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Original Article

Revised histopathological consensus classification of joint implant related pathology

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ABSTRACT

This extended classification of joint implant related pathology is a practical histopathologic classification based on defined morphological criteria covering the complete spectrum of pathohistologic changes in periprosthetic tissues. These changes may occur as a consequence of endoprosthetic replacement of large joints and may lead to a reduction in the prosthesis survival rate. We describe the established consensus classification of the periprosthetic membrane, in which aseptic and septic prosthetic loosening can be subdivided into four histological types, as well as histopathological criteria for additional significant pathologies including endoprosthetic-associated arthrofibrosis, particle-induced immunological, inflammatory and toxic mechanisms (adverse reactions), and bone tissue pathologies. These characteristic tissue alterations and their relationships are summarized in the extended classification. Since particle

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Periprosthetic infection
Particle disease
Endoprosthesis material
Particle identification
Arthrofibrosis
Adverse reactions
Joint arthroplasty registers

heterogeneity in periprosthetic tissue is high and particle identification is a necessary part of diagnosis, the identification of different types of particles is described in the histopathological particle algorithm. The morphological qualities of prosthetic material particles and the demarcation between abrasion and non-abrasion endogenous particles are also summarized. This feasible classification which is based on low cost standard tissue processing and examination and on well-defined diagnostic criteria is a solid platform for the histological diagnosis of implant associated pathologies providing a stable and reproducible tool for the surgical pathologist. Since this classification is suitable for standardized histopathological diagnostics, it might also provide a useful data set for joint arthroplasty registers, particularly for registers based on so-called routine data.

Introduction

Implant loosening and functional failure of artificial hip and knee replacement have significant clinical implications. North American and European studies show implant survival rates between 88% and 94% after ten years [2,3,13,16], which have improved lately to up to 97% [8]. Considering the predicted increase in these procedures in the future, an increased revision burden has to be anticipated. The German National Headquarters for Quality Management gGmbH was able to post about 38,000 replacements each year (info.bqs-online.de). This suggests a revisions burden (the proportion of revision operations and the total number of joint replacements) for total hip replacements of about 11% for Germany [15]. Similar frequencies are observed in other countries, especially regarding infectious cases which carry considerable weight on the economic burden of joint athroplasty [26]. A consensus classification of the periprosthetic membrane and neo-synovium (formerly called "synovial-like interface membrane") presented at the national level in 2004 and at the international level in 2006 classifies the etiology of aseptic and septic implant failures through easily reproducible histopathological criteria [35,36]. The classification has gained international recognition, e.g. in the latest AFIP Atlas on Non-tumor Pathology [24].

Since there are further important phenomena that affect implant function such as endoprothesis associated arthrofibrosis (EAF), bone pathologies and particle associated immunologic as well as inflammatory reactions, and since particle identification is crucial especially to this respect, it has been considered necessary to broaden the classification and to include criteria for morphologic particle identification [27]. All of these peri-implant tissue alterations and their relationships are summarized in the extended classification of joint endoprosthesis pathology (Diagram 1), intended as a feasible classification based on low cost standard tissue processing and on defined criteria [27,34–37,50,58] helping to clarify implant associated pathologies and to identify particles by standard histological examination (Diagram 2) providing a stable and reproducible diagnostic tool for the surgical pathologist.

Pathogenesis of the periprosthetic tissues

There are two areas of interest for pathologists when analyzing changes secondary to joint implants [35]. The first is the joint cavity itself which originally was lined by a synovial membrane, which within the scope of the primary implantation might have been partly or completely removed (synovectomy). Post-operatively, either synovium or a new layer of tissue, the neo-synovium, is formed. The second is mostly represented by the interface between the implant and the bone. Depending on the type of surface coating of the implant and the bony ingrowth into this surface, there can be a thin connective tissue layer between the bone and the implant, which is defined as the periprosthetic membrane [4,5].

The histologic patterns of joint endoprothesis particle disease

Material particle disease describes the process of macrophage activation with consequential release of pro-inflammatory mediators secondary to phagocytosis of metal, polymers or ceramic wear particles [13,21,41]. This leads to the accumulation of macrophages and multinuclear giant cells in the neo-synovium as well as the periprosthetic membrane, which can cause periprosthetic osteolysis [5,14,17,19,31,48,49] (Fig. 1a). In the absence of infection this process ultimately will lead to aseptic loosening. Recent introduction of the metal-on-metal bearing surfaces, modular metallic sleeve adapters, and dual modular necks have contributed to the generation of a new class of particles classified as corrosion products. Of particular importance are the head-neck-stem connections because they can be used with any bearing surface. Corrosion can be caused by multiples mechanisms, such as crevice, fretting and galvanic processes. The size and composition of the particles can vary depending on specific implant composition and biomechanical factors [20].

