Arch Orthop Trauma Surg (2013) 133:1047–1053
DOI 10.1007/s00402-013-1770-1

ORTHOPAEDIC SURGERY

Pigmented villo-nodular synovitis and giant-cell tumor of tendon sheaths: a binational retrospective study

Juergen Bruns · V. Ewerbeck · M. Dominkus · R. Windhager · J. Hassenpflug · H. Windhagen · L. Hovy · J. Loehr · R. Krauspe · H. R. Duerr

Received: 25 December 2012 / Published online: 17 May 2013

Abstract
Aim Pigmented villonodular synovitis is rare. Thus, we initiated a retrospective multi-center study regarding symptoms, location, type of disease, type of surgery, number of recurrences, use of adjuvant therapies and functional outcome.
Results Ten centers contributed. Data from 173 patients were sampled. The disease was seen predominantly in joints, less frequently in tendon sheaths and bursae. Patients with articular lesions suffered mainly from the diffuse type. In tendon sheaths, the relation "diffuse versus nodular" was nearly 50 % each, in bursae most often the nodular type was found. Anatomically, mostly the knee was affected. Institutions with more than 20 patients had a lower rate of recurrence than those with less than 20 cases. Regarding the knee, there were less recurrences in joints treated with open synovectomy than in those treated arthroscopically.
Conclusions Since the rate of recurrence has been rather high, the use of adjuvant treatments (radiosynoviorthesis or radiotherapy) is recommended. In our study, the rate of their application was quite low. Patients who received an adjuvant therapy after primary surgery did not show

Investigation performed for the "Arbeitsgemeinschaft 4: Tumoren des Haltungs- und Bewegungsapparates" of the German Society of Orthopedics and Orthopaedic Surgery (DGOOC).

J. Bruns (✉)
Diakonieklinikum Hamburg, Hohe Weide 17, 20259 Hamburg, Germany
e-mail: j.bruns@d-k-h.de

V. Ewerbeck
Department of Orthopedic Surgery I, University of Heidelberg, Schlierbacher Landstr. 200 a, 69118 Heidelberg, Germany
e-mail: Volker.Ewerbeck@ok.uni-heidelberg.de

M. Dominkus · R. Windhager
Department of Orthopedic Surgery, University Hospital Viena, Währinger Gürtel 18–20, 1090 Wien, Austria
e-mail: martin.dominkus@meduniwien.ac.at

R. Windhager
e-mail: reinhard.windhager@meduniwien.ac.at

R. Windhager
Department of Orthopedic Surgery, University of Graz, Graz, Austria

J. Hassenpflug
Department of Orthopedic Surgery, University Schleswig–Holstein, Campus Kiel, Michaelisstr. 1, 24105 Kiel, Germany
e-mail: joachim.hassenpflug@uksh-kiel.de

H. Windhagen
Department of Orthopedic Surgery Medizinische Hochschule Hannover, im Diakoniekrankenhaus Annastift, Anna-von-Borries-Straße 1–7, 30625 Hannover, Germany
e-mail: henning.windhagen@ddh-gruppe.de

L. Hovy
Department of Orthopedic Surgery, University of Frankfurt-Friedrichsheim, Marienburgstraße 2, 60528 Frankfurt am Main, Germany
e-mail: l.hovy@friedrichsheim.de

L. Hovy
Department of Orthopedic Surgery III, Annastift, Hannover, Germany

J. Loehr
Department of Orthopedic Surgery, University of Schleswig–Holstein Campus, Luebeck, Germany

R. Krauspe
Department of Orthopedic Surgery, University of Duesseldorf, Moorenstr. 5, 40225 Düsseldorf, Germany
e-mail: Krauspe@med.uni-duesseldorf.de

any recurrence. In 14 % of patients in whom an adjuvant therapy had been used, after at least one recurrence, further recurrences were observed. Functional results were excellent in 84 % of patients.

Level of evidence Prognostic multi-center study, Level III.

Keywords Pigmented villonodular synovitis · Teno-synovial giant cell tumor · Treatment · Results · Surgery · Radiosynoviorthesis · Radiotherapy

Introduction

Pigmented villonodular synovitis (PVNS) (nodular and diffuse lesions) and giant cell tumors of tendon sheaths (GCTTS) are a benign disease of the synovial tissue. Most cases of diffuse PVNS are located in the knee and hip joint, whereas GCTTS are seen mainly in tendon sheaths of the hand [1, 2].

