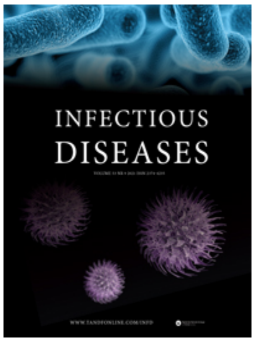

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ORIGINAL ARTICLE

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Effect of a multidisciplinary team on the treatment of hip and knee prosthetic joint infections: a single-centre study of 154 infections

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ABSTRACT

Background: A multidisciplinary team responsible for the management plan of prosthetic joint infections (PJI) was founded in January 2008. The aim of this study was to investigate whether a decrease in the number of surgeries and length of stay (LOS) was seen in the management of PJI with the aid of the multidisciplinary team.

Methods: This retrospective cohort study consisted of a total of 154 postoperative PJIs from three time periods: 21 PJIs from 2005 to 2007 (Group 1), 65 PJIs from 2011 to 2013 (Group 2), and 68 PJIs from 2015 to 2016 (Group 3). Successful outcome was classified as the retention of the original implant or revised implant and no infection-related death.

Results: The median number of operations decreased from 2.0 operations (Group 1) to 1.0 operation (Group 3) ($p = .023$), and the median LOS was shortened from 49.0 days (Group 1) to 17.0 days (Group 3) ($p = .000$). The number of PJIs treated with two-stage exchange decreased from 52.4% (11/21, Group 1) to 16.2% (11/68, Group 3) ($p = .004$). Simultaneously, debridement, antibiotics, and implant retention (DAIR) as primary surgical treatment increased from 42.9% (9/21, Group 1) to 89.7% (61/68, Group 3) ($p = .000$). The successful outcome of DAIR improved from 55.6% (5/9, Group 1) to 85.2% (52/61, Group 3) ($p = .077$).

Conclusions: Treatment of PJI in a specialized centre with the aid of a multidisciplinary team lead to fewer surgeries and reduced LOS. Successful outcome of DAIR improved over time.

KEYWORDS
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Introduction

Periprosthetic joint infection (PJI) is a severe complication of hip and knee arthroplasty leading to reoperations, prolonged hospital stays, long antimicrobial treatments, morbidity, and, at worst, the loss of the joint, limb, or even death [1–3]. Despite the major preventive efforts put into patient related and surgical factors [2,4], the incidence of PJI following hip or knee arthroplasty is reported to be 1–2% [1,2], and PJI is estimated to triple the cost of primary arthroplasty [2,5,6].

The successful treatment of PJI consists of proper diagnosis followed by the surgical and antimicrobial treatment that best aligns with the profile of the patient and infection. Previous studies have shown that better implant survival may be achieved with strict diagnostic algorithms [7–9] as well as with a multidisciplinary team responsible for the decision-making of the treatment options of the PJI [10,11]. One study reported a 53% decrease in the length of stay (LOS) and a 65% decrease in the number of surgical operations after a multidisciplinary team was established in University Medical Centre, Hamburg, Germany [12].

Two-stage exchange was the standard surgical method for treating a PJI earlier [1,2,13,14]. It is expensive, requires 2 operations, leads to an increased LOS [6], causes morbidity and mortality [3], and may lead to impaired and painful joint function [14–17]. More tolerable options are available for selected cases, including one-stage exchange [1,2,14,18] and debridement, antibiotics, and implant retention (DAIR) [1,2,14,16,17,19,20]. DAIR, when successful, demonstrates better functional outcomes compared to two-stage exchange—even similar function to that of non-infected joints [16,17,20].

Our goal here was to evaluate the changes and results of PJI treatment during three different time periods. We were particularly interested in the number of operations performed and the LOS, as these have direct consequences on the overall costs of the treatment. Also, we investigated possible improvements in diagnostics during the time periods.

Materials and methods

Since January 2008, both primary and revision arthroplasty and PJI treatment were centralized from three hospitals to Peijas Hospital in Helsinki University Hospital (an area of 1.2 million inhabitants). Peijas Hospital is a large academic tertiary care university hospital focusing on primary and revision arthroplasty surgery. A new multidisciplinary team responsible for generating instructions regarding diagnostics and decision-making of the treatment options at Peijas Hospital was founded in January 2008. This team includes orthopaedic surgeons specialized in arthroplasty surgery and an infectious disease specialist working in close cooperation with a microbiology laboratory. Also, a plastic surgeon is available if needed. Since 2008, all antimicrobial treatments have been planned by an infectious disease specialist with a special interest in PJI treatment. Diagnostic instructions and the initial PJI antimicrobial guide to be used at Peijas Hospital were published in 2008 and are continuously updated as needed.

