

The Allergic and Irritating Reactions to Metallic Implants with Trauma – Orthopaedic Patients

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Abstract— Revision operations after joint implantation, as well as complications occurring with trauma patients, whose implants are made of metal are becoming more and more frequent economic and medical problem. The most frequent reason for revision operations is aseptic loosening of joints.

As early as the 1970's, there appeared the descriptions of cases, which suggested side reactions, which followed metal implantations. In most cases it is methalosis and fistula. Sometimes they assume a form of: eczema, erythema, pruritus and others in the side of implantation, which point to allergic reaction.

The article presents the analysis of clinical operation complications after the treatment of long bones by mean of osteosynthesis with the use of metal implants and endoprothesoplastic of hip joints.

Index Terms: allergy, implants, orthopaedic patients

I. INTRODUCTION

Introducing an implant into the human body, it is necessary remember, that organism will treat it as an alien body and different reactions can be expected. The awareness of danger arising from introducing an alien element into the body leads to working out some low regulations included in ISO 10993 [1] defining the way of using the new materials and the implants made of them in order to make them suitable to be used in medicine. However, even strict following the rules doesn't remove the danger of some complications [2]. The responsibility results from the fact, that there is a wide variety of reactions occurring between the tissue and the implant.

Chemical compounds present in metallic implants are as a rule well accepted by the body, however, they may have toxic, carcinogen effects or cause allergies [3]. The reaction of the body to implants depends on general body factors. The physicochemical reactions occurring on the implant surface introduced into the body undergo changes caused by the appearance of current inside the implant, as well as corrosion process and friction. The implant surface is subjected to reaction from the tissue, as well as body liquids during the process of oxidation. As a result of metal corrosion tissues may be penetrated by the toxic ions like: vanadium, nickel and chromium. Moreover, an infection can be caused by microorganisms, which stuck to the surface of the implant. The presence of bacteria and biofilm on the implant surface changes the immunological reactions [3,4].

Many publications deal with corrosion and tribology of metallic implants. It was found, that the release of metal from

stainless steel occurs during the contact with sweat, blood and saliva [3,5,6]. The presence of nickel in tissues surrounding implants was confirmed [7]. Moreover, in the area around an implant, the particles resulting from friction in the form of used implant, the compounds of protein with metal, free metal ions, non-organic salts, oxidized metals, as well as metals connected with hemosiderine have been found [8].

The research concerning the releasing of metals with proper mechanical functioning hip joint endoprosthesis revealed the release of chromium and cobalt in case of cobalt-chromium alloy [5,9], as well as the release of titanium in case of titanium endoprosthesis [10]. These elements were discovered in the blood and urine with density dependent on the duration of implant stay in the body. Jacobs et al. [9] found out, that in bodies with dysfunctional implant, density of Co and Cr in serum and urine was much higher, than before introducing an implant, as well as with the patients with properly functioning implant.

In some cases clinically obvious allergic phenomenon resulted in necessity of removing the implant [5,8], because severe allergic skin inflammation, urticaria as well as inflation of blood vessels were found [8]. Some rash changes may be located in the vicinity of an implant or appear in different places (blood eczema). There was also a case of hand rash after using metal joints to treat gaskin bone fraction [11] and also such complications as: methalosis, that is metallising colouring of surrounding tissues, far reaching fibrosis around the implant and tissue necrosis.

Schoberl et al. [12] described a disfunction of the hip joint prosthesis caused by an allergy to cobalt, while doing minest patch tests and without pathological irritation on the skin. The authors [12] stated the presence of CD45RO+ lymphocytes T in tissues surrounding the implant. The lymphocytes revealed the proliferation reaction to cobalt. It was found, that oversensitiveness to metals refers not only to the skin.

Szumlański [13] noticed, that patients with disfunction of endoprosthesis a few weeks after the surgery suffered from intertile fistula undergoing bacteria infection. The patients inquestion were allergic to metals contained in endoprosthesis. Dotterud et al. [14] come to conclusion, that out of 16 patients, who underwent implantation surgery and were allergic to metals contained in them, only 1 showed an increase in irritation and 4 of them suffered slight ailments. Only 3 patients had loosening of hip joints. In case of some complications revision surgeries were performed. Such operations require much experience of the surgical team, frequent bone transplantations or using the prosthesis with special structure [13].

The aim of the research was estimation of occurrence frequency and analysis of clinic cases after post-operation complications related to the long bone treatment by means of osteosynthesis with the use of metal implants as well as endoprothesoplastics of hip joints.

II. THE EXAMINATION METHODS OF METAL ALLERGIES

Patch tests (skin tests) are performed to discover contact allergies, as well as small particle compounds as: metal and drugs. The contact allergy may be caused by contact allergic inflammation (contact rash). Each patient with prolonged itching rash should undergo patch tests.

A like in other skin cases, patch tests should be carried out during the remission of the disease on the healthy skin. Some drugs are responsible for false results of the skin tests. Tests shouldn't be carried on sick skin or with seriously sick patients, as well as in cases of infectuous diseases, malicious tumours as well as autoaggressive illnesses. There is no evidence of harmful effects of skin tests carried out in pregnancy, however, according to the principle of maximum caution test in pregnancy are performed in urgent cases [15].

The skin tests with choosen Ni, Cr and Co haptens were applied to patients as advised by JDCR (International Group Examining Contact Eczema) in shoulder blade vicinity. Stickers with opening covered with polypropylene were used. The results were examined after 48 h, 72 h and 96 h counting from application time (Fig.1).



Fig.1 Skin tests [5,16]

III. DESCRIPTION OF SOME CASES

The first case is associated to the bone disturbances following the inserting of an implant with inflammation in the surrounding area and positive patch tests (Ni, Cr, Co) concerned gaskin fractions joint by means of *Zespol* method (Fig.2). For this case a segment of the body tissue was

removed from the implant area (Fig.3). It revealed, that the tissues surrounding the implant died out and the implant lost balance. After removing the implant and drugs treatment, the tissues started to recover.



Fig.2 The gaskin fractions joint by means of *Zespol* method, X-Ray photo [16]

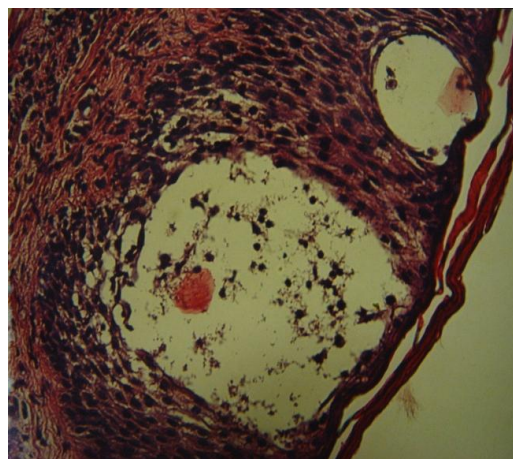


Fig.3 The segment of the body removed from the implant area by use of the *Zespol* method [5,16]

Among many reasons causing complications, increasingly frequent phenomenon is oversensitiveness to metals contained in an implants used in stabilization of fractions (Fig.4). It has been found, that patients suffering from oversensitiveness experienced skin irritation in the area contacting implant (Fig.5). The observations indicated, that the contact rash was stronger, if an implant was inserted nearer the surface of the skin (Fig.6).

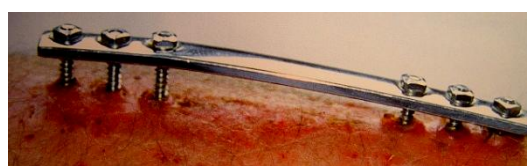




Fig.4 The joining patch [16]

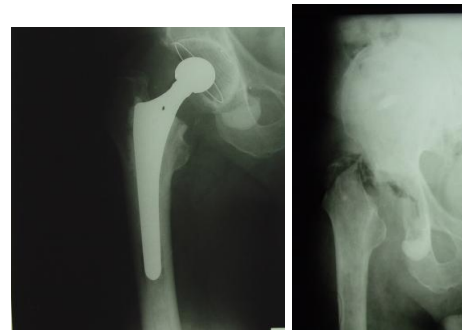


Fig.7 The allergic changes [5,16]

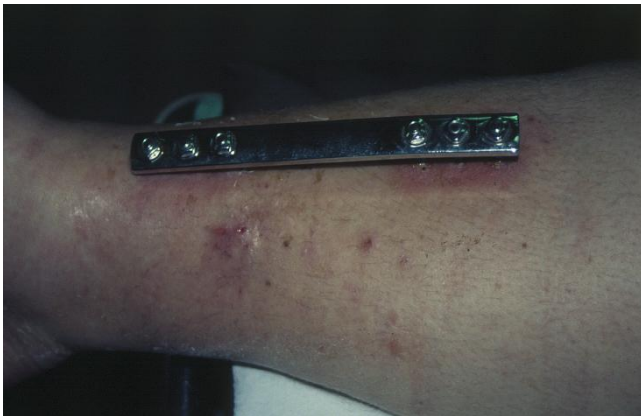


Fig.5 Contact rash [16]

IV. THE EXAMPLE OF FIXATOR USED IN BONE SURGERY TAKEN OUT FROM PATIENT ALLERGIC TO NICKEL [17]



Fig.6 Allergic contact rash [16]

The fundamental role of an implant is performing some definite functions in organism – corrections and repairs of organ disfunctions. It may happen, however, that due to some factors an implant will not be able to perform its role in a proper way. The loss of functional abilities may occur as a result of a mechanical damage of an implant, post-operation complications and infections. Resulting in the rejection of implant by an organism.

The intramedullary nails (which have been taken off the body and examined) belong to short-term implants. The time of their duration in the body does not surpass two years. For that reason, that kind of implants is made of stainless steel, which has good mechanical properties and high corrosion resistance, but is very allergic.

The patient underwent an implantation of intramedullary nail into thigh. A few months after the operation, the wound started to suppurate and a rash appeared. It turned out, that the patient was allergic to nickel contained in the implant. After removing the nail and the patient's treatment, the symptoms disappeared.

The nail was mechanically examined. The microscope examination revealed some fraction in the material in the joint between the screw and the nail (Fig.8).

In most cases allergic changes resulted in the necessity of removing an implant and led to steady disability of the patient (Fig.7). The fig. shows an open wound with abscess after introducing hip implant (fig. in the middle). The fig. on the left presents an endoprosthesis introduced into human body, whereas the fig. on the right shows hip joint after the removal of the implant.

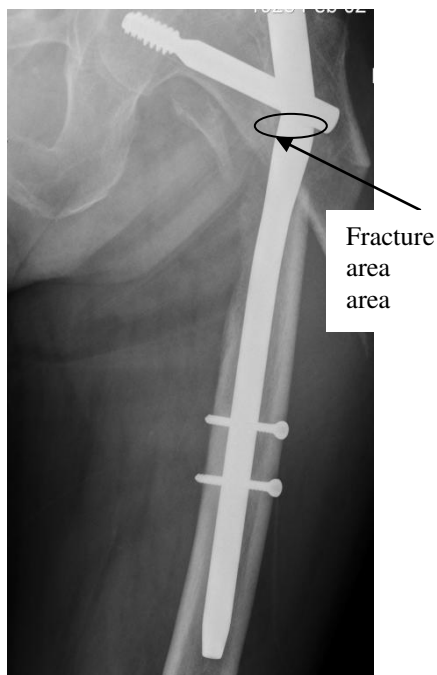
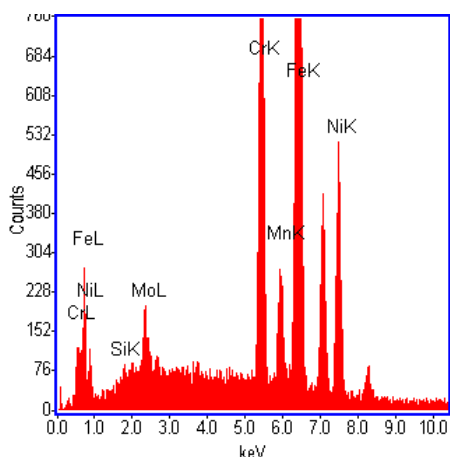


Fig.8 The picture of Gamma nail in the leg with fracture area [16]

The analysis of Gamma nail fracture started with macroscopic observation of the outer surface as well as the whole surface in the fracture area. No signs of mechanical or corrosion destruction were observed on the outer surfaces. While some dishes in the whole surface were spotted in the fracture area. It was plastic deformation of the nail in the contact place with the screw. The chemical composition of the Gamma nail material was examined by means of the Scanning Electron Microscope Philips XL 30, equipped with devices to analyse the chemical composition (EDS), and the results were presented as a spectrum and the print in Fig.9.



Element	Wt %	At %
SiK	0.58	1.16
CrK	17.57	19.09
MnK	1.93	1.99
FeK	59.97	60.68
NiK	14.29	13.75
MoK	5.66	3.34
Total	100.00	100.00

Element	Net Inte.	Bkgd Inte.	Inte. Error	P/B
SiK	2.34	4.71	14.66	0.50
CrK	151.88	6.61	0.85	22.98
MnK	13.25	5.77	3.76	2.30
FeK	358.53	5.32	0.54	67.39
NiK	58.28	4.06	1.40	14.35
MoK	2.07	1.38	10.62	1.50

Fig. 9. The spectrum and the chemical composition of the Gamma nail material

The chemical composition analysis proves that, the material of the examined nail is stainless Cr-Ni-Mo steel. According to the Schöffler’s diagram, the austenitic structure of the examined material was found. Its hardness was defined by means of Vickers method of measurement by loading of 294,2 N. The average hardness of the Gamma nail is presented in Table 1.

Tabl.1. The hardness HV30 of the intramedullary nail

The Gamma nail element	The average hardness HV30
Nail	321
Screw	320

The examination of fixator breaking was restricted exactly to the area of breaking, which is shown in Fig.8.

The observations of the fatigue fracture were performed using the SEM with different magnifications (from 23x to 1000x). The chosen views of the fatigue fractures are presented in Fig.10.

It was found, that both the nail and the screw cooperating with each other are equally hard (320 HV30), which proves the proper combination of the materials in the construction of the examined nail.

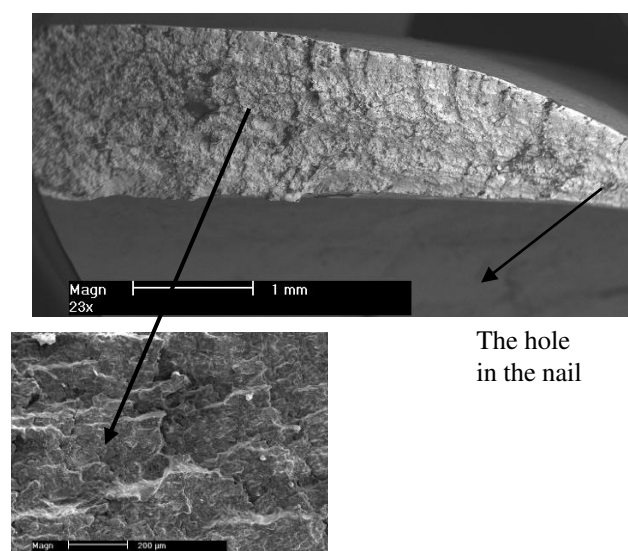


Fig.10. View of the fatigue fracture of the Gamma nail

The observations of the fixator (Gamma nail) fracture show that failure has fatigue nature with characteristic focus of the stresses concentration. The analysis of biomechanical loading of the nail (Fig.8) and the fracture (Fig.10) indicates that concentration of variable stresses most probably appeared of the hole edge in the Gamma nail. It can't be excluded, that the course of fatigue fracture might have been started by micro fracture caused by the impact of loading (for example a fall) and its further advancement in the course of further use of the examined Gamma nail.

V. DISCUSSION

The data concerning the influence of allergic reactions on the joint between an implant and tissue, don't give a definite answer to the question, whether, the sensitivity of implant compounds is responsible for post-operation complications, such as rejection of the implant [18]. However, in the view of shocking statistic pointing to oversensitivity to metals about 10-15% of population [6,19], mainly women have positive allergic result to nickel in patch tests carried out among adults [20]. The appearance of allergic reactions with such a large number of people is a serious problem, taking into account in increasing need for alloplastic joint operations. The risk of post-operation allergic complications requires significant consideration for economical reasons as well as well-being of patients.

One of the simplest methods to prevent the appearance of contact oversensitivity to metals with the trauma-orthopaedics patients appointed for alloplastic surgeries is conducting a medical enquiry as well as doing patch tests, which can prevent the patients from another complicated operation. The results of the tests show, that the most important is carrying out tests on implant compounds, according to the International Group of Contact Rash. Such research allows to diagnose the kind of allergy in the long duration (96h counting from performing the test), which increases the accuracy of analysis.

In case of patients, who suffered from post-operation allergic changes, the symptoms disappeared after doing a reoperation, which is an evidence for the impact compounds on human body. Perceived changes have confirmation in professional literature referring to skin changes after the removal of an implant [7]. Sufficiently early performed sensitivity test to metals allows, that proper choice of metallic biomaterials for implant for individual patient prevents reoperation.

Using protective layers on implants may appear to be an innovative method to prevent allergies to metals. Implant coverings made of chemically inert materials are a perfect obstacle for the emission of allergic metals, which are present of implant alloys. Literature shows, that a few weeks after inserting implants covered with protective material into bodies of lab animals forming of connective tissue around the inserted body without any inflammation changes was observed [8].

Recently there have been found some convincing information concerning allergic reaction to titanium implants. However, it should be taken into consideration, that implant

material isn't pure titanium but alloy of many metallic elements.

As an example to such reactions may be an old man, who had worn metal earrings for 10 years and as a result his ears became covered with rash. Keloid was suspected. A segment was cut off and examined. Macrophages, lymphocytes and malignant plasma cells were found. Examination carried out by means of scanning electron microscope showed particles of titanium, aluminium and vanadium. It indicates, that in some cases titanium alloys can reveal caryopsis skin inflammation [21].

Another example is 6 titanium implants inserted into 49 year old woman jaw. The result was an acute clinic and radiologic reaction around all the implants, which forced the doctors to remove the implants. After that healing followed [22].

Today, due to increasing lifespan, the significance and range of orthopaedics is increasing. Orthopaedic surgeons are increasingly using metallic implants, particularly for younger patients. Some patients have orthopaedic and dermatological complications caused by sensitivity to metals included in metallic implants.

Allergy to metals in patients with metallic implants has been discussed for a long time by many specialists. In the 1970s growth and exacerbation of contact dermatitis especially nickel allergy caused by metallic implants (plates, screws, nails, prostheses), were noticed. Orthopaedic complications such as delayed or non-union of fractured bone and prosthesis loosening were linked with implant-related sensitivity. This problem has remained unresolved so far [19].

The research conducted on rabbits allergic to nickel, which underwent inserting intramedullary wires to join the tibia bones showed decreased of bone endurance increasing of their absorption, decreased number of osteocytes as well as weaker rebuilding of bone tissue [20].

Hierholzer et al. [23] think, that infection in the vicinity of an implant is connected with the increased amount of metals and accumulation of immunocompetition cells. In inflamed tissues active oxygen causes oxidation of 2-value to 3 and 4-nickel value, which causes allergic reactions (activation of T lymphocytes). The infections, according to Oiso et al.[24] makes it easier to provoke metal allergies and they intensify inflammation.

For many years allergic reactions were associated with undesirable effects of metal components such as: disk, screws, nails and endoprosthesis. However, it was supposed, that late oversensitiveness may be an explanation to some orthopaedic complications such as: disturbances in bone growth after using metal joints or dysfunction of endoprosthesis joints [25-33]. Many researchers claim, that skin rash changes are more often caused by static, than dynamic implants [25,27,32].

The new generation implants show much better physical properties, they are more resistant to corrosion and friction and less allergic [7, 34-36]. There isn't an agreement concerning the role of allergies to metals in orthopaedics. Currently, the results of inserting implants are good and orthopaedic complications are estimated at above 5-10%, there are no comments on the appearance of skin reactions [34,35]. However, it should be considered, that all materials inserted into bodies undergo corrosion and use [37]. The

observation period after the implantation should be long, since the breeding of contact allergy may take a few or even several years [38].

There are extreme differences in opinions concerning performing the patch tests before and after operations. Some claim, that patch tests should be done before the implantation [26,28,29,39], and others do not see any reason for doing it [30]. The general opinion is, that doing patch test is advisable in case of some complications [24,29,40]. It should be added, that orthopaedic complications caused by allergy to metals may not reveal any skin changes or may not be confirmed by patch tests [41].

The causes of allergy to metals are not fully known. What is more, at present there does not exist any diagnostic method. Unexplained remains the fact, that some patients, who underwent metal implantation developed tolerance to metals, while some of them experienced dermatologic and/or orthopaedics complications. The risk of the appearance of allergic complications caused by implants inserted in healthy and allergic to metals patients have not been found [19]. Therefore, the most important is carefully conducted interview to find out the symptoms of contact allergy to metals [36].

VI. CONCLUSIONS

On the base of literature review and author's own experiments following conclusions are proposed:

Before the intended metal implantation it is necessary to conduct an interview to exclude oversensitiveness to metals, as well as implant compounds.

In complications following osteosynthesis in over half cases allergic background to Ni, Cr and Co was found.

Simple allergic diagnosis ought to be performed more frequently with patients suspected of tendency to allergy in trauma-orthopaedic hospital units.

In urgent cases, when there isn't a possibility to carry out patch tests, interview is obligatory. If an interview shows allergy to metals an alternative choice of material for implant should be considered.

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