PVNS and GCTTS occur most often in young adults, but the lesion has also been observed in children and adolescents [3]. Symptoms are non-specific. The incidence is estimated to be 9.2 cases per million for GCT, 1.8 [4] per million for PVS. For diagnosis X-rays and MRI are recommended [5, 6, 14].

Complete surgical resection is the treatment of choice [1, 6, 7] and therapy is simple in nodular lesions. Complete resection is somewhat problematic in cases with a diffuse spread, owing to the anatomical conditions of the joints involved. As a result, the rate of recurrence (ROR) is relatively high. However, as the disease is so rare, even large institutions have had very little experience with its treatment. Reports with more than 50 patients are few and, to our knowledge, only one prospective study has compared different therapeutical criteria [8].

Consequently, the Task Force Group for Musculoskeletal Tumors (Arbeitsgemeinschaft Muskuloskeletale Tumoren, DGOOC) of the German Orthopaedic Society initiated a retrospective study to sample a sufficient number of patients suffering from PVNS.

Materials and methods

A standardized questionnaire was sent to all contributing hospitals in Germany and Austria. Questions about location of the disease, duration of symptoms, affected joint or other synovial structure, surgical treatment and adjuvant therapy, outcome and, in particular, number of recurrences and number of patients treated between 1980 and 2002 were asked.

Results

We could sample data from 173 patients treated in 10 orthopedic departments in Germany and Austria. The mean number of patients per institution was 17.3 (range 1–54). In 4 of the 10 institutions, more than 20 patients had been treated. In all, there were 71 (41 %) male patients with a mean age of 35 years and 102 (59 %) female patients with a mean age of 43.1 years. The distribution of age and gender is shown in Fig. 1.

Regarding the anatomical localization, the disease was found mostly in joints (75 %), followed by tendon sheaths (21 %) and bursae (4 %). In joints the disease exhibited more the diffuse (64 %) than the nodular type (36 %). In tendon sheaths the distribution—diffuse versus nodular—was nearly equal (47 vs. 53 %), whereas in bursae the disease was usually diffuse (86 %) rather than nodular (14 %).

Regarding the anatomical regions, the knee joint (56 %) was the most affected, followed by a lesser involvement of the hand (14 %) and the ankle and subtalar joint (9 %) (Table 1). In the hip region, the joint itself was involved in all 11 cases. In the knee and ankle regions, mostly the joint itself was involved (92/97, 15/16). Only in a few patients were tendons and bursae involved in contrast to the hand region and tendon sheaths showed most of the lesions (22/25).

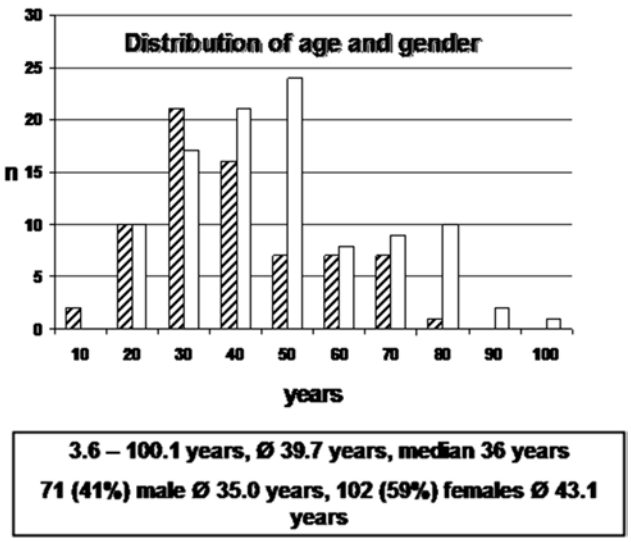

Fig. 1 Age and gender distribution of the patients

H. R. Duerr
Department of Orthopedic Surgery, Ludwig-Maximilian-University Munich, Marchioninistr. 15, 81377 Muenchen, Germany
e-mail: hans_roland.duerr@med.uni-muenchen.de

Table 1 Localization of disease

Knee	97	56 %
Hand	25	14 %
Ankle/subtalar jt.	16	9 %
Hip joint	11	6 %
Elbow	7	4 %
Shoulder	5	3 %
Foot	7	4 %
Others	1	1 %
Missing data	4	3 %

Regarding the distribution—diffuse versus nodular—, the ratio was 82 versus 18 % in the hip joint, 62 versus 38 % in the knee joint and 67 versus 33 % in the ankle and subtalar joint. However, in the hand region mostly the nodular form was found (64 vs. 36 %).

