Aus der Klinik und Poliklinik für Orthopädie und Unfallchirurgie
der Universität Köln
Direktor: Universitätsprofessor Dr. med. P. Eysel

Langzeitergebnisse des navigierten Articular Surface Replacement ™ (ASR) Hüftoberflächensystems
Analyse der Risikofaktoren für Revision

Inaugural-Dissertation zur Erlangung der Doktorwürde
der Hohen Medizinischen Fakultät
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vorgelegt von:
Johannes Henricus Maria van Ochten
aus Nijmegen/ Niederlande

promoviert am 6. März 2019

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2. Index

3. Glossary

PTFE: polytetrafluoroethylene

MoM: metal-on-metal

SSA: stem shaft angle

NSA: neck shaft angle

ASR™: Articular Surface Replacement™

ARMD: Adverse reactions to metal debris

Co: Cobalt

Cr: Chromium

ALVAL: aseptic lymphocyte-dominated vasculitis associated lesion

MHRA: Medicines and Healthcare products Regulatory Agency

ppb: parts per billion (micrograms/L)

NICE: The National Institute for Health and Clinical Excellence

BMI: Body Mass Index

PRO: patient-reported outcome

PROM: patient reported outcome measurement

HOOS: Hip dysfunction and Osteoarthritis Outcome Score

HHS: Harris Hip Score

AP: anteroposterior

MARS: metal artefact reduction sequence

MRI: magnetic resonance imaging

LTFU: lost to follow – up

EFORT: European Federation of National Associations of Orthopaedics and Traumatology

EHS: the European Hip Society

AE: Arbeitsgemeinschaft Endoprothetik

DAH: Deutsche Arthrosehilfe

DGOOC: Deutsche Gesellschaft für Orthopädie und Orthopädische Chirurgie

BHR™: Birmingham Hip Resurfacing™

CAAA: cup articular arc angle

ODEP: Orthopaedic Data Evaluation Panel

4. Introduction

4.1 History of resurfacing hip arthroplasty

Smith-Petersen, whose mould arthroplasty was not intended as a hip replacement originally but as a cobalt – molybdenum alloy (vitallium) mould for cartilage regeneration (interposition arthroplasty), with the intention of removing the mould when the articular surface of the hip had become smooth and congruent, was the designer of the concept of hip resurfacing arthroplasty in 1940. This concept was abandoned, as regenerated surfaces of the hip were incomplete and not optimal for weight bearing, so in the end the moulds were never removed.(1, 2)

In the 1950s Sir John Charnley experimented with PTFE hip resurfacing (first generation) as a continuation of Smith-Petersen's earlier work, but eventually abandoned the technique due to rapid wear. He attributed the failures to the resurfacing procedure and went on developing metal-on-PTFE total hip replacements. When these failed as well, he discovered that PTFE wear was the problem. He also realised that large-diameter hard-on-soft bearing would give rise to excessive wear and warned against resurfacings.(1, 3)

In the late 1970s Wagner developed both metal-on-PTFE and ceramic-on-PTFE resurfacing hip arthroplasty, but revision rates were very high.(4) Problems with these prostheses were loosening of the components and collapse of the femoral head. However, closer examination of the failure patterns learned that it was failure of the materials, not of the concept of resurfacing hip arthroplasty. (5)

In the early 1990s McMinn revolutionized the development of hip resurfacing arthroplasty (second generation) proposing large – diameter MoM bearings with no polyethylene and went against the established principles of low-frictional torque arthroplasty. Studies of retrieved components showed an extremely low wear rate, which attributes to the understanding that these bearings have the potential to function as metal-fluid-metal joints with negligible wear.(3, 6)

The McMinn hybrid resurfacing was withdrawn from clinical use in 1996 and the BHR (third generation) was introduced in 1997 as an as-cast (i.e. no mechanical and/or heat treatment) device, with further improvements in fixation and a much wider range of components. (3)

Modern MoM hip resurfacing was primarily developed in order to address the relatively poor survival of conventional prosthesis in young, active adults. (7) There is also some evidence that patients with MoM hip resurfacing attain higher levels of function than those with conventional hip replacement.(8)

Both the first- (metal-on-polyethylene) and the second-generation (cementless MoM) resurfacings failed because of high rates of wear and aseptic loosening.(9, 10) Since the popularization of the first-generation MoM designs in the 1960's, improvements in implant design and fixation have provided modern MoM implants with some major theoretical advantages over their metal-on-polyethylene counterparts.

4.2 Advantages

4.2.1 Less wear

The current third-generation MoM hip resurfacing implants consist of a cemented femoral component and a press-fit acetabular component.(9, 10) MoM articulations using cobalt-chromium-molybdenum alloys reportedly produce considerably less volumetric wear debris than standard metal-on-polyethelyne components and additionally, the all-metal acetabular component can be made thinner, allowing the use of a larger-diameter femoral head resulting in an increased stability and range of movement compared to implants with small head diameters.(11)

4.2.2 Other advantages

Possible additional advantages of the MoM hip resurfacing include the resection of less bone and an easier conversion to a secondary procedure if failure occurs, good proprioceptive feedback because it mimics normal hip kinematics and reduced risk of leg length discrepancy.(12-15)

Due to promising early results of MoM hip resurfacing prostheses in the beginning of the 2000's, these types of prostheses were widely adopted for implantation across the world. (16) The past decade has seen a great rise in the use of the MoM hip resurfacing implants. In 2008, nearly 35 % of all hip replacements in the US were MoM prostheses. (17)

4.3 Disadvantages

4.3.1 Fracture of the femoral neck

Studies report an incidence of fracture of the femoral neck after hip resurfacing arthroplasty of 1,5 – 7,2%. Accurate placement of the femoral component is of utmost importance to avoid early implant failures for example because of femoral neck fractures. (14) Some studies have identified implantation of the femoral component in varus position as a risk factor for femoral neck fracture after hip resurfacing arthroplasty. A SSA less than 135 degrees and varus angulation greater than 5 degrees relative to the anatomic NSA have been associated with an increased risk failure of the prosthesis. (14, 18)

Cranial notching of the femoral neck may be caused by caudal malpositioning of the femoral component. This can cause mechanical weakening of the femoral neck and disturbance of the blood supply to the femoral head resulting in subsequent fractures as well. (19)

4.3.2 ARMD

A much-discussed disadvantage of use of the materials in MoM arthroplasty is the release of Co and Cr debris from its components. A few years ago ARMD captured a lot of media attention; however already in 1975 collections of fluid and damage of soft tissue were observed in the presence of elevated Co concentrations in hip joint aspirations after MoM hip arthroplasty. These findings were documented in a study with patients who had a first - generation MoM hip prosthesis (McKee prosthesis) implanted.

A few decades later, a significant increase in wear rates was observed in explanted third – generation MoM hip prostheses, which failed because of ARMD compared with control specimens.(7) False position of one the components can result in a high risk for impingement and edge loading. In metal-on-polyethylene hip prostheses, a malpositioned acetabular component is associated with a high wear rate of polyethylene, but in MoM hip prostheses impingement may also cause a lot of wear with a high level of metal ions in whole blood and/or serum.(12, 13)

Another concern in patients who have undergone hip resurfacing arthroplasty is the occurrence of periprosthetic soft-tissue lesions (inflammatory pseudotumors).
These pseudotumors have been associated with highly elevated levels of Co and Cr ions in whole blood and/or serum. (13) Vice versa highly elevated Co and Cr concentrations in whole blood and/or serum can point at a high wear rate and subsequent pseudotumor formation in hip resurfacing arthroplasty as well. ARMD, an umbrella term, is used to describe failure of the prosthetic joint caused by wear or metal debris in the absence of any other clear explanation. It contains metallosis, pseudotumor formation and ALVAL.(20, 21)

However, the relationship between Co and Cr concentrations in whole blood and/or serum and the development of ARMD is not entirely clear. Studies have shown that while in well-functioning MoM resurfacing hip prostheses no significant soft tissue reaction developed, in ARMD-related failure the extent of soft tissue damage due to metal debris exposure did not seem to be dose dependent. It is also possible that increase in Co and Cr levels in asymptomatic patients may be associated with underlying pathology for example osteolysis. Osteolysis does not always cause symptoms per se, but can often only be detected on radiographs or bonescintigraphy.(7)

4.4 Medical device alert

In April 2010, a medical device alert for the inspection of all types of MoM hip prostheses was issued by the MHRA, the government medical regulatory body in the UK. Patients with a whole blood and/or serum level higher than seven ppb for Co or Cr were selected for a more frequent inspection and further testing. Co and Cr ion levels of 0,5 ppb have been proven to be the upper limit of the reference range in the non – exposed population. Studies have shown average blood levels of 1 to 2 ppb in well functioning hip prostheses. The MHRA threshold of 7 ppb provided a sensitivity of 52% and specificity of 89% for discovering an unexplained failed MoM resurfacing prosthesis. This threshold however has been shown to have inadequate sensitivity to be used in isolation as a screening test for implant failure, but it provides almost perfect misclassification rates.(17)

It is unknown if increased blood levels of Co and Cr in the body have severe long – term consequences.(22) In the short term implanted modern MoM prostheses have not been associated with an overall increased risk of cancer. In several epidemiological studies the relationship between the risk of cancer and prior implantation of MoM hip prostheses has been examined, but results have been inconclusive and controversies persist.(23) However, in patients with extremely high blood Co and Cr levels, severe cardiological and neurological disorders have been reported.(16)

