Decision Matrix–Guided Treatment of Infected Hip Resurfacing

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ABSTRACT: Infection can nullify the benefits of a successful hip resurfacing arthroplasty (HRA). Even with infection, it may be feasible to meet a patient's desire to retain the implant. The author reviewed records of 301 patients with infected hip resurfacing. Patients expressed their treatment preference using a decision matrix that considered treatment efficacy, consequences of treatment failure, probability of infection worsening, and treatment side effects. Patient interviews were analyzed to determine their experience with treatment. Treatment alternatives were (1) no surgery, oral antibiotics, and local incision care; (2) surgical debridement, IV antibiotics, and implant retention; (3) one-stage explantation, IV antibiotics, and reimplantation generally with conversion to total hip replacement; and (4) two-stage reimplantation with conversion to total hip replacement. Mean follow-up was 9 years (range, 2–34). Pretreatment qualitative themes found that some patients believed their early infection symptoms were not validated, leading to diagnostic delays. During treatment, themes centered on mobility and lifestyle limitations for those receiving revision surgery. Posttreatment themes were reduced function following revision compared to pretreatment function. Of the 301 patients, 199 (66%) had nonoperative care, with remission for 169 (85%); 40 (13%) had one-stage reimplantation and 36 (90%) had infection remission; 16 (5%) had two-stage reimplantation with remission in 14 (87%); and 46 (16%) had debridement and implant retention, with remission for 38 (83%). The matrix showed that patients with infected HRA preferred nonoperative care, which was successful for 85%. Qualitative themes found less patient distress with nonoperative treatment and the greatest patient distress with two-stage revision.

KEY WORDS: hip resurfacing arthroplasty, infection, treatment outcomes

I. INTRODUCTION

Among the surgical challenges in performing hip resurfacing arthroplasty (HRA), infection stands out for its profound impact. Infections reduce the quality of life for patients and their families and have negative psychological, physical, and financial effects.[1–3] Surgeons are also deeply affected by infection and can experience guilt and frustration because of it.[4] Also, infection is a leading cause of malpractice claims, typically based on delay in diagnosis, antibiotic monotherapy, and inadequate surgical treatment.[5]

Typically, HRA patients are younger, more active, and healthier than total hip replacement (THR) patients. Hip resurfacing arthroplasty patients ask more questions, consume more of the surgeon's time, and have higher expectations. They are focused on limiting the intrusiveness of procedures and retaining their bone and HRA implant.[6,7]

Explanting the prosthesis, infusing the patient with intravenous antibiotics (IV), and then reimplanting the prosthesis in a second stage has been described as the gold standard of treatment.[3,8–10] Two-stage procedures are performed less often than in the past, however, as data on alternative treatments accumulate.[11,12] Many HRA patients and some surgeons see two-stage treatments as a ritualized escape plan rather than a modern-day correct solution. Hip resurfacing patients view infection as a threat to their lifestyle as well as an unwelcome push toward THR.[6,7]

Recently, a combination of debridement, antibiotics, and implant retention (DAIR) has become a more successful and better accepted treatment, particularly when using rifampin followed by chronic oral suppressive antibiotics. This is more effective for acute compared to chronic infections.[11] Typically, oral antibiotics, and local incision care (PoAIR) are offered only to patients who are not surgical candidates because of their coexisting health conditions. As for THR, operative care is offered to good surgical candidates because revision surgery is successful at resolving infection. The weight and authority of opinion favor surgical management. It has not

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been shown that PoAIR can be effective for HRA infections.[3,9]

Hip resurfacing arthroplasty is quite different from THR. Hip resurfacing implants are contained within the joint capsule and do not extend into the femoral intramedullary canal. Resurfacing implants are much smaller and do not have femoral modular fittings that are used with stem-supported THR. There is less surface area to harbor biofilm. Also, there is less dead space inside the hip capsule with HRA compared to THR, as the normal anatomy is preserved more closely. It is not a given that the principles and techniques for treating THR infection apply to HRA infection.