The surgical treatment is decided in consideration of the timeline and severity of the infection, the type of implant, and the comorbidities of the patient. DAIR is performed if the duration of the clinical symptoms is less than 3 weeks, the implant is stable, and the soft tissues are in good condition [1]. Also, DAIR may be exceptionally attempted even if its optimal time window is exceeded if the patient's comorbidities or the implant type (e.g. tumour mega prosthesis) do not allow for two-stage exchange. In PJI cases not suitable for DAIR, two-stage or one-stage exchange is usually performed. The antimicrobial treatment follows the original concepts of Zimmerli et al. [1] and continues to be updated according to the current literature. If postoperative long-term suppressive antibiotics are used in our clinic, they are usually not for the treatment of an active infection but rather in selected cases to diminish the risk for relapse in especially fragile patients. Sonication of the implant material and a dedicated microbial sampling instrumentation according to the Oxford, UK, Bone Infection Unit tissue sampling protocol [21] were introduced at the end of 2013 and 2015, respectively.

To be able to evaluate the effect of the multidisciplinary team, we compared a control group from an earlier time period, called Group 1 here, and two time periods representing the subsequent improvements in the treatment. The differences between the Groups are explained in Table 1.

The PJIs were retrieved from the postoperative surgical site infection surveillance database [22] and the patients' data from their electronic health records were thoroughly examined by the corresponding author (MV). All information regarding patient comorbidities, diagnostics, and PJI treatment (e.g. in-patient ward periods and LOS in the Helsinki University Hospital, antibiotics used, cultured bacteria, operations done, and number of microbiological samples obtained) was collected.

Table 1. The differences in the three study groups.

	Group 1	Group 2	Group 3
Time period of index operation	1 January 2005 to 31 December 2007	1 January 2011 to 31 December 2013	1 January 2015 to 31 December 2016
Number of PJIs*	21	65	68
Changes in the treatment of PJI*	• Arthroplasties and PJI treatment in three hospitals	• Arthroplasties and PJI treatment centralized in one hospital • Multidisciplinary team responsible for PJI treatment • Orthopaedic surgeon specialized in arthroplasty surgery responsible for all PJI operations	• Arthroplasties and PJI treatment centralised in one hospital • Multidisciplinary team responsible for PJI treatment • Orthopaedic surgeon specialized in arthroplasty surgery responsible for all PJI operations • Implant sonication introduced in late 2013 • Dedicated microbial sampling instrumentation according to the Oxford, UK, Bone Infection Unit tissue sampling protocol introduced in 2015

*Prosthetic joint infection.

Table 2. Demographics of the prosthetic joint infection cases.

	Group 1 (*n* = 21) (2005–2007) *n* (%)	Group 2 (*n* = 65) (2011–2013) *n* (%)	Group 3 (*n* = 68) (2015–2016) *n* (%)
Age at diagnosis of PJI* (median, Q1–Q3, years)	64.0 (58.5–72.5)	67.0 (59.0–76.0)	69.0 (60.0–77.5)
Gender (male)	10 (47.6)	37 (56.9)	39 (57.4)
BMI (median, Q1–Q3)	31.2 (27.2–34.2)	28.5 (25.5–33.0)	28.1 (24.6–34.1)
No comorbidities	2 (9.5)	7 (10.8)	9 (13.2)
More than 3 comorbidities	6 (28.6)	28 (43.1)	22 (32.4)
Index operation type (primary)**	12 (57.1)	41 (63.1)	42 (61.8)
Infected joint (knee)***	13 (67.9)	20 (30.8)	20 (29.4)
Acute postoperative PJI (0–3 months)****	17 (81.0)	59 (90.8)	66 (97.1)
Follow-up time (median, Q1–Q3, months)	127.0 (53.5–142.5)	62.0 (55.5–71.0)	53.0 (46.3–62.0)

*Prosthetic joint infection.
**Index operation primary or revision. Result for primary shown.
***Infected joint knee or hip. Result for knee shown.
****Infection acute (0–3 months) or delayed (3–24 months) postoperatively. Result for acute postoperative shown.