The histologic patterns of peri-implant infection

Contamination during the initial surgery or secondary hematogenous spread to the implant are the most likely reasons for deep implant infection, and multidisciplinary strategies have been defined for diagnosis [9,11,42–44,58] and sufficient therapies [43]. Depending on the quantity and quality of bacteria encountered the clinical presentations is either an acute infection or an indolent low-grade infection. Acute infections usually require a virulent organism and a considerable bacterial load inside the joint and show a very typical histological picture of an acute inflammation. In contrast bacterial contamination with a small bacterial load or a non-virulent organism (low-grade infection) may have minimal symptoms. Various rod-shaped or coccoid bacteria, especially the so-called small colony variants [31] of the staphylococcus, are responsible for low-grade infections. The diagnosis of this type of infection can be difficult since cultures are frequently negative or require several weeks before turning positive [40]. The most common bacterial pathogens identified in deep implant infection are coagulase-negative staphylococci, including primarily *Staphylococcus epidermidis*, and *Staphylococcus aureus* [33,54]. *Staphylococcus aureus* is responsible for approximately 22% and coagulase-negative staphylococci for approximately 12% of all deep implant infections [30]. Infections secondary to streptococcus subspecies, enterococcus subspecies, *Proteus mirabilis*, *Bacteroides fragilis*, *Pseudomonas aeruginosa*, *Propionobacterium* subspecies, *Corynebacterium* subspecies or other gram-negative rods are less common [54]. Propionobacteria seem to be a frequent cause in periprosthetic infections after shoulder arthroplasty [47]. In addition, infections with vancomycin-resistant enterococci (VRE) are gaining significance [12]. Fungal and mycobacterial infections

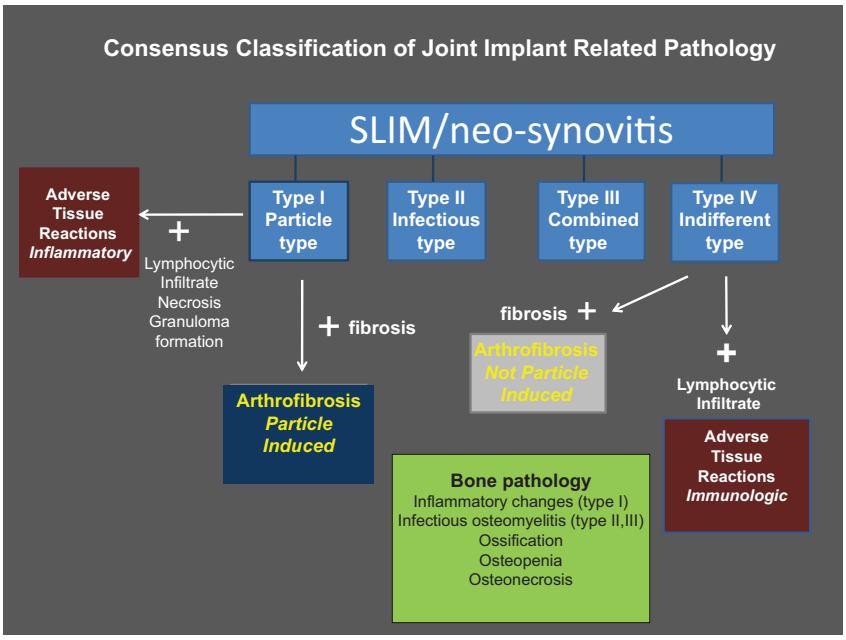

Diagram 1. Comprehensive chart of the extended consensus classification.

