Radiol med (2018) 123:28–35
https://doi.org/10.1007/s11547-017-0811-1

MUSCULOSKELETAL RADIOLOGY

Fluoroscopy- vs ultrasound-guided aspiration techniques in the management of periprosthetic joint infection: which is the best?

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Received: 7 March 2017 / Accepted: 13 September 2017 / Published online: 20 September 2017

Abstract
Background Fluid samples obtained from an affected joint still play a central role in the diagnosis of periprosthetic joint infection (PJI). It is the only preoperative test able to discover the causative microbiological agent. In the hip, fluid aspiration can be performed through fluoroscopy, ultrasound, or, less commonly, computed tomography. However, there is still a lack of consensus on which method is preferable in terms of efficacy and costbenefit.
Purposes We, therefore, asked whether (1) the benefits in terms of sensitivity and specificity and (2) the costs were comparable between fluoroscopy- and ultrasound-guided joint aspirations in a suspicious of hip PJI.
Methods Between 2013 and 2016, 52 hip aspirations were performed on 49 patients with clinical, radiological, or serological suspicion of PJI, waiting for a revision surgery. The patients were divided in two groups: fluoroscopy- ($n = 26$) vs ultrasound-guided hip aspiration group ($n = 26$). These groups were also divided in control and infected patients. The criteria of MusculoSkeletal Infection Society (MSIS) were used, as gold standard, to define PJI.
Results (1) Ultrasound-guided aspiration revealed valid sensitivity (89% vs 60%) and specificity (94% vs 81%) in comparison with fluoroscopic-guided aspiration. (2) The cost analysis was also in favor of ultrasound-guided aspiration (125.30€) than fluoroscopic-guided aspiration (343.58€).
Conclusions We concluded that ultrasound-guided hip aspiration could represent a valid, safe, and less expensive diagnostic alternative to fluoroscopic-guided aspiration in hip PJI.

Keywords PJI · Fluoroscopy · Ultrasound · Hip · Aspiration · Infection

Introduction

Periprosthetic joint infection (PJI) is a devastating complication of hip arthroplasty, mostly requiring revision surgery. The diagnosis is often a challenge for orthopaedic surgeons. The MusculoSkeletal Infection Society (MSIS) recently developed a definition for PJI based on different criteria [1].

In this setting, the role of hip aspiration is of paramount importance for the management of PJI. Furthermore, it is the only preoperative test that can bring to the identification of the causative pathogen defining its antibiotic sensitivity. Hip aspiration can be performed under fluoroscopy (F) [2–23], ultrasound (US) [24–26], or, less commonly, computed-tomography (CT) guidance [27]. Fluoroscopy-guided hip aspiration is the most common and described procedure worldwide; nevertheless, ultrasound aspiration is gaining popularity, especially for patient safety, because of the absence of X-rays and iodinated contrast agents. However, there is still a lack of consensus on which

Investigation performed at Milan, Italy.

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method is preferable in terms of diagnostic efficacy and risk–benefit for patients.

The main purpose of this retrospective study was to compare the diagnostic characteristics (sensitivity and specificity) between fluoroscopy and ultrasound-guided hip aspirations in a suspicious of PJI. Because of this primary objective, we compared the results of these preoperative hip aspirations with the results of cultures from multiple intraoperative tissue samples obtained during revision surgery, together with all the other MSIS criteria, to evaluate the accuracy of these two radiological techniques. The costs and pros/cons of these two procedures were also analyzed and discussed.

Methods

A retrospective cohort study comparing two different aspiration techniques for PJI diagnosis was performed in collaboration between Hip and Radiology Departments at our institution.

Patients who underwent hip aspiration between January 2013 and August 2016 before total hip arthroplasty revision (rTHA) were studied. The inclusion criteria were defined as:

- clinical, radiological, or serological suspicion of PJI;
- antibiotics suspension at least 3 weeks before hip aspiration and revision surgery;
- revision surgery after hip aspiration;
- informed consent for hip aspiration and revision surgery.

All procedures followed were in accordance with the 1975 Declaration of Helsinki, as revised in 2000 and 2008. The study was approved by the local ethics committee. Details that might disclose the identity of the subjects under the study were omitted, in accordance with HIPAA.

Fluoroscopy was mostly performed until 2015; then, due to different management and policy of health resources at our institutions, ultrasound has been especially used.

