Role of Gallium-SPECT-CT in the Management of Patients With Ventricular Assist Device-Specific Percutaneous Driveline Infection

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ABSTRACT

Background: Percutaneous driveline infection is a major complication of left ventricular assist device (LVAD). This study evaluated the role of gallium-67 single-photon emission computed tomography (Ga-SPECT)-CT in LVAD-specific percutaneous driveline infection.

Methods: Thirty-six patients with implantable continuous-flow LVAD, who underwent Ga-SPECT-CT to evaluate percutaneous driveline infections, were enrolled and divided into uptake and no-uptake groups based on tracer concentration uptake on Ga-SPECT-CT. Primary outcomes were surgical intervention and readmission for driveline infection.

Results: Twenty-two patients had uptake on Ga-SPECT-CT. No significant differences were noted in patient characteristics, wound appearance, or laboratory results. The prevalence of positive skin culture at the driveline exit site (DLES), and usage and duration of antibiotics did not differ. However, the uptake group had higher 1-year event rates (surgical intervention: 39% vs 0%, $P = .019$; readmission: 74% vs 6.9%, $P = .0016$). In addition to positive skin culture at DLES and short duration of antibiotic therapy, uptake on Ga-SPECT-CT was a risk factor for surgical intervention (odds ratio 9.00; $P = .018$) and readmission (odds ratio 7.86; $P = .0051$).

Conclusions: Ga-SPECT-CT could be one of the clinical modalities for guiding the treatment of driveline infection in patients with a LVAD. (*J Cardiac Fail 2019;25:795−802*)

Key Words: Driveline infection, gallium scintigraphy, SPECT-CT, ventricular assist device.

Implantable left ventricular assist device (LVAD) has dramatically improved the prognosis of patients with advanced heart failure.[1] With ongoing technological innovation, patient survival and quality of life are further improving,[2,3] and major complications related to LVAD such as pump thrombosis and stroke have decreased[3]; however, these complications have not been completely overcome. Infection remains a major complication in up to 60% of VAD patients and worsens prognosis and quality of life.[4−6] Percutaneous driveline infections are the most commonly occurring infections in VAD patients and can lead to deeper infections such as pocket, pump, and cannula infections.[6,7] Additionally, driveline infections often relapse, requiring readmission and retreatment.[6,8] Because of the readmissions and long-term hospitalization associated with these infections, VADs result in significantly increased lifetime costs.[9] Therefore, the precise diagnosis and evaluation of driveline infection are essential for appropriate treatment.

Recently, fluorine 18-fluorodeoxyglucose positron emission tomography (FDG-PET) and leucocyte radio-labeled scintigraphy have been introduced as useful techniques for the diagnosis of LVAD-specific and related infections.[6,10,11] Combination of these technologies with single-photon emission computed tomography (SPECT)-CT has increased the sensitivity for infection detection and retained the specificity for anatomic location of infections.[6] Similarly, gallium-67 (Ga) scintigraphy can detect an inflammatory site

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and be useful for diagnosis in fever of unknown origin (FUO).[12] However, the role of Ga scintigraphy in the diagnosis and evaluation of LVAD-specific and related infections has not been fully elucidated. Therefore, the purpose of this study was to investigate the role of Ga-SPECT-CT in decision-making regarding the appropriate treatment for LVAD-specific driveline infection.

Methods

Patient Population

This retrospective study was conducted using the medical records of 36 consecutive patients with implantable continuous-flow LVAD who were diagnosed with driveline infection and underwent Ga-SPECT-CT to evaluate the infection at the National Cerebral and Cardiovascular Center (NCVC) between October 2011 and October 2017. Patients were enrolled for this study at the time of initial Ga-SPECT-CT and were followed-up at NCVC. The driveline infection was diagnosed based on clinical findings, wound appearance and laboratory data using International Society for Heart and Lung Transplantation (ISHLT) guidelines.[7] The wound appearance was assessed by an expert doctor and nurses proficient in LVAD management, and clinical features of driveline infection were defined as follows: exudate, erythema, bleeding, swelling, and wound pain at the driveline exit site (DLES). Ga-SPECT-CT was underwent as a part of routine clinical care, when attending physicians, including an expert in the management of LVAD, decided to take into account a patient's wound appearance. Patients with implantable LVAD who underwent Ga-SPECT-CT for other purposes were excluded (investigation of FUO [n = 39], evaluation for intestinal nephritis [n = 3], diagnosis of mediastinitis [n = 1], and assessment of another wound [n = 1]; Fig. 1). The included patients were divided into uptake and no-uptake groups based on tracer concentration uptake on Ga-SPECT-CT. Patient characteristics, clinical findings, treatment for driveline infection, and outcomes were compared between uptake and no-uptake groups.