Hip resurfacing has a strong evolutionary connection to cup arthroplasty. Cup arthroplasty was the preferred method of treating advanced arthritis starting in the 1930s, before THR was available. With cup arthroplasty, an unsecured metal cap is placed over the reshaped femoral head. Infection occasionally occurred, particularly in the preprophylactic antibiotic era. Surgeons treating an infected cup arthroplasty typically retained the implant and performed debridement as necessary. This was usually successful, particularly later when antibiotics became available.[13–15]

The author hypothesized that an infected HRA is similar to an infected cup arthroplasty and that it can respond more favorably to less intrusive treatment than an infected THR. An infected HRA may not require surgery or IV antibiotics in all cases. In the absence of other data, surgeons have treated infected HRA the same as THR. This is problematic since the commercially available spacer implants are designed for THR. Opening the femoral canal and placing a stem-supported spacer is counterintuitive to both HRA patients and surgeons. The fear is that infection can propagate into the femoral canal.

The purpose of this work is to review the results of treating infected HRA. A decision matrix method was used to determine the patient's preferred treatment choice. Patient interviews provided qualitative data about the care experience. The study asked (1) What are the results of treatment of an infected HRA? (2) Are there less invasive methods that can be used with HRA compared to THR? (3) Is a decision matrix a useful patient tool? (4) What are the qualitative themes patients offer about their infection care?

II. METHODS

The Institutional Review Board approved this retrospective study. The inclusion criteria were all patients with an infected HRA between 1976 and 2018. The diagnosis was based on symptoms; clinical examination such as localized pain, erythema, temperature > 38°C; results of deep cultures and laboratory tests (C-reactive protein and sedimentation rate); and imaging (Fig. 1). The exclusion criteria were death and lost to follow-up. There was a thorough discussion of infection, the body microbiome, and the rationale for infection treatment with each patient. The use and possible adverse consequences of antibiotics were discussed.

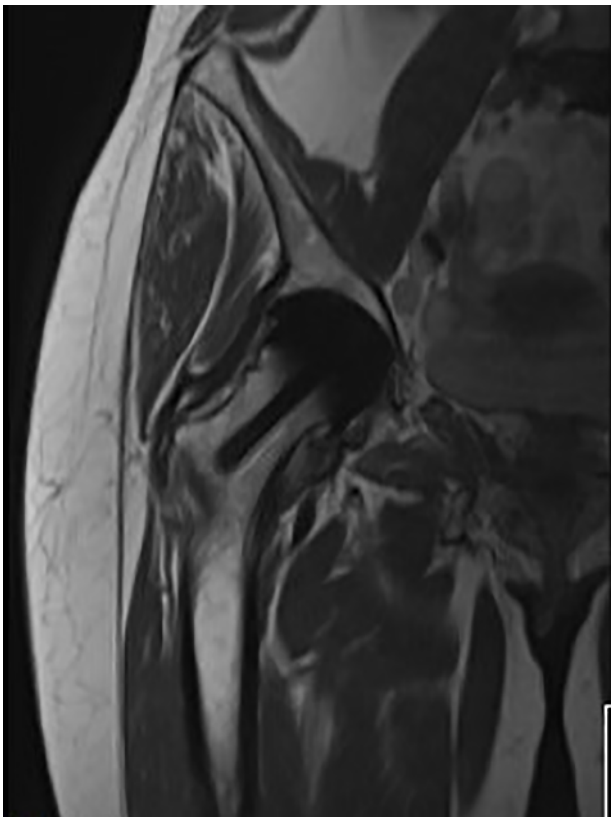

FIG. 1: MRI of the pelvis showing a large abscess connecting with the right HRA in a 57-year-old woman

Patients were assessed using McPherson's criteria.[16,17] The host grade was assessed based on the presence of diabetes, cardiac or pulmonary insufficiency, HIV infection, xenobiotics (smoking or nicotine use, drugs, alcoholism), or other immune compromise. Patients with no health issues were Grade A hosts. Patients with one or two factors were Grade B hosts, and those with three or more criteria present were Grade C hosts. The lower extremity itself was classified as Grade 1, 2, or 3 based on whether there were any local compromising conditions. All patients in this study were Grade A or B and all were Grade 1 with no compromise of their limb.

Four treatment methods were discussed:

1. Oral antibiotics, local incision care, and implant retention (PoAIR)
2. Surgical debridement, IV antibiotics, and implant retention (DAIR)
3. One-stage explantation and reimplantation and six weeks of IV antibiotics
4. Two-stage explantation and reimplantation and six weeks of IV antibiotics.