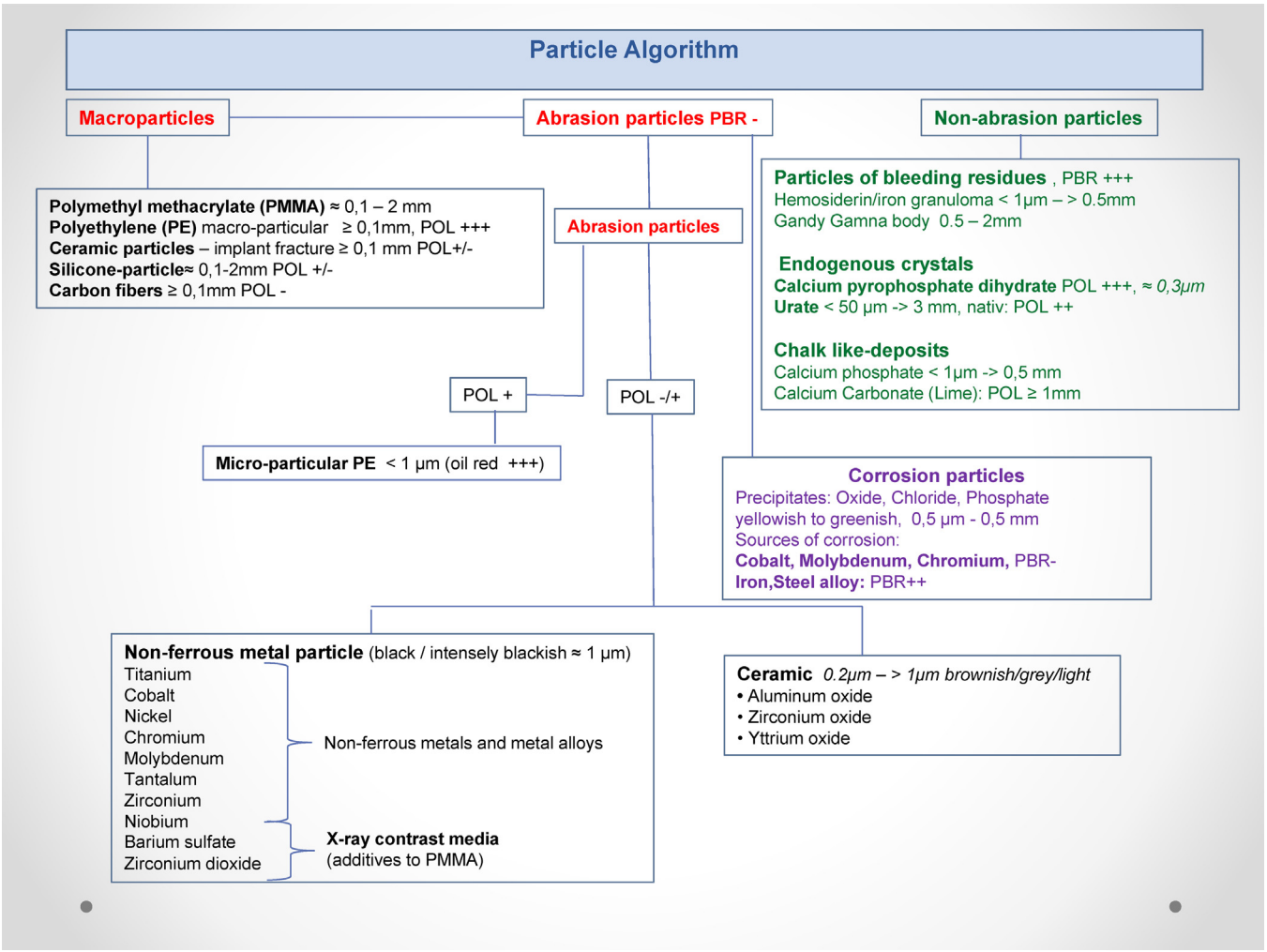

Diagram 2. Histopathological particle algorithm.

are very rare [1,32]. The Musculoskeletal Infection Society (MSIS) published a definition for periprosthetic joint infections in 2011 in order to align the already existing and partly contradictory classifications [42]. These criteria and the diagnostic criteria defined at the International conference of periprosthetic infection [44,58] are the basis for the current extended consensus classification in respect to infectious tissue alterations.

Histopathological diagnostics and classification of implant failure

Periprosthetic tissue sampled during revision surgery is usually fixed in formalin and processed for standard histopathological examination [35]. The joint cavity communicates with the periprosthetic space, so that the histological changes in both the periprosthetic membrane and the neo-synovium are often comparable [4,40,51]. The neo-synovium offers the diagnostic advantage of being accessible by preoperative arthroscopy, while the periprosthetic membrane can only be submitted if the implant is revised. Therefore, the neo-synovium may play an important role in pre-revision diagnostics. The consensus classification of the neo-synovium/periprosthetic membrane was presented for the first time in 2004 [36]. It provides standardized histological analysis of both and identifies the characteristic changes of implant loosening. It has been validated [8] and is currently routinely used for histopathological diagnostics in German speaking countries [27,29,35,36] and it is also recommended in the present volume of the AFIP Non-tumor Pathology series [24]. The current consensus classification includes four major histological patterns (type I–IV, Diagram 1), which are described in detail below.