Symptoms

The median duration of symptoms was 12.7 years with a wide range (6 days–52 years). Most of the patients suffered from pain (87 %), swelling (66 %) and/or a reduced range of motion (41 %). If an osteolytic lesion was present, the rate of patients suffering from pain increased from 84 to 93 % and the rate of limited range of motion from 58 to 93 %.

Diagnostic procedures

Diagnostically, radiographs were used in 151 cases (87 %) and MRI in 90/161 cases (56 %). Less frequently a CT (10/155) or an arthrography (5/144 = 3 %) was carried out. Owing to the long study period, the use of MRI slowly replaced other diagnostic methods (Fig. 2).

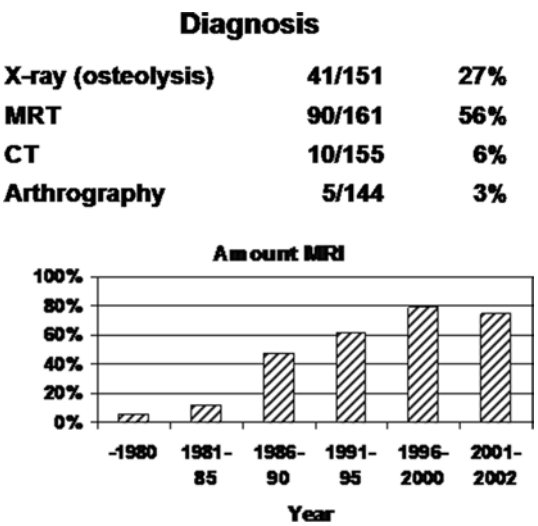

Fig. 2 The used diagnostic tools

Table 2 Type of surgical therapy

Arthrotomy with or without synov.[a]	78	45.0 %
Arthroscopy with or without synov.[a]	20	11.6 %
Excision/resection/curettage[a]	47	27.2 %
Synovectomy[a]	9	5.2 %
Endoprosthesis[a]	9	5.2 %
Biopsy	7	4.0 %
No answer	3	1.7 %

[a] No further differentiation

Osseous lesions

Major osseous lesions which were detectable with X-rays were seen in 41/151 patients (27 %); minor lesions, probably detectable only in tomographies (MRI and CT), were not counted.

Therapy

The surgical treatment procedures are listed in Table 2. Adjuvant treatment had been used in 26/152 patients (17 %), this usually being radiosynoviorthesis (RSO) (65 %) followed by radiation therapy (RT) (31 %); in 4 % of cases phenol was applied intraoperatively for osteolytic lesions. These procedures were used more often in recurrent (62 %) than in primary forms of the disease (38 %).

Recurrence

The most striking result was that the ROR was dependent on the number of cases treated in a single institution. At the end of the study, those institutions which had treated at least 20 patients had a distinctly lower ROR (27.8 %, range 15–37 %) than those with less than 20 patients (56 %) (Table 3).

The ROR was also dependent on the *type of disease*; in nodular lesions the mean ROR was 20 % (in articular

Table 3 Recurrence depending on the single institution

Recurrence (including also recurrent cases)	51/162	31.5 %
Institutions with more than 20 cases (79 % of all cases)		
Hospital A	30 %	
Hospital B	15 %	
Hospital C	37 %	
Hospital D	29 %	
Institutions with less than 20 cases (missing data in 11 cases)		56 %

Table 4 Recurrence rate depending on the type of disease

	Total		Circumscript (%)	Diffuse (%)
Joints	127	34 %	24	38
Tendons	34	29 %	7	50
Bursae	7	0 %	0	0
			20	39

	With	Without
Osteolysis	34	26
Pain	42	29
Swelling/joint effus.	52	17

lesions it was 24 %, in tendon sheaths 7 % and in bursae 0 %). In diffuse type of disease, the ROR was 38 % in articular lesions, 50 % in tendon sheaths and 0 % in bursae (Table 4). The ROR in cases who had already developed one recurrence was not reduced to zero after a second surgery but, with repeated surgeries, the ROR could be reduced from 38 to 1 %.

Regarding the *anatomical site*, the ROR was found to be highest in the hip joint (50 %) and lowest in the feet (1 %) (Table 5).