4.5 NICE Guidelines

NICE, a special health authority founded in 1999 to reduce variation and the availability and quality of NHS treatments, states that only if prostheses for total hip replacement and resurfacing hip arthroplasty have revision rates of 5% or less (new guideline) or 10% or less (old guideline) at 10 years, implantation is recommended in patients with end – stage osteoarthritis of the hip. (17)

4.6 Risk factors for revision

Until now several factors have been discovered to influence the outcome of the resurfacing hip arthroplasty. Prosthesis and surgeon related factors linked to accelerated wear in resurfacing components include a smaller diameter of the bearing, suboptimal placement of the acetabular component and low volume surgeons. (10, 21)

Steeply-inclined acetabular components, with abduction angles greater than 45 – 50 degrees and anteversion angles of less than 10 and greater than 20 degrees in case of the ASR combined with a small size component are likely to give rise to higher whole blood and/or serum levels of Co and Cr ions as well.(22, 24, 25) There are several patient related factors influencing revision rates in MoM hip resurfacing. The most important factors are female gender, age (younger patients), and dysplasia as the indication for surgery.(8)

4.7 Computer navigation in total joint arthroplasty

Alongside the development of the new MoM resurfacing implants, the use of computer navigation in total joint arthroplasty is increasing. The use of conventional guidewire alignment instruments can result in inconsistency between the planned position of the implant and the end result. Image-free navigation systems have shown increased accuracy in orientation in both total hip and total knee replacement, and may improve the long-term outcome. (14, 18, 26, 27) In our clinic only the femoral component of the resurfacing hip prosthesis was implanted using image-free navigation.

4.8 Goals of the study

Our primary goal was to present a survival analysis and the mid- to long-term results of the navigated ASR™ resurfacing prosthesis at our clinic in terms of clinical and radiological outcome and serum metal ions and compare them with the literature. Secondary goals were to analyse the revised prostheses (e.g. reason for revision, risk factors) and to determine whether the ASR™ resurfacing prosthesis meets the NICE guidelines.

5. Patients and Methods

5.1 Patient characteristics

From Mai 2006 to Mai 2009 46 total hip prostheses of the ASR™ Hip Resurfacing System in 43 patients have been implanted. Median age of the patients at the time of the operation was 55 years (Range 45 – 74 years). Mean patient length at the time of the operation was 173,7 ± 6,8 cm with a mean patient weight of 84,0 ± 14,3 kilogram. Mean BMI was therefore 27,8 ± 4.0 kg/m2 (Table 1). Annual check ups were routinely planned. At final follow-up, we followed the Depuy recall guidelines.

Table 1. Patient demographics of the population as a whole

Variable	*ASR Resurfacing*
Number of hips	46
Number of patients	43
Male: Female	26:17
Age at time of operation (years)*	55 (45 – 74)
Femoral head diameter (mm)**	47.9 (3.1)
Height (cm)**	173.7 (6.84)
Weight (kg)**	84 (14.3)
BMI**	27.8 (±4.0)

* Median (Range)

** Mean (Standard deviation)

5.2 Resurfacing system in our clinic

The MoM hip resurfacing system that was used in our clinic, the ASR™ (Depuy Orthopedics, Warsaw, IN, USA) was released in Europe in 2003. It was initially designed as part of the ASR™ Hip Resurfacing System and later approved by the Federal Drug Administration (FDA) for use in total hip arthroplasty in 2006 as part of the ASR™ XL Acetabular System.(11) (Figure 1.)

Figure 1. The ASR™ Resurfacing system

.

5.3 Operating technique

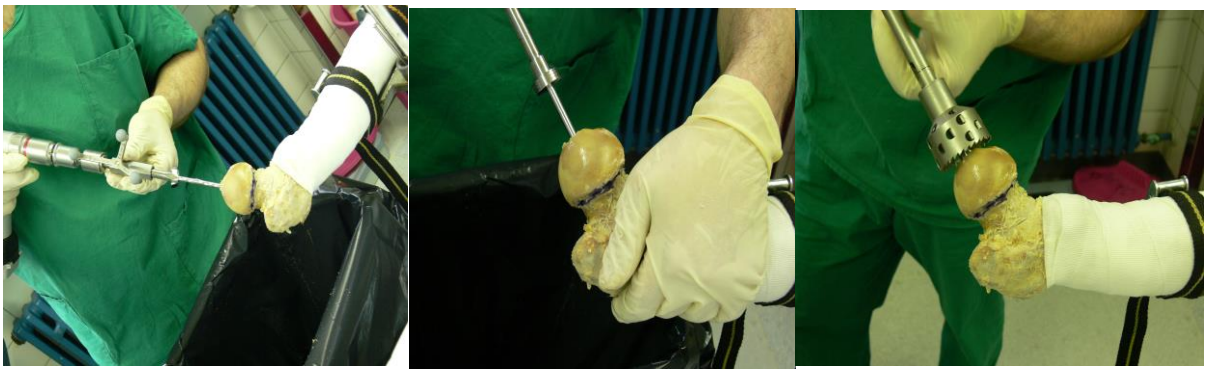
The patient is operated lying on the non – affected hip. After a single shot of antibiotics, the leg is desinfected and dressed properly. The posterolateral approach to the hip is used for the implantation of the prosthesis. First the iliotibial tract and part of the gluteus maximus are incised. Then the trochanteric bursa is excised.

The next step is to separate the exorotating tendons from the great trochanter without damaging the ischiadical nerve. After the hip capsule is opened using a T-shaped incision, the femoral head is exarticulated. Measurement of the femoral head takes place to determine the size of the femoral component.

The hip is relocated again and a Steinmann – nail is placed in the femoral neck to position the navigationstar. The centre of the hip by pivoting the joint and the other necessary landmarks of the knee and hip are determined for use in the navigation tool. The navigation instrument calculates the actual size of the femoral component.

After that, a central kirschnerwire is drilled in the femoral head and the femoral head is overreamed to the calculated component size. (Figure 2.) After reaming the femoral head, the acetabulum is exposed using two Hohmann – hooks and three Steinmann – nails. After a complete synovectomie, the acetabular component is underreamed 1 millimetre to the calculated component size.

Figure 2. Reaming of the femoral head in a cadaver femur



Probes are inserted to check the stability of the construct. The original acetabular component is placed in pressfit – technique. Then the femoral head is exposed again and reamed one last time. The probe of the femoral head is placed and the depth of the probe is marked. Irrigation (using jet lavage) of the reamed femoral head is the next step and placement of the original femoral component using bone cement (after vacuum mixing of the methyl methacrylate bone cement) till the necessary depth is reached. Bone cement rests are removed and the Steinmann nail is removed from the femoral neck.

Afterwards irrigation of the exposed operation area and relocation of the hip joint are performed. Range of motion and stability of the hip joint are checked one last time and then the different layers of the hip are subsequently closed using sutures.

5.4 Measurements

Measurements are essential for medical research and clinical practice. A large number of disease specific outcome measurements have been developed in the last few years for measuring the outcome from patient's point of view. These patient relevant outcomes are now considered the primary outcome measure in clinical trials.

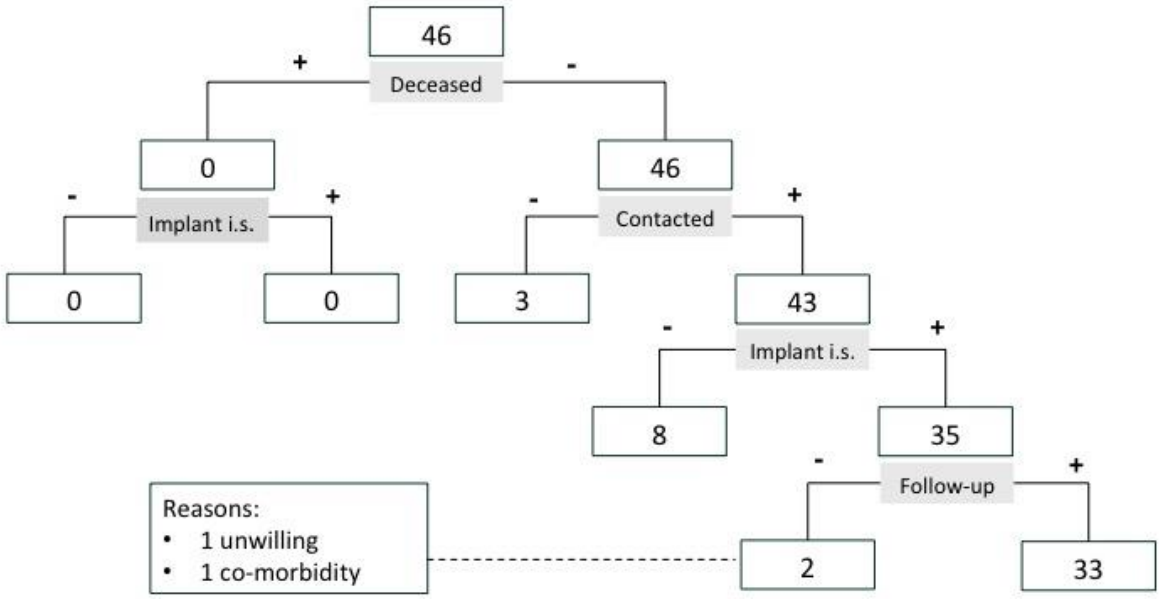
A PROM is a questionnaire used in a clinical setting, where the responses are collected directly from the patient and is defined as any report coming directly from the patient about how he or she feels in relation to a health problem and its treatment, i.e. without the interpretation of the patient's responses by a physician or anyone else. Thus, PROMS are a means of gathering patient rather than clinical or other views on outcomes.(28)
The term PRO is synonymous with the use of the term PROM, which is used in this manuscript.