Type I: neo-synovium/periprosthetic membrane of abrasion-induced type

Histological diagnostic criteria are defined by the published data [35,36]. The hallmark is the infiltrate of macrophages (often with foamy features) and multinuclear giant cells (Fig. 1a), in which prosthesis wear can be detected. Particles larger than approximately 5 μm are more likely to be found in multinuclear giant cells, whereas smaller particles (mostly 1 μm in diameter) are rather phagocytized by macrophages [37]. These two cell types together can occupy more than 20% of the membrane surface. Occasional or scattered small lymphocytes can be present. The greatest proportion of multinuclear giant cells is most frequently found near the surface of the periprosthetic membrane. The abrasion particles differ in quality, quantity and size subject to the materials, the kind of tribological pairing implemented and the intensity of the mechanical stress involved.

Characterization of particles: histopathologic particle algorithm

Particle-induced foreign body reactions as well as immunological and toxic changes in the periprosthetic tissue are influenced by the following factors: particle quality (material, size, and surface) and quantity, the type of tissue and cells involved by the particulate material and probably genetic factors influencing the immunological response to foreign-particles [23]. Particle related changes in the periprosthetic tissue are analyzed in conventionally stained H-E according to the histopathologic particle algorithm (Diagram 2) in paraffin sections based on three criteria: (1) light microscopic morphological characteristics like shape, size and staining features, (2) optical properties under polarized light, POL and (3) enzyme-histochemical characteristics (oil red O staining and Prussian blue reaction, PBR). The identification criteria of the particles are summarized in the so-called histopathological particle algorithm (Diagram 2) and its value has been previously discussed [27]. Besides the light-microscopy and enzyme-histochemical properties of the wear particles, the algorithm also includes the differential diagnosis of wear and non-wear related particles. Identification by light microscopy with and without polarized light of particulate material is the low cost standard examination performed by the general surgical pathologist [25,52]. A more definite and accurate material identification of wear particles, particularly of metal and ceramic particles, is only possible by physical methods [28].

Physical characterization of abrasion particles: scanning electron microscopy (REM), energy dispersive X-ray (EDX) and multi-element analysis (e.g. ICPMS)

Quantitative detection of particles derived from wear and corrosion processes requires sophisticated analytic methods [28]. Most wear particles are not diagnosed by light-microscopy examination due to their small size. Histologic cuts can be analyzed with high resolution by means of scanning electron microscopy, and the elementary constituents of the particles can be determined by means of energy dispersive x-ray (EDX). However, this method is not suitable to precisely differentiate polymer materials such as PE or PMMA, due to the fact that their principal constituents (hydrocarbon compounds) are also naturally present in the tissue [28]. To identify these materials it is advised to isolate, filter and separately analyze the particles from the tissue, e.g. by means of digestion in accordance with ISO 17853. Once separated, the particles can be semi-quantitatively analyzed in terms of their size, morphology and number. However, chemical detection of the material can be difficult. With high particle concentrations, the particles can be identified by means of Fourier transform-infrared spectrometer (FTIR). The latter utilizes the characteristic wavelengths of the CH_2 molecules. Alternatively this can also be achieved by Raman spectroscopy. To determine the total particle burden within the sample, one option is to digest the entire tissue sample and subsequently determine the ionic concentration by means of multi-element analysis, e.g. inductively-coupled-plasma mass-spectrometry (ICPMS).

Abrasion-induced fibrinoid necrosis

Wear particles can induce varying degrees of fibrinoid necrosis [18,27,36,39]. Considering that wear particles are mostly found in the necrotic areas, it has been suggested that fine PE particles may induce necrosis. At microscopic examination under polarized light these wear particles are only detectable to a limited extent due to their sometimes very small size. Oil red O staining might be helpful. However it is also possible that the formation of necrosis is caused by additional immunological factors. In histopathological diagnostics, the extent of the necrosis should be reported as the percentage of a total area determined by semi-quantitative analysis. Type-I periprosthetic tissue with necrosis (percentage of total area in excess of 30%) can be determined and designated as necrotic subtype. This type of necrosis must be distinguished from infectious granulomata with central necrosis as in Mycobacterium infections. If a mycobacterial or mycotic infection is suspected, a microbiological or PCR-analytical determination in the tissue is recommended.