Comparison of the two *principal surgical procedures* in the knee joint (arthrotomy vs. arthroscopy) exhibited that the ROR was distinctly higher after arthroscopy than after arthrotomy (69 vs. 25 %).

The overall rate of application of *adjuvant therapeutic tools* was relatively small (17 %): those patients ($n = 10$) who were additionally treated with either RSO or RT after the primary occurrence did not exhibit any recurrence. In contrast, 86 % of those patients with a recurrent disease in whom RSO or RT had been applied, after at least the first recurrence ($n = 16$), were free from any further recurrence.

Functional results

In nearly 85 % of the patients, an excellent or good functional result could be detected (Fig. 3).

Table 5 Recurrence rate depending on the localization

	Total	Recurrence	
	N	*N*	%
Knee joint	90	29	32
Hand	22	7	32
Ankle/subtalar jt.	16	3	19
Hip joint	10	5	50
Elbow	7	2	29
Foot	7	1	14

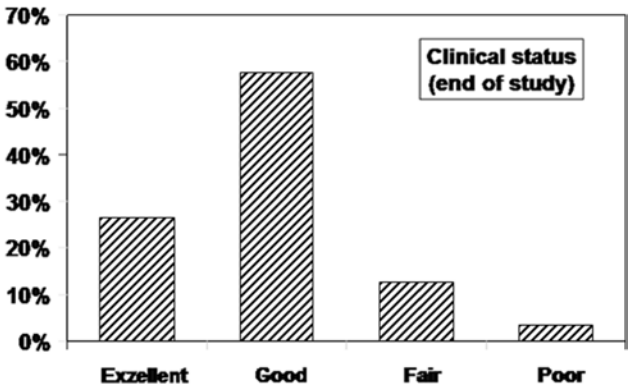

Fig. 3 The graph shows the distribution of the functional results

Discussion

Owing to the rarity of the disease, the main purpose of the study was to sample a sufficient number of cases to give relevant therapeutical recommendations. The rarity does not allow prospective single- or multi-center studies within an acceptable period of time (Fig. 4).

Recurrence was the most important concern. Our major result was that the ROR was lower in institutions which had treated more than 20 patients; institutions with less than 20 cases had a distinctly higher ROR. This indicates that this disease should be treated in a center and/or by a surgeon experienced with its treatment.

We found a high ROR in *nodular cases* as well as in affected tendon sheaths. The ROR should be zero or near to it, at least in joints with a nodular PVNS, and marginal

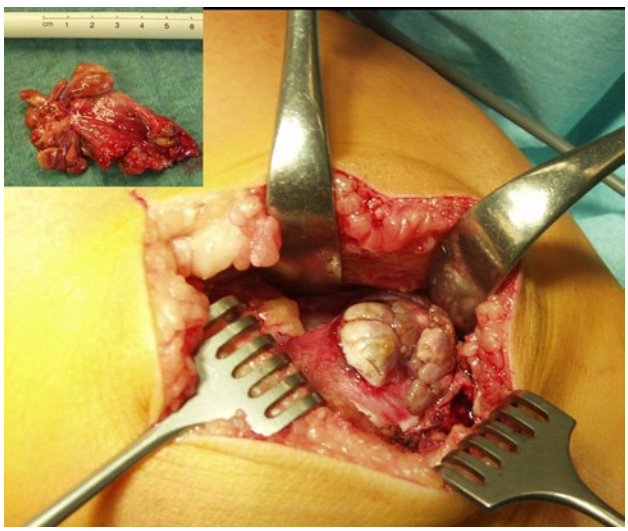

Fig. 4 Clinical case of a circumscript pigmented villonodular synovitis located in the superior recessus of the knee; *small inset* shows surgical resection specimen

excision is recommended [5, 6, 9–19]. The ROR of GCTTS was 8 % [30]. Sharma and Cheng [20] reported a recurrence-free survival of 91 % for the localized type versus 70 % for the diffuse type after 2 years and a recurrence-free survival of 73 and 48 %, respectively, after 5 years. Kim et al. [6] did not observe any recurrence after a follow-up of 30 months in 11 cases treated arthroscopically. Chiari et al. [10] noted a recurrence-free survival 1 year after surgery in digits rather than in large joints. Recurrence is due to incomplete resection [1, 2, 13, 21].