The HOOS is an example of a PROM. The HOOS measures the following patient related components; symptoms, stiffness, pain, function; daily living, function; sports and recreational activities and quality of life.(29) Thus it gives us a lot of information on the patients' hip status. It has been validated in different languages.(30-33) It has been validated in German by Blasimann et al and also in our clinic (34, 35) (See Appendix 1 for the English version).

5.5 Clinical follow - up

At final follow – up, we were able to contact 35 patients. One patient had a metastasized pulmonary carcinoma and was unable to visit our clinic, one patient, who had already undergone a revision of one hip, was dissatisfied and refused to visit our clinic, three patients were unable to be contacted. A flowchart of the implants is depicted in Figure 3. One patient moved away and had the annual check-up in another clinic but filled out the HOOS and sent it by mail and was included in the clinical follow – up. HHS was missing in this patient.

Figure 3. Flowchart



The remaining 31 patients visited our clinic. Mean follow-up of the 32 patients (33 implants) was 89,6 months (SD 8,6). In one patient both score forms were missing and in another patient HHS failed. In 29 patients (30 implants) the HHS and in 31 patients (32 implants) the HOOS was completed. As stated, during final follow-up patients completed the HOOS form, HHS (Appendix 2) was completed by the physician, radiographs of the operated hip in 2 directions were obtained (AP and Lauenstein, Figure 4.) and in case of complaints blood was drawn from the patient to determine the Co and Cr whole blood levels and/or a Metal Artefact Reduction Sequence (MARS) – Magnetic Resonance Imaging (MRI) (Figure 5., see 5.7 Radiographic analysis) was acquired according to guidelines as composed by Depuy. (Appendix 3)

Figure 4. Radiographs of the Hip in AP and Lauenstein

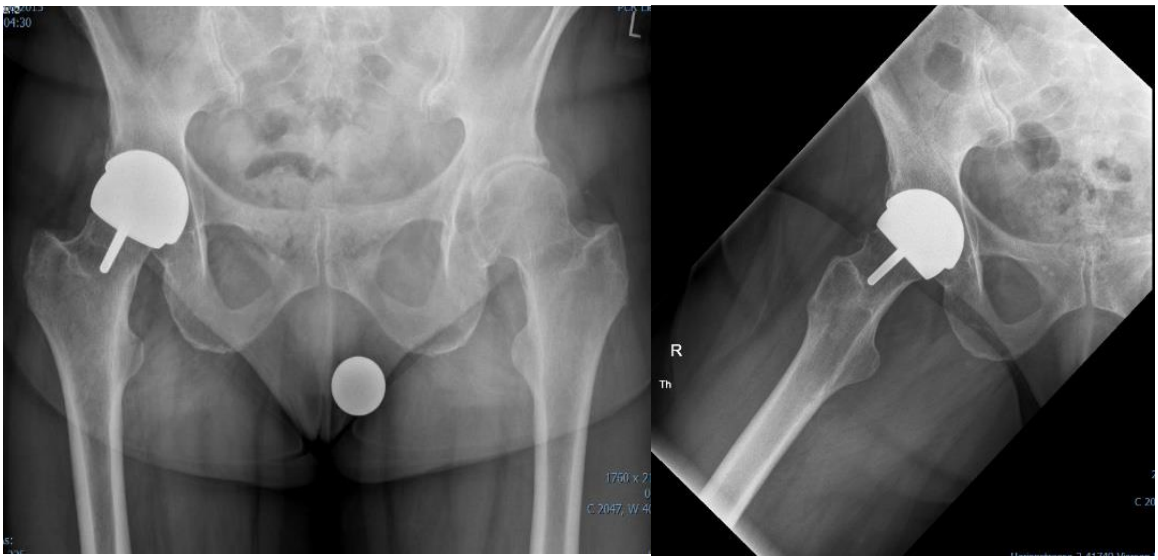
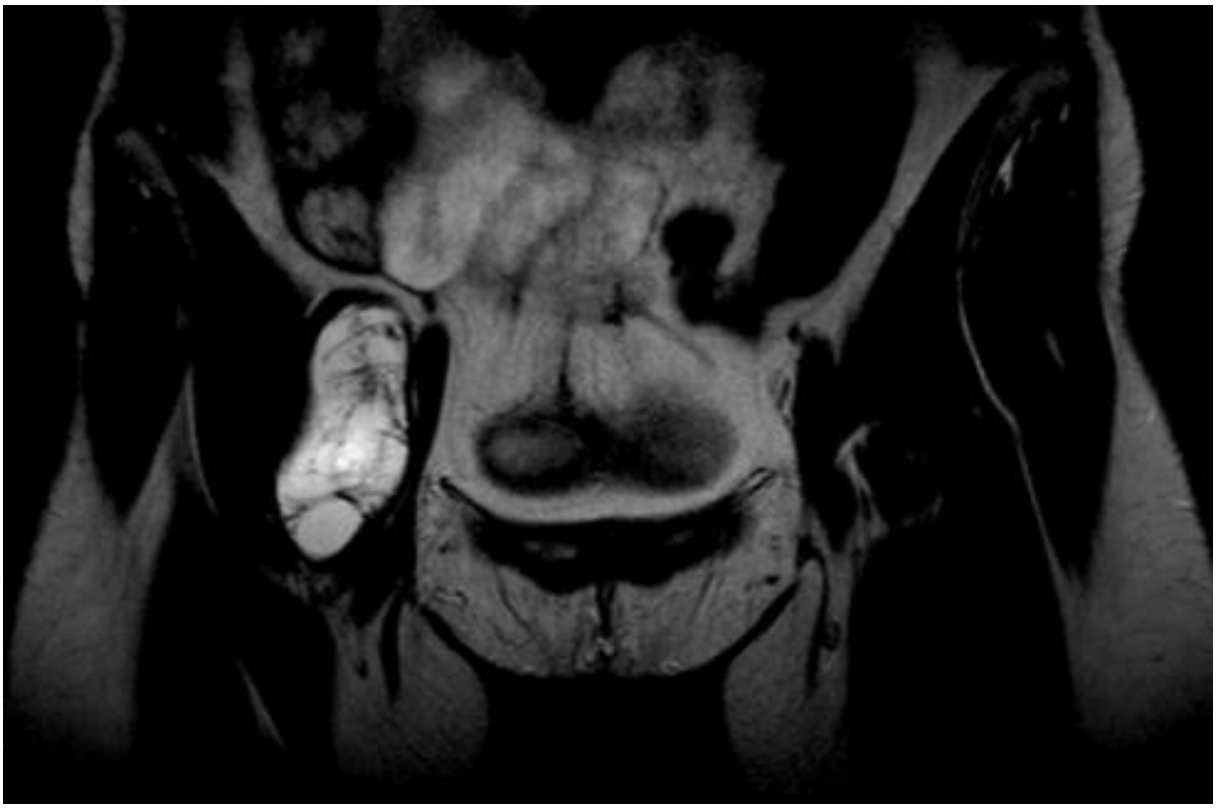


Figure 5. MARS – MRI of a different patient showing a large pseudotumor before revision



5.6 Radiographic analysis

On the AP radiograph, the acetabular angle of inclination was measured as described by Beaulé et al.(36) Inclination angles of the cup, NSA and SSA (Figure 6.) and the difference between these two angles (varus or valgus positioning, see Figure 7. for an example of a femoral neck fracture in a varus implanted resurfacing) were measured by two observers and the mean angle was used, since good interobserver reliability exists.(37-39)

Unfortunately measuring the NSA on preoperative radiographs was not possible. At the time that the resurfacing prostheses were implanted, the radiographic system in our clinic was changed from an analogue to a digital system. The analogue preoperative radiographs were no longer available for evaluation. Instead the NSA on the contralateral side on the latest radiographs was measured. Studies have shown none to minimal side differences in NSA (Figure 6.). (40, 41)

Any femoral radiolucencies were classified in the three zones as described by Beaulé et al.(36) Radiolucensies were measured in millimetres and acetabular radiolucency was classified in three zones according to DeLee and Charnley.(42) Heterotopic bone formation was classified as described by Brooker et al..(43) All available digital radiographs of the latest visit to our clinic were used to obtain the measurements.