Data Collection

Patient characteristics evaluated included age, sex, body mass index (BMI), etiology of heart failure, comorbidity, history of smoking, type of implantable LVAD, usage of extracorporeal LVAD, and adverse events related to LVAD, such as cerebrovascular accident, hemolysis, and pump thrombosis. Adverse events were defined by the ISHLT Mechanically Assisted Circulatory Support Adverse Definitions.[13] Additionally, clinical findings (body temperature and wound pain) and wound appearances at DLES were assessed by professional nurses with experience in LVAD management. Laboratory data (white blood cell count, neutrophil, C-reactive protein [CRP], creatinine [Cr], estimated glomerular filtration rate [eGFR], cholinesterase, and lactase dehydrogenase), sequential organ failure assessment (SOFA) score,[14] skin culture at DLES, and blood culture were analyzed. eGFR was calculated using the formula for Japanese patients[15]: $194 \times \mathrm{Cr}^{-1.094} \times \mathrm{age}^{-0.287} \times 0.739$ (if female).

Gallium-67 SPECT-CT Protocol

Whole-body Ga scintigraphy was performed 48 hours after injection of 111 MBq gallium-67 citrate. Planar scintigraphy was performed by a dual-head, variable-angle SPECT γ camera (Symbia T6, Siemens Healthcare) using a

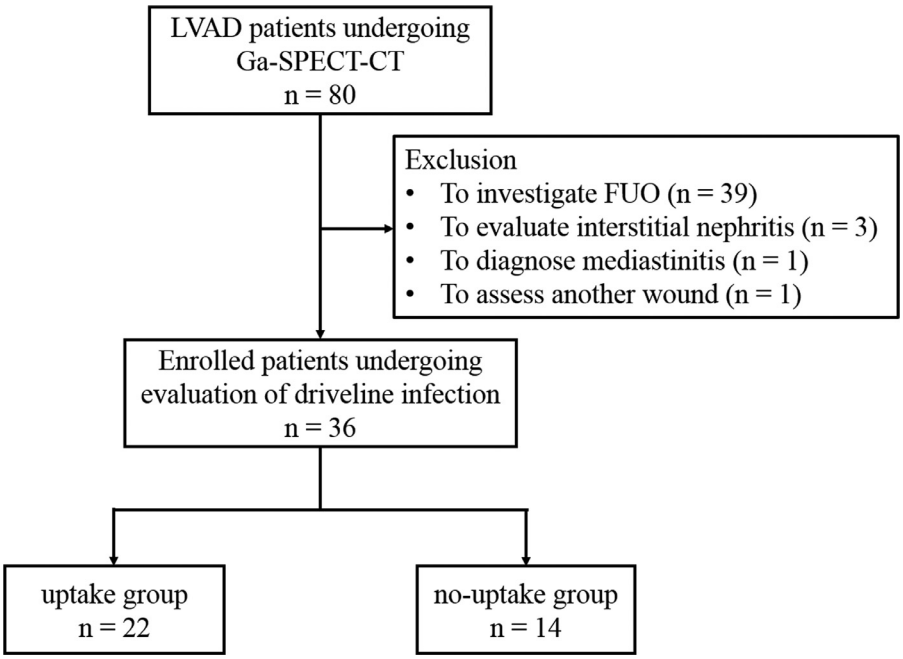


Fig. 1. Flowchart of the patient inclusion process.

medium-energy collimator. SPECT images were acquired in a 60-step, 360° noncircular orbit and reconstructed in a 128 × 128 matrix, using a three-dimensional ordered subsets expectation maximization algorithm. Data were reconstructed using the work station of Siemens Healthcare. A low-dose CT scan was acquired after the SPECT study with a voltage of 130 kVp at the slice thickness of 10 mm, and was fused to SPECT imaging. Interpretation and diagnosis of Ga-SPECT-CT were performed by experienced nuclear medicine physicians.