The patients were so divided in two groups on the basis of the used radiological technique: (1) fluoroscopy- vs (2) ultrasound-guided hip aspiration. Each patient of the fluoroscopy or ultrasound group was defined infected (PJI) or control (non-infected) using the MSIS criteria selected as the gold standard for PJI diagnosis. Based on these criteria, a patient was defined as affected by PJI when at least one of the major criteria or four of the minor criteria were satisfied [1].

Major criteria:

1. A sinus tract communicating with the prosthesis before revision; or
2. A pathogen isolated by culture from at least two separate tissues or fluid samples obtained from the affected prosthetic joint at the time of revision surgery.

Minor criteria:

a. Elevated serum erythrocyte sedimentation rate (ESR) and serum C-reactive protein (CRP) concentration before revision,
b. Elevated synovial leukocyte count,
c. Elevated synovial neutrophil percentage (PMN%),
d. Presence of purulence in the affected joint,
e. Isolation of a microorganism in one culture of periprosthetic tissue or fluid, or
f. Greater than five neutrophils per high-power field in five high-power fields observed from histologic analysis of periprosthetic tissue at 400× magnification.

A patient who fulfilled the criteria was considered infected (PJI group). A patient who did not fulfil the previous criteria was considered as non-infected (control group). Therefore, matching the aspiration technique and the presence or absence of infection, each procedural group was subdivided in two subgroups: fluoroscopy-PJI group, fluoroscopy-control group, ultrasound-PJI group, and ultrasound-control group.

The preoperative aspiration of each patient was then compared to the definitive intraoperative multiple cultures (one of the two major criteria) and all the other MSIS criteria to determine the rate of true positive, false positive, true negative, and false negative of both radiological groups (Table 1). The patient was so considered true positive when multiple intraoperative cultures or other MSIS criteria were satisfied and the preoperative aspiration was positive. A false positive was considered when multiple intraoperative cultures or the other MSIS criteria were finally negative, but the preoperative aspiration was positive. A true negative patient had multiple intraoperative cultures negative and the other MSIS criteria unsatisfied for an infection and the preoperative aspiration was negative. The patient was described as false

Table 1 Correspondence between preoperative hip aspirations and MSIS criteria for infection after revision

Group	Confirmed PJI Definitive MSIS criteria positive[a]	Control Definitive MSIS criteria negative
Positive preoperative hip aspiration	True+	False+
Negative preoperative hip aspiration	False−	True−

[a]Patients in the PJI group had at least one of the MSIS major criteria or four of the minor criteria satisfied preoperatively

negative if bacterial growth was not reported after preoperative aspiration, but then, the multiple intraoperative cultures or the other MSIS criteria reported the presence of infection.

Fluoroscopic aspiration

The patient was admitted for a day-hospital procedure for local regulatory laws. The procedure was carried out by two experienced orthopaedic surgeons with at least 15 years expertise in hip surgery. In the operating room, the patient was place supine on a fluoroscopic table. The sterile operative field was limited to few centimeters around the hypothetical entry point above the greater trochanter. Once the operative field was ready, under a C-arm fluoroscopy view, a 17-gauge spinal needle was inserted through the standard antero-lateral (AL) arthroscopic portal into the hip joint.

Fluoroscopy was used intermittently during the procedure to guarantee the correct insertion and advancement of the needle (Fig. 1). A loss of resistance was appreciated when the spinal needle penetrated the joint capsule. Excessive resistance suggested that the needle was about to penetrate through the labrum rather than the capsule. Once the fluoroscopic position of the needle was considered satisfactory, the inserter was removed from the needle and then the vacuum phenomenon caused by the negative intracapsular pressure was appreciated, indicating the intra-articular position.

Because of its bacteriostatic effect, injection of contrast media (arthrogram) was not performed to confirm the intra-articular position of the needle [28]. Routinely, the aspirated fluid was inoculated into two culture blood bottles and two swabs (containing aerobic or anaerobic liquid enrichment medium) in sterile conditions.

Ultrasound aspiration

The ultrasound investigation was performed by radiologists with at least 5 years of musculoskeletal experience, using a 5-MHz convex ultrasound probe with puncture guide. Under sterile conditions, a 17-gauge needle was advanced into hip joint at the level of the head–neck prosthesis junction, and then, fluid was aspirated with continuous control on the screen (Fig. 2).

Local anesthesia was not performed prior to aspiration, because of its possible bactericidal effect [29]. All samples (two blood bottles and two culture swabs) were sent to laboratory for culture.

