrographic technique (Lindgren & Rauschning). In these cases contrast medium from the joint cavity readily passed over to the cyst, while no passage in the opposite direction occurred when the cyst was manually compressed. As membranes and synovial folds were found at operation in these cases, it is conceivable that they constitute the pathoanatomical basis of the valve mechanism.

Cryosectioning of undecalcified specimens frozen *in situ* and then removed, as modified to suit the purpose of this study, allowed an examination of the true and undistorted anatomy of the ice-filled joint and bursa and the relation of the bursa to the capsule and tendons. As no artifacts such as may result from conventional histological procedures occurred, the sections reflected the true interrelationship of structures at each particular level. The filling of the synovial cavities with coloured water was helpful in delineating the extensions of the bursa, as the synovial membrane was tinted blue. No difficulties were encountered in sectioning the bone, not even the cortical bone in the metaphysis. The image obtained from the rubbed surface of the block displayed natural colours, making it easy to recognise and interpret the individual structures. By observing the variations of fluid-filling of the different compartments of the bursa in different positions of the knee, the functional anatomy could be examined in a "frozen" state. The modifications of the technique described here do not preclude the customary collection of sections on tape (Ullberg 1979). This would permit a study of the functional anatomy not only on the macroscopic but also on the microscopic level. As a particular anatomical detail can be traced and its location determined throughout the specimen, a three-dimensional image is obtained. Cryosectioning rendered valuable and unequivocal information in this study and would certainly be applicable to similar investigations of other musculoskeletal organs. As a frozen specimen can be radiographed and sectioned in identical planes, it would lend itself particularly to comparative radiographic-anatomical investigations.

In the knife-dissection study 54 of the 58 communicating bursae were *composite bursae,* as they consisted of the bursa beneath the gastrocnemius tendon and the capsule and the bursa between the tendons of the gastrocnemius and semimembranosus muscle. This bursa is called the gastrocnemio-semimembranosus bursa, although bursa subgastrocnemio-gastrocnemio-semimembranosa would be the proper denomination.

Despite the high incidence of such communications and the fairly uniform shape of the opening, this is not described in any detail or illustrated in the contemporary standard textbooks, including those of Corning, Lang & Wachsmuth, Rauber-Kopsch, Cunningham, Benninghoff-Goerttler, Grant, Hafferl and Gray. In the orthopaedic literature the communication is commonly depicted as a hole through which the synovial membrane protrudes (see Introduction).

In addition, the present study demonstrated *a thin area in the capsule* in all specimens immediately distal to the line at which the postero-medial capsule conjoined with or had separated from the gastrocnemius tendon. Apart from this particular weak portion, the capsule was thick. No other preformed soft spots liable to yield to a synovial protrusion were seen, even at the level of the posterior oblique ligament (Figures 12 and 14).

The deep portion of the bursa, commonly referred to as the "neck", i.e. the subgastrocnemial portion, constantly forms a cavity of considerable extent in the mediolateral direction but narrow in the sagittal plane. On lateral arthrograms only its narrow dimension is seen, and for this reason it may have been misinterpreted as being a narrow stalk or pedicle.

During knee extension the upper rim of the capsule is firmly compressed between the condyle and the overlying tendons. Especially on the cryosections of knees that had been frozen during extension, this mechanism invariably caused a hermetic *closure of the communication.* The thin capsular rim admittedly resembles the cusp of a heart valve (Figures 8 and 9), but this does not imply a unidirectional valve mechanism in all communicating bursae (Taylor & Rana 1973). As the synovial fluid is emptied from the anterior to the posterior portions of the bursa (cyst) on extension of the knee, this obviously distends its wall and this would explain why patients with popliteal cysts experience most discomfort when the knee is extended.

The attachment of the medial meniscus to the capsule is rather loose posteriorly, whereas its central portion is intimately interwoven with the capsular fibres, a finding consistent with the observations of Oretorp (1978). The loose capsular connection of the posterior horn does not prevent the semimembranosus tendon from exerting *traction on the capsule* via its capsular arm. This was also confirmed by the simulated pull on this tendon in the course of the present dissection study. On the other hand, the diagonal deformation of the communication observed on application of torque stress to the knee might have been due to traction forces from the meniscus acting on the postero-medial portion of the capsule.