The *diffuse type* is more difficult to treat. The necessity of a complete synovectomy is demonstrated by Sharma and Cheng [20] surveilling 49 patients. They compared an arthroscopic partial synovectomy with a complete open synovectomy, using an anterior and posterior approach to the knee, and found a highly significant, better recurrence-free survival for the open procedure in knee joints [20]. Ogilvie-Harris et al. [17] compared partial with complete arthroscopic synovectomies and found a lower ROR after complete as opposed to partial synovectomy.

In our study, a combined anterior and posterior open synovectomy was found to be followed by a distinctly lower ROR than after arthroscopic synovectomy. In addition, Blanco et al. [8] observed after 1 year a clinically, ultrasound-detected ROR of 14 % following an anterior arthroscopic partial synovectomy combined with postoperative radiation therapy. Recurrence was most frequent in the knee and in patients with recurrences [19]. The cumulative ROR was significantly higher after incomplete as opposed to complete synovectomies [19].

The ROR also seems to depend on the *anatomical region*. We found the highest ROR in the hip joint and lowest one in the foot. To achieve a complete synovectomy in the hip joint, a surgical dislocation or even the implantation of a total hip arthroplasty is necessary [21–23]. Thus, implantation of a total arthroplasty is recommended and results in a lower ROR than after an incomplete synovectomy without disarticulation [7, 19, 21, 24].

After *arthroscopic resection* in the knee joint, the ROR was distinctly higher than after *open synovectomy*. Similar statements are given by Tyler et al. [25] and De Ponti et al. [26]. They noted a lower ROR and had better clinical results after an extended arthroscopic synovectomy using 4–5 portals. Schwartz et al. [19] reported a cumulative ROR of 7.1 % after 1 year, 15 % after 5 years, 27 % after 10 years and 31 % after 15 years. Recently, Liu et al. [27], after an average follow-up time of 22 months, found a ROR in PVNS treated with arthroscopic resection of 13.6 %. Sharma and Cheng [20] reported a recurrence-free survival of 95 % following open synovectomies, as compared to a recurrence-free survival of 62 % after 2 years and 71 versus 41 % after 5 years following arthroscopy.

In our study, only 17 % of all cases underwent *adjuvant therapy*. Radiotherapy (RT) and RSO [28–30] are recommended, the overall number of patients treated with either RSO or RT remains small.

For RSO mostly 90-Yttrium [31–33] has been used. Chin et al. [34] applied 165-dysprosium-ferric-hydroxia macro-aggregates. Shabat et al. [33] and Chin et al. [34] reported the largest number of 10/40 patients who received RSO. Nine of these patients had suffered no recurrence of the tumor and, in one patient, the disease had remained stable. Chin et al. [34] treated 30 patients who received postoperatively 165-dysprosium, 40 % suffered from recurrence. Similar results have been reported by Ward et al. [35] on RSO using 32-P. Zook et al. [36] found three recurrences of nine patients also treated with 32-P. Complications were reported by Bickels et al. [37]: From seven patients, two suffered from skin necroses.

RT has the advantage of being also applicable in patients with extra-articular spread. Chin et al. [34] reported on three groups of patients. The ROR was zero in patients treated with surgery alone, 17 % in those who received RSO and 40 % in those treated with RT.

RT, like RSO, seems to have a similar influence on the ROR. There are a few papers with a small number of patients, the groups being heterogenous regarding history, localization, primary or recurrent disease and treatment [29, 34, 38, 39]. The ROR in all groups ranged from 0 % [38] to 40 % [34]. Only two papers reported on a larger group: Blanco et al. [8] had treated patients with only a partial anterior arthroscopic synovectomy with additional small radiation dose and found a ROR of 13.7 %. O'Sullivan et al. [29], reporting on 14 patients suffering from an intra- and extra-articular disease observed quite good results after a mean follow-up of 69 months. Similar results were found in a multi-center study [40]. This study analyzed 41 patients on whom either a primarily incomplete resection was performed or who suffered from recurrence. Local control was achieved in 95.1 %.

Functional results have been reported by several authors. Comparison is difficult owing to different scores and heterogenous groups. Arthroscopic treatment has been reported by Liu et al. [27]. The Lysholm score and the IKDC score increased significantly after treatment. Dines et al. [12] reported on a long-term follow-up (65.8 months) of 10/26 patients who had been treated either arthroscopically or with an arthrotomy for nodular PVNS in the knee with six excellent and one good result (Lysholm-Score). After open synovectomy and adjuvant RT, Wu et al. [39] reported a distinct postoperative improvement. Similar results using different scores were reported by Horoschak et al. [41], Heydt et al. [40], and de Visser et al. [11].