If a patient presented with an infection and the implants were loose, or the surrounding bone and tissues were degraded, or the function was less than good or excellent prior to infection, they were offered options (3) or (4) only. Reimplantation usually with a THR was performed eight weeks after HRA explantation. If the femur was healthy after removing the infected femoral component, a revision HRA was performed (Fig. 2). Conversion to THR was performed if there was any doubt about the health of the femur or if the patient preferred a THA (Fig. 3). Implant loosening was defined using accepted resurfacing criteria.

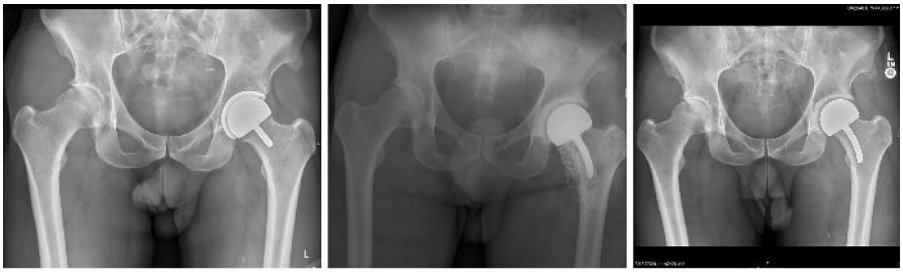

FIG. 2: (a) AP pelvis radiograph of a healthy 47-year-old man showing a cementless left metal-on-polyethylene HRA. (b) AP pelvis radiograph showing left HRA revised to a cemented HRA using an all polyethylene acetabular component with antibiotic cement and a curved-stem femoral prosthesis; antibiotic beads have been placed. (c) AP radiograph taken 11 years after surgery; clinical result is good and implants remain secure with no sign of wear.

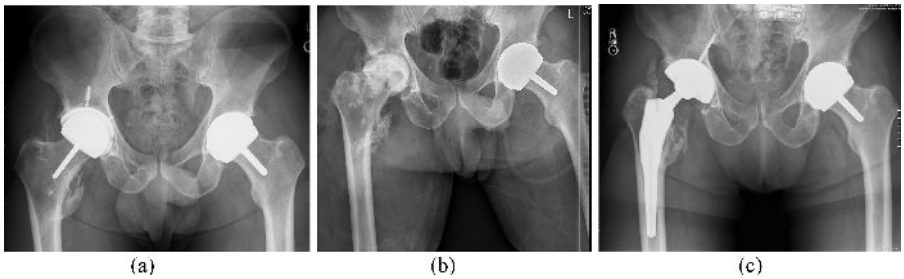

FIG. 3: (a) AP pelvis radiograph showing a right metal-on-polyethylene HRA and a left metal-on-metal HRA in a 43-year-old man; infection occurred seven years after surgery in the right hip. (b) AP pelvis radiograph showing the right HRA implant removed and placement of a surgeon-molded polymethylmethacrylate antibiotic spacer. (c) AP pelvis radiograph showing a second-stage revision to a cementless THR.

Patients presenting with a well-functioning HRA with healthy tissues and bacteria sensitive to oral antibiotics were offered implant retention and oral antibiotic treatment (PoAIR). Local incision care was provided in the surgeon's office. If the incision required debridement, this was performed with (33) or without (30) antibiotic bead placement (Fig. 4). Implants were not exchanged, and the hip was not dislocated in the DAIR technique.

The typical antibiotic protocol was levofloxacin 500 mg daily and rifampin 300 mg bid. C-reactive protein and erythrocyte sedimentation rate levels were obtained and repeated in alternate weeks for 12 weeks. Between 1987 and 1994, ciprofloxacin 500 mg bid was used before levofloxacin was available. Between 1976 and 1987, clindamycin 300 mg qid was used before quinolones were introduced. Rifampin was always used. If there was an adverse reaction to levofloxacin, ciprofloxacin, or clindamycin, then either trimethoprim/sulfamethoxazole (TMP-SMX) or doxycycline 100 mg bid was substituted. There were nine patients with resistant organisms requiring treatment with linezolid and rifampin. Dual therapy with rifampin was provided typically for 12 weeks (range 6 to 16 weeks). Patients were then transitioned to monotherapy to complete 12 months. The monotherapy antibiotics used to maintain the remission were amoxicillin, TMP-SMX, cephalexin, cefadroxil, doxycycline, minocycline, oxacillin, and penicillin. Doxycycline and minocycline are preferred (76%).