Revision surgery

During revision surgery, three-to-five samples were obtained from the hip joint and nearby tissues and then transferred to microbiology and cultured for a minimum of 15 days. Standard microbiological techniques were performed to identify the possible pathogen and determine antibiogram, screening for aerobic, anaerobic, acid-fast bacillus, and fungal microorganisms.

Costs

Any surgical procedure comprises direct costs, measurable, such as operating room and surgical performance, and indirect costs, not so easily quantifiable, such as social costs, loss of work, or salary [30]. This retrospective study considers only direct costs of fluoroscopy- and ultrasound-guided hip aspirations. The costs of hip aspiration were calculated by summing the costs of operating room, performance, and microbiological culture.

The cost of the operating room was calculated per hour of procedure (€1000/h) (Region of Lombardy, Italy), considering the start of the procedure as the moment of making the first insertion of the needle and the end as when the procedure was completed. The ultrasound performance in the radiology department comprised the investigation of the joint (€36.55/patient) and hip aspiration (€28.50/patient).

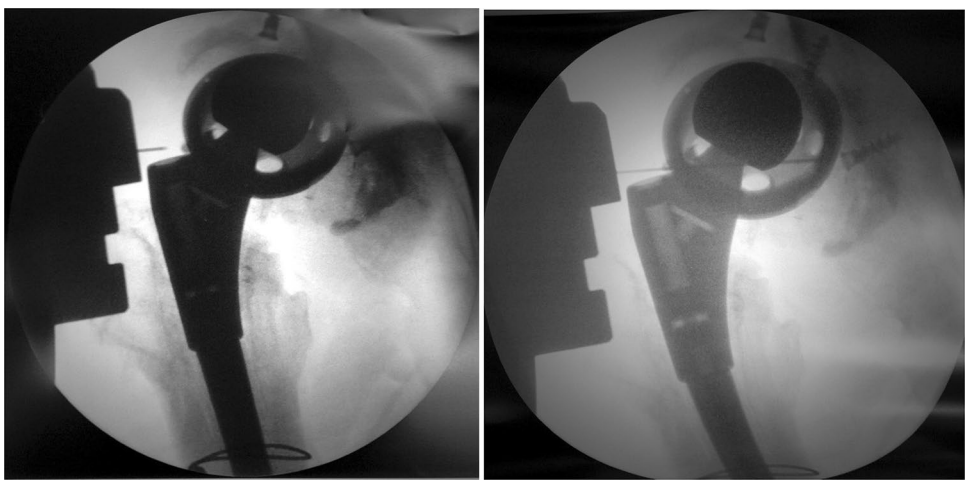

Fig. 1 On the left, the advance of the needle in direction of the joint. On the right, the intra-articular position of the needle

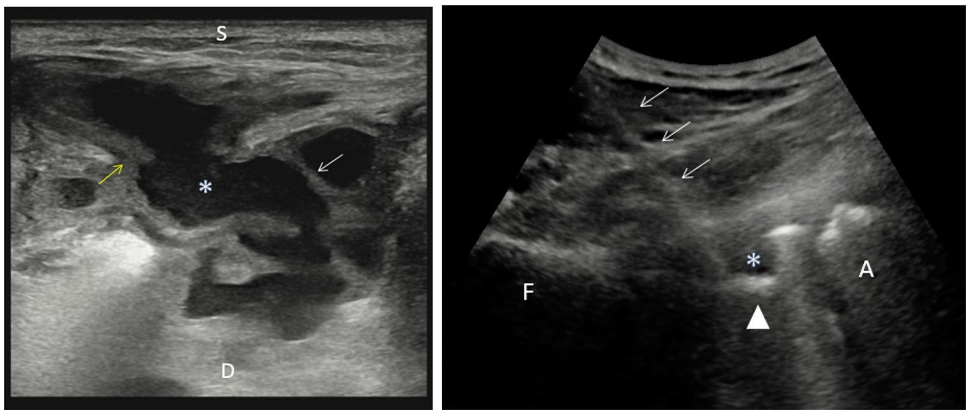

Fig. 2 On the left, ultrasound image shows periprosthetic fluid collection (white asterisk). The collection extends from superficial (S) to deep (D) soft tissues showing multiloculated aspect with thick synovial walls (yellow arrow) and septa (white arrow). On the right, ultrasound-guided procedure of hip aspiration. The needle (arrows) is advanced with an in-plane approach up to reach a small fluid collection (white asterisk) surrounding the hyper-echoic surface of hip prosthesis (arrowhead). *F* femur, *A* acetabulum

The microbiological culture costs, which were the same for both procedures, account for two stabs (€13.35 × 2/patient), two blood bottles (€13.35 × 2/patient), culture procedure (€6.85/patient), and only in case of microbiological growth, microorganism identification (€13.90/patient), and antibiogram (€7.55/patient).