Treatment for Driveline Infection

For all patients, dressing changes were performed daily with close inspection of the DLES and driveline immobilization was optimized. Antibiotic treatment protocol was decided by attending physicians, including an expert in the management of LVAD, by taking into account patients' laboratory results and wound appearances. Decisions regarding surgical intervention were made taking into consideration the results of not only clinical imaging such as CT and Ga-SPECT-CT but also clinical findings including the appearance of DLES; spreading erythema, swelling, or wound pain suggesting deeper tissue infection; or refractory inflammation indicated by fever, increased white blood cell count, and high CRP level despite appropriate medical therapy. If driveline infection progressed and resulted in pump and/or cannula infection despite the aforementioned treatments, pump replacement was considered.

Outcomes

Main outcomes were surgical intervention (debridement, translocation of DLES, or pump replacement) and readmission for driveline infection. We compared the event rates after Ga-SPECT-CT between the uptake and no-uptake groups. Additionally, the risk factors associated with surgical intervention and readmission for driveline infection were identified.

Ethics

The research protocol was approved by the institutional review board of the National Cerebral and Cardiovascular Center according to the ethical guidelines of the 1975 Declaration of Helsinki and its amendments (M30-129). Because this was a retrospective study, the requirement for written informed consent was waived and the patients' records and data were anonymized before analysis.

Statistics

Continuous variables were expressed as medians and interquartile range (IQR). Categorical variables were expressed as numbers and percentages. When comparing the 2 groups, Pearson's chi-square test or Fisher's exact test was used for categorical variables and the unpaired *t* test or Wilcoxon rank sum test was used for continuous variables, as appropriate. Event rates were computed by the Kaplan−Meier method and compared using the log rank test. The patients who underwent heart transplantation were counted as censors. Univariate analyses for the risk factors associated with surgical intervention and readmission for driveline infection were performed, and the odds ratios (ORs) and 95% confidence intervals (CIs) were computed using the chi-square test. Because of the small sample size, we did not perform multivariate regression analysis. A P value $< .05$ was considered statistically significant in all analyses. Statistical analyses were performed using JMP software, v14 (SAS Corporation, Cary, NC).

Results

Patient Characteristics and Clinical Findings

Thirty-six patients were enrolled and all patients have been completely followed-up for a median of 640 days (IQR: 263−894 days) after initial Ga-SPECT-CT. Enrolled patients were divided into the uptake group (n = 22) and no-uptake group (n = 14) based on the finding of uptake on initial Ga-SPECT-CT (Fig. 1). The sensitivity of Ga-SPECT-CT in detecting driveline infection was 61%. The regions of uptake were driveline exit site (n = 9, 41%), subcutaneous driveline tunnel (n = 10, 45%), and sub-rectus driveline tunnel (n = 3, 14%). The clinical characteristics of the patients are summarized in Table 1. There were no significant differences in patient characteristics, including the type of implantable LVAD and the prevalence of switch from extracorporeal LVAD.

Table 2 shows physical findings and laboratory data of the patients. Physical findings were not significantly different between the 2 groups, whereas the prevalence of bleeding at the DLES was higher in the uptake versus the no-uptake group (15/22 [68%] vs 4/14 [29%], respectively, $P = .02$). There was no significant difference in makers of inflammation, renal function, and indicators of nutritional status assessed by blood tests. Additionally, the prevalence of positive skin culture at the DLES was not significantly different (uptake vs no-uptake: 21/22 [95%] vs 12/14 [86%]; $P = .30$). The most common pathogens were gram-positive cocci such as *Staphylococcus aureus*, *epidermidis*, and *lugdunesis,* and more than one-half of these pathogens were resistant to methicillin (Table 3). Methicillin-resistant *Staphylococcus aureus* (MRSA) was more frequently cultured in the uptake group, although the difference was not statistically significant (8/22 [36%] vs 1/14 [7.1%]; $P = .06$). Blood cultures were performed in only 11 patients; none of these patients showed positive outcomes.

Treatment for Driveline Infection

The administration of antibiotics and duration of antibiotic therapy were not different between the 2 groups (uptake vs no-uptake: 20/22 [91%] vs 11/14 [79%], $P = .30$; 20 [IQR: 12−37] days vs 17 [IQR: 6−29] days, $P = .19$, respectively; Table 4). Cefazolin was the most commonly used antibiotic (43%), followed by antibiotics for MRSA