Adverse reactions, toxic, and immunological reactions by implant materials

Corrosion particles

Metallic prosthetic tribological pairings, sleeve adapters, and dual modular femoral necks potentially represent important

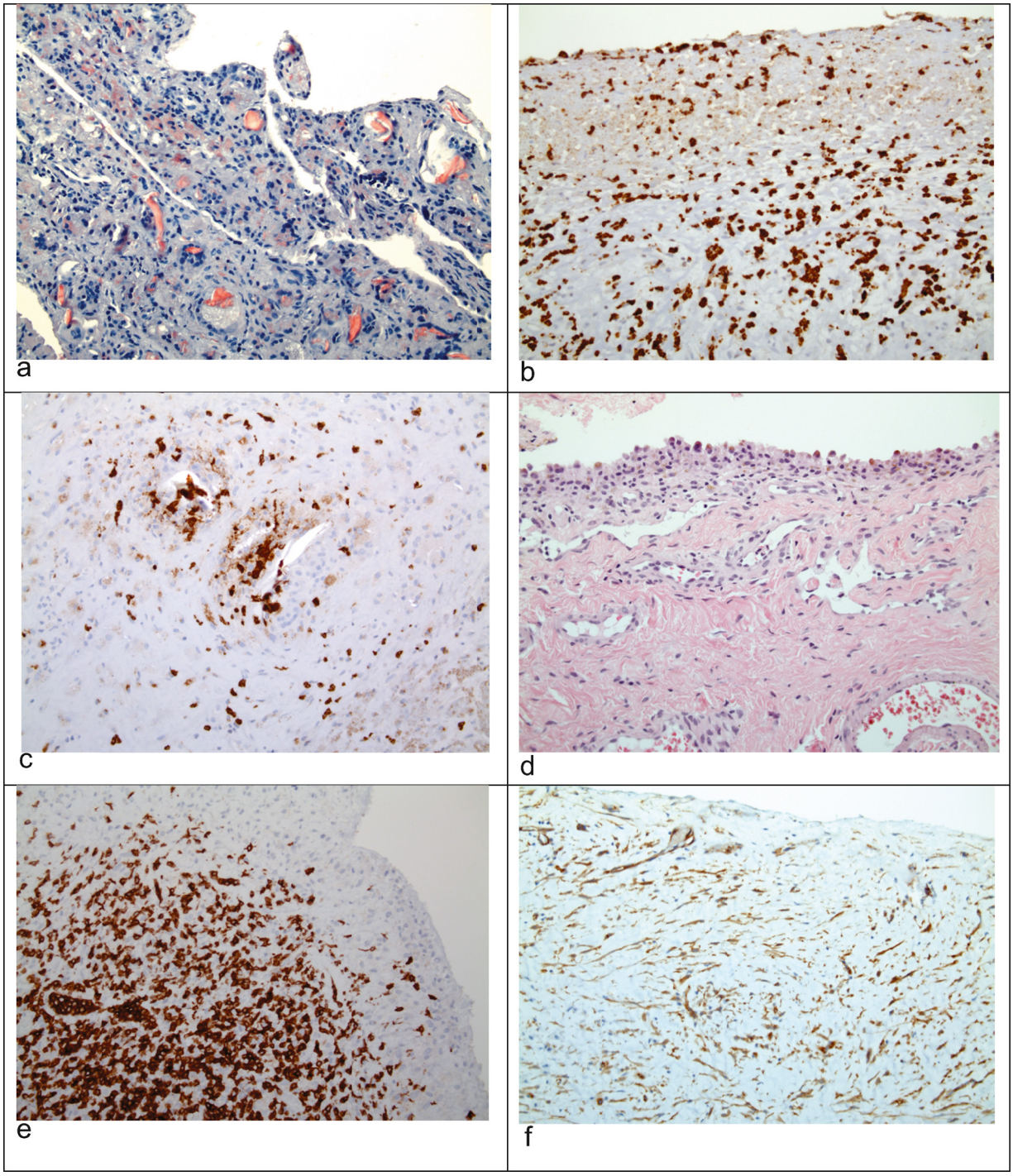

Fig. 1. Types of the neosynovium/periprosthetic membrane. (a) *Type-I membrane*: infiltrate of macrophages and multinuclear giant cells with oil red positive macro- and micro PE particles (oil red O staining, original magnification 200×). (b) *Type-II membrane*: partly diffuse, partly confluent infiltrate of CD 15 positive neutrophilic granulocytes with formation of micro abscesses (indirect immunohistochemistry, original magnification 200×). (c) *Type-III membrane*: characteristics and combination of both the *Type-I membrane and Type-II membrane*, of CD 15 positive neutrophil granulocytes with formation of micro abscesses near to macro-PE particles with intense polarization (indirect immunohistochemistry, original magnification 200×). (d) *Type-IV membrane*: fibrous connective tissue, no abrasion particles, no detectable infiltration of inflammatory cells (H-E staining, original magnification 200×). (e) *Type-I membrane* with adverse reaction: high number of CD 3 lymphocytes (indirect immunohistochemistry, original magnification 200×). (f) Endoprosthesis-associated arthrofibrosis: grade 3 exhibiting a high cellularity with intense cytoplasmic β-catenin expression with more than 20 β-catenin-positive fibroblasts/HPF (indirect immunohistochemistry, original magnification 200×).

sources of corrosion at the present time [20,22,55,56]. A corrosion process composed of adhesion and tribochemical reactions is defined as chemically dominated wear in comparison to the mechanically dominated process of abrasion and surface fatigue. Tribochemical reactions and surface fatigue are considered the predominant processes of formation of corrosion products as a result of the interaction between the metal surface and the synovial fluid, with formation of the so-called tribolayer. Crevice and fretting corrosion are of clinical concern in dual exchangeable necks and/or sleeve adapters, and the effects can be potentiated by the use of metal-on-metal bearing surfaces. Therefore these reactions depend on prosthesis design, loading, and positioning.

Material composition can also play a significant role in the generation and complexity of the particles. Corrosion products are detectable subject to the metal as an oxide, chloride and phosphate. Solid corrosion products made of cobalt–chromium–molybdenum alloys comprise, by way of example, chromium orthophosphate [13,30]. At light-microscopy analysis, they are yellowish to greenish and variable in size (<1–500 μm). These particle aggregates are not only to be found in the fluid or extracellular layer, but also in the periprosthetic tissue, lined by multinucleated giant cells or by granulomas with lymphocytic cuffing. A gradual transition to broken down smaller particles is observed in the cytoplasm of single giant cells and mononuclear macrophages occasionally mixed with metal particles [13,30].