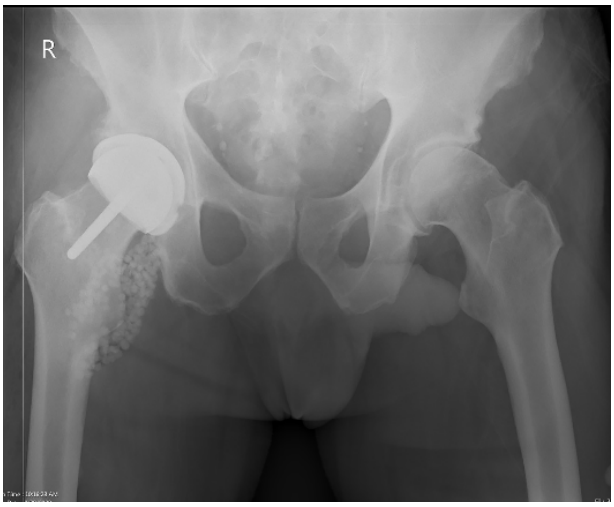

FIG. 4: AP pelvis radiograph showing, in a 61-year-old man, an infected cementless right ceramic-coated femoral HRA prosthesis on a polyethylene acetabular component; antibiotic beads were placed under local anesthesia in the surgeon's office

Local incision care included aspiration or expression of any fluid collections with or without imaging. In-office debridements were performed with or without local anesthesia, and dressing changes including negative pressure were placed and changed frequently. Reducing the burden of collagenolytic enzymes can help reverse pathoadaptive wound healing. Antibiotic beads were placed under local anesthesia if there was incisional dead space (Fig. 4).

To determine the patient's choice of treatment, a decision matrix was used (Fig. 5). The matrix items included the probability of remission of the infection, the consequences of treatment failure, the probability of the infection worsening, and treatment side effects. Also, the life disruption of treatment, functional outcome, and preservation of bone were assigned values. Patients completed the matrix, a decision-making tool,[18] after instruction. The weighted criteria were evaluated against the four treatment choices. Other criteria could have been used, but those chosen seemed most useful. The weight and value given to each criterion was entered by the patient. The supporting factors behind the facts given about the effectiveness and risk of the four treatment options were literature derived and surgeon provided. Often, however, patients used their surgeon as a second source for their own online research.

Qualitative semi-structured interviews were conducted 12 weeks to 12 months following treatment to avoid recall bias. Data were transcribed, anonymized, and analyzed using a thematic approach. The interviewer (BJA) was an experienced qualitative methodologist with a background in physical therapy, nursing, and psychology. The interviewer was flexible during the interviews to cover both the necessary topics and to allow patients to offer their own items of interest. Interviews lasted a mean of 66 minutes (range 42 to 120). Thematic analysis was used with themes, and then subthemes were

Hip PJI Decision Model
Date: 12/28/19

Option	Infection Management				Conseq. Failure (-)			Prob. Worse Infection/Side Effects (-)			Function							Bone Retention			Life Disruption			TOTAL SCORE	
	Value	Prob. Remission	Raw Score	Weighted Score	Value	Prob.	Raw Score	Value	Prob.	Raw Score	Weighted Score	1-10 yrs. (Wt.=70)	Prob.	Score	11-15 yrs. (Wt.=20)	Prob.	Score	16+ yrs. (Wt.=10)	Prob.	Score	Total Raw Score	Total Weighted Score	Value	Weight	Raw Score	Value (-)	Weight	Raw Score	Weighted Score	RAW	WEIGHTED
Category Weighting Factor				*30.0%*			*15.0%*				*10.0%*		*70.0%*		*20.0%*			*10.0%*			*20.0%*			*12.5%*			*12.5%*		*100.0%*
PoMR	100	25%	25	8	-10	20%	-2	-100	5%	-5	-1	100	90%	63	90	90%	16	90	80%	7	86	17	100	95%	95	12	-100	20%	-20	-3	179	33
DAIR	100	60%	60	18	-50	40%	-20	-100	10%	-10	-1	100	80%	56	90	70%	13	80	50%	4	73	15	100	80%	80	10	-100	50%	-50	-6	133	32
Replacement - 1 Stage	100	80%	80	24	-100	20%	-20	-100	15%	-15	-2	70	70%	34	60	70%	8	60	60%	4	46	9	100	30%	30	4	-100	50%	-50	-6	71	26
Replacement - 2 Stage	100	90%	90	27	-200	10%	-20	-100	20%	-20	-2	70	90%	44	60	70%	8	60	60%	4	56	11	100	0%	0	0	-100	70%	-70	-9	36	24