References

1. Goldmann AB, Di Carlo EF (1988) Pigmented villonodular synovitis: diagnosis and differential diagnosis. Radiol Clin North Am 26(6):1327–1347
2. Klompmaker J, Veth RPH, Robinson PH, Molenaar WM (1990) Pigmented villonodular synovitis. Arch Orthop Trauma Surg 109:205–210
3. Bruns J, Schubert T, Eggers-Stroeder G (1993) Pigmented villonodular synovitis in children. A case report. Arch Orthop Trauma Surg 112:148–151
4. Myers BW, Masi AT (1980) Pigmented villonodular synovitis and tenosynovitis. Medicine 59:223–238
5. Flandry FC, Hughston JC, McCann SB, Kurtz DM (1994) Diagnostic features of diffuse pigmented villonodular synovitis of the knee. Clin Orthop Relat Res 300:212–220
6. Kim SJ, Shin SJ, Choi NH, Choo ET (2000) Arthroscopic treatment for localized pigmented villonodular synovitis of the knee. Clin Orthop Relat Res 379:224–230
7. Hamlin BR, Duffy GP, Trousdale RT, Morrey BF (1998) Total knee arthoplasty in patients who have pigmented villonodular synovitis. J Bone Joint Surg Am 80:76–82
8. Blanco CE, Leon HO, Guthrie TB (2001) Combined partial arthroscopic synovectomy and radiation therapy for diffuse pigmented villonodular synovitis of the knee. Arthroscopy 17:527–531
9. Byers PD, Cotton RE, Deacon OW, Lowry M, Newman PH, Sisson HA, Thompson AD (1968) The diagnosis and treatment of pigmented villonodular synovitis. J Bone Joint Surg Br 50:290–305
10. Chiari C, Pirich C, Brannath W, Kotz R, Trieb K (2006) What effects the recurrence and clinical outcome of pigmented villonodular synovitis? Clin Orthop Relat Res 450:172–178
11. de Visser E, Pruszcynski M, Wobbes T, Van de Putte LB (1999) Diffuse and localized pigmented villonodular synovitis evaluation of treatment of 38 patients. Arch Orthop Trauma Surg 119:401–404
12. Dines JS, DeBerardino TM, Wells JL, Dodson CC, Shindle M, DiCarlo EF, Warren RF (2007) Long-term follow-up of surgically treated localized pigmented villonodular synovitis of the knee. Arthroscopy 23:930–937
13. Flandry FC, Hughston JC (1987) Current concepts review: pigmented villonodular synovitis. J Bone Joint Surg Am 69:942–949
14. Flandry FC, Hughston JC, Jacobson KE, Barrack RL, McCann SB, Kurtz DM (1994) Surgical treatment of diffuse pigmented synovitis of the knee. Clin Orthop Relat Res 300:183–192
15. Granowitz SP, D'Antonio J, Mankin HL (1976) The pathogenesis and long-term results of pigmented villonodular synovitis. Clin Orthop Relat Res 114:335–351
16. Mendenhall WM, Mendenhall CM, Reith JD, Scarborough MT, Gibbs CP, Mendenhall NP (2006) Pigmented villonodular synovitis. Am J Clin Oncol 29:548–550
17. Ogilvie-Harris DJ, McLean J, Zarnett MJ (1992) Pigmented villonodular synovitis of the knee. The results of arthroscopic synovectomy, partial arthroscopic synovectomy and arthroscopic local excision. J Bone Joint Surg Am 74:119–123
18. Rao AS, Vigorita VJ (1984) Pigmented villonodular synovitis (giant cell tumor of the tendon sheath and the synovial membrane). A review of eighty-one cases. J Bone Joint Surg Am 66:76–94
19. Schwartz HS, Unni KK, Pritchard DJ (1989) Pigmented villonodular synovitis. Clin Orthop Relat Res 247:243–255
20. Sharma V, Cheng EY (2009) Outcomes after excision of pigmented villonodular synovitis of the knee. Clin Orthop Relat Res 467:2852–2858
21. Vastel L, Lambert P, De Pinieux G, Charrois O, Kerboull M, Courpied JP (2005) Surgical treatment of pigmented villonodular synovitis of the hip. J Bone Joint Surg Am 87(5):1019–1024
22. Cotten A, Flipo RM, Chastanet P, Desvigne-Noulet MC, Duquesnoy B, Delcambre B (1995) Pigmented villonodular synovitis of the hip: a review of radiographic features in 58 patients. Skeletal Radiol 24:1–6