Successful outcome of treatment was defined by the type of operation conducted. With DAIR, retaining the original implant was considered to represent a success. With one-stage or two-stage exchange, retaining the revised implant was considered to represent success. Death due to infection was considered a failure in all of the treatment modalities.

Study objects

We included all consecutive patients with acute postoperative (0–3 months) and delayed postoperative (3–24 months) PJI that fulfilled the criteria of the Musculoskeletal Infection Society (MSIS) modified at the International Consensus Meeting [23]. Infections treated conservatively were excluded.

A total of 163 PJIs were identified, of which 156 cases fulfilled the criteria for PJI. 2 of the infections were treated conservatively because of end-stage malignancy and excluded from the study, leaving a total of 154 PJIs. The distribution of the PJI cases among the groups was following: 21 cases in Group 1, 65 cases in Group 2, and 68 cases in Group 3. One patient from Group 3 suffered another acute postoperative PJI following a primary total knee arthroplasty (TKA) in the contralateral knee. Both infections were caused by different bacteria and classified and followed up as two separate infections. Patients were followed until their chart review or death. 2 patients from Group 2 suffered a haematogenic infection of the same or contralateral prosthesis; these haematogenic infections were excluded from the analysis. The patient demographics are presented in Table 2.

The current study is an observational study, and anonymized databases were used; therefore, the patients' consent was not required, and the study follows the principles of the Declaration of Helsinki. Approval from the Hospital District Study Committee was acquired.

Statistical analysis

For the categorical variables, we used the chi-squared test and Cochran–Mantel–Haenszel test, and, for the continuous variables, the Kruskal–Wallis pairwise test. A *p*-value of .05 was considered statistically significant. The analyses were performed according to the consultation of the Biostatistics Unit of the University of Helsinki. For

Table 3. Numbers and outcomes of surgical treatment of prosthetic joint infections.

Number of	Group 1 ($n=21$) (2005–2007) *n* (%)	Group 2 ($n=65$) (2011–2013) *n* (%)	Group 3 ($n=68$) (2015–2016) *n* (%)	*p* Value
PJI* cases treated with DAIR** as primary surgical treatment	9 (42.9)	53 (81.5)	61 (89.7)	.000
PJI cases treated with DAIR, modular parts exchanged	7 (77.8)	48 (90.6)	58 (95.1)	.187
PJI cases treated with one-stage exchange (all primary surgical treatments)	1 (4.8)	0 (0)	2 (2.9)	.285
PJI cases treated with two-stage exchange	11 (52.4)	20 (30.8)	11 (16.2)	.004
PJI cases treated with two-stage exchange as primary surgical treatment	9 (81.8)	9 (45.0)	5 (45.5)	.000
PJI cases treated with resection arthroplasty, amputation or other operation	5 (23.8)	7 (10.8)	4 (5.9)	.062
PJI cases treated with resection arthroplasty, amputation or other as primary surgical treatment	2 (40.0)	3 (42.9)	0 (0)	.071
Operations (median, Q1-Q3)	2.0 (1.0–3.0)	1.0 (1.0–2.5)	1.0 (1.0–2.0)	.023
Successful outcome of				
PJI cases treated with DAIR as primary surgical treatment	5 (55.6)	39 (73.6)	52 (85.2)	.077
PJI cases treated with DAIR, modular parts exchanged	4 (57.1)	35 (72.9)	50 (86.2)	.088
PJI cases treated with one-stage exchange (all primary surgical treatments)	1 (100)	0 (0)	2 (100)	Undefined
PJI cases treated with two-stage exchange	9 (81.8)	17 (85.0)	9 (81.8)	.963
PJI cases treated with two-stage exchange as primary surgical treatment	8 (88.9)	8 (88.9)	4 (80.0)	.873
PJI cases treated with DAIR, one-stage or two-stage exchange as primary surgical treatment, combined	14 (73.7)	47 (75.8)	58 (85.3)	.311

*Prosthetic joint infection.
**Debridement, antibiotics, and implant retention.
Successful outcome (DAIR): retaining original implant and no death due to infection.
Successful outcome (one-stage and two-stage exchange): Retaining revised implant and no death due to infection.

the statistical analyses, SPSS for Windows (IBM, Armonk, USA) version 26.0 was used.