Table 1. Clinical Characteristics of Patients

	All n = 36	Uptake Group n = 22	No-Uptake Group n = 14	*P* Value
Age (median [IQR), year)	41 (29.5, 52.8)	39 (28.8, 53.3)	41.5 (34.8, 53.3)	0.60
Male sex (n [%])	31 (86)	20 (91)	11 (79)	0.36
BMI (median [IQR], kg/m^2)	22.4 (19.4, 24.9)	23.0 (19.7, 25.6)	21.1 (18.0, 23.2)	0.10
Etiology (n [%])				0.11
DCM	24 (67)	17 (77)	7 (50)	
DHCM	5 (14)	1 (4.5)	4 (29)	
ICM	3 (8)	1 (4.5)	2 (14)	
Others	4 (11)	3 (14)	1 (7)	
Hypertension (n [%])	1 (2.8)	0 (0)	1 (7.1)	0.39
Diabetes mellitus (n [%])	5 (14)	4 (18)	1 (7.1)	0.58
Dyslipidemia (n [%])	13 (36)	6 (27)	7 (50)	0.17
Smoking (n [%])	20 (56)	11 (50)	9 (64)	0.40
Type of LVAD (n [%])				0.55
HeartMateII	17 (47)	11 (50)	6 (43)	
EVAHEART	8 (22)	5 (23)	3 (21)	
DuraHeart	8 (22)	4 (18)	4 (29)	
Jarvik2000	3 (9)	2 (9)	1 (7)	
Switch from extracorporeal LVAD (n [%])	9 (25)	6 (27)	3 (21)	0.69
Adverse events related to LVAD (n [%])				
Cerebrovascular accident	11 (31)	7 (32)	4 (29)	0.84
Hemolysis	11 (31)	7 (32)	4 (29)	0.84
Pump thrombosis	4 (11)	2 (9)	2 (14)	0.63
Inpatient (n [%])	33 (92)	20 (91)	13 (93)	0.84
Duration of LVAD support* (median [IQR], day)	408 (208, 712)	347 (194, 612)	539 (209, 756)	0.31
Follow-up time (median [IQR], day)	640 (263, 894)	471 (247, 885)	687 (267, 957)	0.61

DCM, dilated cardiomyopathy; DHCM, dilated phase of hypertrophic cardiomyopathy; ICM, ischemic cardiomyopathy.
*Duration of LVAD support at the time of driveline infection definition.

such as teicoplanin, linezolid, and daptomycin. Surgical debridement and translocation of DLES, as well as vacuum-assisted closure (VAC) therapy, were required more frequently in the uptake group (8/22 [36%] vs 1/14 [7.1%], $P = .048$; 9/22 [41%] vs 1/14 [7.1%], $P = .027$, respectively; Table 4). The prevalence of pump replacement was not significantly different between the 2 groups (1/22 [4.6%] vs 0/14 [0%], $P = .42$, respectively).

Main Outcomes

During the follow-up period, the uptake group had a higher surgical intervention rate (1 year: 39% vs 0%, 2 year: 49% vs 11%, 3 year: 49% vs 11%; $P = .019$) and a higher readmission rate (1 year: 74% vs 6.9%, 2 year: 82% vs 28%, 3 year: 91% vs 28%; $P = .0016$; Fig. 2). The median time between initial Ga-SPECT-CT and surgical

Table 2. Physical Findings and Laboratory Data

	All n = 36	Uptake Group n = 22	No-Uptake Group n = 14	*P* Value
Clinical finding				
Body temperature (median [IQR], °C)	36.4 (36.1, 36.7)	36.5 (36.1, 36.7)	36.3 (36.1, 36.7)	0.36
Maximum body temperature* (median [IQR], °C)	37.1 (36.6, 37.1)	37.0 (36.6, 37.4)	36.9 (36.7, 36.9)	0.10
Wound pain (n [%])	26 (72)	15 (68)	11 (79)	0.50
Wound appearance				
Exudate (n [%])	34 (94)	21 (95)	13 (93)	0.74
Erythema (n [%])	24 (67)	15 (68)	9 (64)	0.81
Bleeding (n [%])	19 (53)	15 (68)	4 (29)	0.02
Swelling (n [%])	11 (31)	7 (32)	4 (29)	0.84
Laboratory data				
WBC (median [IQR], μL)	5400 (4500, 6650)	5650 (4575, 6550)	4850 (4350, 6875)	0.60
Neutrophil (median [IQR], %)	66.8 (58.1, 71.9)	66.7 (58.6, 70.5)	69.1 (53.3, 73.2)	0.64
CRP (median [IQR], mg/dL)	0.29 (0.08, 1.56)	0.35 (0.11, 1.96)	0.21 (0.08, 0.60)	0.16
Cr (median [IQR], mg/dL)	0.84 (0.67, 1.03)	0.86 (0.69, 1.08)	0.79 (0.66, 0.97)	0.31
eGFR (median [IQR], mL/min/1.73m^2)	85 (61, 106)	82 (57, 105)	87 (65, 107)	0.68
Alb (median [IQR], g/dL)	4.1 (3.8, 4.4)	4.0 (3.8, 4.4)	4.2 (3.8, 4.5)	0.67
ChE (median [IQR], U/L)	275 (226, 363)	274 (232, 376)	269 (191, 360)	0.57
LDH (median [IQR], U/L)	250 (225, 345)	251 (204, 373)	250 (233, 335)	0.51
SOFA score (median [IQR])	0 (0, 0.8)	0 (0, 1.0)	0 (0, 0.3)	0.41
Positive skin culture (n [%])**	33 (92)	21 (95)	12 (86)	0.30