In case of complaints or when Co and Cr blood levels were elevated, a MARS – MRI was scheduled to exclude pseudotumors and signs of ARMD. Assessment of MRI after arthroplasty has been considered very difficult because of image artefacts caused by metallic components. However, artefact reduction and improved visualization of periprosthetic tissue are possible by modifying pulse sequences, enabling an improved assessment of possible joint pathologies.(44)

The MARS reduces size and intensity of susceptibility artefacts from magnetic field distortion. For example the MARS – MRI technique leads to better visualization of bone marrow next to hip screws in patients with persistent complaints after femoral neck fracture, allowing to diagnose avascular necrosis of the femoral head. Other usage of the

MARS technique in the hip include assessment of periprosthetic soft tissues after hip joint arthroplasty, postoperative assessment after resection and reconstruction of bone in tumours, and localizing unopacified bone cement before hip revision surgery(45)

Figure 6. Measurement of the NSA and SSA on AP radiograph

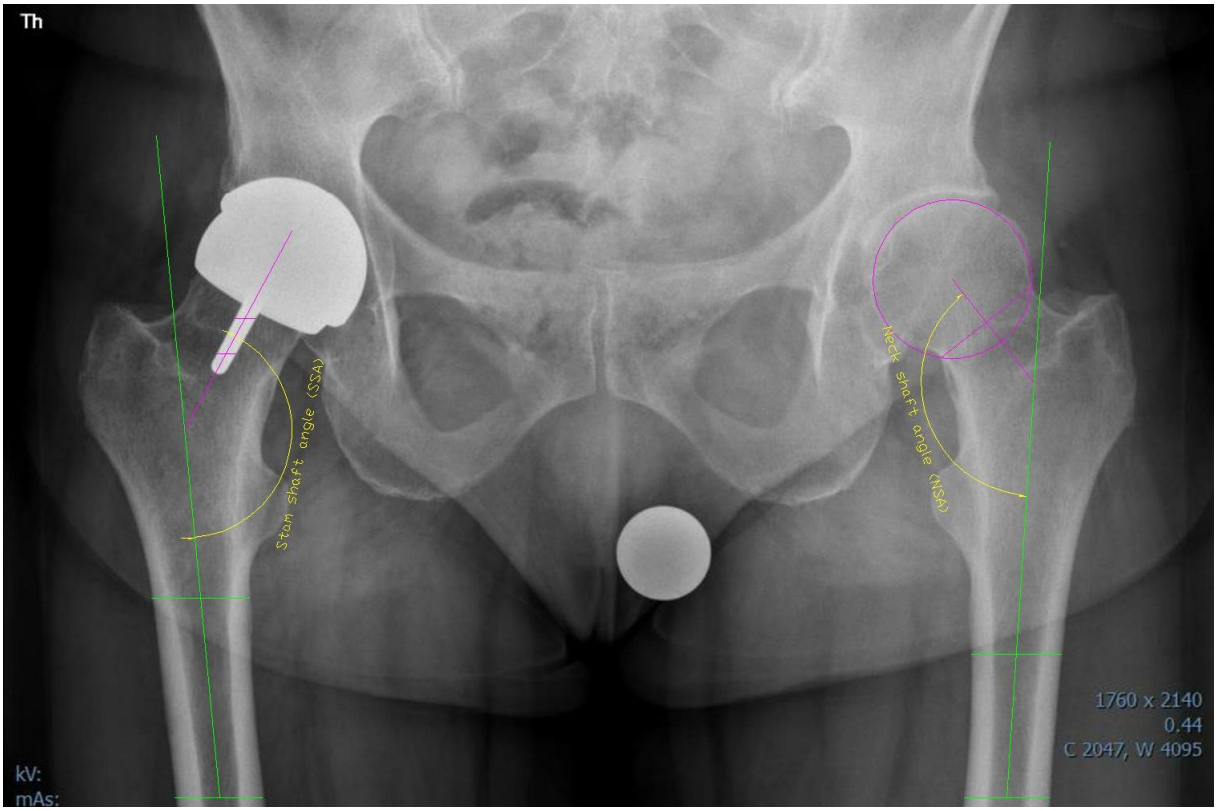
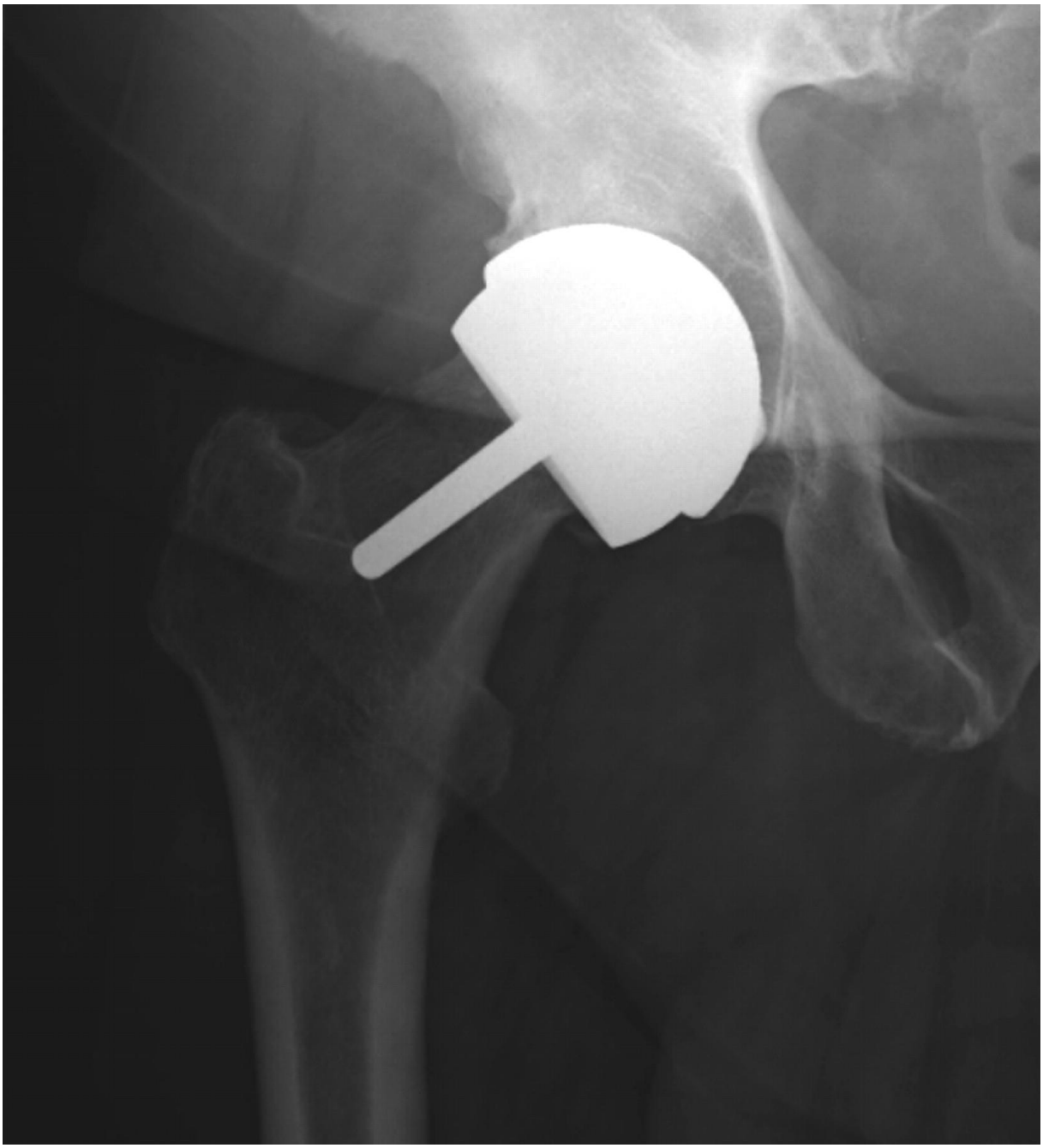


Figure 7. Femoral neck fracture after varus implanted resurfacing hip prosthesis (an example from the literature (46))



5.7 Statistical analysis

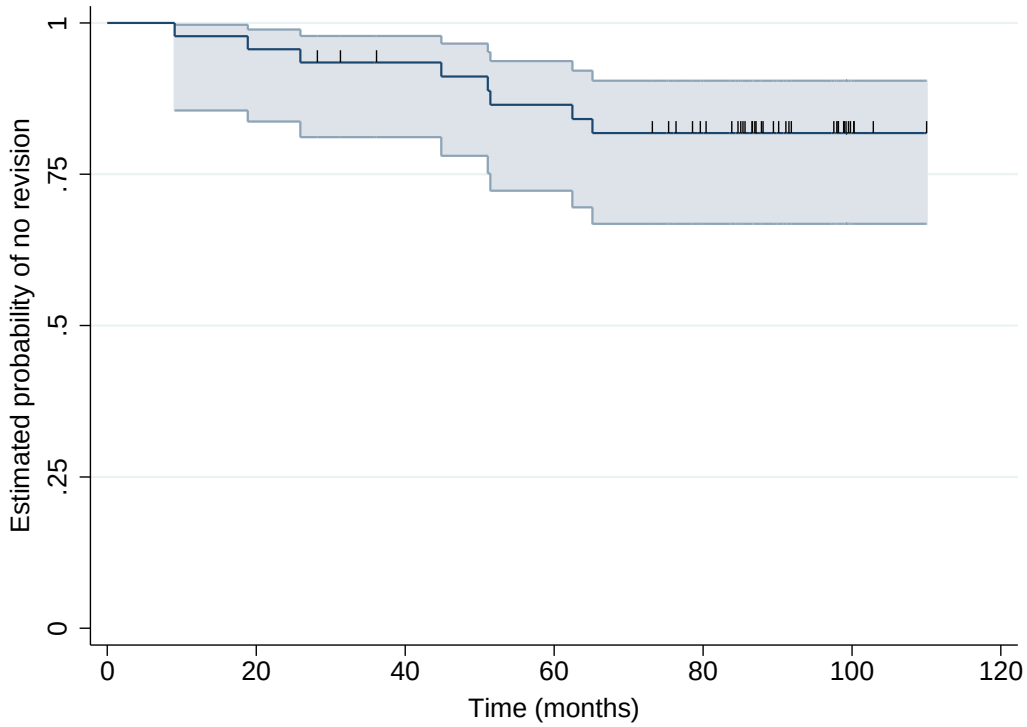
Descriptive statistics were used to summarize the data. Data were presented as mean (SD), median (range), or n (%). Kaplan-Meier survival analysis was used to estimate the survival for endpoints revision of any component for any reason. Patients lost to follow-up were considered censored at the time of last follow-up. Differences in riskfactors in the revision – and non – revision group were tested using a two – sample Wilcoxon rank-sum (Mann Whitney) test or two – sample t test, where appropriate. A gender analysis was performed using Fisher's exact test. Statistical analyses were performed using STATA 13.1 (StataCorp, College Station, TX, US). P-values < 0.05 were considered statistically significant.