Results

During the study period, the number of operations performed for the treatment of PJIs decreased from a median of 2.0 operations per PJI in Group 1 (total of 46 operations) to a median of 1.0 operation per PJI in Group 2 and 3 (total of 117 operations and 114 operations, respectively) ($p=.023$). There was a shift from the two-stage exchange to DAIR as the primary operation. The distribution and outcome of the operations are presented in Table 3.

A total of 135 DAIR operations were performed for 123 (79.9%) PJI cases. Of the acute postoperative PJIs, 52.9% (9/17), 86.4% (51/59), and 90.9% (60/66) were treated with DAIR as the primary surgical treatment in Group 1, 2, and 3, respectively ($p=.001$). In 114 (92.7%) cases, a single DAIR operation was performed, in 6 (4.9%) cases 2 were performed, and in 3 (2.4%) cases, 3 were performed. The success rate of DAIR was 78.0%, improving from Group 1 to Group 2 and 3 (Table 3).

In 42 (27.3%) PJI cases, a two-stage exchange was initiated; in 6 cases, the second stage was not completed. The success rate of the two-stage exchange was 83.3%. The numbers and outcomes of PJI treatment are shown in Table 3.

The median total LOS decreased sequentially from Group 1 to Group 2 to Group 3: 49.0 (Q1–Q3 24.5–60.5), 22.0 (Q1–Q3 13.5–42.5), and 17.0 (Q1–Q3 11.0–26.0), respectively ($p=.000$). The median time from onset of the patient's first symptoms of infection to surgery (days) was reduced from 20.0 (Q1–Q3 7.0–56.5) in Group 1 to 8.0 (Q1–Q3 5.0–17.0), and 8.0 (Q1–Q3 5.0–14.75) in Groups 2 and 3, respectively ($p=.026$).

In 62 (40.3%) of the PJIs *Staphylococcus aureus* was detected as only pathogen or as a part of multibacterial aetiology. The other most common bacteria detected were 54 (35.1%) Coagulase-negative staphylococci, 20 (13.0%) *Streptococcus spp.*, 17 (11.0%) *Enterococcus spp.*, 14 (9.1%) Gram-negative rods, and 17 (11.0%) other bacteria. 1 (0.6%) PJI was caused by Methicillin resistant *Staphylococcus aureus*. Multibacterial (2 or more organisms) aetiology was seen in 38 (24.7%) of the PJIs. Of the PJIs, culture-negative were 15 (9.7%): 8 (38.1%) in Group1, 5 (7.7%) in Group 2, and 2 (2.9%) in Group 3 ($p=0000$). Diagnostic bacterial samples were gathered before any antibiotic treatment was given in 3 (14.3%), 41 (63.1%), and 54 (79.4%) of the PJI cases in Group 1, Group 2, and Group 3, respectively ($p=.000$). The median number of deep intraoperative bacterial samples obtained during the first operation increased from 2.5

(Q1–Q3 1.0–4.0) in Group 1, 4.0 (Q1–Q3 3.0–6.0) in Group 2 and to 5.0 (Q1–Q3 4.0–6.0) in Group 3 ($p = .001$).

The cumulative duration of the intravenous antibiotics shortened when moving from Group 1 to Group 3: median 57.0 (Q1–Q3 43.0–88.0) days in Group 1, 31.0 (Q1–Q3 28.0–47.0) days in Group 2, and 28.0 (Q1–Q3 24.0–37.5) days in Group 3 ($p = .000$). The median cumulative duration of the interim peroral antibiotics was 88.5 (Q1–Q3 23.3–175.0) days in Group 1, 62.0 (Q1–Q3 42.0–129.5) days in Group 2, and 68.0 (Q1–Q3 56.5–153.5) days in Group 3 ($p = .085$). The median cumulative duration of the intravenous and interim peroral antibiotics combined was 167.0 (Q1–Q3 98.0–277.3) days in Group 1, 96.0 (Q1–Q3 79.0–169.5) days in Group 2, and 93.0 (Q1–Q3 87.0–188.50) days in Group 3 ($p = .085$). At the time of chart review, long-term suppressive antibiotics were in use in 30 (19.5%) of the PJI cases: 14.3% in Group 1, 24.6% in Group 2, and 16.2% in Group 3 ($p = .382$). Rifampin was combined with the antimicrobial treatment (minimum 14 days) in 80.2% (89/111) of the PJIs caused by *Staphylococci*, with no difference among the groups ($p = .713$).

A total of 11 patients died within one year following the PJI diagnosis, 3 (14.3%) belonging to Group 1, 4 (6.2%) belonging to Group 2, and 4 (6.0%) belonging to Group 3 ($p = .707$). 5 patients died due to reasons related to the infection, 3 (4.6%) belonging to Group 2 and 2 (3.0%) belonging to Group 3 ($p = .180$).

Discussion

The current study shows that fewer operations and shorter LOS can be achieved in the treatment of PJIs in a specialized centre with a multidisciplinary team without compromising the treatment outcome. During the study period, the use of DAIR as primary surgical treatment increased from 43 to 90%, and, simultaneously, the number of two-stage exchanges performed decreased from 52 to 16%. This change in treatment methods led to a decrease from 2 to 1 in the median number of operations per PJI. Additionally, a decrease of 65% in the median LOS was achieved after the multidisciplinary team in our clinic was established.

The time from the onset of the patient's first symptoms of infection to the surgery was significantly reduced from 20 to 8 days (median) over the study period. In general, the short delay from symptoms to surgery allows for the use of DAIR, which is a more tolerable treatment method for the patient in terms of morbidity and mortality, compared to two-stage exchange [3]. DAIR also demonstrates better functional outcomes—even similar to those of noninfected joints [16,17,20]. A successful DAIR could save resources for the health-care system, and the total cost of PJI treated with DAIR is reported to be one-third of the cost of a two-stage exchange [6].

Compared to previous studies investigating the effect of algorithms and a multidisciplinary team, our study cohort was larger, and we focussed on the use of DAIR. In our study, the use of DAIR as a primary operation increased, and, in the last study group, DAIR was performed on 91% of the acute PJI cases, with a success rate of 85%. A substantial decrease in LOS was achieved from a median of 49 days to 17 days, and a clinically significant decrease in the number of operations performed was also noted when comparing Group 1 and 3. Use of outpatient intravenous therapy also helped to reduce the LOS. In previous studies, DAIR was performed on 18 to 58% of PJI cases [7,8,12], with a success rate of 60–70% [7,8]. One previous study reported the effect of a multidisciplinary team on the LOS and number of operations, which exhibited a decrease from a mean of 62 to 29 days and a decrease from 5.1 to 1.8, respectively [12].

In the current study we saw a decrease in culture-negative PJI from 38 to 3% during the study period, much of which must be accredited to diagnostic guidance generated by the multidisciplinary team instructing how to obtain bacterial culture samples and availability of better diagnostics in the last two study groups. The percentage of joint aspiration or deep intraoperative samples obtained before administration of antibiotics increased from 14% in Group 1 to 79% in Group 3. Moreover, the number of deep bacterial samples obtained during the first operation doubled from a median of 2.5 in Group 1 to 5.0 in Group 3 after the dedicated microbial sampling instrumentation was introduced 2015, which helped to obtain an adequate amount of high-quality tissue samples. In the literature, the optimal number of samples obtained is suggested to be 4 or 5 in order to detect the causative microbe [24,25].

The current study is a single tertiary care centre study, which is a strength of its design. All the patients with a postoperative PJI were included to reflect a more real-life situation and make the study more reproducible. All the orthopaedic surgeons responsible for the treatment of PJI at our hospital are specialized in arthroplasty surgery. Previous studies have shown that centres specialized in revision arthroplasty surgery may obtain better results in terms of infection control [26,27], and these results should be more reproducible when the experience of the surgeon is not questionable.

A limitation of this study is that it is retrospective: information on the treatments and their results was gathered retrospectively, and information on the functional outcomes of the joints (e.g. hip or knee scores) was not available. Prior to 2008, the treatment and diagnostics for a PJI were unorganized, the treatment was initiated in three hospitals, some PJIs may have been missed in Group 1. Also, some acute PJI may have been suppressed with antibiotics causing delay to the diagnosis and treatment of PJI, hence counted as delayed PJIs in Group 1.

Since the end of the study period in year 2016, the goal of the multidisciplinary team in our clinic has been to also perform more often one-stage exchanges in suitable situations instead of two-stage and further shorten the duration of antimicrobial treatment in PJI patients.

When PJI occurs, treatment at a specialized centre with a multidisciplinary team and standardized guidelines for diagnostics and patient-tailored decision-making for treatment are of great importance in order to yield a more rapid diagnosis, produce good results, and help identify a cost-effective treatment plan for each specific case.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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