23. Della Valle AG, Piccaluga F, Potter HG, Salvati EA, Pusso R (2001) Pigmented villonodular synovitis of the hip. Clin Orthop Relat Res 388:187–199
24. Yoo JJ, Kwon YS, Koo KH, Yoon KS, Min BW, Kim HJ (2009) Cementless total hip arthroplasty performed in patients with pigmented villonodular synovitis. J Arthroplasty 25:552–557
25. Tyler WK, Vidal AF, Williams RJ, Healey JH (2006) Pigmented villonodular synovitis. J Am Acad Orthop Surg 14:376–385
26. De Ponti A, Sansone V, Malcherè M (2003) Result of arthroscopic treatment of pigmented villonodular synovitis of the knee. Arthroscopy 19:602–607
27. Liu C, Zhao J, Chen L (2009) Clinical results of arthroscopic treatment for localized pigmented villonodular synovitis of knee. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 23:1042–1044
28. Gumpel JM, Shawe DJ (1991) Diffuse pigmented villonodular synovitis: non-surgical management. Ann Rheum Diss 50:531–533
29. O'Sullivan B, Cummings B, Catton C, Bell R, Davis A, Fornasier V, Goldberg R (1995) Outcome following radiation treatment for high-risk pigmented villonodular synovitis. Int J Radiat Oncol Biol Phys 32:777–786
30. Wiss DA (1982) Recurrent villonodular synivitis of the knee. Successful treatment with Yttrium-90. Clin Orthop Relat Res 169:139–144
31. Kampen WU, Voth M, Pinkert J, Krause A (2007) Therapeutic status of radiosynoviorthesis of the knee with yttrium [^{90}Y] colloid in rheumatoid arthritis and related indications. Rheumatology 46:16–24
32. O'Sullivan MM, Yates DB, Pritchard MH (1987) Yttrium 90 synovectomy—a new treatment of villonodular synovitis [letter]. Br J Rheumatol 26:71–72
33. Shabat S, Kollender Y, Merimsky O, Flusser G, Nyska M, Meller I (2002) The use of surgery and yttrium 90 in the management of extensive and diffuse pigmented villonodular synovitis of large joints. Rheumatology 41:1113–1118
34. Chin KR, Barr SJ, Winalski C, Zurakowski D, Brick GW (2002) Treatment of advanced primary and recurrent diffuse pigmented villonodular synovitis of the knee. J Bone Joint Surg Am 84:2192–2202
35. Ward WGS, Boles CA, Ball JD, Cline MT (2007) Diffuse pigmented villonodular synovitis: preliminary results with intralesional resection and P32 synoviorthesis. Clin Orthop Relat Res 454:186–191
36. Zook JE, Wurtz DL, Cummings JE, Cardenes HR (2011) Intra-articular chromic phosphate ((32)P) in the treatment of diffuse pigmented villonodular synovitis. Brachytherapy 10(3):190–194
37. Bickels J, Isaakov J, Kollender Y, Meller I (2008) Unacceptable complications following intra-articular injection of yttrium 90 in the ankle joint for diffuse pigmented villonodular synovitis. J Bone Joint Surg Am 90(2):326–328
38. Berger B, Ganswindt U, Bamberg M, Hehr T (2007) External beam radiotherapy as postoperative treatment of diffuse pigmented villonodular synovitis. Int J Radiat Oncol Biol Phys 67:1130–1134
39. Wu CC, Pritsch T, Bickels J, Wienberg T, Malawer MM (2007) Two incision synovectomy and radiation treatment for diffuse pigmented villonodular synovitis of the knee with extra-articular component. Knee 14(2):99–106

40. Heydt R, Micke O, Berger B, Eich HT, Ackermann H, Seegenschmiedt MH (2010) Radiation therapy for treatment of pigmented villonodular synovitis: results of a national patterns of care study. Int J Radiat Oncol Biol Phys 78:199–204

41. Horoschak M, Tran PT, Bachireddy P, West RB, Mohler D, Beaulieu CF, Kapp DS, Donaldson SS (2009) External beam radiation therapy enhances local control in pigmented villonodular synovitis. Int J Radiat Oncol Biol Phys 75(1):183–187