Alb, albumin; ChE, cholinesterase; LDH, lactase dehydrogenase; WBC, white blood cell.
*Maximum body temperature during therapeutic course of driveline infection.
**Positive skin culture of driveline exit site.

Table 3. Skin Culture of Driveline Exit Site

Bacterial Species	All n = 36	Uptake Group n = 22	No-Uptake Group n = 14	*P* Value
***Staphylococcus* species (n [%])**	27 (75)	18 (82)	9 (64)	0.24
Methicillin-sensitive *Staphylococcus aureus*	10 (28)	8 (36)	2 (14)	0.25
Methicillin-resistant *Staphylococcus aureus*	9 (25)	8 (36)	1 (7.1)	0.06
Methicillin-resistant *Staphylococcus epidermidis*	6 (17)	3 (14)	3 (21)	0.66
Methicillin-resistant *Staphylococcus lugdunensis*	6 (17)	3 (14)	3 (21)	0.66
***Enterococcus faecalis* (n [%])**	2 (5.6)	2 (9.1)	0 (0)	0.51
Gram-negative rods (n [%])	10 (28)	7 (32)	3 (21)	0.50
Klebsiella pneumoniae	4 (11)	4 (18)	0 (0)	0.14
Pseudomonas aeruginosa	3 (8.3)	1 (4.6)	2 (14)	0.54
Morganella morganii	3 (8.3)	3 (14)	0 (0)	0.27
Acinetobacter species	1 (2.8)	0 (0)	1 (7.1)	0.39
Stenotrophomonas maltophilia	1 (2.8)	1 (4.6)	0 (0)	1.00
***Corynebacterium species* (n [%])**	2 (5.6)	0 (0)	2 (14)	0.14

intervention was 66 days (IQR: 17−287 days). Six patients required surgical intervention during initial admission for driveline infection and 5 patients underwent surgical intervention within 30 days of enrollment, whereas the other 5 patients underwent surgical intervention >100 days after enrollment (range, 103−544 days). There were no patients who died from infections in both groups during a median follow-up of 3.1 years after LVAD implantation. In the uptake group, 2 patients died from cerebral bleeding and 1 patient died from renal failure; there were no deaths in the no-uptake group.

In univariate analyses, the factors associated with increased odds of surgical intervention were MRSA cultured at DLES (OR: 5.50, 95% CI: 1.10−30.74, $P = .038$) and uptake on Ga-SPECT-CT (OR: 9.00, 95% CI: 1.39−178.33, $P = .018$). The prolonged duration of antibiotic therapy reduced the risk of surgical intervention (OR: 0.95, 95% CI: 0.89−0.99, $P = .0018$; Table 5). Additionally, the factors associated with an increased risk of readmission were positive skin culture at DLES (OR: not available, $P = .035$) and uptake on Ga-SPECT-CT (OR: 7.86, 95% CI: 1.81−43.86, $P = .0051$; Table 5).