6. Results

6.1 Revisions

At final follow – up a total of eight revisions had been performed. In five patients the ASR prosthesis was revised because of ARMD. In one patient the stem component showed signs of aseptic loosening and was revised and in one patient the stem component was revised after a pertrochanteric fracture due to a direct fall on the hip, in one patient the prosthesis was revised because of unexplained persistent complaints. Thus, as depicted in the Kaplan-Meier plot (Figure 8.), mean cumulative survival of the ASR™ Hip Resurfacing System after 99,9 Months was 81,8% (95% CI: 66,6 – 90,5).

Figure 8. Kaplan – Meier plot: Mean cumulative survival of 46 hip resurfacings, with revision surgery defined as failure event. The small vertical spikes represent the censored data.



6.2 Final clinical follow – up

At final follow – up median HHS was 97 (68 – 100) (N = 30) and median HOOS was 87,2 (24,4 – 100) (N = 32). During complete follow-up blood samples measuring Co and Cr levels were only taken in case of complaints or irregularities on the radiographs of the

operated hip. In the included implants whole blood samples were collected during follow-up. Median Co value was 1.15 (0.3 – 28.3) ppb. Median Cr value was 0.95 (0.1 – 11.3) ppb.

Table 2. Scores, radiographs, metal ion concentrations and failure rates

Variable	ASR Resurfacing
HHS	97 (68 - 100)
HOOS	87.2 (24.4 - 100)
Cup inclination (°)	47.3 (5.0)
Cobalt (ppb)	1.15 (0.3 – 28.3)
Chromium (ppb)	0.95 (0.1 – 11.3)
Revisions	8
Revision rate	17.4%
Failure mode	
Periprosthetic fracture	1 (2.2%)
Aseptic loosening	1 (2.2%)
ARMD	5 (10,8%)
Unexplained complaints	1 (2,2%)

6.3 Final radiographic follow – up

Mean cup inclination of the 33 included implants was 47,3 (5,0). Median SSA was 137,9 (131,8 – 151,2) and median NSA was 131,2 (111,4 – 141,2). Difference between these parameters therefor was -6,7 (-22,2 – 0,35). All prostheses were implanted in a slight valgus position compared to the NSA with one exception, which was implanted in a minimal varus position. In four prostheses radiolucent lines were observed. In all prostheses the radiolucent lines were bigger than 2 mm. In all four prostheses the cup was involved, in two the stem in addition. Heterotopic ossifications were observed in nine prostheses. In four prostheses grade I, in two prostheses grade II and in three prostheses

grade III ossifications were observed. Cystic changes around the stem were observed in one patient.

6.4 MARS – MRI results

According to the Depuy follow – up guidelines, a MARS – MRI was arranged only when patients either had complaints, had signs of loosening on the radiographs or had high levels of Co and/or Cr in blood. During complete follow – up from 2011 until 2015 a total of fourteen patients of the total population underwent a MARS – MRI. A small, non – specific, periprosthetic fluid collection was observed in four patients. A small, non – specific fluid collection both intra - articular and in the bursa trochanteric was observed in two patients. A large fluid collection, both intra - articular and in the trochanteric bursa (most likely to be a pseudotumor) was observed in four patients. Three of these patients underwent a revision, one because of a fracture after a fall directly on the hip (only the stem was revised) and two because of ARMD. The patient in whom only the stem was revised, has been observed more often and because the pseudotumor did not grow further and the patient experiences only minor complaints, a conservative "watchful waiting" strategy has been applied. The fourth patient in which a pseudotumor in MARS – MRI has been detected, has not been revised, because the patient experiences no complaints. No abnormalities were observed in three patients. In one patient the MARS – MRI showed oedema in the femoral neck, possibly as a result of loosening of the femoral component. But, while the patient experiences no complaints, no revision has been performed.

6.5 Analysis of the risk factors

Although the group of patients was relatively small, known risk factors for revision (as discussed in the introduction) were analysed using a two – sample Wilcoxon rank sum test or two – sample t – test, where appropriate (revised versus unrevised, significance of $P < 0,05$). The diameter of the femoral component was significantly smaller in the revised group ($P = 0,0125$). The acetabular angle of inclination did not significantly differ between revised and unrevised patients ($P = 0,50$). A gender analysis using Fisher's exact test was performed to determine whether female gender had a higher risk of undergoing a revision. This test was not statistically significant ($P = 0,12$), although there was a trend towards female gender. Age was significantly lower in the revised group ($P = 0,0345$)

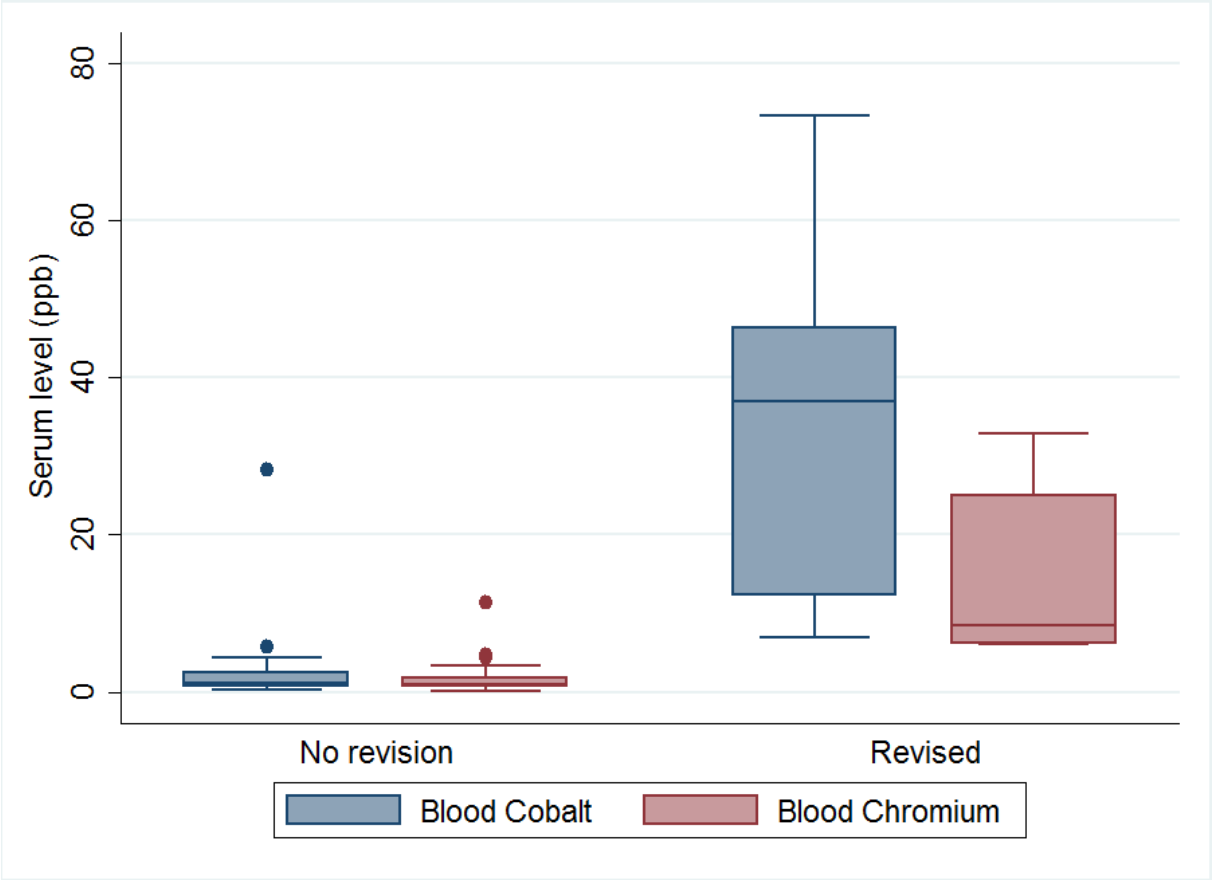
than in the non – revised group. Both median pre – revision Co (P = 0,0005) and Cr blood values (P = 0,0006) were significantly higher in the revised group (Figure 9.) compared with the unrevised group.

