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Histological Patterns of Periprosthetic Synovial Membrane of the Knee Joint with Instability of the Endoprosthesis

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Abstract

Gonarthrosis is one of the most common osteoarthrosis problems affecting large joints. It accounts for 50.6–54.5% of cases among patients with degenerative-dystrophic diseases of the large joints of the lower extremities. In 86% of cases, the disease affects individuals of working age, and in 6.5–14.6% of cases, it leads to disability. The aim of the study is to investe the periprosthetic synovial membrane to identify the cause of instability of the primary knee endoprosthesis. A total of 25 cases of periprosthetic synovial tissue obtained from patients with instability of the primary knee joint endoprosthesis during revision endoprosthetics were morphologically studied. The average age of patients was 64.6 ± 2.11 (78-44) years. The cohort included 17 women (68%) and 8 men (32%). Histological examination of periprosthetic synovial tissue revealed synovitis of varying severity and activity of pathological signs. Based on histological signs, all periprosthetic synovial tissues were divided into four etiopathological groups: periprosthetic synovitis caused by endoprosthesis wear; periprosthetic synovitis caused by infection; periprosthetic synovitis caused by fibrosis; and periprosthetic synovitis caused by autoimmune activation. Our studies have shown that in revision knee arthroplasty a histological examination of the periprosthetic synovial membrane is necessary. We identified 4 different histological patterns of changes in the synovial membrane in cases of endoprosthesis instability: wear-induced periprosthetic synovitis; infection-induced periprosthetic synovitis; fibrosis-induced (indifferent) periprosthetic synovitis; and immune-induced periprosthetic synovitis.

Keywords: revision arthroplasty, knee joint, synovial membrane, pathomorphological studies.

1. Introduction

Gonarthrosis is one of the most common osteoarthritis problems affecting large joints. Among patients with degenerative-dystrophic diseases of large joints of the extremities, it accounts for 50.6–54.5% of cases. The disease affects people of working age in 86% of cases, and in 6.5–14.6% leads to disability [1,2].

Total knee arthroplasty is currently one of the most effective and popular methods of treating osteoarthritis of stages III-IV. The goal of arthroplasty is to reduce pain, improve the motor function of the affected joint, stabilize the weight-bearing ability of the lower limb, and improve the quality of life of patients. In patients with stage III arthritis, total joint arthroplasty is one of the most successful treatment methods. With the increase in the number of primary arthroplasties, the number of revision interventions is steadily increasing, and currently their share reaches 6-8% of the total number of endoprostheses, and by 2030, an increase in the absolute number of revisions by 600% is predicted [3, 4]. The causes of endoprosthesis instability leading to endoprosthesis revision vary from case to case, although there are several predominant mechanisms. Clinically, instability can be due to implant wear with or without aseptic loosening, purulent inflammation, mechanical damage to the implant, problems associated with peri-implant musculoligamentous soft tissues. Knee arthroplasty is becoming an increasingly common method of treating a wide range of diseases and consequences of knee joint injuries [4]. Today, knee arthroplasty is the second most frequently performed procedure for conditions associated with bone pathology (osteoporosis, osteopenia, osteolysis, heterotopic ossification, osteonecrosis or periprosthetic fractures/microfractures). Standardized pathological examinations of periprosthetic tissue pathology are an important tool for determining the causes of primary failure of knee arthroplasty. Histological examination provides important information for clarifying the multifactorial etiopathogenesis of knee arthroplasty instability. A wide etiologic spectrum of knee arthroplasty instability is determined by the identification of various histological signs. However, to obtain more reliable information and achieve optimal results, histological examination must be integrated with clinical, biomechanical, immunological, microbiological and surgical data. Revision knee arthroplasty, being a more complex surgical intervention, creates a number of complex challenges for doctors, both in terms of general patient management tactics and in terms of technical aspects of the operation. According to authors, 70–90% of patients who have undergone revision knee arthroplasty have a bone mass deficiency that requires compensation and is the most difficult problem of revision arthroplasty [5-14].

Pathomorphological aspects of revision knee arthroplasty currently remain unresolved and are insufficiently covered in the works of authors, which served as the basis for this study. In this regard, the study of structural and morphological changes in the periprosthetic synovial membrane seems to be very relevant for the development of technology for adequate repeated surgical interventions.

The purpose of pathomorphological studies is to study the periprosthetic synovial membrane to identify the cause of instability of the primary knee endoprosthesis.

