DIAGNOSING INFECTION IN HIP REPLACEMENTS

THE USE OF FINE-NEEDLE ASPIRATION AND RADIOMETRIC CULTURE

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In 78 consecutive patients, we performed fine-needle aspiration of the hip before revision surgery. At the revision operation biopsies were taken from the capsule and joint tissues. The aspirate and the homogenised soft-tissue specimens were cultured using a radiometric technique.

Fifteen hips proved to be infected and 63 sterile on culture of the tissues taken during revision surgery; 94% of the aspiration results were correct. The sensitivity of the technique was 87% and the specificity 95%.

Fine-needle aspiration combined with a radiometric culture technique is a simple and reliable method of diagnosing infection of hip prostheses.

The diagnosis of infection in hip replacements is important. High-grade infection, with inflammation, abscess or sinus formation, and systemic illness is usually obvious, but low-grade infection often presents as prosthetic loosening. In such cases it may be missed unless an active search is made (Hunter et al 1979; Whyte et al 1981). Haematological tests, plain radiography, isotope scanning and biopsy are used to distinguish septic from aseptic loosening, but all have limitations.

Persistent elevation of the erythrocyte sedimentation rate (ESR) suggests infection but is neither very sensitive nor very specific (Carlsson 1978; Sanzén and Carlsson 1989). The combined measurement of C-reactive protein levels and the ESR is more accurate but is also unreliable (Shih, Wu and Yang 1987; Sanzén and Carlsson 1989).

Plain radiographs and arthrograms can detect femoral loosening, but rarely differentiate between mechanical loosening and low-grade sepsis (Weissman 1983; O'Neil and Harris 1984; Maus et al 1987). Isotope bone scanning is sensitive but not specific unless it shows diffuse uptake with congruency of the early and late images. Not all infected prostheses show these features however (Rushton et al 1982; Taylor et al 1989), and it is much less useful in the assessment of the acetabular component than the femoral (Tehranzadeh, Schneider and Freiberger 1981). Labelled white-cell scanning may be better than conventional technetium bone scanning, but gives a high incidence of false-positive results (Pring et al 1986; Wukich et al 1987; Magnuson et al 1988).

There is no very accurate non-invasive test, and therefore the best method of detecting infection and identifying the organism is biopsy, either by open capsular biopsy or by aspiration of the joint fluid.

We report the use of fine-needle aspiration and a radiometric culture technique for the diagnosis of infected hip prostheses.

PATIENTS AND METHODS

We performed fine-needle aspiration of the joint in 81 consecutive patients awaiting revision of a hip replacement. Antibiotics were stopped three weeks before the aspiration. In 69 of the patients the ESR was measured shortly before their revision operation.

Aspiration. A full aseptic technique was used, with skin preparation, towelling, and an adhesive plastic drape. A point anterior to the centre of the neck of the femoral prosthesis was located under fluoroscopic control. The skin and subcutaneous tissues were infiltrated with local anaesthetic, but this was not injected into the joint because it has some antimicrobial activity (Schmidt and Rosenkranz 1970). An 18-gauge spinal needle was then inserted perpendicular to the skin. Confirmation that the joint had been entered was made by the distinctive feel of the needle tip on the metal of the prosthesis. When the femoral artery lay in front of the neck of the prosthesis, the needle was started more laterally and passed obliquely under fluoroscopic control.

A 10 ml syringe was used to aspirate the joint. If no fluid was obtained the needle was repositioned, without

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withdrawing it, and passed deep to the inferomedial aspect of the neck, under fluoroscopic control. If no fluid could be obtained in this position the procedure was described as a 'dry tap' and 10 ml of sterile isotonic saline were injected into the joint through the spinal needle. A fresh syringe was used to aspirate this fluid, often recovering only 2 to 3 ml (Fig. 1).

Culture. Once fluid had been recovered, the suction on the syringe was released and the needle withdrawn. A fresh needle was used to inoculate the fluid immediately into two BacTec culture bottles, one containing aerobic liquid-enrichment medium 6B and the other anaerobic liquid-enrichment medium 7D. The bottles were then incubated at 37°C.