Table 3. Comparison of the risk factors

Variable	**Implants in situ (N = 33, included)**	**Revisions (N=8, drop – out)**	**P – Value**
Age at surgery (yrs.)	55 (45-74)	52 (47-55)	0.0345
BMI (kg/m2)	27.6 (4.4)	28.0 (2.5)	0.82
Cup inclination (degrees)	47.3 (5.0)	48.9 (6.3)[1]	0.50
Cobalt (ppb)	1.15 (0.3 – 28.3)[2]	36.9 (6.96 – 73.3)[3]	0.0005
Chromium (ppb)	0.95 (0.1 – 11.3)[2]	8.52 (6.08 – 32.8)[3]	0.0006
Diameter femoral component (mm)	48.2 (2.2)	45.3 (4.7)	0.0125
Gender (male/female)	20/13	2/6	0.12
Difference NSA – SSA (degrees)	-6.7 (-22.2 – 0.35)[4]	-4.3 (-6.3 - -4.1)5	0.35
Stem Shaft Angle (degrees)	137.9 (131.8 – 151.2)[2]	137.5 (133.3 – 145.0)[3]	0.93
Neck Shaft Angle (degrees)	131.2 (111.4 – 141.2)[4]	130.9 (129.0 – 131.2)5	0.52

[1] 2 missing [2] 1 missing [3] 3 missing [4] 7 missing [5] 5 missing

Figure 9. Cobalt and chromium values (revised versus unrevised)



7. Discussion

7.1 The MoM resurfacing hip arthroplasty: Huge benefit or another early failure?

When the third generation MoM resurfacing hip arthroplasty was introduced, the general tenure was that it was a great invention. Advantages such as less wear and less bones resection propelled many surgeons to adapt the MoM resurfacing hip arthroplasty quite early, despite a lack of evidence for a good prosthesis. It will be discussed if introduction of a type of MoM resurfacing hip arthroplasty (ASR) really was a failure or if some indications to implant this prosthesis still exist.

7.2 Recall guidelines

In contrast to the latest guidelines as developed by the MHRA, according to the Depuy recall guidelines of the ASR™ resurfacing hip system, routine Co and Cr serum tests are not warranted unless the patient experiences complaints of the operated hip. (27) A recent study however has shown that in the long term not only symptomatic patients with elevated metal ion levels (who have the highest prevalence of pseudotumors (63%)), but also asymptomatic patients with elevated ion levels (42%) and symptomatic patients with non - elevated metal ions (11%) are at risk of developing a pseudotumor. This result suggests that routine metal ion measurement should be combined with clinical assessment in asymptomatic patients as well.(47) In 2012 the EFORT, the EHS, the AE and the DAH had a consensus meeting about MoM resurfacing hip arthroplasty. Consensus was reached recommending annual check-up of the prosthesis for the first five years, followed by regular check-ups after hip arthroplasty. In case of the presence of risk factors for revision (e.g. female gender, small femoral component < 50 mm) an annual check-up for the lifespan of the prosthesis is recommended.(48) A routine Co and Cr serum test is also recommended in asymptomatic patients during annual check-ups.(48)

7.3 Different types

Not all resurfacing prostheses have high failure rates. The ASR™ hip resurfacing has a higher failure rate compared with the BHR™ (Smith and Nephew orthopaedics, Warwick,

UK). Its manufacturer recalled The ASR™ in August 2010 because of the high failure rates reported by multiple sources. (10, 16)

Data from the National Joint Registry for the United Kingdom had shown a five-year revision rate of 12 % for the ASR™ Resurfacing. In contrast the comparable rate for the BHR system, which has the lowest five-year revision rate of all current generation resurfacing systems, was 4,3 %.(49) These findings are similar in studies analysing the Australian National joint registry data with revision rates at five years of 10,9 % for the ASR™ compared to 4,0% for the rest of the resurfacing implants.(25) A high revision percentage was found in our study as well, showing a cumulative percentage revision at 99 months of 18,2%. The ASR™ has a reduced CAAA and clearance compared with the BHR™, and the rim of the acetabula component has a smaller radius. These factors increase the theoretical risk of edge contact and high wear and the higher possibility of revision of the prosthesis. (49)

7.4 Quality label

In 2010 there were thirteen different brands of resurfacing implants being used of which only one met the ODEP standards. In order to meet these requirements, medical products need to comply with the ten-year benchmark set out by the NICE as described in the introduction of this thesis. The BHR™ is currently the only resurfacing implant that has an ODEP 10A rating (25), which means following criteria had to be met; A minimum cohort of 500 at the start of the study (consisting of data from beyond the developing centre and from more than 3 centres/surgeons) demonstrating Kaplan - Meier survivorship data of better than or equal to 90% (showing confidence limits on the data with the lower limit of 90%) at the benchmark of ten years. A maximum of 20% loss to follow-up is permitted.(21) The ASR resurfacing system, as described in this manuscript does not meet the benchmark set out by the NICE with a survivorship of only 81.8% after 99 months.

7.5 Femoral neck fractures after hip resurfacing

Femoral neck fractures are an important disadvantage of hip resurfacing arthroplasty. As stated several studies have identified varus malpositioning as a risk factor for femoral neck fracture after hip resurfacing. A stem-shaft angle less than 135 degrees and varus

angulation greater than 5 degrees relative to the anatomic neck-shaft angle have been associated with an increased risk of implant failure. (14, 18) It has been reported that placing the femoral component in 10° of valgus protects the femoral neck from cyclical stresses in patients with normal bone mineral density.(50, 51) In this study only one pertrochanteric fracture occurred after a direct fall on the hip. Femoral neck fractures did not play a role in our revision cases, possibly because of the use of navigation, which theoretically allows us to implant the femoral component of the prosthesis more accurately (e.g. a slight valgus position). In our series only one femoral component was implanted in a minimal varus position. The rest was implanted in valgus position.

7.6 Pseudotumordevelopment

As stated earlier pseudotumors are associated with increased wear at the MoM articulation, the most important question is if asymptomatic patients with these pseudotumors should undergo a large revision operation, of which we know the outcome will be worse than in primary total hip arthroplasty with a re-revision rate of 25% being reported within five years after revision surgery.(13, 52) Wong et al showed that revision of a primary hip resurfacing arthroplasty is associated with a high risk of re - revision with a cumulative re - revision percentage at 10 years of 26%.(53) A recent study has shown that these asymptomatic pseudotumors show little change over time in MRI after MoM hip resurfacing, but cause muscle atrophy in their surroundings (52, 54) and it has to be further investigated what the effects of these pseudotumors combined with elevated serum Co and Cr ion levels are. Thus it is unknown whether asymptomatic resurfacings with high ion levels really warrant revision.(23) A recent study conducted by Van Lingen et al. showed that asymptomatic patients with highly elevated Co and Cr serum levels did not develop any adverse reactions in the short term. They therefore conclude that a large revision is not warranted in asymptomatic patients with highly elevated blood metal ions.(55)

7.7 Effects of elevated Co and Cr serum levels

A recent study has shown that the toxicological weight of evidence suggests that MoM hip implants are unlikely to be associated with an increased risk of systemic cancers, which is consistent with published and on-going epidemiologic studies investigating the

relationship between elevated Co and Cr serum levels and increase in systemic cancers.(56) Another recent study, which examined the connection between Co serum concentrations and adverse biological effects, concluded that only under very unusual circumstances biologically important systemic effects might occur in MoM hip implant patients with Co serum concentrations of less than 300 ppb. Patients with MoM hip implants who exhibit signs or symptoms potentially related to polycythaemia, hypothyroidism, neurological or cardiac dysfunction should be clinically evaluated for these conditions.(57)

7.8 Analysis of the revisions

Three patients of whom one had a pseudotumor in MARS – MRI, that underwent a revision, had elevated Co and/or Cr blood values. One patient had undergone a revision, because of persistent unexplained complaints of the hip. In one patient, the stem component was revised because of loosening. Although our series is relatively small, age, the diameter of the femoral head and possibly gender seem to influence the outcome of resurfacing hip arthroplasty. Other tested variables such as BMI, cup inclination angle and NSA did not play an important role in our series. The difference in Co and Cr blood values in the two groups is explainable by the fact that elevated Co or Cr blood values were a reason for revision and not an actual risk factor.

7.9 Limitations of the study

There are several limitations to this study. First, it was a retrospective non-randomized study, no learning curve is accounted for and some differences in surgical technique between the three surgeons must be suspected, although one surgeon conducted most of the operations together with a permanent assistant. Another limitation of the study was the relatively low number of prostheses implanted. Because low volume surgery is a risk factor for revision, this has to be taken into account as well.

7.10 Our recall guidelines

Although there are few studies investigating the relationship between elevated Co and Cr serum levels and systemic toxicity, it can be cautiously concluded that the guidelines as composed by Depuy should suffice in recalling patients with MoM hip implants. Meaning

all patients get an extensive physical examination and radiographic control. Symptomatic patients additionally get Co and Cr serum level control and a MARS MRI.

8. Summary

Introduction

In the early 1990s McMinn revolutionized the concept of hip resurfacing arthroplasty and since then several companies introduced their kind of hip resurfacing arthroplasty to the market. Possible advantages include less wear, less bone resection so theoretically easier to revise. But during the last years some disadvantages (including ARMD with its pseudotumor development) raised concerns in some types of resurfacing prostheses. Our primary goal was to present a survival analysis and the mid- to long-term clinical, radiological and metal serological results of the navigated ASR™ resurfacing prosthesis at our clinic and compare them with the literature.

Methods

From Mai 2006 to Mai 2009 46 total hip prostheses of the ASR™ Hip Resurfacing System have been implanted in 43 patients. Median age of the patients was 55 years old (45 – 74 years). At final follow-up, Depuy recall guidelines were followed (annual check up including physical examination and radiographs (AP and Lauenstein) and in case of complaints blood samples were tested on cobalt and chromium concentrations and MARS – MRI of the affected hip was obtained). A total of 32 patients (33 implants) were available at final follow – up. Mean follow – up was 89,6 months (SD 8,6).

Results

The mean cumulative survival of the ASR™ Hip Resurfacing System after 99,9 Months (8,3 years) was 81,8% (95% CI: 66,6 – 90,5). At final follow – up a total of eight revisions had been performed. In five patients the ASR prosthesis was revised due to ARMD. In one patient the stem component showed signs of aseptic loosening and was revised and in one patient the stem component was revised after a pertrochanteric fracture due to a direct fall on the hip, in one patient the prosthesis was revised due to unexplained persistent complaints. At final follow – up median Harris Hip Scores was 97 (68 - 100) and Hip disability and Osteoarthritis Outcome Score was 87,2 (24,4 - 100). In four prostheses signs of loosening and in nine prostheses heterotopic ossifications were observed. All shaft components, except for one, were placed in a slight valgus position to avoid risk for fracture. Known risk factors for revision were analysed. The diameter of the femoral

component was significantly smaller in the revised group (P = 0,0125). Patients were significantly younger in the revision group (P = 0,0345). A gender analysis using Fisher's exact test was performed to determine whether female gender had a higher risk of undergoing a revision. This test was not statistically significant (P = 0,12), although there was a trend towards female gender. Both median pre - revision Co (P = 0,0005) and Cr blood values (P = 0,0006) were significantly higher in the revised group compared with the unrevised group.

Discussion

Revision rates are comparable to results found in other studies. Patients with complete final follow – up in general had very good objective and subjective clinical scores and few signs of loosening in the radiological follow – up. Since no femoral neck fracture occurred in our population, navigation possibly lowers the risk on this complication. Although our number of prostheses is relatively small, the diameter of the femoral head, age of the patient and possibly gender seem to influence the outcome of resurfacing hip arthroplasty. Highly elevated Co and Cr blood values were taken into account making a decision to revise a prosthesis, which explains the difference in Co and Cr blood values in the two groups.

9. Zusammenfassung

Einleitung.

Anfang der 1990er Jahre revolutionierte McMinn das Konzept des Hüftgelenkoberflächenersatzes. Seitdem haben verschiedene Firmen ihre Version von Oberflächenersatz auf den Markt gebracht. Mögliche Vorteile sind eine geringere Knochenresektion und ein geringerer Verschleiß und damit theoretisch einfachere Revisionsmöglichkeiten. Aber in den letzten Jahren kamen verschiedene Nachteile bezüglich des Oberflächenersatzes zur Sprache (unter anderem ARMD und die Entwicklung von Pseudotumoren). Unser Hauptziel war eine Analyse bezüglich der Lebensdauer des Implantates sowie mittel- bis langfristige klinische, radiologische und metallserologische Ergebnisse der navigierten ASR-Oberflächenprothese an unserer Klinik zu beschreiben und diese mit vorhandener Literatur zu vergleichen.

Methoden.

Von Mai 2006 bis Mai 2009 wurden 46 ASR™ Oberflächenhüftprothesen in 43 Patienten implantiert. Das Medianalter der Patienten betrug 55 Jahre (45 – 74 Jahre). Am Ende des Follow–ups wurden die Patienten nach den Depuy Recall Guidelines untersucht (jährlicher Check–up inklusive körperlicher Untersuchung und Röntgendiagnostik (a.p.- und Lauenstein-Aufnahme)). Bei Beschwerden wurden Blutuntersuchungen auf Kobalt und Chromkonzentrationen und ein MARS–MRT durchgeführt. Insgesamt waren 32 Patienten (33 Implantate) für ein vollständiges Follow–up verfügbar. Das durchschnittliche Follow–up betrug 89,6 months (SD 8,6).

Ergebnisse.

Die kumulative durchschnittliche Lebensdauer des ASR™ Hüftoberflächenersatzsystems nach 99,9 Monate (8,3 Jahre) lag bei 81,8% (95% CI: 66,6 – 90,5). Am Ende des Follow–ups wurden insgesamt acht Revisionen durchgeführt. Die ASR-Prothese wurde bei fünf Patienten bei bestehendem ARMD gewechselt. Bei einem Patient zeigte die Schaftkomponente Lockerungszeichen und wurde gewechselt. Eine Schaftkomponent wurde bei pertrochantärer Fraktur nach Sturz auf die Hüfte gewechselt. Bei einem Patient wurde die Prothese bei unklaren Schmerzen gewechselt. Am Ende des Follow–ups war die mediane HHS 97 (68 – 100) und HOOS 87,2 (24,4 – 100). Radiologisch wurden bei vier

Prothesen Lockerungszeichen beobachtet und bei neun Prothesen heterotope Ossifikationen. Alle Schaftkomponenten, außer einer, wurden in minimaler Valgusstellung implantiert. Der Durchmesser der femoralen Komponente war signifikant kleiner in der Revisionsgruppe (P = 0,0125). Patienten waren signifikant jünger in der Revisionsgruppe (P = 0,0345). Eine Geschlechtsanalyse mit Fischer´s Exakt Test wurde durchgeführt um zu bestimmen, ob das Geschlecht einen Einfluss auf die Revisionsrate hat. Dieser Test war nicht statistisch signifikant (P = 0,12), aber tendenziell waren weibliche Patienten häufiger betroffen. Vor der Revision waren sowohl der mediane Kobaltwert (P = 0,0005) als auch der mediane Chromwert im Blut (P = 0,0006) signifikant höher in der Revisionsgruppe im Vergleich zu der Nicht–Revisionsgruppe.

Diskussion.

Die Revisionsraten sind vergleichbar mit Ergebnissen anderer Studien. Patienten mit komplettem Follow–up hatten im Allgemeinen sehr gute objektive und subjektive klinische Scores und wenig Lockerungszeichen im radiologischen Follow–up. Die Navigation der Kappe verringert möglicherweise das Risiko auf eine mediale Schenkelhalsfraktur. Obwohl unser Patientenzahl relativ klein ist, scheinen der Durchmesser des Femurkopfes, das Alter des Patienten und möglicherweise das Geschlecht das Ergebnis des Oberflächenersatzes zu beeinflussen. Stark erhöhte Kobalt- und Chromwerte im Blut wurden in der Entscheidung zur Revision miteinbezogen und sind deshalb in der Revisionsgruppe signifikant höher.

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11. Appendices

11.1 Appendix 1. Hip dysfunction and Osteoarthritis Outcome Score (HOOS)

HOOS HIP SURVEY

Today's date: _____/__ ____/_____ Date of birth: _____/__ ____/_____

Name: _____

INSTRUCTIONS: This survey asks for your view about your hip. This information will help us keep track of how you feel about your hip and how well you are able to do your usual activities.
Answer every question by ticking the appropriate box, only one box for each question. If you are uncertain about how to answer a question, please give the best answer you can.

Symptoms

These questions should be answered thinking of your hip symptoms and difficulties during the **last week**.

S1. Do you feel grinding, hear clicking or any other type of noise from your hip?

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

S2. Difficulties spreading legs wide apart

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

S3. Difficulties to stride out when walking

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Stiffness

The following questions concern the amount of joint stiffness you have experienced during the **last week** in your hip. Stiffness is a sensation of restriction or slowness in the ease with which you move your hip joint.

S4. How severe is your hip joint stiffness after first wakening in the morning?

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

S5. How severe is your hip stiffness after sitting, lying or resting **later in the day**?

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Pain

P1. How often is your hip painful?

Never	Monthly	Weekly	Daily	Always
☐	☐	☐	☐	☐

What amount of hip pain have you experienced the **last week** during the following activities?

P2. Straightening your hip fully

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

What amount of hip pain have you experienced the **last week** during the following activities?

P3. Bending your hip fully

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P4. Walking on a flat surface

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P5. Going up or down stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P6. At night while in bed

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P7. Sitting or lying

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P8. Standing upright

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P9. Walking on a hard surface (asphalt, concrete, etc.)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P10. Walking on an uneven surface

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Function, daily living

The following questions concern your physical function. By this we mean your ability to move around and to look after yourself. For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your hip.

A1. Descending stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A2. Ascending stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A3. Rising from sitting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A4. Standing

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your hip.

A5. Bending to the floor/pick up an object

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A6. Walking on a flat surface

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A7. Getting in/out of car

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A8. Going shopping

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A9. Putting on socks/stockings

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A10. Rising from bed

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A11. Taking off socks/stockings

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A12. Lying in bed (turning over, maintaining hip position)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A13. Getting in/out of bath

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A14. Sitting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A15. Getting on/off toilet

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A16. Heavy domestic duties (moving heavy boxes, scrubbing floors, etc)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A17. Light domestic duties (cooking, dusting, etc)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Function, sports and recreational activities

The following questions concern your physical function when being active on a higher level. The questions should be answered thinking of what degree of difficulty you have experienced during the **last week** due to your hip.

SP1. Squatting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP2. Running

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP3. Twisting/pivoting on loaded leg

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP4. Walking on uneven surface

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Quality of Life

Q1. How often are you aware of your hip problem?

Never	Monthly	Weekly	Daily	Constantly
☐	☐	☐	☐	☐

Q2. Have you modified your life style to avoid activities potentially damaging to your hip?

Not at all	Mildly	Moderately	Severely	Totally
☐	☐	☐	☐	☐

Q3. How much are you troubled with lack of confidence in your hip?

Not at all	Mildly	Moderately	Severely	Extremely
☐	☐	☐	☐	☐

Q4. In general, how much difficulty do you have with your hip?

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Thank you very much for completing all the questions in this questionnaire.

11.2 Appendix 2. Harris Hip Score

Harris Hip Score	**Hip ID:**
	Study Hip: ☐ Left ☐ Right
	Examination Date (MM/DD/YY): / /
	Subject Initials: |____|____|____|
	Medical Record Number:

Interval: _____

Harris Hip Score

Pain *(check one)*

- ☐ None or ignores it (44)
- ☐ Slight, occasional, no compromise in activities (40)
- ☐ Mild pain, no effect on average activities, rarely moderate pain with unusual activity; may take aspirin (30)
- ☐ Moderate Pain, tolerable but makes concession to pain. Some limitation of ordinary activity or work. May require Occasional pain medication stronger than aspirin (20)
- ☐ Marked pain, serious limitation of activities (10)
- ☐ Totally disabled, crippled, pain in bed, bedridden (0)

Limp

- ☐ None (11)
- ☐ Slight (8)
- ☐ Moderate (5)
- ☐ Severe (0)

Support

- ☐ None (11)
- ☐ Cane for long walks (7)
- ☐ Cane most of time (5)
- ☐ One crutch (3)
- ☐ Two canes (2)
- ☐ Two crutches or not able to walk (0)

Distance Walked

- ☐ Unlimited (11)
- ☐ Six blocks (8)
- ☐ Two or three blocks (5)
- ☐ Indoors only (2)
- ☐ Bed and chair only (0)

Sitting

- ☐ Comfortably in ordinary chair for one hour (5)
- ☐ On a high chair for 30 minutes (3)
- ☐ Unable to sit comfortably in any chair (0)

Enter public transportation

- ☐ Yes (1)
- ☐ No (0)

Stairs

- ☐ Normally without using a railing (4)
- ☐ Normally using a railing (2)
- ☐ In any manner (1)
- ☐ Unable to do stairs (0)

Put on Shoes and Socks

- ☐ With ease (4)
- ☐ With difficulty (2)
- ☐ Unable (0)

Absence of Deformity (All yes = 4; Less than 4 =0)

- Less than 30° fixed flexion contracture ☐ Yes ☐ No
- Less than 10° fixed abduction ☐ Yes ☐ No
- Less than 10° fixed internal rotation in extension ☐ Yes ☐ No
- Limb length discrepancy less than 3.2 cm ☐ Yes ☐ No

Range of Motion (**indicates normal)*

- Flexion (*140°) _____
- Abduction (*40°) _____
- Adduction (*40°) _____
- External Rotation (*40°) _____
- Internal Rotation (*40°) _____

Range of Motion Scale

211° - 300° (5)	61° - 100 (2)
161° - 210° (4)	31° - 60° (1)
101° - 160° (3)	0° - 30° (0)

Range of Motion Score _____

Total Harris Hip Score _____

11.3 Appendix 3: Guidelines as developed by Depuy (in Germany)

DePuy
companies of Johnson&Johnson

ASR™ Hüftsystem, Ablaufdiagramm zur Patientenbehandlung

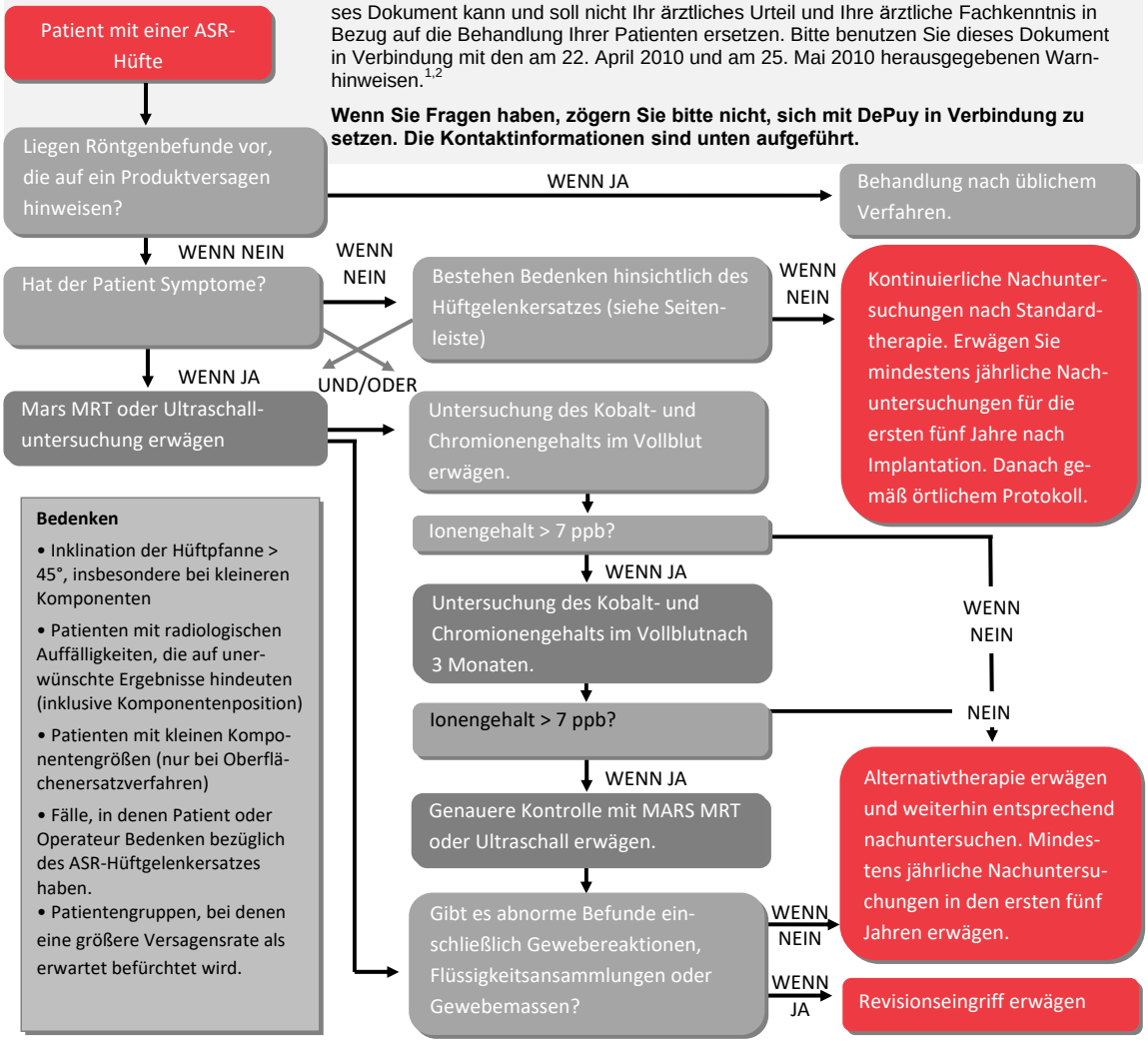
Nach den Sicherheitsinformationen der englischen Gesundheitsbehörde MHRA vom 22. April 2010 und 25. Mai 2010

DePuy hat das ASR™ XL Hüftpfannensystem und das DePuy ASR™ Hüft-Oberflächenersatzsystem freiwillig zurückgerufen. Patienten, die ein ASR-System erhalten haben, sollten über den Rückruf informiert und aufgefordert werden, einen Termin für eine Nachuntersuchung zu vereinbaren.

DePuy unterstützt die Anwendung der Behandlungsempfehlungen, die am 22. April und am 25. Mai von der UK Medicines and Healthcare products Regulatory Agency (MHRA) im Rahmen von Sicherheitsinformationen herausgegeben wurden.

DePuy stellt Ihnen diese Zusammenfassung lediglich als Service zur Verfügung. Dieses Dokument sollte in Verbindung mit Ihrer üblichen klinischen Praxis verwendet werden. Dieses Dokument kann und soll nicht Ihr ärztliches Urteil und Ihre ärztliche Fachkenntnis in Bezug auf die Behandlung Ihrer Patienten ersetzen. Bitte benutzen Sie dieses Dokument in Verbindung mit den am 22. April 2010 und am 25. Mai 2010 herausgegebenen Warnhinweisen.[1,2]

Wenn Sie Fragen haben, zögern Sie bitte nicht, sich mit DePuy in Verbindung zu setzen. Die Kontaktinformationen sind unten aufgeführt.



Parts of this thesis were published :

Long - term survivorship and clinical results of the navigated withdrawn ASR ™.

van Ochten JHM, Arbab D, Eysel P, König DP.

J Orthop. 2018 Aug 16;15(3):869-873. doi: 10.1016/j.jor.2018.08.013. eCollection 2018 Sep.

Mein Lebenslauf wird aus Gründen des Datenschutzes in der elektronischen Fassung meiner Arbeit nicht veröffentlicht.