Immunological reactions

The significance of an immunological, allergic reaction (hypersensitivity reaction, type IV reaction) to implant materials is being currently discussed in the scientific community. Hip implants with metallic components are usually well tolerated; however cases of allergic cutaneous reactions to some metals have been described. In addition, there are case reports of suspected symptomatic metal hypersensitivity, which resolved after revision to a different implant material [54]. In current publications, it has been postulated that an allergic reaction is only probable in those Type-I periprosthetic membranes, in which there is pronounced lymphocytic infiltration. Particular attention has been devoted to the lymphocytic infiltrate without correlation to the characterization of the macrophagic infiltrate or to the morphological and elemental characteristics of the wear particles. Three different lymphocytic infiltration patterns have been described so far [57] (1): diffuse pattern with no aggregates; predominantly lymphocytes, sporadic plasma cells, (2): perivascular aggregates of predominantly T-cells; and (3): perivascular aggregates containing T and B cells with formation of germinal centers, associated with the presence of high endothelial cell venules. However, the clinical and prognostic importance of these lymphocytic infiltration patterns has not been clarified and the relationship to hypersensitivity reactions remains unclear [57]. Due to the fact that to date no unequivocal histopathological correlate for hyperergic type IV reactions in the neo-synovium/periprosthetic membrane has been characterized, the diagnosis of a hypersensitivity reaction relies on data provided by interdisciplinary cooperation [53]. Excessive lymphocytic/plasmacellular infiltration in a Type-I neosynovium is indicative of an adverse tissue reaction to implant material and hypersensitivity should be considered especially if also an eosinophilic infiltrate or granuloma formation is present. Final interpretation should also be based on clinical data [53]. Indicator of this type of reaction may be a history of allergies (contact eczema through costume jewelry or other artifacts, occupational and leisure exposure, etc.), or positive epicutaneous skin test. However, the results of epicutaneous testing have to be considered with caution and [53] should always be reported to the pathologist to be considered for the histological evaluation. Whether the analysis of cytokine release patterns can be implemented for diagnostic purposes remains to be determined. Since CD3+ lymphocytes represent a cellular equivalent of the hypersensitivity type IV reaction, a hypersensitivity reaction in a periprosthetic membrane of the fibrous type (Type-IV) with absent T-cell infiltration is unlikely.