Lindgren and Willén (1977) reported progressive rarefaction and degeneration of the fibroelastic tissue between the joint cavity and the gastrocnemio-semimembranosus bursa during ageing, which eventually, for example in combination with a sudden strain, causes the communication to occur. On the other hand, the likewise constant bursa beneath the lateral head of the gastrocnemius muscle is reported to communicate with the joint far less frequently (Bardeleben & Haeckel 1901, Fick 1904, Testut & Jacob 1909, Hafferl 1969). This difference might be explained by continuous attrition due to capsular pull, since at the medial side a heavy tendon (of the semimembranosus) inserts directly into the capsule and medially the semilunar cartilage is intimately attached to the capsule, whereas the lateral side lacks a capsular tendon insertion and the lateral meniscus is mobile in relation to the capsule. The increasing incidence of communication between the knee joint and the g-s bursa with advancing age and the functional and morphological findings of the present investigation would seem to suggest that this communication is a condition which is acquired during life.

CONCLUSIONS

Some anatomical features established in the present studies would seem to be of special importance for the surgical technique in operations on popliteal cysts and should receive particular attention:

1. All popliteal cysts in the present series were unequivocally identified as distended communicating gastrocnemiosemimembranosus bursae.
2. For surgical exposure a longitudinal incision following the semitendinosus tendon would provide good access to the capsular opening and involve little risk of damage to cutaneous nerves. Flexion of the knee facilitates retraction of the tendons.
3. The deep portion of a popliteal cyst is the natural (bursal) synovial lining of the joint capsule and the tendons. It has a considerable extension in the mediolateral direction, but is narrow ventrodorsally.
4. This part of the cyst cannot be isolated by dissection unless a substantial amount of tendon and muscle tissue is taken along with it. Not even if this is done will a pedicle (stalk, neck, narrow canal) form that can be ligated, divided and inverted.
5. As the constancy and size of the bursa would seem to reflect its functional purpose of reducing friction between the capsule and the tendons, it might be questioned whether at operation on popliteal cysts all synovial lining tissue should be radically excised, as is commonly advocated axiomatically by many surgeons (see Introduction).
6. The communication between the cyst and the joint cavity invariably has the shape of a transverse slit and is located beneath the tendon of the medial head of the gastrocnemius muscle, roughly 3 cm distal to its origin.
7. At operation all popliteal cysts were found to communicate with the joint cavity, but in 50% extraarticular synovial membranes partially or totally concealed the bursal communication with the joint.
8. The upper rim of the capsule is sharp and the adjacent portion of the capsule is thin, and on the gastrocnemius tendon no rim exists that would facilitate suturing. Moreover, after such closure the adjacent capsule would still be thin and liable to be torn or to yield. A durable closure of the communication would also seem to demand a reinforcement of this particular area but for anatomical reasons free tendon grafts are not easily fitted into the opening.
9. Capsular tearing forces obviously exert pull on the capsular opening and they must be taken into account at the surgical repair.
10. As the gastrocnemius tendon is thick and as it always covers the capsular opening with sufficient overlapping, it lends itself to form a pedicle flap, which is easily sutured to the capsule. This repair appears appropriate both to eliminate the capsular tearing forces and to reinforce the thin portion of the capsule without appreciably weakening the tendon. A series of operations on popliteal cysts using this capsuloplasty has given encouraging results.

SUMMARY

A survey of the literature on human popliteal cysts revealed a marked divergence of opinion regarding their origin. Some recent publications indicate, however, that these cysts arise from the gastrocnemio-semimembranosus bursa (g-s bursa). Following routine excision of a popliteal cyst, recurrences and postoperative complications are common, even if a closure of its communication with the joint cavity has been attempted. The present investigation was therefore undertaken to study the topographical and functional anatomy of the normal g-s bursa in 120 post-mortem specimens and to record the surgical morphology during the course of 26 operations on popliteal cysts.