Notes:

FIG. 5: Decision matrix used to evaluate patients' treatment preferences

developed, reviewed, and placed into pretreatment, during treatment, and posttreatment phases. The Odom criteria were used to describe the functional outcome.[19,20] The Odom categories are:

- Excellent: no complaints and able carry out lifestyle without impairment.
- Good: intermittent or mild symptoms that do not interfere with lifestyle.
- Satisfactory: improved, but physical activities are significantly limited.
- Poor: unimproved or worse compared to prior treatment.

III. RESULTS

All patients with a deep HRA infection (311) were treated. Six patients died of causes unrelated to their HRA and 4 were lost to follow-up, leaving 301 for analysis. All patients had both a femoral and an acetabular component. Sixty-two percent of patients had a metal-on-polyethylene prosthesis and 38% had a metal-on-metal prosthesis. Thirty-five percent (105) had their index surgery in the author's practice and 65% (196) were referred from other practices, including two predecessor practices (COT and RLL). The mean age was 49 years (range 19–67 years). There were 157 men (52%), 141 women (47%), and 3 nonbinary (1%). The preoperative diagnoses were osteoarthritis (117, 39%), prior trauma (19, 6%), degeneration from dysplasia (135, 45%), inflammatory arthritis (15, 5%), and avascular necrosis (15, 5%).

The mean time from the HRA to diagnosis of infection was 39 days (range 18–1,095). *Staphylococcus aureus* and *Staphylococcus epidermidis* comprised 60% of infections (Table 1). The infection was culture negative in 7% of patients. For infections within the first six weeks of HRA, it was assumed that the incision was confluent with the joint space. All hips had a deep joint aspiration before initiating treatment. During the qualitative interviews, it became clear that determining the time of onset of the infection was not reliable according to the patients and these data were not further collected or analyzed as acute versus chronic. This is different from other studies in which acute versus chronic is emphasized. Patients were hospitalized as necessary but typically only when surgery was performed.

TABLE 1: Organisms isolated

Organism	No. of patients	Percentage
Staphylococcus aureus	96	32
Sensitive	91	30
Resistant	5	2
Staphylococcus epidermidis	84	28
Sensitive	76	25
Resistant	8	3
Staphylococcus sanguinis	9	3
Staphylococcus capitis	9	3
Viridans	6	2
Enterobacter	3	1
Streptococci	15	5
Culture negative	22	7
Gram negative	21	7
Polymicrobial	12	4
Enterococcus	12	4
Cutiform	12	4

Patients used the decision matrix to express their treatment choice as follows:

- PoAIR: 240 (76%)
- DAIR: 37 (13%)
- One-stage: 18 (6%)
- Two-stage: 16 (5%)

Forty-two patients were not candidates for PoAIR for the following reasons: loose implant(s) or compromised supporting bone (10); bacteria resistant to oral antibiotics or unable to take oral antibiotics (15); incision required surgery; and (9) poor functional outcome from HRA prior to infection (8). These 42 patients were offered alternate treatments.

A. Treatment Outcomes

Table 2 shows the number of patients starting and completing treatments. Table 3 shows infection outcomes. Table 4 shows Odom criteria functional outcomes.

TABLE 2: Results of treatment of 301 patients with HRA infections

Initial treatment	Further treatments and outcomes
PoAir *n* = 199, 169+	9 one-stage revision, 7+; 1 two-stage revision, 1+; 1 chronic suppression 10 two-stage revision, 8+; 1 two-stage revision and re-revision+; 1 chronic suppression 11 DAIR, 9+; 1 two-stage revision, 1+; 1 chronic suppression
DAIR *n* = 46, 38+	3 one-stage revision, 2+;1 chronic suppression 5 two-stage revision, 4+; 1 chronic suppression
One-stage *n* = 40, 36+	4 two-stage revision, 3+; 1 chronic suppression
Two-stage *n* = 16, 14+	1 two-stage re-revision, 1+; 1 chronic suppression
Totals	301 primary treatments, 44 secondary treatments, 345 total treatments

+ = remission

TABLE 3: Infection outcomes

Treatment	Successful (*n* patients/percentage)	Revision necessary (*n* patients/percentage)	Chronic infection (*n* patients/percentage)
PoAIR	169/85	26/13	4/2
DAIR	38/83	6/13	2/4
One-stage	36/90	2/5	2/5
Two-stage	40/87	4/9	2/4

TABLE 4: Functional outcomes (Odom classification)

Treatment (final)	Excellent	Good	Satisfactory	Poor
PoAIR, 169	149 (88%)	20 (12%)	0	0
DAIR, 49	41 (83%)	7 (15%)	1 (2%)	0
One-stage, 48	6 (13%)	30 (63%)	8 (17%)	3 (7%)
Two-stage, 28	2 (7%)	16 (56%)	6 (21%)	4 (16%)

1. PoAIR

Of the 199 patients treated with PoAir, 169 (85%) had remission of their infection and 100% of these had an excellent (88%) or good (12%) functional outcome. There were 30 (15%) patients who failed their PoAIR treatment and proceeded to other treatments (9, one-stage revision; 10, two-stage revision; 11, DAIR).

2. DAIR

DAIR treatment was successful in 38 (83%) of 46 patients; 8 (13%) required a subsequent one- or two-stage revision and 2 (4%) had chronic suppression.

3. One-Stage Revision

Forty patients were treated with one-stage revision either to THR (36) or another HRA (4). This was successful for 36 (90%), with 4 requiring an additional revision and 1 treated with chronic antibiotic suppression.

4. Two-Stage Revision

Sixteen patients were treated initially with a two-stage revision. Of these, 14 (87%) had a remission of their infection, 2 required a second revision, and 1 was treated with chronic antibiotic suppression.

5. Secondary Treatments

There were 44 patients who had additional procedures after the initial choice for treating their infection was unsuccessful. There were 37 (84%) additional procedures that achieved remission and 7 (16%) ended in chronic suppression of the infection.

B. Adverse Events from Antibiotics

Side effects from antibiotics affected 15 (5%) patients (severe rash, intermittent diarrhea) who were unable to continue with their initial treatment and required a change of treatment. Ten patients chose oritavancin, which is an IV infusion given over three hours and repeated every 10 days for three doses. It avoids the need for either oral or catheter infusion antibiotics, but it is very expensive. Oritavancin is a semisynthetic derivative of vancomycin that is effective against gram-positive bacteria including methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant enterococci (VRE).[21] There were no tendon ruptures, which represent a black box warning associated with the quinolones that were used commonly. No patients required hospitalization for antibiotic complications or sepsis.

C. Qualitative Outcome Themes

The qualitative themes encompassed the three phases of care.

1. Pretreatment

Patients described a sense that something was wrong. They stopped improving or lost ground in their recovery process and had more pain and less mobility. Another theme was that their symptoms were not validated when they were assessed by their therapist, surgeon's office staff, or in some instances their surgeon, and this led to a delay in diagnosis and treatment. Another pretreatment theme was that patients were not provided a satisfactory explanation as to why they developed an infection or why the preventive measures were unsuccessful in their case.

2. During Treatment

Patients expressed difficulty in understanding the rationale for explanting their prosthesis. They expected it could be sterilized either directly or with antibiotic administration. Another theme was difficulty understanding why IV antibiotics were preferred over oral. Patients expressed confusion over the clinical signs surgeons used as meaningful or not meaningful. Two-stage patients stated that their recovery was difficult to the point of being overwhelming; PoAIR and DAIR patients did not express this. The side effects from antibiotics, such as feeling unwell, intermittent diarrhea, diminished taste, rash, or other skin sensitivities, were expressed commonly but were not overwhelming.

3. Posttreatment

One- and two-stage exchange patients noted a less favorable functional outcome compared to before the infection treatment. There was a theme of disappointment in the outcome; PoAIR and DAIR patients did not have this. Living with an infection and fear of infection returning was a common posttreatment theme.

IV. DISCUSSION

This study found that 85% of healthy patients with a well-functioning infected HRA and a sensitive bacterium were treated successfully with oral antibiotics and local incision care (PoAIR). When successful, this treatment resulted in a better functional outcome than other options. Also, patients preferred avoiding revision surgery and an indwelling catheter for antibiotics. The qualitative theme analysis showed that patients preferred nonoperative treatment that retained their implant compared to a one- or two-stage revision.

The results of treating an infected HRA are not generalizable to THR. There are several differences between THA and HRA. Hip resurfacing implants are (1) less intrusive and do not extend into the femoral medullary space; (2) uncomplicated, with a smaller surface area for biofilm; (3) associated with less intracapsular dead space; and (4) used typically in younger and healthier patients. Hip resurfacing

patients have higher functional abilities compared to patients with THR.[6,7] Also, HRA patients who retain their implants have much higher function than patients recovering from a one- or two-stage revision. Despite infection, their function after treatment was similar to their function after primary HRA.

The successful results in this study are similar to the results of some other studies.[11,14,15] Ninety-two percent of THR implants were retained with treatment by DAIR in healthy patients treated early if rifampin was part of the oral antibiotic suppression. The difference with the present study is the operative debridement with (70%) or without (30%) modular component exchange. Hip resurfacing femoral components are not modular. Some acetabular components are monoblock, and disassembly of the remaining two-piece HRA acetabular components is difficult and has not been validated as useful. The likelihood of resolving a THR infection is 80% to 90% with one- or two-stage revision.[4,9,20,22] However, patient-reported outcomes are often fair or poor with staged procedures because of decreased function and physical, emotional, and financial exhaustion. The clinical outcomes from infection treatment in patients with THR are distinctly inferior to primary THR outcomes. The results of the present study do not support the belief that two-stage reimplantation is the gold standard.[2,3,9,17,22]

It has been found that prosthetic infection is less common with HRA than with THR. Wagner[18] believed that HRA rather than THR should always be used in instances of prior septic arthritis of the hip. His opinion was that entering the medullary space was an unnecessary risk. Both Townley and Wagner treated infected HRAs with antibiotics with or without debridement rather than implant removal.[6,7,23–27]

Aufranc used cup arthroplasty as a spacer after removing stem-supported implants. He found that removing the infected stemmed implant was the key.[13] Placing a cup arthroplasty on the residual femur allowed the patient to get around reasonably well, and he rarely performed a reimplantation of the stemmed prosthesis. Several authors reported good results with retention of infected cup arthroplasty implants, particularly when antibiotics became available.[13–15]

A decision matrix is a useful tool for patient-surgeon communication. It allows physicians to provide medical information and allows patients to assign values and preferences to it. This may be the best way to ensure shared decision making. Qualitative studies extend the limits of quantitative work because they explore the "why" in patients' preferences for one treatment over another. The qualitative themes show a strong preference for less intrusive infection management strategies. There is not always strong alignment between surgeons and patients on outcome. Infectious disease specialists recommend surgery routinely.[1,8,21] Surgeons place a high emphasis on infection remission, while HRA patients are concerned with function and bone retention.[3] A decision matrix can increase understanding of patients' goals in their care.[18]

The qualitative analysis showed that explanations about infections need to evolve from probabilistic statistical statements into a mechanistic and deterministic explanation of why some patients develop infection and others do not. Explanations that bacteria can promiscuously swap genes and pivot from commensal one minute to a pathogen the next can be offered to patients. With the advanced prevention measures in place today, it is time to move away from the assumption that intraoperative contamination, tissue handling, and technical errors can explain most infections. The Trojan horse, whereby dormant pathogens in the intestinal tract or elsewhere are taken by neutrophils and delivered silently to a remote but hypermetabolic operative site, has better scientific support as an explanation.[28]

It is timely to restate that the goal of treatment is to obtain a sustained remission rather than a cure. Cure is an elusive concept that is difficult to ascertain. There are similarities between infection treatment and cancer treatment both in outcomes and in life interruption. A clinically successful outcome can be a stable symbiotic host-invader relationship. A successful outcome for the patients in this study was a healed incision that was free of drainage, with no pain, good function, normal laboratory values, and a stable implant.

Antibiotic suppression for THR patients is usually reserved for those who are not able to withstand the rigors of a one- or two-stage revision

procedure.[1,9,22] In the present study, 66% of HRA patients were treated with implant retention and antibiotics (PoAIR). Each patient was offered surgery; 24% chose it but 76% did not. However, clinical practice should not change based on one report. Three different studies of translational advances have shown that it takes, on average, 17 years to adopt new medical evidence and best practices into clinical practice.[29]

Rifampin and quinolones are the keys to successful oral treatment of HRA infection.[1,12,27] They have equal bioavailability compared to the IV route and they are highly effective. Linezolid also has excellent oral bioavailability and is useful against MRSA and other resistant organisms, but it must be monitored closely for possible bone marrow toxicity.[30] Oral medications are cheaper, more convenient, and avoid venous access complications such as thrombosis and embolus, which occur in up to 20% of patients. Doxycycline and TMP-SMX also have value and excellent oral bioavailability, but are considered second-line choices from an efficacy standpoint although useful to maintain a remission. Oral antibiotics have been found to be just as effective as IV antibiotics and there are thromboembolic complications of indwelling catheter treatments.[12]

The microbiome is disturbed by antibiotics. This remains a concern and probiotics with nutritional support should be considered. Close patient monitoring is mandatory. Using any antibiotic for long-term treatment raises concerns. It is not known if oral antibiotics over a longer interval are more of a concern than IV antibiotics for a shorter interval. There may be some evidence that oral antibiotics have some benefits through their direct action on the intestinal tract, which is the source of bacteria for some infections. The consequences of antibiotic suppression can include minocycline discoloration of skin or nails and doxycycline photosensitivity, rash, intermittent diarrhea, malaise, dizziness, and decreased appetite. Side effects depend both on the individual and on the antibiotic used. There were no cases of *Clostridium difficile* colitis in this study.

There are four key principles when considering HRA retention:

- The patient must be healthy and able to tolerate antibiotic treatment.
- The HRA must be high functioning with the expectation of continued need for high function.
- The patient must be exceptionally well informed and capable of making a complex decision with several competing choices. The patient must accept the inherent risk of the choices.
- The surgeon must be capable of close follow-up with frequent visits for incision care, antibiotic surveillance, and emotional support.

There are limitations to this study. While the patients came from several centers, their treatment care was evaluated by just one surgeon. There is concern for selection bias on the part of both the patient and the surgeon. Patients with HRA prefer the procedure over THR. Many will continue with their HRA to avoid conversion to THR. Treating surgeons are biased toward implant retention.

Choosing the correct treatment plan involves a judgment call by the surgeon. Surgeons base at least some of their decisions about infection management on nonanalytical processing (i.e., gut feeling). The positive predictive value of physician intuition in diagnosis and treatment increases up to 3% per year of experience for some conditions.[31] A limitation of the study is that surgeon experience influenced the determination of whether office incision care or operative care was necessary, and the monitoring of patients for signs of treatment response or failure.

Successful treatment requires more than just remission of the infection. A reasonable plan that retains the implant and moves with the momentum of the patient may be better accepted by the patient than a redirective plan such as staged revision. Treatment decisions based on astute situational awareness using small but close observations support patient confidence through the difficult challenge of infection.[10]

The number of patients treated in this study was relatively modest but many more than in any other published study. An infected HRA is not a common problem. The criteria used to define infection and remission are the same as in other studies.[12] Patients' hips were not reaspirated. There remains a gap between identifying all actual infections rather than just those that are clinically evident.

The Odom criteria have been validated as a simple and reasonable method of evaluating surgical outcomes.[19,20] There are many other evaluation methods that could have been used. The criteria of determining a successful outcome as a high-functioning retained HRA with no ongoing evidence of infection can be questioned as correct.

V. CONCLUSION

An infected HRA has characteristics distinct from those of THR. It responds more favorably to treatment and PoAIR is a reasonable treatment in carefully selected patients. Infection is the most common reason for prolonged recovery, increased cost, and poor outcome. Infection erodes the craftsmanship of the surgery and the recovery efforts of the patient. Surgical infection creates a hardship for the patient, the surgeon, and the patient-surgeon relationship. If every infection is to count, we need to do more than count and treat infections. Patients have a dual goal—they want both a good hip and remission of their infection, not just freedom from infection.

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