Metal/metal wear couples: metal particles and coagulation necrosis

In the so-called second generation of metal-on-metal hip resurfacing and also large head modular total hip implants, pronounced necrosis and inflammatory changes in the periprosthetic membrane have been described [34]. The reaction is composed of macrophagic infiltrate containing metallic wear material, a variable amount of coagulative necrosis, and perivascular lymphocytic infiltrate with or without eosinophils and/or plasma cells or formation of sarcoid-like granulomas [34]. Vascular changes and especially the presence of high endothelial venules with plump cuboidal endothelium associated with lymphocytic cuffing have been described by Natu et al. and further classified by Mittal et al. in (1) diffuse lymphocytic infiltrate with no aggregates; (2) lymphocytic aggregates of predominant T cell population; (3) lymphocyte aggregates with T and B cells with formation of lymphoid follicles. Apart from direct toxicity through metal wear particles, a possibly secondary hypersensitivity reaction (Type 4) to implant materials is discussed [34,38,53].

Since characteristic morphological alterations which are associated with adverse implant material reactions may be detected in periprosthetic tissue with Type-I (Fig. 1e) and Type-IV morphology they should be classified according to the revised classification as morphological subtypes of Type-I and Type-IV (Diagram 1). As lymphocyte infiltrates in the Type-I and Type-IV membranes are not necessarily the result of an allergic or toxic reaction the diagnosis of an allergic or toxic reactions to implant materials should only be made with cautions, only in the context of the dermatological, allergological, immunological and clinical-orthopedic data. Therefore a diagnosis of implant allergy can only be made by a multidisciplinary team [53].

Type II: neo-synovium/periprosthetic membrane of the infectious type

Criteria for diagnosis and therapeutic strategies for periprosthetic joint infection had been defined on an international level [42–44]. Differentiation between low-grade and a high-grade infection can be made based on different histological criteria [11,37,42]. The histological pattern of low-grade infection is characterized by formation of granulation tissue with fibroblasts, reactive vascular proliferation, chronic edema and an inflammatory infiltrate made of neutrophil granulocytes (Fig. 1b), plasma cells as well as small lymphocytic aggregates. The detection and quantification of neutrophil granulocytes (NG) are at the core of the histological diagnosis of low grade infections. Individual studies have defined various cut off levels for the number of NG per field of vision [11]. These defined values lay between one and ten NG in a defined numbers of high-power-field [37,40,51] or are defined by number of CD15 positive NG in a focus which may be additionally evaluated by computer assisted techniques [29]. Sensitivity and specificity for the different cut of levels range from 60% to 100% [56]. A recent study has analyzed 147 periprosthetic membranes without initially determining a limit value, and subsequently determined that there is optimum agreement of the histopathological examination with the microbiological findings and the clinical picture, if infection is diagnosed with 23 NG in a total of ten HPFs [37]. This limit value of a total of 23 NG in ten HPFs is recommended for histological diagnosis of a periprosthetic low-grade infection.

With high-grade infection, the number of NG in the tissue is considerably higher; however, specific cut offs for high grade infections have not been established. In contrast with microbiological diagnosis, an intraoperative request of a frozen section examination [10] raises the possibility of an immediate diagnosis of infection. This allows the surgeon to adjust the surgical plan intraoperatively. However, quantifying the number of NG on the frozen section is difficult, so that intraoperative diagnosis can only be made in 78% of the cases, and needs to be confirmed in paraffin embedded sections. Low grade infections remain a problem because of the high risk of sampling error in the tissue send for the frozen section. In

most cases, the report will state that the material is "suspicious for infection" or "infection cannot be excluded" and the definitive diagnosis is deferred until paraffin embedded sections are analyzed. For these reasons, a defined histological sampling of the tissue for macroscopic examination and subsequent embedding in paraffin are mandatory [58] and the final diagnosis should take the results of bacterial culture into consideration.

Type III: neo-synovium/periprosthetic membrane of the combined type

Histological criteria: Histological, diagnostic criteria are defined by the published data [35] exhibiting a combination of particle-induced and infectious neo-synovium/periprosthetic membrane (Types I and II). Therefore there are characteristics of both wear particle induced reaction as well as of bacterial infection in the same tissue (Fig. 1c).

Type IV: neo-synovium/periprosthetic membrane of the fibrous type

Histological, diagnostic criteria are defined by the published data [35] exhibiting features of neither Type-I nor Type-II membranes. Consequently there is no evidence of wear particles or inflammatory infiltrates indicating a bacterial infection. This membrane is histologically characterized by connective tissue with high collagen content, the surface of which is characterized by a cell layer similar to the synovial lining. Abrasion particles are either non-detectable or are present only in small quantity (Fig. 1d). Neutrophil granulocytes occur only sporadically in the area of fibrin deposits and fibrinous exudates; even when counted exactly, there are fewer than 23 NG per ten consecutive HPFs [37]. Slight lymphoplasmacytic infiltrates may be detectable. The etiology of this histologic pattern may be multifactorial: primary mechanical instability with insufficient implant stability, poor quality of the bone interface (e.g. osteoporosis) or non-optimal implant positioning with resultant pressure spikes, muscular weakness or atrophy and similar mechanical and physiological factors. This type occurs significantly more often in uncemented prostheses, while the Type-I membrane is seen more frequently in cemented implants.

Endoprosthesis-induced arthrofibrosis

Endoprothesis-induced arthrofibrosis is a pronounced, periarticular or intraarticular fibrous reaction secondary to arthroplasty and is associated with painful restricted movements. Immunohistochemical analyses have shown presence of CD3-positive lymphocytes as well as Ki-67-positive proliferating cells [6]. The fibroblast reaction and fibrosis shows a great variation and elevated levels of profibrotic BMP-2 concentration in the synovial fluid have been detected [46]. Three-stage graduation is recommended for the diagnosis, which is based on the cell density of the fibroblastic tissue and the number of β-catenin positive fibroblasts per HPF (Fig. 1f) [27,50]. Arthrofibrosis Grade I is a macroscopic tissue alteration, histologically composed of a loose collagenous connective tissue with low fibroblast density; this pattern is very similar to neo-synovium of the fibrous type (Type-IV). Clinical information is therefore essential to diagnose arthrofibrosis Grade I. Arthrofibrosis Grades II and III can be differentiated from a Type-IV membrane, since they display an elevated cell density. In Grade II, there is moderate cell density, and in Grade III there is a high cell density similar to fibromatosis or Morbus Dupuytren in the proliferative phase. Since in some cases wear particles are detected in arthrofibrotic tissue, it should be examined under polarized light, and any prosthetic wear particles should be described [51]. The chloracetate esterase reaction or CD15 staining enables the detection of granulocytes for exclusion of infection. Hemosiderin deposits can be differentiated from wear particles by the Prussian blue reaction [27]. Abrasion particles might represent a pathogenetic factor of arthrofibrosis; therefore wear particle presence or absence at histological examination could differentiate an abrasion-induced type from a non-wear-induced type. However, this issue is not conclusively clarified. An expression of β-catenin can be detected immunohistologically in the fibroblasts of the arthrofibrosis [50] which had been described in fibromatoses and other fibroproliferative diseases [11]. There is a correlation between the grade of arthrofibrosis and the number of β-catenin-positive fibroblasts. Considering a cutoff at 20 β-catenin-positive fibroblasts per HPF, endoprosthesis-associated arthrofibrosis can be diagnosed with a sensitivity of 72% and a specifity of 87% [50]. For this reason, immunohistochemical staining for β-catenin is recommended to evaluate for endoprosthesis-associated arthrofibrosis [50].

Bone pathologies

The most relevant bone pathologies in the periprosthetic compartment include: local osteopenia, aseptic bone necrosis, inflammatory reactions due to intramedullary particle reactions, ossification [45]. Since bone tissue is not always submitted for histopathology, bone tissue should only be evaluated in cases were bone is especially biopsied for diagnostic reasons or in cases of revision surgery where large bone fragments may be obtained more easily. Poor quality of the bone interface, caused by metabolic diseases [7], by ischemic alterations, bone tissue necrosis [59], particle induced inflammation and by bacterial infections [37] may be relevant to the pathogenesis of implant failure. Therefore in tissue samples including bone tissue the pattern of bone tissue lesions should be evaluated as a part of a histopathological diagnosis.

Future perspectives

Histopathologic diagnosis carried out according to the criteria of this proposed extended consensus classification of joint endoprosthesis pathology is relevant to the diagnostics of joint implant failure and may represent a crucial set of data for joint implant registries. Implant registries have been established since more than 30 years ago, as exemplified by the Swedish Registry (1975) and the Finnish Endoprosthesis Register (1980). They play an important role in the detection of implant failures. A comprehensive histopathological system is important for a standardized diagnosis of the different failure mechanisms.

Therefore we believe that the implementation of this classification could provide a substantial contribution to a more precise definition of the modalities of implant failures that the ones currently adopted by the national registries.

Conflict of interests

There is no conflict of interests.

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