In the *anatomical investigations* both conventional knife dissections and serial cryosectioning of large, undecalcified, specimens frozen in situ were performed. The original technique (Ullberg 1954, 1977), which mainly concerned whole body autoradiography of experimental animals, was applied on human joints and modified to permit a detailed examination of the undistorted macroscopic anatomy of the structures in the vicinity of the bursa. The optimum surgical approach to the capsular opening was sought, with due regard to the popliteal sensory nerves. In knees without a communication between the joint and the g-s bursa fibre light transillumination invariably revealed a weak area in the joint capsule distal to its junction with the gastrocnemius tendon. No other thin portions were disclosed. When a communication was present, it always appeared as a transverse slit separating this thin capsular portion from the overlying tendinous origin of the gastrocnemius. Rotation of the lower leg and pull on the semimembranosus tendon, simulating intravital conditions, deformed and widened the capsular opening, indicating that even during normal use of the joint tearing forces from the capsule might exert traction on the communication. The increasing incidence of communication with advancing age and the morphological findings in the present studies would suggest that this condition is acquired during life.

During operation all popliteal cysts were unequivocally identified as fluid-distended communicating g-s bursae, but in 50% the normal bursal communication with the joint was concealed by synovial membranes. The deep portion of the cyst lacked a fibrous wall of its own and only consisted of the bursal lining of the tendons and capsule, from which the cyst could not be dissected free.

Based on these morphological results an improved surgical approach is proposed. The necessity for radical excicion of all cyst tissue is questioned. The thick gastrocnemius tendon lying over the communication lends itself to form a pedicle flap for closure of the opening and for reinforcement of the weak capsular portion.

REFERENCES

Ackerman, L. V. (1959) *Surgical pathology,* 2nd ed., The C. V. Mosby Comp., St. Louis.

Adams, R. (1840) Chronic rheumatic arthritis of the knee joint. *Dublin J. med. Sci.* **17,** 520—522.

Adams, R. (1839—1847) Abnormal conditions of the knee joint. *Cyclopedia anat. physiol.* (London) **3,** 48—78.

Aegerter, E. and Kirkpatrick, J. A. (1975) *Orthopaedic diseases, physiology—pathology—radiology,* 4th ed., W. B. Saunders Co., Philadelphia, London, Toronto.

Albin, B. S. (1734) Historia musculorum hominis. Lugd. Batav.

Anson, B. J. and Maddock, W. G. (1952) *Callander's surgical anatomy,* 3rd ed., W. B. Saunders Co., Philadelphia—London.

Apley, A. G. (1968) *A system of orthopaedics and fractures.* 3rd ed., Butterworths, London.

Baker, W. M. (1877) The formation of synovial cysts in the leg in connection with disease of the knee joint. *St. Bart. Hosp. Rep.* **13,** 245—261.

Baker, W. M. (1885) The formation of abnormal synovial cysts in connection with the joints (second communication). *St. Bart. Hosp. Rep.* **21,** 177—190.

Bardeleben, K. and Haeckel, H. (1901) *Atlas der topographischen Anatomie des Menschen.* 2. Auflage, G. Fischer, Jena.

Baudouin, (1855) *Des kystes synoviaux tendineux de la region poplitée.* Thèse de Paris.

Beatty, D. C. (1959) Rheumatoid cysts of the calf. *Proc. roy. Soc. Med.* **52,** 1106—1108.

Benninghoff, A. and Goerttler, K. (1960) *Lehrbuch der Anatomie des Menschen,* 7. Auflage, Lehmann, München.

Billroth, T. (1876) *Von dem chronischen Hydrops der Sehnenscheiden.* In: Die allgemeine chirurgische Pathologie und Therapie in fünfzig Vorlesungen. 8. Aufl., G. Reimer, Berlin, 600—601.

Bond, C. J. (1890) The treatment of enlarged bursae and ganglia by excision. *Practitioner* **44,** 440—443.

Borellini, A., Mammi, G. I. and Ferrarini, P. (1971) Sindrome associata: Cisti poplitea e lesione meniscale. *Chir. Organi Mov.* **60,** 673—679.

Bryan, R. S., Di Michele, J. D. and Ford, G. L. (1967) Popliteal cycts. Arthrography as an aid to diagnosis and treatment. *Clin. Orthop.* **50,** 203—208.

Brösicke, (1899), *Lehrbuch der normalen Anatomie des menschlichen Körpers,* Berlin.

Buck, R. M., McDonald, J. R. and Ghormley, R. K. (1943) Adventitious bursas. *Arch. Surg.* **47,** 344—351.

Burguet, (1854) *Du diagnostic différentiel des tumeurs du creux poplité.* Thèse de Paris.

Burleson, R. J., Bickel, W. H. and Dahlin, D. C. (1956) Popliteal cyst. A clinico-pathological survey. *J. Bone Jt. Surg.* **38-A,** 1265—1274.

Childress, H. M. (1954) Popliteal cysts associated with undiagnosed posterior lesions of the medial meniscus. *J. Bone Jt. Surg.* **36-A,** 1233—1240.

Childress, H. M. (1970) Popliteal cysts associated with undiagnosed posterior lesions of the medial meniscus. *J. Bone Jt. Surg.* **52-A,** 1487—1492.

Ciolina, (1904) *Ueber Hygrome der Kniekehle.* Dissertation, Erlangen.

Clark, W. E. (1949) *Practical anatomy, revised and rewritten.* E. Arnold, London.

Colombo, O. (1965) Die Arthrozele der Kniekehle. *Chir. Praxis* **9,** 583—588.

Corning, H. K. (1907) *Lehrbuch der topographischen Anatomie für Studierende und Ärzte.* J. F. Bergmann, Wiesbaden.

Crasselt, C. (1968) Arthrocelen bei rheumatischen Kniegelenkserkrankungen. *Z. Orthop.* **104,** 570—579.

Cravener, E. K. (1932) Hernia of the knee joint (Baker's cyst). *J. Bone Jt. Surg.* **14,** 186—187.

Cruveilhier: Vide Adams, R., 1839—47.

Cunningham, D. J. (1951) *Cunninghams textbook of anatomy.* Williams & Wood Co., New York.

Davis, G. G. (1918) *Applied anatomy. The construction of the human body.* 5th ed., Lippincott Co., Philadelphia.

Dinham, J. M. (1975) Popliteal cysts in children. The case against surgery. *J. Bone Jt. Surg.* **57-B,** 69—71.

Doppman, J. L. (1965) Baker's cyst and the normal gastrocnemiosemimembranosus bursa. Amer. J. Roentgenol. **94,** 646—652.

Dupuytren, G. (1829) Hydrarthrose énorme du genou. — Antiphlogistiques. — Purgatifs répétés. — Guérison. *La Clinique Hum. de Med. Univ. (Paris)* **1,** No 42, 251.

Edmunds, L. H. and Hebble, J. G. (1939) Posterior herniation of the knee joint. *Seattle, Virginia Mason Hosp. Clin.* **18,** 8—11.

Étienne, J. C., Menanteau, B., Gérard, Y. and Gougeon, J. (1976) Les kystes synoviaux du creux poplité: étude radio-clinique et pathogénique d'une série de 122 observations (13 genoux). *Un. méd. Can.* **105,** 544—558.

Ficat, P. (1957) *Pathologie synoviale,* In: *L'arthro-graphie opaque du genou,* Masson et Cie, Paris.

Fick, R. (1904) *Handbuch der Anatomie und Mechanik der Gelenke unter Berücksichtigung der bewegenden Muskeln.* G. Fischer, Jena.

Fischedick, O. (1969) Veränderungen des hinteren Anteils der Kniegelenkskapsel im Arthrogramm. *Chirurg* **40**, 408—411.

Fischedick, O. (1971) Zur Pathologie des Band- und Kapselapparates im Arthrogramm. *Fortschr. Röntgenstr.* **115**, 312—320.

Foucher, E. (1856) Mémoire sur les kystes de la région poplitée. *Arch. gén. Méd.* **8**, 313—335.

Fullerton, A. (1916) The surgical anatomy of the synovial membrane of the knee joint. *Brit. J. Surg.* **4**, 191—200.

Garnier, M. (1890) *Étude sur les kystes poplités,* Thèse de Paris.

Gask and Wilson: Vide Wiles, P., 1949.

Goldscheider, E. (1898) Ein Beitrag zu den Hygromen des Knies. *Brun's Beitr. klin. Chir.* **22**, 169—190.

Goldstein, L. A. and Dickerson, R. C. (1974) *Atlas of orthopaedic surgery.* The Mosby Company, St. Louis.

Grant, B. J. (1962) *An atlas of anatomy.* 5. ed., Williams, Baltimore.

Gray's Anatomy: Descriptive and applied. Vide Johnston and Davis, 1974.

Gribbon, G. C. (1885) Enlargement of the bursa beneath the semimembranosus muscle after injury; suppuration extending to the knee joint; aspiration; amputation; recovery; remarks. *Lancet i,* 427—428.

Gristina, A. G. and Wilson, P. D. (1964) Popliteal cysts in adults and children. A review of 90 cases. *Arch. Surg.* **88**, 357—363.

Gruber, W. (1845) Über die Ausstülpungen der Synovialkapsel des Kniegelenkes und über die chirurgische Wichtigkeit der Communikation derselben mit einigen benachbarten Kniesschleimbeuteln. *Vierteljschr. prakt. Heilk.* **5**, 95—105.

Gruber, W. (1846) *Über die durch Wassersucht bedingte krankhafte Erweiterung des zwischen dem Musculus gastrocnemius internus, dem Musculus semimembranosus und der Kniegelenkskapsel gelagerten Schleimbeutels in chirurgisch-anatomischer, chirurgisch-diagnostischer und operativer Beziehung.* G. Wigand, Leipzig, 1—28.

Gruber, W. (1856) Vorläufige Anzeige der Entdeckung des Processus supracondyloideus ossis femoris internus und der Bursa supracondyloidea genu des Menschen. *Bull phys.-mathém. de l'Acad. Imp. des Sc. de St. Petersbourg* **14**, 267—270.

Gruber, W. (1857) *Die Knieschleimbeutel (Bursae mucosae genuales).* F. Ehrlich, Prag.

Gruber, W. (1865) Zu den hernienartigen Aussackungen der Bursae mucosae ausserhalb ihrer Lagerstätte. I. Hernienartige Aussackung der Bursa mucosa genualis supracondyloidea in die Fossa poplitea von enormer Grösse. *Österreich. Zschr. f. prakt. Heilk.* **11**, 607—611.

Gruber, W. (1869) Hygrom der Bursa mucosa genualis retrocondyloidea interna semimembranoso-gastrocnemialis. *Österreich. Zschr. prakt. Heilk.* **15**, 961—964.

Gruber, W. (1885) Hygrom von enormer Grösse an der Bursa genu mucosa retrocondyloidea interna. *Virchows Arch. path. Anat.* **99**, 489—492.

Hafferl, A. (1969) *Lehrbuch der topographischen Anatomie,* neubearb. von W. Thiel, 3. Auflage, Springer, Berlin-Heidelberg-New York.

Haggart, G. E. (1938) Posterior hernia of the knee joint. A cause of internal derangement of the knee. *J. Bone Jt. Surg.* **20**, 363—373.

Haggart, G. E. (1943) Synovial cysts of the popliteal space: Clinical significance and treatment. *Ann. Surg.* **118**, 438—444.

Hammer, U. (1920) Beiträge zur Kenntnis des Hygroms der Bursa semimembranosa. *Bruns' Beitr. z. klin. Chir.* **118**, 610—626.

Harvey, J. P. and Corcos, J. (1960) Large cysts in lower leg originating in the knee occurring in patients with rheumatoid arthritis. *Arthr. and Rheum.* **3**, 218—228.