The costs of the fluoroscopic procedure, requiring hospital admission, were on charge of the Italian National Health Service (Servizio Sanitario Nazionale—SSN). The costs of the ambulatorial ultrasound procedure were on charge of both the SSN and the patient, with the payment of a co-pay fee (ticket), except for those who were entitled to exemptions.

Statistical analysis

Continuous variables were expressed as mean and standard deviation (SD). Demographical and clinical data were analyzed using t test independent for continuous variables. The level of statistical significance was fixed to 5% ($p < 0.05$) to reject the null hypothesis. The sensitivity and specificity along with the exact confidence intervals (CIs) were calculated. Fisher's exact test was used to compare sensitivities and specificities of the two diagnostic procedures [31]. Calculations were performed using analysis computer software (Excel, Microsoft) and interactive statistical pages (http://www.statpages.org for exact tests and 95% CI). The ROC plot was used to graphically compare the two tests under investigation according to the considerations of Biggerstaff [32]. Specifically, each test is represented according to its sensitivity and 1-specificity and connected to the point (0,0) and (1,1) through two lines. The slope of the two lines represents the likelihood ratio positive and negative of the test.

Results

Fifty-two hip aspirations were performed on forty-nine patients (23 men and 26 women). Twenty-six were performed under fluoroscopy guidance and 26 under ultrasound guidance. The average age in the F group was 66.7 ± 15.4 years, while that in the ultrasound group was 66.3 ± 9.2 years. The average time from hip aspiration to revision surgery was 126.5 ± 235.3 days in the fluoroscopy group and 118.5 ± 69.1 in the ultrasound group. There were no statistically significant differences when comparing the mean age of patients ($p = 0.93$) and the mean wait time for revision surgery ($p = 0.20$) of the two groups.

In the fluoroscopy group, ten patients (38.5%) were considered infected (fluoroscopy-PJI group) (Table 2). After the revision surgery, of these 10 infected hips, 6 patients (60%) had positive preoperative hip aspiration (true positive) and 4 patients (40%) had negative preoperative hip aspiration (false negative). In the fluoroscopy-PJI group, seven hips presented MSIS major criteria (sinus tract or positive multiple intraoperative culture) and three hips multiple minor criteria. In the fluoroscopy-control group, three positive hip aspirations (18.8%) were considered false positive, because the MSIS was not satisfied even after revision surgery.

The sensitivity of hip aspiration in the fluoroscopy group was 60% (95% CI 26–88%). The specificity was

Table 2 Fluoroscopy aspiration

Hip aspiration	PJI group	Control group	Tot
Positive culture	6	3	9
Negative culture	4	13	17
	10	16	26

Table 3 Ultrasound aspiration

Hip aspiration	PJI group	Control group	Tot
Positive culture	8	1	9
Negative culture	1	16	17
	9	17	26

Table 4 Fluoroscopy PJI group

Case	Age	MSIS diagnosis	Hip aspiration cultures	Revision cultures
1	44	Culture	*E. faecalis*	*E. faecalis*
2	81	Minor criteria	*Bacillus* spp.	–
3	50	Sinus tract	–	*S. mitis*, *S. oralis*
4	76	Culture	*S. aureus*	*S. aureus*
5	75	Culture	–	*S. capitis*
6	89	Minor criteria	–	–
7	79	Minor criteria	–	–
8	75	Sinus tract	*C. striatum*	–
9	60	Culture	*S. auricolaris*	*S. epidermidis*, *S. capitis*, *S. auricolaris*
10	83	Culture	*S. aureus*	*S. aureus*

81% (95% CI 54–96%). Hip aspiration under fluoroscopy guidance required an average time of 17 ± 6.7 min.

In the ultrasound group, nine patients (34.6%) were diagnosed septic after MSIS criteria (ultrasound-PJI group) (Table 3). Preoperative hip aspirations were positive in 8 of these 9 infected patients (89%) (true positive). One preoperative hip aspiration (11%) was negative (false negative) in this septic-ultrasound group. All these nine infected hips had multiple intraoperative positive samples during revision surgery (MSIS major criteria). In the ultrasound-control group, only one false-positive preoperative aspiration (5.9%) was reported.