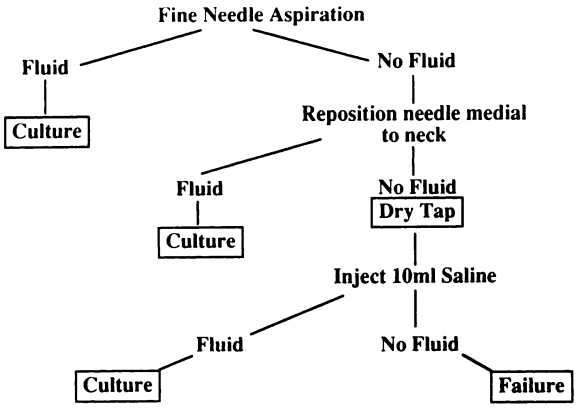

Fig. 1

Algorithm for the technique of aspiration.

Each culture bottle contained ^{14}C-labelled substrates and other ingredients listed in Table I. The head gas in the bottles was automatically analysed using a BacTec 460 machine (Becton-Dickinson UK, Oxford, England), on each day for the first week and thereafter weekly for the next two weeks. A rise in the level of $^{14}CO_2$ indicated that organisms were metabolising the ^{14}C-labelled substrates. When bacterial activity had been detected by this method, a sample of the medium was subcultured on to blood agar plates, both aerobically and anaerobically, in the knowledge that there were large numbers of organisms in the primary medium. Incubation of the solid media was continued until macroscopic growth was evident. Standard bacteriological techniques were used to identify the isolates and determine antibiotic sensitivities.

Open biopsy. At the time of revision surgery, biopsy specimens were taken from the capsule and pseudomembrane surrounding the femoral and acetabular components. Each was put in a separate, dry, sterile, glass container and taken to the laboratory for immediate processing. Any fluid present in the joint was aspirated and immediately inoculated into BacTec culture bottles.

Table I. Ingredients of the liquid-enrichment media

	Aerobic medium 6B	Anaerobic medium 7D
Processed water	30 ml	30 ml
Soy bean-casein broth	*2.75%* wv	*2.75%* wv
Haemin	*0.0005%* wv	*0.0005%* wv
Vitamin K	*0.00005%* wv	*0.00005%* wv
^{14}C-labelled substrates	2.0 μCi	2.0 μCi
Sodium bicarbonate	*0.0375%* wv	-
Yeast extract	-	*0.42%* wv
Animal tissue digest	-	*0.0585%* wv
Sodium citrate	-	*0.021%* wv
Sodium carbonate	-	*0.011%* wv
Thiols	-	*0.123%* wv
Dextrose	-	*0.25%* wv
Sodium hydroxide	-	*0.0375%* wv
Sucrose	*0.25%* wv	-
Vitamin B_6	*0.001%* wv	-
SPS	*0.025%* wv	*0.025%* wv
Antifoaming agent	*0.01%* wv	-

Table II. Organisms isolated from 15 infected hip replacements

	Number of isolates
Coagulase-negative staphylococcus	7
Pseudomonas aeruginosa	4
Streptococcus sanguis	2
Peptostreptococcus species	1
Peptococcus species	1
Bacillus species	1
Staphylococcus aureus	1
Aerococcus species	1

Two hips were infected with more than one type of organism

If both components of the hip were revised three soft-tissue specimens and a sample of joint fluid were usually obtained. No prophylactic parenteral antibiotics were given until the biopsy specimens had been taken.

The soft-tissue specimens were homogenised with sterile isotonic saline in their glass universal container using a sealed-unit homogeniser (Ultra-Turrax 725; Northern Media Scientific, Nottinghamshire, England). The homogenate was aspirated by a sterile needle and

Table III. Organisms isolated as contaminants in false-positive cultures from eight non-infected hips

	Number of isolates
Coagulase-negative staphylococcus	5
Diphtheroids	2
Proprionibacterium acnes	1
Bacillus species	1

One hip contaminated with two different organisms

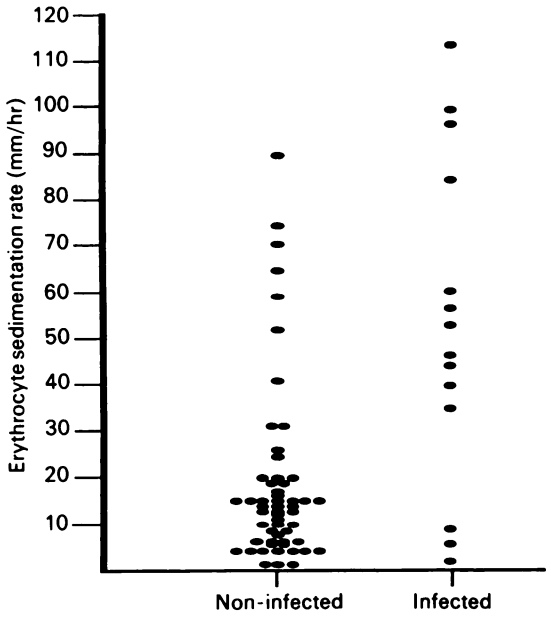

Fig. 2

Erythrocyte sedimentation rates in 69 patients awaiting revision surgery for non-infected and infected hip replacements.

syringe and inoculated into BacTec culture bottles for processing as described above.

We defined the status of the hip by the results of the open biopsies. Hips were recorded as 'not infected' if none or only one of the specimens was positive (a single positive result was regarded as probable contamination), or as 'infected' if all the specimens, or three out of four, were positive.

RESULTS

In three cases aspiration failed to recover any fluid from the joint, even after injection of saline. These failures were excluded, leaving 78 cases for analysis.

At open biopsy 15 hips were infected. In 13 of these all the biopsy specimens were positive; in the other two, three of four specimens were positive. The infecting organisms are shown in Table II. Two hips were infected with several types of organism: one had two strains of *Pseudomonas aeruginosa* at all three sites, the other had *Streptococcus sanguis* and two different strains of coagulase-negative staphylococci at both of the two sites biopsied.

Thirteen of the 15 infected hips were identified by aspiration (true-positive 13, false-negative 2). In one of the false-negative cases the hip was infected with a coagulase-negative staphylococcus and in the other with *Bacillus cereus*. In each of the two hips infected with multiple types of organism, aspiration detected only one of the types.

Of the 63 hips recorded as not infected, eight had an organism isolated from only one of the open biopsy specimens, and were considered to be cases of contamination. The contaminating organisms are shown in Table III. Sixty were identified by aspiration (true-negative 60, false-positive 3). The false-positive aspirations grew *Streptococcus sanguis* in one case, a coagulase-negative staphylococcus in a second and diphtheroids in a third. In each there was no growth from any of the specimens taken at revision surgery.

The sensitivity of fine-needle aspiration for detecting an infection by this culture technique is thus 87% and the specificity 95%. In all, 94% of the aspiration results were accurate. Thirty-eight of the aspirations were dry taps (49%). The absence of fluid does not indicate that the hip is sterile. Five hips with dry taps were shown to be infected at the time of revision surgery; three had been identified by saline injection, but the other two had given false-negative results.

The distribution of the ESR results is shown in Figure 2. The ESR tended to be higher in infected than in non-infected cases, but of the 20 cases with an ESR > 30 mm/hr, only 11 were infected. Three infected cases had an ESR of < 20 mm/hr.

DISCUSSION

The identification of an infected implant before a revision operation is important, as it will determine the extent of the surgery required. In the presence of infection, cement removal must be complete and radical excision of infected soft tissue and bone is required. The use of bone grafts is probably contra-indicated. Pre-operative knowledge of the antibiotic sensitivity of the infecting organism will allow the appropriate use of antibiotics both parenterally and in the cement.

Non-invasive techniques may suggest infection but they are frequently inconclusive; biopsy is the most important investigation. Fine-needle aspiration offers considerable advantages over open biopsy: it is quick and easy under local anaesthesia, there is no wound, and there is less chance of specimen contamination giving false-positive results.

Early reports of fine-needle aspiration of failed hip replacements were disappointing, however, with many false-positive results (Patel, Karchmer and Harris 1976;

Hughes et al 1979; Philips and Kattapuram 1983; O'Neil and Harris 1984). Buchholz et al (1981) reported the results of aspiration of 205 failed hip replacements, comparing them with the culture of tissue taken at revision surgery. Only 73% were correct, with a sensitivity of approximately 66% and a specificity of 87%.

One problem with aspiration is that sample volumes are often small, and in our series 50% had been diluted with sterile isotonic saline. Since the number of organisms in such samples may be very low, it is necessary to use a liquid-enrichment primary culture medium that can be maintained for several weeks. Delay in transport of the aspirate to the laboratory is another problem which could lead to the loss of sensitive organisms, particularly anaerobes. Inoculation in theatre is therefore desirable. In addition, many of the organisms that cause prosthetic infection are skin commensals (Carlsson, Josefsson and Lindberg 1978; Lidwell et al 1983) and it is these which are most likely to contaminate the sample, either at aspiration or during laboratory processing. It was important to reduce the risk of laboratory contamination on repeated subculture.

The BacTec radiometric culture system meets all these requirements. The sample is inoculated immediately into liquid-enrichment media. Conventional bacteriological techniques involve repeated sampling and subculture of this medium to agar plates, and this is subject to laboratory contamination. A radiometric system allows repeated analysis of the head space gas with minimal risk of contamination. Subculture need only be carried out when growth in the primary culture bottles has been demonstrated. Both false-positive and false-negative results should therefore be reduced.

The three false-positive results in this series were probably due to contamination at the time of aspiration, since the primary culture media are exposed only to a minimal risk of contamination in the laboratory. On each occasion the organism was isolated from only one of the primary culture bottles. The organisms were, however, all facultative anaerobes, and therefore growth would have been expected in both aerobic and anaerobic media. This suggests that contamination was caused by very few colony-forming units, or even a single one, which ended up in only one bottle. When an organism that would be expected to grow in both aerobic and anaerobic media is isolated from one bottle only, it is now reported as 'probable contamination' and the aspiration is repeated.

Postoperative management depends on a firm decision on the infective status of the hip and this definitive diagnosis must also be the standard for assessing any method used pre-operatively to diagnose infection. Hughes et al (1979) proposed a scoring system for prosthetic sepsis in which clinical diagnosis, radiological diagnosis, laboratory investigations, operative findings, and bacteriological results were all taken into account. We feel that modern bacteriological techniques should allow the definitive diagnosis of infection to be based solely on the culture of specimens taken at revision surgery. Even ultra-clean air systems, however, do not provide sterile air (Charnley and Eftekhar 1969; Lidwell et al 1982; Sanzén, Carlsson and Walder 1990). Some peri-operative wound contamination is therefore inevitable (Fitzgerald et al 1973; Aglietti et al 1974) and may lead to false-positive results from operative samples.

To distinguish contamination from genuine infection we adopted the methods of Kamme and Lindberg (1981) and Whyte et al (1981): multiple biopsies were taken from the deep tissues and infection was considered to be proven when the same organism was found at multiple sites. Kamme and Lindberg (1981) considered growth at one or two of five sites to be contamination, but in our study we reduced the risk of contamination during processing by using a radiometric culture system. We therefore defined infection as genuine when the same organism was found at all, or three, of four sites. Contamination was easily identified; all eight cases had growth at one site only and in four the organism was isolated from only one primary culture bottle.

Conclusions. No non-invasive test can reliably exclude infection: all failed hip replacements should therefore be aspirated or biopsied before a revision operation.

Fine-needle aspiration combined with a radiometric culture technique is a relatively accurate and simple method of diagnosing infection, but a few false-negative results are probably inevitable. Where other tests suggest infection, a negative aspiration should be repeated, especially if it is a dry tap. False-positive results are rare, and some can be identified by the pattern of bacterial growth in aerobic and anaerobic media.

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