Hawkes, F. (1899) Inflammation of the bursa gastrocnemio-semimembranosa. With a report of four cases of enlargement and distention of this bursa treated by excision. *Ann. Surg.* **30**, 61—78.

Heineke, W. (1868) *Die Anatomie und Pathologie der Schleimbeutel und Sehnenscheiden* (Dissertation). A. Deichert, Erlangen.

Hémet, P. (1900) *Contribution à l'étude des kystes poplités.* Thèse, La Faculté de Médicine, Paris.

Henle, J. (1871) *Handbuch der systematischen Anatomie des Menschen.* Band 1: Knochenlehre. 3. Auflage, F. Vieweg, Braunschweig.

Hoffman, B. K. (1963) Cystic lesions of the popliteal space. *Surg. Gynec. Obstet.* **116**, 551—558.

Holmes, T. (1870) *A system of surgery, theoretical and practical in treatises by various authors.* 2nd ed., Longmans, Green and Co., London.

Hooper, J. C. and Brookler, M. (1971) Popliteal cysts and their rupture in the rheumatoid arthritis simulating thrombophlebitis. *Med. J. Aust.* **1**, 1171—1173.

Hort, W. and Mittelmeier (1975) Die Weichteilgeschwülste der Kniekehle. *Z. Orthop.* **113**, 102—110.

Hutton, J. A. (1895) Bursa communicating with the knee joint: excision. *Brit. med. J.* **1**, 417.

Johnston and Davis (1974) *Gray's Anatomy: Descriptive and applied.* 35. ed., Longmans, New York.

Justis, J. (1971) *Affections of fascia and bursae.* In: *Campbell's operative orthopaedics,* 5th ed., ed. by Crenshaw, A. H., The Mosby Company, St. Louis.

Kessler, I. and Silberman, Z. (1960) The development of popliteal cysts; an arthrographic study. *Clin. Orthop.* **18,** 149—156.

Kirmisson, E. F. (1892) *Maladies des membres.* In: Duplay, S. and Reclus, P. *Traité de chirurgie,* Tome 8, G. Masson, Paris.

Kirpilä, J. and Ripatti, N. (1958) On Baker's cyst and its treatment. *Acta rheum. scand.* **4,** 296—302.

Kuhn, H. H. and Hemphill, J. E. (1944) Baker's cyst: Posterior herniation of the knee joint. *Radiology* **42,** 237—240.

Lang, J. and Wachsmuth, W. (1972) *Praktische Anatomie. Ein Lehr- und Hilfsbuch der anatomischen Grundlagen ärztlichen Handelns: Bein und Statik.* 2. Auflage, Springer, Berlin-Heidelberg-New York.

Lapayowker, M. S., Cliff, M. M. and Tourtellotte, C. D. (1970) Arthrography in the diagnosis of calf pain. *Radiology* **95,** 319—323.

Lewin, P. (1952) *The knee joint and related structures. Injuries, deformities, diseases, disabilities.* Lea and Febiger, Philadelphia.

Lindgren, P. G. and Willén, R. (1977) Gastrocnemio-semimembranosus bursa and its relation to the knee joint. I. Anatomy and histology. *Acta radiol. (Stockh.)* **18,** 497—512.

Lindgren, P. G. (1977) — II. Post mortem radiography. *Acta radiol. (Stockh.)* **18,** 698—707.

Lindgren, P. G. (1978) — III. Pressure measurements in joint and bursa. *Acta radiol. (Stockh.)* **19,** 377—388.

Lindgren, P. G. (1978) — IV. Clinical considerations. *Acta radiol. (Stockh.)* **19,** 609—622.

Lindgren, P. G. (1979) Personal communication.

Lindgren, P. G. and Rauschning, W. Clinical and arthrographic studies on the valve mechanism in communicating popliteal cysts. *Arch. Orthop. Traumat. Surg.* (in press).

Longy (1852) *Essai sur le diagnostic des tumeurs du creux poplité.* Thèse de Paris.

Malgaigne, J. F. (1853) Observation des kystes séreux du jarret. *Revue médico-chirurgicale* **14,** 343.

Malloch, J. D. (1970) Popliteal cysts in children. *Brit. J. Surg.* **57,** 616—618.

Mathias, K. (1977) Klinische und arthrographische Aspekte der Poplitealcysten. *Chirurg* **48,** 384—388.

Maudsley, R. H. and Arden, G. P. (1961) Rheumatoid cysts of the calf and their relation to Baker's cysts of the knee. *J. Bone Jt. Surg.* **43-B,** 87—89.

Meire, H. B., Lindsay, D. J., Swinson, D. R. and Hamilton, E. B. D. (1974) Comparison of ultrasound and positive contrast arthrography in the diagnosis of popliteal and calf swellings. *Ann. rheum. Dis.* **33,** 221—224.

Merkel (1907) Handbuch der topographischen Anatomie. Braunschweig. Vide Hammer, U., 1920.

Meyerding, H. W. and van Demark, R. E. (1943) Posterior hernia of the knee (Baker's cyst, popliteal cyst, semimembranosus bursitis, medial gastrocnemius bursitis and popliteal bursitis). *J. Amer. med. Ass.* **122,** 858—861.

Monro, A., secundus (1788) *A description of all the bursae mucosae of the human body.* Elliot, Edinburgh.

Morscher, E. (1957) Semimembranaceuscysten. Vorkommen und Besonderheiten im Kindersalter. *Helv. chir. Acta* **3,** 266—294.

Moser, H. (1950) Traumatische kommunizierende Arthrozele in der Kniekehle. *Zbl. Chir.* **75,** 942—950.

Myles, A. B. (1971) Posterior synovial leaks in arthritis of the knee. *Proc. roy. Soc. Med.* **64,** 262—264.

Nélaton (1851) *Leçon clinique sur les tumeurs de la région poplitée.* (Paris) Vide Hémet, P., 1900.

Ollivier (1855) *Du diagnostic différentiel des tumeurs du creux poplité.* Thèse de Paris.

Oretorp, N. (1978) On the diagnosis and treatment of meniscus and ligament injuries in the knee especially on the medial side. *Linköpings University Medical Dissertations No.* **63.**

Orr, T. G. (1951) *Operations of general surgery.* 2nd ed., W. B. Saunders Comp., Philadelphia and London.

Pallardy, G., Fabre, P., Ledoux-Lebard, G., Renoux, J. P. and Delbarre, F. (1971) Diagnostic des bursites et kystes poplités par arthrographie du genou. *Rev. Rhum.* **38,** 345—360.

Perri, J. A., Rodnan, G. P. and Mankin, H. J. (1968) Giant synovial cysts of the calf in patients with rheumatoid arthritis. *J. Bone Jt. Surg.* **50-A,** 709—719.

Piersol, G. A. (1919) *Human anatomy including structure and development and practical considerations.* 7th ed., J. B. Lippincott Co., Philadelphia-London.

Pinder, I. M. (1973) Treatment of the popliteal cyst in the rheumatoid knee. *J. Bone Jt. Surg.* **55-B,** 119—125.

Pitha, Vide Gruber, W. (1845).

Poirier, P. (1886) Bourses séreuses du genou (région postérieure). Bourses séreuses de la région poplitée. *Arch. gén. Med.,* 539—575.

Power, D. (1885) An account of four cases of intermuscular synovial cysts. *Trans. path. Soc. Lond.* **36,** 337—342.

Power, D. (1887) Further specimens of intermuscular synovial cysts. *Trans. path. Soc. Lond.* **38,** 381—386.

Pulich, J. J. (1975) Asymptomatic popliteal cysts. *J. Amer. Osteopath. Ass.* **75,** 319—323.

Rauber-Kopsch (1955) *Lehrbuch und Atlas der Anatomie des Menschen.* Band 1. 19. Auflage, G. Thieme, Stuttgart.

Rauschning, W. (1979) Serial cryosectioning of human knee-joint specimens for a study of functional anatomy. *Science Tools* **26**, 47—50.

Rauschning, W. and Lindgren, P. G. (1979) Popliteal cysts (Baker's cysts) in adults. I. Clinical and roentgenological results of operative excision. *Acta orthop. scand.* **50**, 583—591.

Rauschning, W. Popliteal cysts (Baker's cysts) in adults. II. Capsuloplasty with and without a pedicle graft. *Acta orthop. scand.* **51** (in press).

Reinhardt, K. (1972) Popliteazysten und popliteogene Unterschenkelzysten. (Bakerzysten). *Radiologe* **12**, 77—86.

Rosenmüller, J. C. (1799) *Alexander Monros Abbildungen und Beschreibungen der Schleimsäcke des menschlichen Körpers (Edinburg 1788),* übersetzt, umgearbeitet und vermehrt herausgegeben. Breitkopf und Haertel, Leipzig.

Sachs, A. E. and Rubinstein, L. (1946) Bilateral popliteal hernia. Case report. *Surgery* **20**, 385—387.

Saegesser, M. (1956) *Spezielle chirurgische Therapie.* 4. Auflage, H. Huber, Bern und Stuttgart.

Sheild, A. M. (1898) Treatment by excision of bursal cysts in connection with the knee joint. *Clin. J.* **11**, 371—375.

Smillie, I. S. (1974) *Affections of the synovial membrane.* In: *Diseases of the knee joint.* Churchill Livingstone, Edinburgh and London.

Solomon, L. and Berman, L. (1972) Synovial rupture of the knee joint. *J. Bone Jt. Surg.* **54-B**, 460—467.

Sonntag, E. (1916—17) Hygrom und Corpora libera der Bursa semimembranosa. (Beitrag zur Pathogenese und Klinik der Schleimbeutelerkrankungen. *Langenbecks Arch. klin. Chir.* **107—108**, 245—280.

Synnestvedt, A. S. D. (1869) En anatomisk beskrivelse af de paa over- og underextremiteterne forekommende bursae mucosae, støttet paa egne iakttagelser og ledsaget af tegninger efter udførte praeparater. Thesis, Christiania.

Taylor, A. R. and Rana, N. A. (1973) A valve. An explanation of the formation of popliteal cysts. *Ann. rheum. Dis.* **32**, 419—421.

Testut, L. and Jacob, O. (1909) *Traité d'anatomie topographique avec applications médico-chirurgicales.* 2 ème édition, Octave Doin et fils, Paris.

Tillaux, P. (1892) *Traité d'anatomie topographique avec applications à la chirurgie.* Asselin et Houzeau, Paris.

Touloukian, R. J. (1971) Popliteal cysts in childhood. *Surgery* **69**, 629—632.

Ullberg, S. (1954) Studies on the distribution and fate of S^{35}-labelled benzylpenicillin in the body. *Acta radiol. (Stockh.) Suppl.* **118**, 1—110.

Ullberg, S. (1977) The technique of whole body autoradiography. Cryosectioning of large specimens. *Science Tools,* Special issue, 2—29.

Ullberg, S. (1979) Personal communication.

Vahvanen, V. (1973) Popliteal cyst. A follow-up study on 42 operatively treated patients. *Acta orthop. scand.* **44**, 303—310.

Wieser, C., Steiger, U. and Zinn, W. (1967) Zystische Pseudotumoren der Kniekehle im Kniearthrogramm. *Radiol. clin.* **36**, 333—336.

Wiles, P. (1949) *Essentials of orthopaedics.* J. & A. Churchill, London

Wilson, P. D., Eyre Brook, A. L. and Francis, J. D. (1938) A clinical and anatomical study of the semimembranosus bursa in relation to popliteal cyst. *J. Bone Jt. Surg.* **20**, 963—984.

Wolfe, R. D. and Coloff, B. (1972) Popliteal cysts. An arthrographic study and review of the literature. *J. Bone Jt. Surg.* **54-A**, 1057—1063.