Pathogen identified pre and intraoperatively at revision surgery is shown in Tables 4 and 5.

In the ultrasound group, the sensitivity of preoperative hip aspiration was 89% (95% CI 51–100%), while the specificity was 94% (95% CI 71–100%). The diagnostic performances of the two tests are reported in Fig. 3. There was no evidence of statistically significant difference comparing sensitivities or specificities of the two techniques (sensitivities: $p = 0.73$; specificities: $p = 0.80$).

The costs of the fluoroscopy-guided procedure was calculated as follows: 17 min of the average operating theater time at an hourly cost of €1000 (€283.33) + cost of microbiological cultures (€60.25) = €343.58. The costs of the ultrasound-guided procedure was calculated as follows: radiological performance (€65.05) + cost of microbiological culture (€60.25) = €125.30. In the PJI groups, all these costs increased of €21.45 for microbiological identification and sensitivity.

Discussion

Defining preoperatively, the microbiological pathogen responsible for PJI is crucial. The accuracy of different aspiration techniques to achieve this step has been reported in the literature. Fluoroscopy-guided aspiration with or without injection of iodinated contrast (hip arthrography) is the most commonly technique published in the literature (Table 6) [2–23]. It appears to be an effective and reproducible procedure, but there are risks derived from doses of radiations and the potential adverse reactions against iodinated contrast.

In this retrospective study, ultrasound-guided aspiration showed good and superior outcomes in comparison with fluoroscopy-guided procedure evaluating sensitivity (89% vs 60%) and specificity (94% vs 81.3%), even if the difference was not statistically significant.

In our study, a low sensitivity was found for fluoroscopy. In fact, four false-negative results (40%) were found. This rate of false-negative outcomes could be explained by the incapability of fluoroscopy to drive the needle toward a fluid collection, collecting potentially less fluid to cultivate than US. Scarce fluid for culture and consequentially low

Table 5 Ultrasound PJI group

Case	Age	MSIS diagnosis	Hip aspiration cultures	Revision cultures
1	75	Culture	–	*S capitis*
2	77	Culture	*S. epidermidis*	*S. haemolyticus*
3	63	Culture	*Peptococcus* spp.	*S. epidermidis*
4	60	Culture	*A. prevotii*	*A. prevotii*
5	73	Culture	*S. agalactiae*	*S. agalactiae*
6	50	Culture	*P. asaccharolyticus*	*S. epidermidis, S. hominis*
7	60	Culture	*S. hominis, S. epidermidis*	*S. epidermidis*
8	74	Culture	*S. epidermidis*	*S. epidermidis*
9	54	Culture	*S. epidermidis*	*S capitis, P. acnes*

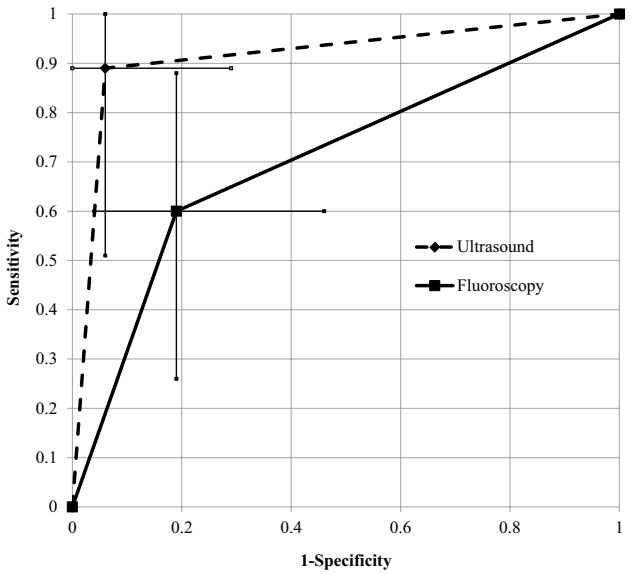

Fig. 3 ROC plot: ultrasound had superior diagnostic performance compared to fluoroscopy, although the confidence interval (represented by crosses) for sensitivity and specificity was wide