Discussion

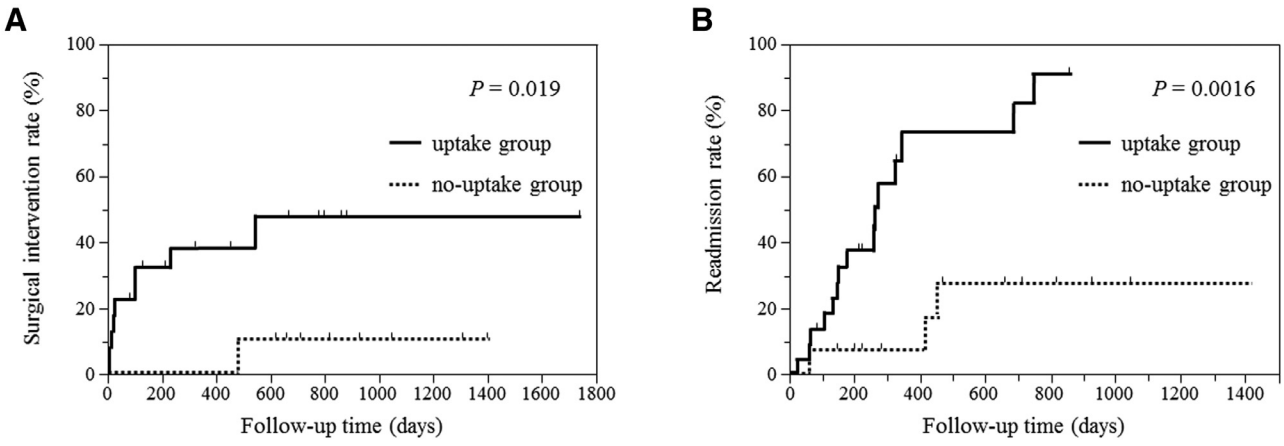
The main findings of this study are as follows: 1) the sensitivity of Ga-SPECT-CT in detecting driveline infection was 61%; 2) MRSA cultured at DLES, short duration of antibiotic therapy, and uptake on Ga-SPECT-CT were risk factors for surgical intervention; 3) positive skin culture at DLES and uptake on Ga-SPECT-CT were risk factors associated with readmission for driveline infection; and 4) driveline infection patients with uptake on Ga-SPECT-CT had higher surgical intervention and readmission rates.

The mechanism of Ga scintigraphy is related to multiple factors. First, the enhanced capillary permeability and increased blood flow contribute to the accumulation of gallium-67.[16,17] In addition, leukocytes take up gallium-67 into cytoplasmic granules and release it at the site of inflammation; furthermore, bacteria directly bind gallium-67.[16,17] Via these mechanisms, gallium-67 concentrates in regions of severe inflammation coincident with increased numbers of white blood cell or bacteria. Therefore, the uptake of gallium-67 on Ga-SPECT-CT might indicate severe inflammation, leading to poor outcomes. However, the sensitivity of Ga scintigraphy in detecting inflammatory lesions is not high in previous reports.[12,18,19] In fact, some possible difficulties are indicated when Ga scintigraphy is utilized for diagnosis of LVAD infection.[17] Gallium-67 could accumulate in wound healing with inflammatory process.[17,20] Additionally, the physiologic uptake in blood, bones, and bowel can obscure the diagnosis.[17] In the present study, the sensitivity of Ga-SPECT-CT in detecting driveline infection was 61%; therefore, Ga-SPECT-CT may not have enough high sensitivity to use as the screening tool for driveline infections.

In the present study, MRSA tended to be frequently detected as a pathogen responsible for driveline infection in patients with uptake on Ga-SPECT-CT. Furthermore, MRSA increased the risk of surgical intervention. MRSA colonizes skin, adheres to implanted materials, and creates a biofilm, in addition to being resistant to many

Table 4. Treatment for Driveline Infection

	All n = 36	Uptake Group n = 22	No-Uptake Group n = 14	*P* Value
Medical intervention				
Antibiotics (n [%])	31 (86)	20 (91)	11 (79)	0.30
Duration of antibiotic therapy (median [IQR], day)	19 (11, 33)	20 (12, 37)	17 (6, 29)	0.19
Surgical intervention				
Surgical debridement and translocation of DLES (n [%])	9 (25)	8 (36)	1 (7.1)	0.048
VAC therapy (n [%])	10 (28)	9 (41)	1 (7.1)	0.027
Pump replacement (n [%])	1 (2.8)	1 (4.6)	0 (0)	0.42



	Surgical intervention rate (%)		
	1 year	2 year	3 year
uptake group	39	49	49
no-uptake group	0	11	11

	Readmission rate (%)		
	1 year	2 year	3 year
uptake group	74	82	91
no-uptake group	6.9	28	28

Fig. 2. Event rate in the uptake and no-uptake groups. (**A**) Surgical intervention rate. (**B**) Readmission rate.

antibiotics.[21] Therefore, MRSA is reported to be difficult to treat with antibiotic treatment in patients with driveline infection, and surgical debridement is often needed with aggressive antibiotics and VAC therapy.[22,23] Furthermore, MRSA exhibits more rapid migration than *Staphylococcus epidermidis*.[21] Therefore, driveline infection caused by MRSA may have a high risk of progression to deep tissue infection. In fact, