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Digital subtraction arthrography in preoperative evaluation of painful total hip arthroplasty

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Abstract *Objective.* The objective of this clinical study was to define the diagnostic value of plain radiography, digital subtraction arthrography and two-phase bone scintigraphy in patients with clinically loose or infected hip prostheses.
Design. Digital subtraction arthrograms, scintigrams and plain radiographs of 70 consecutive patients who underwent revision hip arthroplasty were scored individually and in masked fashion for the presence or absence of features indicating loosening of femoral and/or acetabular components. The operative findings acted as the gold standard.
Results. Digital subtraction arthrography was best ($P<0.001$) for predicting a loose acetabular component, while no significant additional predictive value was found for plain radiographs ($P=0.24$) and scintigraphy ($P=0.27$). Digital subtraction arthrography was also the most important modality for predicting a loose femoral component ($P=0.001$), while the plain radiograph was of significant ($P=0.04$) additional value and scintigraphy was of no additional value ($P=0.13$) on multivariate analysis.
Conclusion. Digital subtraction arthrography gives the best results in the prediction of loosening of acetabular and femoral components. Plain radiographs give additional information on loosening of the femoral component, but scintigraphy offers no additional advantage.

Key words Digital subtraction · Hip arthrography · Hip arthroplasty · Loose hip prosthesis · Preoperative evaluation

Introduction

There is a worldwide increase in the number of total hip arthroplasties being carried out. This steady increase is largely due to increased longevity of the population and a trend for operating on younger patients due to continuing improvements in prosthetic design and surgical technique. Hip replacement surgery can increase function and reduce pain in most patients with diseased or painful hips, but the return of these symptoms may indicate a complication of arthroplastic surgery [1].

Mechanical loosening of prosthetic components appears to be the major late complication leading to surgical revision of hip arthroplasty. The most common symptoms that bring the patient for orthopedic consultation are pain and disability. Since pain may be due to causes other than a loose prosthesis, it is desirable to document loosening as the cause of the patient's symptoms before deciding to operate, as there are increased risks associated with revision surgery [2].

Plain radiographs are not always sufficient to diagnose loosening. Hip arthrography (combined with joint fluid aspiration) and two-phase bone scintigraphy are the specific investigations for the diagnosis of a loose or infected prosthesis. Digital subtraction arthrography has not been universally employed for this purpose but we started its use at our institution in 1988.

The purpose of this study was to define the diagnostic value of digital subtraction arthrography, plain radiography and two-phase bone scintigraphy in loosening of hip arthroplasty.

Materials and methods

Seventy consecutive patients (53 women, 17 men; age range 34–86 years) who underwent revision hip arthroplasty and in whom digital subtraction arthrography and scintigraphy had been carried out preoperatively were studied. Digital subtraction arthrography and scintigraphy were carried out either on the same day or within 1 week of each other in patients with suspected loose hip arthroplasty.

Conventional plain radiographs were available in all but 1 case in anteroposterior and lateral views (frogleg or axial). There was often an interval of 1–26 weeks between the plain radiographs and arthrography. Plain frontal digital radiographs were, however, always available as a scout view before contrast injection for arthrography.

The types of hip prostheses were: 16 Charnley, 14 McKee-Farrar, 14 McKee-Arden and 14 Muller. The remaining 3 patients had a hemiarthroplasty. There was thus a total of 70 femoral components and 67 acetabular components in this study. There were 64 cemented, 4 uncemented coated and 2 uncemented noncoated prostheses.

The digital subtraction arthrograms, plain radiographs and scintigrams of the patients undergoing revision arthroplasty were evaluated in masked fashion (in relation to each other and regarding the outcome of surgery) for signs of loosening of one or both components of hip arthroplasty. All studies were read independently by two radiologists. In cases of discrepancies in readings (5 examinations) a consensus opinion was reached.

Surgical findings acted as the gold standard for this study. No differentiation was made between toggle (limited movement of the prostheses) and frank loosening. All patients in this study were operated on by the same orthopedic surgeon.

Technique of digital subtraction arthrography

Arthrography was performed on a Philips DVI system (14-inch image intensifier, 512×512 image matrix).

The leg on the side of the examination was immobilized using a strap over the knee and the thigh regions. To avoid puncturing the femoral artery its position was marked on the skin with an indelible marker. The puncture area was cleaned and draped with sterile covers. About 10 ml of 1% nonbacteriostatic xylocaine was used as local anaesthetic. A 12.5 cm long spinal puncture needle (20 gauge) was then introduced parallel to the table top and directed slightly cranially for a lateral puncture route [3, 4]. We used a lateral puncture in most patients but in difficult cases, particularly those with heterotopic bone formation, an anterior or anterolateral route had to be used. When the pseudocapsule around the hip prosthesis is punctured and the tip of the needle touches the metallic neck of the femoral component, the position is usually correct and is confirmed fluoroscopically.

In all cases an attempt was made to aspirate joint fluid before contrast injection. In cases where no fluid could be aspirated, a few millilitres of nonbacteriostatic physiological saline were injected into the joint and reaspirated. The aspirate was saved and sent for bacteriological analysis and culture.

The patient was positioned so that both components were fully visible for evaluation before contrast injection. A scout view was obtained and the non-ionic contrast medium Iohexol 300 (Omnipaque) injected using a connecting tube and hand injection. The amount of contrast medium varied between 10 and 40 ml (mostly 20 ml) according to the size of the capsule and presence of bursae or cavities around the prosthesis. Digital subtraction views were obtained at a speed of 1 per second with a maximum of 20 views. These were later studied and a few of the most representative images were saved on X-ray film by means of a laser imager. Post-processing by means of pixel shift was often necessary to obtain images of reasonable quality. Post-ambulatory anteroposterior and axial views (without subtraction) of the hip were also obtained after the patient had walked for a couple of minutes.

The criterion used to define loosening of the femoral component consisted of any contrast leakage at the prosthesis-cement interface up to or beyond the intertrochanteric level (zones 1 or 7; Figs. 1, 2) at the cement-bone interface. In the case of the acetabular component, contrast leakage at the bone-cement interface had to be in at least two zones or around the whole of the component in order for it to be considered loose (Figs. 1, 3). These criteria are similar to those described by others [5, 6].

Two-phase bone scintigraphy

Two-phase bone scintigraphy was performed (on the same day as arthrography or within 1 week of it) after intravenous injection of 370 MBq ^{99m}Tc-labelled methylene diphosphonate. The first image was taken 2–6 min after injection in an anteroposterior position with counts obtained for 2 min. Increased uptake of isotope indicates hyperaemia, and can be a sign of infection. After 2 h anteroposterior, posteroanterior and, if necessary, oblique images were taken by collecting 400000 counts to detect increased uptake along the acetabular or femoral components which was indicative of loosening. Scintigrams of 4 patients were not available for evaluation.

Plain radiography

Plain radiographs were available in all patients as digital scout views obtained before subtraction arthrography, but large-format radiographs were missing in 1 patient. Criteria used for loosening of the femoral and acetabular component were similar to those already well described in the literature.

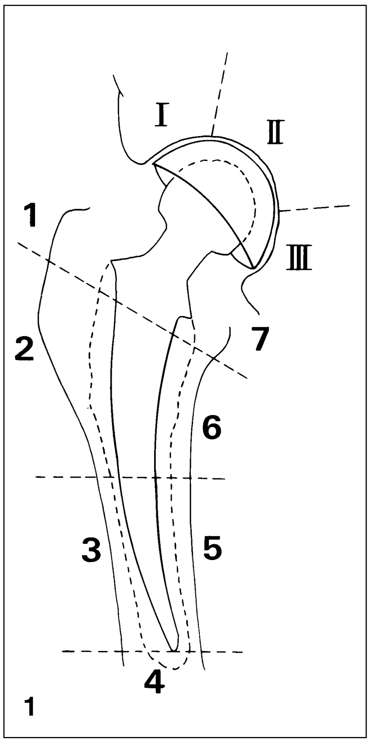
Surgical evaluation

The decision to operate was based on both clinical signs and symptoms and the results of the imaging studies in all patients except 1 (see Results). The interval between diagnostic investigation and surgical revision was usually a few weeks, but varied between 1 and 26 weeks. The revisions were all performed by the same orthopaedic surgeon (F.v.B.), who by means of traction and rotation of the prosthesis at surgery evaluated macroscopic loosening of the prosthetic components. No differentiation in scoring was made between toggle and frank loosening. Antibiotic cover was started 1 h before surgery and continued postoperatively. Joint fluid was obtained at surgery for bacteriological analysis.

Statistics

Surgical findings acted as the gold standard for this study.

Percentages were compared between groups of patients using Fisher's exact test. Multivariate analysis regarding the probability of a loose component at surgery in relation to the three diagnostic modalities was carried out using multiple logistic regression [7]. Comparison of paired percentages within groups of patients was carried out using McNemar's test. A P value of 0.05 (two-sided) was considered the limit of significance.



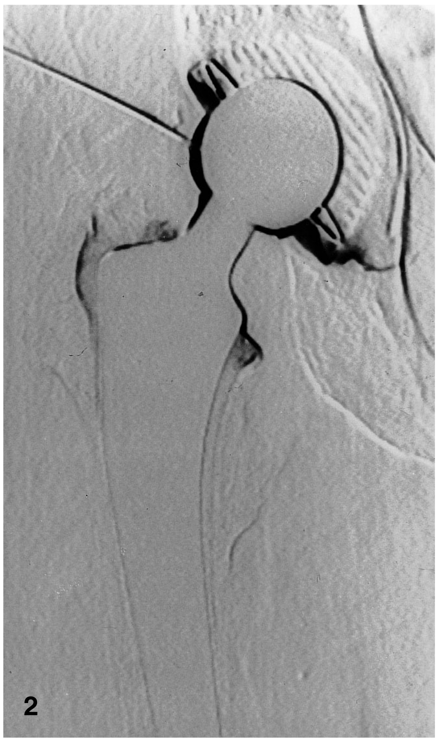


Fig. 1 A diagrammatic representation of the various zones used in defining loosening of the femoral and acetabular components of hip arthroplasty. System also used by Lyons et al. [6]

Fig. 2 Subtraction arthrogram showing contrast in zones 1 and 7 (see Fig. 1) at the cement-bone interface, graded as a loose femoral component. The component was also found to be loose at surgery

Fig. 3 Subtraction arthrogram showing a loose acetabular component with contrast in zones I, II and part of zone III at the cement-bone interface. The femoral component shows no signs of loosening

Results

The lateral or anterolateral technique of hip puncture for performance of digital subtraction arthrography was easy in 60 patients. In 10 patients difficulty arose in puncture due mainly to heterotopic bone formation and obesity, and in these patients a repuncture or anterior route had to be employed. In 2 patients a longer needle was necessary for puncture, due to obesity. Motion artifacts due to patient movement were correctable on subtraction views by using post-processing (pixel shift), which gave adequate quality views in all patients.

Four of the patients operated on did not have a loose prostheses at surgery. Two of these 4 had a femoral hemiarthroplasty and on revision a total hip prosthesis (THP) was placed. In the other 66 patients, of whom 65 had a THP, the femoral, acetabular or both components were found to be loose at surgery. In all patients except 1 at least one diagnostic method indicated loosening of one or both components. The indication for surgery in the 1 patient operated without any radiological signs of loosening was severe disability and pain.

Acetabular component (*n*=67)

On plain radiographs a diagnosis of loose acetabular component was made in 50% of patients. At surgery the percentage of loose acetabular components was 70% in this group. Of the 50% of components considered solid on plain radiographs, 52% (P=0.20) were found to be loose at surgery.

On scintigraphy a loose acetabular component was diagnosed in 52% of patients and at surgery 76% of these components were found to be loose. Of the 48% considered solid on scintigraphy, 43% (P=0.01) were found to be loose at surgery.

On digital subtraction arthrography a loose acetabular component was diagnosed in 67% of patients and 84% of these components were found to be loose at surgery. Of the 33% considered solid on digital subtraction arthrography, 14% (P<0.001) were found to be loose at surgery.

Multivariate analysis of the three modalities showed that subtraction arthrography was best (P<0.001) for predicting a loose acetabular component, while no significant additional predictive value was found for plain radiographs (P=0.24) or scintigraphy (P=0.27). The outcomes of the three diagnostic methods in relation to the surgical findings are shown in Table 1. The upper half of the table groups patients according to whether a loose

Table 1 Acetabular component. The upper part of the table presents patients grouped according to various combinations of loose (+) or solid (–) prosthetic component as scored on digital subtraction arthrography (AR), plain radiography (X) and two-phase bone scintigraphy (SC). The lower part of the table shows the surgical results in patients with a loose or solid prosthesis, with percentages in parentheses. [In 5 additional patients one diagnostic method was not performed: 2 patients (X+) and (AR+) (both loose at surgery); 1 patient (X–) and (AR–) (loose at surgery); 1 patient (X+) and (AR–) (solid at surgery); 1 patient (AR+) and (SC+) (loose at surgery)]

	Diagnostic group							
	A	B	C	D	E	F	G	H
Imaging findings								
AR	–	–	–	–	+	+	+	+
X	–	–	+	+	–	–	+	+
SC	–	+	–	+	–	+	–	+
Surgical results								
Loose	0 (0)	1 (33)	0 (0)	1 (33)	6 (67)	9 (82)	7 (100)	13 (93)
Solid	9	2	5	2	3	2	0	2
Total	9	3	5	3	9	11	7	15

(+) or solid (–) prosthesis was scored on digital subtraction arthrography (AR), plain radiography (X) and two-phase bone scintigraphy (SC). The lower half of the table gives the surgical results in the same patients. Of the 9 patients in whom only subtraction arthrography indicated loosening (group E), only 67% showed a loose acetabular component at surgery. However, this percentage did not differ significantly from the groups in which one or both of the other diagnostic methods also indicated loosening (groups F, G and H).

The superiority of subtraction arthrography for predicting a loose acetabular component was confirmed when only those patients were considered who had a loose component at surgery. In this group, the percentage of patients who had a loose component on subtraction arthrography (93%) was significantly higher compared with those with a loose component indicated by plain radiographs (58%) or scintigraphy (66%). The latter two percentages did not differ significantly from each other.

No significant differences between the three modalities were found regarding the percentages of patients in whom a loose component was falsely diagnosed in the light of the findings at surgery.

Femoral component (n=70)

The plain radiographs showed loosening of the femoral component in 74% of patients, of whom 88% were found to have a loose component at surgery. Of the 26% in whom a solid femoral component was diagnosed on plain radiographs, 44% (P<0.001) were found to have a loose component at surgery.

On scintigraphy 68% loose femoral components were diagnosed, of which 89% were found to be loose at surgery. Of 32% considered solid on scintigraphy, 52% (P<0.003) were found to be loose at surgery.

On digital subtraction arthrography 79% loose femoral components were diagnosed, of which 91% were found to be loose at surgery. Of 21% considered solid on digital subtraction arthrography, 20% (P<0.001) were found to be loose at surgery.

Multivariate analysis of the three diagnostic investigations showed that the most important one for predicting a loose femoral component at surgery was subtraction arthrography (P=0.001), while plain radiographs were of significant (P=0.04) additional diagnostic value. No additional predictive value (0.13) was found for scintigraphy.

Table 2 shows the surgical findings for the femoral component in relation to combinations of outcomes of the three diagnostic modalities. In the group of patients with a loose femoral component indicated by subtraction arthrography as well as plain radiographs (n=44), 98% (43/44) of patients appeared to have a loose component at surgery. This percentage, however, was significantly lower (70%; P=0.02) in the group of 10 patients who had a loose component indicated by subtraction arthrography but not by plain radiograph.

The inferior value of scintigraphy for the diagnosis of a loose component was confirmed when only those patients were considered who were found to have a loose component at surgery. In this group the percentage of cases with a loose component as indicated by scintigraphy (78%) was significantly lower than the corresponding percentage (98%) in which a loose component was indicated by subtraction arthrography and/or plain radiograph. No significant differences were present between the percentages of patients in whom a loose component was indicated falsely by subtraction arthrogram, plain radiograph or scintigraphy but who did not have a loose component at surgery.

Infection was found in 8 (11%) patients in this series, as shown by a positive culture of the joint fluid.

Table 2 Femoral component. The upper part of the table presents patients grouped according to various combinations of loose (+) or solid (–) prosthetic component as scored on digital subtraction arthrography (AR), plain radiography (X) and two-phase bone scintigraphy (SC). The lower part of the table shows the surgical results in patients with a loose or solid prosthesis, with percentages in parentheses. [In 5 additional patients one diagnostic method was not performed: 2 patients (X–) and (AR–) (both solid at surgery); 2 patients (X+) and (AR+) (both loose at surgery); 1 patient (AR+) and (SC–) (solid at surgery)]

	Diagnostic group							
	A	B	C	D	E	F	G	H
Imaging findings								
AR	–	–	–	–	+	+	+	+
X	–	–	+	+	–	–	+	+
SC	–	+	–	+	–	+	–	+
Surgical results								
Loose	0 (0)	1 (50)	0 (0)	2 (66)	3 (100)	4 (57)	8 (89)	33 (100)
Solid	4	1	4	1	0	3	1	0
Total	4	2	4	3	3	7	9	33

Discussion

The decision to carry out a revision hip arthroplasty in our patient group was based both on the clinical symptoms and the results of the imaging techniques, i.e. subtraction arthrography, plain radiographs and scintigraphy. None of the patients underwent surgery on the basis of the results of the imaging techniques alone.

Of 70 patients operated on, 66 were found to have loosening of the femoral, acetabular or both components. Four patients had solid prostheses at surgery but positive arthrograms (false positive). Each of these 4 patients (2 with a hemiarthroplasty) had a very small pseudocapsule. Extravasation of contrast medium between bone and cement was seen up to but not beyond zone 1 or 7. This has been known to occur in cases with a small capsule [6]. Caution is therefore required in making a diagnosis of femoral component loosening solely on the basis of contrast leakage up to zone 1 or and 7 in these circumstances. The decision to operate, however, was not based solely on the results of the arthrograms but also on the severity of symptoms, i.e. pain and disability.

Subtraction arthrography gives better differentiation of contrast extravasation between radiopaque cement and prosthesis or cement and bone [8] compared with non-subtraction films. Conventional subtraction arthrography, which is well described in the literature, has the disadvantages of being time consuming, requiring darkroom personnel and no patient movement during the injection, which limits the clarity of the subtraction views [9, 10]. It has been shown that digital subtraction arthrography is equal to or better than manual subtraction technique [10]. The results are immediately available as the technique allows real time review of injection dynamics. Data manipulation by pixel shift after the examination [10] is often necessary despite immobilization of the leg with a strap and Polythene blocks. The enhanced contrast resolution of this technique also allows detection of even tiny amounts of contrast at the cement-bone or cement-prosthesis interfaces.

The lateral approach for hip joint puncture has been advocated and described previously [4, 11, 12]. In 10 patients a repuncture and a more anterior route was necessary. We came across no complications associated with this procedure.

There appears to be a wide variation between criteria used by different authors for defining prosthetic loosening [13–15]. Many studies do not use surgical assessment as a reference standard for prosthetic loosening, which may account for the variability in results [1]. Surgery is probably the best available gold standard but it certainly does not appear to be objective. In our study, however, all patients were tested and operated on by the same orthopaedic surgeon.

It must be recognized that the group of patients in our study is highly selected. All had clinical evidence of failure of hip prostheses with sufficient disability to require revision surgery. Our results, however, are very similar to those of other authors [6, 16–19].

We used the same classification zones as described by other authors [1, 6] for defining loosening or leakage of contrast during digital subtraction arthrography (Fig. 1). For the femoral component any contrast leakage between metal-cement interface beyond or at least up to the intertrochanteric line in the cement-bone interface was considered to indicate loosening of the component (Figs. 1, 2). In femoral component loosening many authors have described accumulation of contrast medium at the tip of the stem [20], but we have rarely observed this in our series. We also do not agree with Bloom et al. [21] that more than 1 cm of contrast leakage around the femoral component is a significant sign of loosening. For the acetabular component, the criterion for loosening consisted of contrast at the cement-bone interface in at least two zones (Figs. 1, 3).

According to some authors post-ambulation radiographs help to improve the sensitivity of digital subtraction arthrography, as signs of loosening may be clearly visible only on these films [22, 23]. In our experience the post-ambulatory views did not show sufficient increase in the extent of contrast leakage around a prosthetic component to alter significantly the diagnosis made on subtraction views.

There was an interval of 26 weeks in some cases between plain films and arthrography. The digital scout view obtained before subtraction was, however, always available to show any significant changes that occurred during this long time interval.

The plain film criteria for femoral component loosening include a lucent zone at the metal-cement or bone-cement interface greater than 2 mm, particularly when progressively increasing. Migration and/or subsidence of the femoral component into the femoral shaft is accepted as a definite indication of prosthetic loosening. Cracks in the cement and radiolucency are indirect signs that the prosthesis has moved [24]. For indicating acetabular component loosening, radiolucency of more than 2 mm between cement and bone around almost the whole of the component on the anteroposterior view or any change in position such as tilting or migration are similar to the criteria used by other authors [16, 25].

According to Weissman [26] the explanation for false positive radiographic studies includes the observation that radiographic abnormalities may precede "true" loosening and that surgical testing of component loosening may be limited! A small pseudocapsule may also lead to a higher pressure within the capsule and small leakage of contrast may take place at the bone-cement interface [6]. These factors may in part explain the false positives found in our study, where contrast was definitely seen at the bone-cement interface but at surgery the prosthesis was found not to be loose.

Some of the false negative results on arthrography are explainable on the basis of interpositional soft tissue (such as granulation tissue, fibrous tissue or pus) blocking passage of contrast into the metal-cement or cement-bone interface [12, 23]. Another reason for false negative results can be large bursae or cavities around the prosthesis which may hinder filling of the bone-cement or cement-metal interface due to reduced injection pressure.

When the plain film is strongly suggestive of a loose or solid prosthesis and arthrography results show a discrepancy then the results of plain films should be taken into consideration [27].

Bone scintigraphy is a sensitive indicator of bone turnover but does not distinguish infection from loosening. Increased isotope uptake may be due to loosening and infection but could also be due to heterotopic ossification, stress fracture, tumour, Paget's disease or reflex sympathetic dystrophy syndrome [28]. Recent studies have shown a high rate of false positive scintigraphy related to increased activity, probably due to endosteal remodelling around the prosthesis and cement [29].

Joint fluid aspiration and culture was used as the definitive criterion for the diagnosis of infection in our series. Prosthetic loosening caused by infection may account for 7–56% of the total number of loose prostheses [16]. In our series cultures were positive in 8 patients (11%). Joint aspirate could not be obtained in 7 patients at arthrography, but aspirates at surgery were regularly obtained. The results of the surgical specimens were similar to the joint aspirates obtained at arthrography. The lower incidence of infection may be partly due to antibiotic cover at the time that surgical aspirates were obtained.

In conclusion, digital subtraction arthrography of the hip gives the best results in predicting loosening of acetabular and femoral components in the preoperative evaluation of patients with painful hip arthroplasty. It is quick and easy to perform, and causes little discomfort to the patient. The ability to view the subtraction images in real time and to manipulate the digital images after the arthrography are clear advantages of this method of examination.

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