Table 6 Fluoroscopy aspiration: overview of literature

Study	*N* cases	Sensitivity	Specificity
Barrack et al.	291	60	88
Fehring et al.	166	50	88
Gould et al.	78	87	100
Lachiewicz et al.	156	92	97
Spangehl et al.	180	86	94
Phillips et al.	148	91	82
Mulcahy et al.	71	68	91
Ali et al.	77	82	91
Levitsky et al.	72	57	97
Pons et al.	80	62	96
Williams et al.	273	80	94
Tigges et al.	147	93	92
Taylor et al.	97	93	96
Kraemer et al.	45	57	97
Jonhson et al.	24	12	81
Glithero et al.	54	89	97
Roberts et al.	78	87	85
Lieberman et al.	49	100	100
Itsaka et al.	48	40	92
Cheung et al.	34	83	100
Somme et al.	109	83	100
Cross et al.	110	59	100
Battaglia et al.	60	27	75
Randelli et al.	52	60	81

concentrations of the microorganisms has been described as potential causes of false-negative results [33]. The main limitation of this study is the small sample size that does not permit the detection of a statistical difference in terms of sensibility and specificity, even if the main purpose of the study was to show US as valid as fluoroscopy in detecting PJI. Larger randomized controlled clinical trials are needed to confirm and validate these clinical results and to draw the future role of the radiologist and ultrasound in the preoperative management of PJI.

A first question dealing with effectiveness of a diagnostic procedure in PJI is how this procedure may resemble fluoroscopy-guided aspiration results. Ultrasound-guided hip aspiration is an emerging technique showing the advantage of avoiding X-rays and contrast exposure. US has been reported an excellent modality to visualize the soft tissues surrounding the hip (greater trochanteric bursa, iliopsoas tendon/bursa, gluteal tendons, and iliotibial band), cystic or solid soft-tissue masses [34], and extra-articular fluid collections communicating with the joint: these structures, undetectable with fluoroscopy, can be possible locations of pathologies after hip arthroplasty and may be passible of aspiration [35, 36]. Colour and power Doppler imaging has been described as potential tools in differentiating synovitis from hip effusion [37]. US provide theoretical advantages also considering needle insertion, which can be more precise and safer, monitoring continuously on the screen the tip of the needle, to avoid accurately heterotopic ossifications or septic extra-articular collections, with the potential risk of introducing infective microorganisms into a sterile joint [38].

There are few studies about the accuracy of ultrasound-guided aspiration for hip PJI diagnosis [24–26]. Results seem comparable to the fluoroscopy procedure (Table 7). However, Eisler et al. [25] do not suggest the use of preoperative US: the fluid cultures showed high specificity but were of limited clinical value because of poor sensitivity. Battaglia et al. [26] compared the clinical outcomes of ultrasound vs fluoroscopy hip aspiration, reporting similar results to our study, but different statistical comparison was performed.

The cost analysis of our study showed an average difference of €218.28. Fluoroscopy-guided hip aspiration costs more than double compared to the ultrasound-guided one.

This is the first study, to our knowledge, that included a full statistical analysis, focusing on the accuracy, pros/

Table 7 Ultrasound aspiration: overview of literature

Study	*N* cases	Sensitivity	Specificity
van Holsbeeck et al.	33	100	74
Eisler et al.	74	0	96
Battaglia et al.	60	69	94
Randelli et al.	52	89	94

cons, and costs of the two procedures, with updated criteria (MSIS) as gold standard to evaluate the validity of each hip aspiration technique for PJI detection. Usually, in the literature, the intraoperative culture results obtained during revision surgery were considered as the gold standard for the attestation of PJI: this methodology does not appear completely reliable to differentiate PJI from aseptic failure in our case series and in literature, due to possibility to underestimate the presence of PJI. We had 4 patients in 19 infected (21%) that presented intraoperative negative cultures: with the use of other major (sinus tract) or minor criteria, we were able to differentiate the septic failure of the prosthesis and better investigate the accuracy of the radiological techniques in managing PJI.

Conclusions

Preoperative hip aspiration is a useful diagnostic tool for detection of PJI. There is still debate in the literature on which technique of aspiration is preferable, based on accuracy, costs, and pros/cons. In our study, ultrasound-guided aspirations showed good outcomes compared to fluoroscopy, but at lower costs.

Acknowledgements None.

Funding The current study received no funding.

Compliance with ethical standards

Conflict of interest All authors of this manuscript declare that they have no conflict of interest.

Ethical standards All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study, formal consent is not required.

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