Premature wear of the ABG artificial hip-joint and resulting complications

We report and analyse the case of catastrophic failure of the AGB I artificial hip-joint. Possible reasons of premature acetabulum wear and following complications are discussed. The results of histopathological studies are presented revealing a vast amount of metal particles in the granulation tissue formed around the hip prosthesis. The presence of polyethylene debris in the tissue is detected by Raman microspectroscopy method. The size of the polyethylene particles is estimated to be within the range known to cause the most severe osteolysis, ponting to the quality of polyethylene as one of the reasons for poor prosthesis performance. It is concluded that the vastness of prosthesis wear and associated periacetabular lesions may not be obvious from the radiological examination and thus that early surgical interventions would be desirable to avoid severity of osteolysis-associated complications.

Introduction

Hip arthroplasty has become a commonly used and widely accepted method of treatment of degeneration of the hip joint. Since the first hip joint endoprosthesis implantation there has been a significant improvement in technology and design of these devices as well as development of new surgical techniques. However the latter are still threatened by early and remote, local and systemic complications.

One of them is osteolysis around the implanted acetabulum resulting in its aseptic loosening [1], caused by mechanical wear of a polyethylene lining.

The problem of bone resorption in the regions adjacent to the implanted endoprostheses with no symptoms of infection was noticed and reported in the 70s [2]. After gaining experience with subsequent generations of endoprostheses it was found that this problem concerned all types of endoprostheses and all types of interfaces between the prosthesis and the bone [3]. Histopathological examination of the soft tissues collected from the joints enabled more accurate establishing the cause of the problem. In the 80s, in the histopathological samples, macrophages, giant cells, as well as polyethylene particles of various sizes were observed. Cytochemical examinations showed the presence of high concentrations of collagenase, cytokines (IL-1), (IL-6) and TNF (Tumour Necrosis Factor), regarded as the main mediators of osteolysis [4]. Generated by friction, polyethylene particles disperse within the joint in accordance with the gradient of the intra-articular fluid pressure and deposit in the effective regions of the joint described by Schmalzreid [5], where some of them undergo phagocytosis and the rest is coated by giant cells. It is generally assumed that the process of wear of polyethylene lining is unavoidable, and the amount of released polyethylene particles is related to the quality of polyethylene [1,6,7]. It has been reported in literature that prostheses with polyethylene wear rate up to 80 mm3 per year do not cause osteolysis, but the wear rate of over 140 mm3 per year is related to high osteolysis rate [8]. Matthews et al. stated that the particles of the size of 0.24±0.094 µm cause osteolysis at a...
smaller volume than the particles of the size of 0.42±0.22 μm or 1.7±0.99 μm [9,10]. In his experiments in vitro, Green et al. show that polyethylene particles of the size of 0.3-10 μm are the most active biologically [11].

Nowadays, the new kind, high cross-linked polyethylene is offered which is obtained by polyethylene gamma irradiation at high temperature. This favours the formation of additional bonds between carbon chains, which increases hardness of the material, but on the other hand, degrades its mechanical properties like elasticity and flexibility [12,13]. The experiments have also been conducted on introducing gradient crosslinking into UHMWPE by irradiation in the molten state, with the aim of improving wear resistance of the articulating surface of the lining without compromising mechanical properties of the polymer [14].

The majority of contemporary hip endoprostheses show durability of over 90% after a 10-year period. Introduced in 1989 artificial ABG I acetabulum became very popular due to promising early results of treatment [6,15]. After 5-6 years of observations, its excellent durability was reported, which reached 95-99% [6,16,17]. However, after 6-8 years of observations, its durability was reported to be only 62-79% [17,7]. It especially concerned young, physically active people, in whom significant mechanical wear of lining accompanied by osteolysis adjacent to metal acetabular part was noted [16,18,19].

Factors causing osteolysis and loosening of the acetabulum related to the implant are: polyethylene quality mentioned earlier, decreased resistance of the lining to friction, type of sterilisation, articulation of the prosthetic head with polyethylene acetabulum, improper lining fixation, numerous openings in the acetabular metal part which enable penetration of fluid and polyethylene particles to the bone [17,19-21]. Factors related to the patient are: body weight, type of physical activity, the number of revision surgeries and age. All the elements are important risk factors of periprosthetic osteolysis observed most often in patients below 50 years of age. Age is therefore inversely proportional to the intensity of use of the prosthesis and dynamics of its wear, and thus this problem is rare in the patients above the age of 70 [22,5].

The investigations carried out in a number of centres indicate that mechanical wear of endoprosthetic polyethylene components may be related to the change of their physical and chemical properties, resulting from long-lasting use and effect of body fluids. These changes can be of various intensity which most probably depend on aggressiveness of the physiological fluids and on patient’s activity [23]. Microscopically, the wear is frequently manifested by discoloration of the polyethylene. Examination of the physical and chemical properties of the polyethylene revealed changes in its crystallinity and formation of carbonyl bonds, which led to significant decrease in mechanical resistance of the prosthetic acetabulum resulting in its early abrasion [24,25].