2. Materials and methods

The biopsies of periprosthetic synovial tissue of 25 patients with revision endoprosthetics, operated on for knee joint instability in 2023 and the first half of 2024 at the Republican Scientific and Practical Center of Traumatology and Orthopedics (Minsk, Republic of Belarus), were studied.

The average age of patients was 64.6 ± 2.11 (44–78) years. Of these, 17 (68%) were women and 8 (32%) were men. Based on histological features, all periprosthetic synovial tissues were divided into four groups: wear-induced periprosthetic synovitis – 13 patients (52%); infection-induced periprosthetic synovitis – 4 patients (16%); fibrosis-induced (indifferent) periprosthetic synovitis – 7 patients (28%); and immune-induced periprosthetic synovitis – 1 patient (4%).

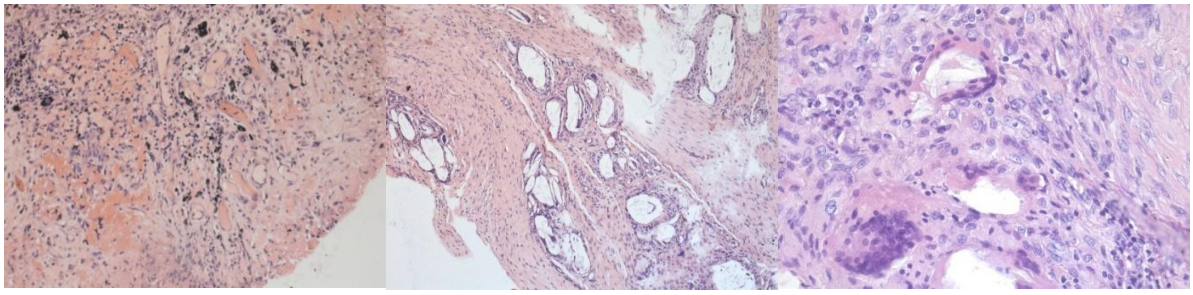
Pathomorphological studies of the material were carried out according to the generally accepted histological technique for studying soft tissues. Tissue samples were fixed in 10% formalin. Then the tissues were cut out, degreased in alcohols of ascending concentration, embedded in paraffin blocks, histological preparations 4 μm thick were made, stained with hematoxylin and eosin and according to Van Gieson.

The preparations were examined under a light microscope. The severity of general pathological processes (dystrophy, inflammation, metallosis, necrosis, sclerohyalinosis, myxomatosis, calcinosis, chondromatosis and osteomatosis) was assessed semi-quantitatively on a four-point scale: 0 – no signs; 1 – mild; 2 – moderate; 3 – severe.

3. Results

In the present study, tissue samples from 25 patients with instability of the primary knee joint endoprosthesis who underwent revision endoprosthetics were examined. The average age of the patients was 64.6 ± 2.11 (44-78) years. Of these, 17 (68%) were women and 8 (32%) were men. Histological examination of the periprosthetic synovial tissue revealed synovitis of varying severity and activity of manifestation of pathological signs. Based on histological signs, all periprosthetic synovial tissues were divided into four groups with a specific etiopathogenetic nature of histological changes: wear-induced periprosthetic synovitis; infection-induced periprosthetic synovitis; fibrosis-induced (indifferent) periprosthetic synovitis; and immune-induced periprosthetic synovitis.

Wear-induced periprosthetic synovitis is characterized primarily by a macrophage infiltrate with multinucleated giant cells of the foreign body type. Accumulation of wear debris of varying sizes can be found extracellularly or in the cytoplasm of macrophages and/or giant cells. Endoprosthetic wear debris in the periprosthetic tissue accumulates either as black metal particles that do not transmit light under a microscope (metallosis) or as translucent polyethylene particles surrounded by multinucleated giant cells. Varying numbers of lymphocytes and plasma cells can also be found in the stroma of periprosthetic synovitis. In a histological examination of 25 cases of periprosthetic synovitis, we diagnosed 13 (52%) cases of periprosthetic wear synovitis (Figure 1).



A *B* *C*

Figure 1 – Wear-induced periprosthetic synovitis. Hematoxylin and eosin stain. A – Presence of metal wear particles of various sizes (metallosis). Magnification ×200. B and C – Numerous polyethylene particles with perifocal giant cell inflammatory reaction. B – Magnification ×100 and C – Magnification ×630

Infection-induced periprosthetic synovitis can be histologically confirmed in cases of instability of the primary knee joint endoprosthesis, which is of great importance for the tactics of further patient management. In this case, histological studies can be used intraoperatively with frozen tissue sections to determine the presence of neutrophils and microabscesses. Intraoperative histological studies (Cito) of periprosthetic tissue can be used intraoperatively in case of clinical suspicion of infection or to confirm the advisability of a two-stage endoprosthesis revision procedure. To confirm infection, the main attention is paid to the detection and quantitative assessment of the presence of polymorphonuclear leukocytes. In this case, it is necessary to identify and differentiate the subtypes of purulent inflammation in the periprosthetic synovial membrane: with a low content of polymorphonuclear leukocytes; with a high content of polymorphonuclear leukocytes; and purulent-abscessing form of purulent inflammation. Of all the patients examined, four (16%) were diagnosed with infectious periprosthetic synovitis (Figure 2).

In fibrosis-induced (indifferent) periprosthetic synovitis, accumulation of wear particles (metallosis or polyethylene microfragments) with macrophage reaction is not observed histologically. Leukocyte polymorphonuclear infiltration, indicating infection, is also not observed. In samples of fibrosis-induced (indifferent) periprosthetic synovitis, proliferation of granulation tissue (pannus) with extensive foci of sclerotic and necrobiotic processes is most often detected.

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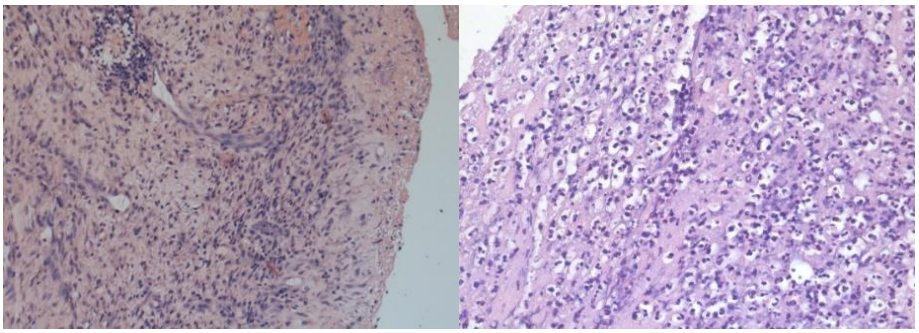


A *B*

Figure 2 – Infection-induced periprosthetic synovitis. Hematoxylin and eosin staining. A – periprosthetic purulent synovitis with a high content of polymorphonuclear leukocytes. Magnification ×200. B – periprosthetic purulent synovitis, a purulent-abscessing form of purulent inflammation. Magnification ×400

Mild to moderate round cell inflammatory infiltration is noted. In a histological examination of all 25 cases of periprosthetic synovitis, we diagnosed 7 (28%) cases of fibrosis-induced (indifferent) periprosthetic synovitis (Figure 3).

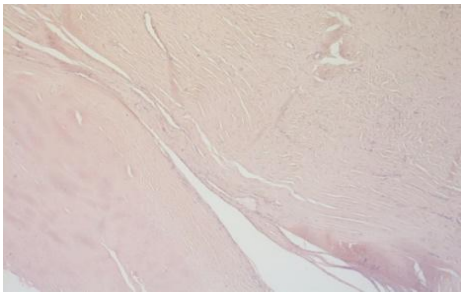
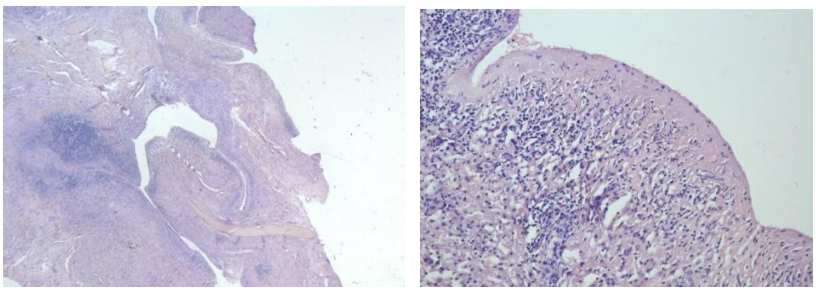


Figure 3 – Fibrosis-induced (indifferent) periprosthetic synovitis. Fragments of synovial tissue with pronounced necrobiotic and sclerotic changes. Hematoxylin and eosin staining. Magnification ×50

In one case (4%) out of 25, we diagnosed immune-induced periprosthetic synovitis. In these synovitis, the synovial membrane acquires more specific histological signs characteristic of rheumatoid synovitis. These include: focal destructive changes in the synovial membrane from hyalinosis and necrobiosis to necrosis; foci of necrosis of the intimal layer with desquamation; palisade arrangement of cells in the subintimal layer combined with proliferation of synoviocytes; productive endovasculitis and capillaritis; focal and diffuse infiltration by lymphocytes and plasma cells; formation of lymphoid follicles; superposition of fibrinoid masses on the surface of the synovial membrane; formation of pannus granulation tissue (Figure 4). Chondrocytes are damaged as a result of TNF-α and IL-1β exposure, which disrupts cartilage regeneration and accelerates its degradation [32].



A *B*

Figure 4 – Immune-induced periprosthetic synovitis. Hematoxylin and eosin staining. A – Marked papillary hyperplasia and formation of lymphoid follicles in the stroma. Magnification ×25. B – Necrosis of the intimal layer and lymphoplasmacytic infiltration in the subintima

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4. Discussion

Histological examination of periprosthetic tissues is a crucial diagnostic method for determining the etiopathogenesis of instability after primary knee arthroplasty. This examination can also help predict the course of revision arthroplasty. Our studies demonstrate that the presence of certain common pathological processes in periprosthetic tissue samples removed during revision arthroplasty allows for a reliable determination of the etiopathogenesis of failed primary arthroplasty. Based on histological patterns, four groups of instability following primary knee arthroplasty can be distinguished: wear-induced periprosthetic synovitis; infection-induced periprosthetic synovitis; fibrosis-induced (indifferent) periprosthetic synovitis; and immune-induced periprosthetic synovitis.

Wear-induced periprosthetic synovitis accounts for the largest proportion of patients with primary instability after knee arthroplasty. Its primary cause is the ingress of wear debris from the endoprosthesis and the subsequent development of chronic, productive giant cell inflammation of the periprosthetic tissue. Fibrosis-induced (indifferent) periprosthetic synovitis is another interesting etiopathogenetic cause of instability, which ranks third among causes of instability in knee arthroplasty. In these cases, signs of inflammatory changes in histological specimens are minimal. Infection-induced periprosthetic synovitis is the third most common cause of instability in knee arthroplasty according to our studies. A profound examination of patients before primary and revision arthroplasty is essential to identify hidden infectious foci and exclude cases of periprosthetic purulent infection. Immune-induced periprosthetic synovitis as a cause of joint failure should always be considered in both primary and revision arthroplasty. Patients with autoimmune diseases are always at risk for developing joint instability.

6. Conclusions

Thus, our studies have shown that in revision knee arthroplasty a histological examination of the periprosthetic synovial membrane is necessary. Examination of the synovial membrane allows us to determine the cause of instability of the primary knee arthroplasty. Based on the histological examination of the synovial membrane in revision knee arthroplasty, we identified 4 different etiopathogenetic patterns of histological changes in the synovial membrane: wear-induced periprosthetic synovitis (instability caused by wear); infection-induced periprosthetic synovitis (instability caused by infection); fibrosis-induced (indifferent) periprosthetic synovitis (instability caused by fibrosis); and immune-induced periprosthetic synovitis (instability caused by autoimmune activity). Periprosthetic synovitis caused by wear is due to the spread and accumulation of metal or polyethylene particles in the periprosthetic synovial membrane. Infectious periprosthetic synovitis most often occurs as a result of hematogenous spread of pyogenic bacteria into the area of the endoprosthesis, developing deep late purulent periimplantitis. fibrosis-induced (indifferent) periprosthetic synovitis occurs due to insufficiency of the musculoskeletal system or ligamentous apparatus. For example, it develops with severe osteoporosis or muscle weakness. Immune-induced periprosthetic synovitis can be observed in patients with rheumatoid arthritis.

Conflicts of Interest. The authors declare no conflicts of interest.

Author Contributions: Authors equally contributed to this work. All authors have read and agreed to the published version of the manuscript.

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Эндопротездің тұрақсыздығы кезіндегі тізе буынының перипротездік синовиальды қабығының гистологиялық паттерндері

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Түйіндеме

Ірі буындардың остеоартроздарының ішінде ең өзекті мәселелердің бірі – гонартроз болып табылады. Аяқ-қолдың ірі буындарының дегенеративті-дистрофиялық аурулары бар науқастар арасында ол жағдайлардың 50,6-54,5%-ын құрайды. Ауру жағдайлардың 86%-ында еңбекке қабілетті жастағы адамдарға әсер етеді, ал 6,5–14,6%-ында мүгедектікке әкеледі. Бұл зерттеудің мақсаты тізе буынының бастапқы эндопротезінің тұрақсыздығының себебін анықтау үшін перипротездік синовиальды қабықты зерттеу. Морфологиялық зерттеуге ревизиялық эндопротездеу барысында тізе буынының бастапқы эндопротезі тұрақсыз болған науқастардан алынған перипротездік синовиальды тіннің 25 жағдайы енгізілді. Науқастардың орташа жасы 64,6±2,11 (44–78) жасты құрады, олардың ішінде 17 (68%) әйелдер, 8 (32%) ер адамдар болды. Перипротездік

синовиальды тінге жүргізілген гистологиялық зерттеу нәтижесінде патологиялық белгілердің айқындылығы мен белсенділігі әртүрлі дәрежедегі синовиттер анықталды. Гистологиялық белгілеріне сәйкес барлық перипротездік синовиальды тіндер 4 этиопатологиялық топқа бөлінді: эндопротездің тозуынан туындаған перипротездік синовит, инфекцияға байланысты перипротездік синовит, фиброзға байланысты перипротездік синовит және аутоиммундық активациямен байланысты перипротездік синовит. Біздің зерттеулерімізде тізе буынының ревизиялық эндопротездеу жүргізу кезінде перипротездік синовиальды қабыққа міндетті түрде гистологиялық зерттеу жүргізу қажеттігін көрсетті. Эндопротездің тұрақсыздығы жағдайларында синовиальды қабықтағы өзгерістердің 4 түрлі гистологиялық нұсқасы анықталды: тозуға индукцияланған перипротездік синовит, инфекцияға индукцияланған перипротездік синовит, фиброзға индукцияланған (индифферентті) перипротездік синовит және иммундық индукцияланған перипротездік синовит.

Түйін сөздер: ревизиялық эндопротездеу, тізе буыны, синовий, патоморфологиялық зерттеулер.

Гистологические паттерны перипротезной синовиальной оболочки коленного сустава при нестабильности эндопротеза

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Резюме

Среди остеоартрозов крупных суставов одной из наиболее актуальных проблем является гонартроз. На его долю приходится 50,6–54,5% случаев среди пациентов с дегенеративно-дистрофическими заболеваниями крупных суставов нижних конечностей. В 86% случаев заболевание поражает лиц трудоспособного возраста, а в 6,5–14,6% случаев приводит к инвалидности. Целью настоящего исследования является изучение перипротезной синовиальной оболочки для выявления причины нестабильности первичного эндопротеза коленного сустава. Морфологически изучены 25 случаев перипротезной синовиальной ткани, полученной у пациентов с нестабильностью первичного эндопротеза коленного сустава при ревизионном эндопротезировании. Средний возраст пациентов составил 64,6±2,11 (78-44) лет. Из них 17 (68%) женщин и 8 (32%) мужчин. При гистологическом исследовании перипротезной синовиальной ткани наблюдались синовиты разной степени выраженности и активности проявления патологических признаков. На основании гистологических признаков все перипротезные синовиальные ткани были разделены на 4 этиопатологические группы: перипротезный синовит, вызванный износом эндопротеза; перипротезный синовит, вызванный инфекцией; перипротезный синовит, вызванный фиброзом; и перипротезный синовит, вызванный аутоиммунной активацией. Наши исследования показали, что при ревизионном эндопротезировании коленного сустава необходимо гистологическое исследование перипротезной синовиальной оболочки. В случаях нестабильности эндопротеза были выявлены 4 гистологических варианта изменений в синовиальной оболочке в случаях нестабильности эндопротеза: износ-индуцированный перипротезный синовит, инфекционно-индуцированный перипротезный синовит, фиброз-индуцированный (индифферентный) перипротезный синовит и иммуно-индуцированный перипротезный синовит.

Ключевые слова: ревизионное эндопротезирование, коленный сустав, синовиальная оболочка, патоморфологические исследования.