The works on subsequent generations of polyethylene, like the highly cross-linked polyethylene, have been conducted, however these still require long-term clinical observations and standardization of methods of both production and sterilization.

Case presentation

A 42-year-old female teacher who had earlier undergone a total-hip-replacement operation on both hips, was admitted to the St Lucas Provincial Hospital in Tarnów because of impairment of gait requiring the use of crutches and pain upon movement. On admission, restriction of active and passive mobility of the right hip joint with preserved ability of its straightening and 80º bending were noted together with inability to perform rotary movements due to pain. The patient did not show any skin contact allergy to metal parts of clothes or ornaments. The X-ray picture of both hip joints revealed bilateral decentralization of the endoprosthetic head indicating the asymmetric wear of polyethylene lining in both endoprostheses. Moreover, on the right side, an extensive region of osteolysis around the metal acetabular cup was visible (marked with arrows in fig. 1b).
The patient (medium size, slim, having active lifestyle) underwent total hip arthroplasty surgery to her left, and the right hip joint, in 1998 and 1999 respectively. The implant was cementless ABG I prosthesis consisting of the backing acetabular cup made of the Ti-6Al-4V alloy and the polyethylene lining articulate with a CoCrMo-alloy femoral head. The surgery was required due to degenerative changes in the course of congenital hip joint dysplasia. Earlier, at the age of 2 the patient underwent corrective operations on both hip joints. The postoperative scars, deformation of the trochanteric region and bony wire are visible in the radiograph.

Since 2005 the patient suffered pain in the lumbar spine and in the region of the right hip joint. She was treated conservatively with no improvement and later qualified for the revision surgery. At the first stage the right hip joint was operated on. After the incision in the hip was made to expose the joint, abundant black and brown discharge flew out spontaneously from the opening, under its own pressure (fig. 2).

After the joint was lavaged, an extended granulation was seen. This was removed, revealing loosened endo-prosthetic acetabulum and damage to its metal part as well as polyethylene lining (Fig. 3). The retrieved component showed extensive, eccentric damage of the polyethylene cup whose lateral part was completely worn through and a spherical indentation in the metallic backing shall, caused by the femoral head.

After the removal of the endo-prosthetic damaged parts, the extensive loss of the acetabulum was noted, which was much larger than the region of osteolysis visible in the X-ray picture; through the hole at the socket's bottom the lumen of the pelvis could be seen. The stem of the endoprosthesis was stable, however at its part near the 1/3 of proximal length, in the space between the stem and the bone the granulation was found which was subsequently removed. The collected material was sent for bacterial culture; the granulation and bone fragments were subjected to histopathological examination.

Results and discussion

The case was dealt with in several stages. At the first stage a spacer (a temporary, cemented acetabulum impregnated with an antibiotic to eliminate the possible infection) was inserted into the

Figure 2
The incision showing a large amount of brown, tarry substance formed around the artificial hip joint.

Figure 3
Acetabulum of the ABG I endoprosthesis removed from the patient's body: the retrieved component with the remainders of the granulation (a), polyethylene lining showing severe, eccentric wear (b) and the Ti-6Al-4V backing shall with the spherical groove pointed by the arrow (c).

Figure 4
The hip joints after the final revision procedure.
right acetabulum after the granulation was thoroughly removed and the bony socket cleaned out.

Two months after the right hip replacement, the patient underwent the second replacement surgery - to the left hip. During the operation, the damaged polyethylene lining was removed. The remaining endoprosthesis elements were stable and free of mechanical damages. A small amount of granulation was found and removed through the openings in the metal acetabulum. Then, through the same openings, a small amount of bony rubble was compacted and a new polyethylene lining designed for revision of ABG I endoprostheses was implanted. The healing was uncomplicated.

The last surgery was performed 4 months later. The right hip joint was opened again, altogether 6 months after the first revision surgery. During operation no signs of inflammation were found. The temporary acetabulum was removed and the bone loss at the socket bottom was closed with solid, frozen bony graft made from a femur head. Then the bone socket was reconstructed (pointed by arrows in the inset of fig. 4) using allogenic bony rubble. Into thus prepared bony socket a revision Exeter prosthetic acetabulum, impregnated with an antibiotic, was glued with the acrylic cement and a new head was placed on the stem (fig. 4).

Microbiological examination also in this case did not reveal any pathogenic micro-organisms. In the peri-operational period no complications were observed.

The patient is being followed-up.

Bacteriological examination of both the fluid and granulation collected during the first operation did not reveal any pathogenic micro-organisms. The samples collected for histopathological examination contained several irregular, grey and black tissue fragments from the region of the right hip joint stem. Microscopic picture of the samples routinely stained with hematoxylin and eosin revealed fragments of cicatricial connective tissue with numerous macrophages and deposits of metal particles (fig. 5). Occasional resorptive granuloma with foreign body giant cells were also seen (fig. 6).

The above samples when viewed at higher magnification revealed a presence of a great number of white particles dispersed in the material (fig. 7); some of them were clustered into bigger conglomerates. It was anticipated that the particles were polyethylene debris released in the process of wear of the polyethylene acetabular lining. The size of the particles was assessed to be of the order of micrometers. The most abundant were particles in the range of 0.9 µm - 1.2 µm. The apparently bigger fragments were in fact clusters of many, much smaller debris. The biggest diameter of the single particles observed, was about 2.5 µm.
Raman micro-spectroscopy method was used to examine the nature of the particles present in the collected material. The Raman spectra were measured using an Nicolet Almega XR, Raman microspectrometer of spectral resolution 2 cm⁻¹, equipped with a silicon CCD camera. The incident laser beam wavelength was 532 nm. The spatial resolution was better than 1 μm and thus sufficient to probe the debris of micrometer size.

Fig. 8 shows the Raman spectrum observed typically for the probed white particles and thus considered as representative of the debris. For comparison the spectrum collected for the unworn part of the retrieved polyethylene acetabular liner is shown at the bottom. This spectrum appears to be typical of Ultra High Molecular Weight Polyethylene (UHMWPE) (see e.g. [26-29]). It can be seen that the UHMWPE Raman bands shown in the lower panel are present in the spectrum of the debris confirming that these are also the UHMWPE material. The additional bands present in the spectrum of the debris are a manifestation of a presence of some additional vibrational states formed in the polyethylene (due to its degradation or reaction with other wear products) but this issue is outside the scope of the paper. The analysis of the UHMWPE bands' relative intensities and their spectral positions leads to the conclusion that the debris are characterised by ill-defined, mostly amorphous polyethylene structure; the bands assigned to the crystalline phase nearly vanish or are much weakened. All the Raman bands in the debris spectrum are broadened due to the small size and low crystallinity of the particles. Moreover, some bands are shifted towards higher frequency values indicating that a significant amount of compressive strain is present in the debris which can be expected of a heavily worn material.

Conclusions

The presented case of premature, catastrophic failure of polyethylene liner of the ABG I is yet another case where the eccentric polyethylene wear took place leading to the wear of the underneath metal backing and as a result to heavy metallosis and other complications. According to Castoldi et al. [30] the ABG I system widely used since 1989 has shown high rate of failure due to polyethylene wear, with the eccentric polyethylene wear occurring in nearly 94% of the patients. Our findings are another example of early lining wear of the ABG I prosthesis and development of premature osteolysis and endoprosthesis loosening, thus confirming reports by other authors [16,31,17,17].

The factor contributing to the high wear rate in our patient was on the other hand the changed kinetics of the patient’s gait due to altered anatomy of the pelvis caused by the two corrective operations in the childhood due to bilateral hip joint dysplasia. The lack of congruence of the prosthetic acetabulum with the femoral head created unfavourable bio-mechanical conditions in the artificial joint, which speeded up the process of the endo-prosthesis wear.

The massive release of polyethylene debris and metal particles led to immune response, resulting in periprosthetic osteolysis and considerable bone destruction. The size of polyethylene debris in the presented case was found to fall within the range considered the most biologically active (0.4-1.7 μm according to [9,10] and 0.3-10 μm [11]) which is consistent with the vastness of the bone loss in the vicinity of the artificial hip joint.

Loosening of the endoprosthesis is one of the complications of arthroplasty. It may affect the acetabulum, the bone shaft or both. The first symptom of the complication of this type is pain in the region of the operated joint. The changes observed radiologically are frequently the symptoms of already advanced destruction of the endoprosthesis. In the described case, the radiologically detected symptoms were incomparably small to the destruction of the acetabulum found intra-operationally. The X-ray pictures showed only the mechanical wear of a polyethylene lining and osteolysis around the metal acetabular parts. However, the surgery showed extensive destruction of all endoprosthetic elements, as well as massive bone loss of the patient's acetabulum and considerable loss of the socket bottom (about 5 cm x 5 cm).

The surgical intervention in the initial period of prosthetic damage is restricted to the exchange of the polyethylene lining and cleaning of the osteolytic focus with simultaneous complementation of the lost tissue with small amount of bone grafts.

On the other hand, advanced prosthetic damage requires the use of large amount of bone grafts and the final effect is not always successful. Therefore, in case of finding any radiological symptoms indicating loosening of the endoprosthesis, the revision operation should be performed as soon as possible to prevent extensive damage to the bony tissue as it occurred in the presented case.

References
4. Chiba J, Rubash HE, Kim KJ, Iwaki Y. The characterisation of cytokines in the interface tissue obtained from failed cementless total hip

Figure 8
Raman spectra collected for the debris and for the unworn part of the UHMWPE liner. The arrows mark polyethylene Raman bands in the spectrum of debris.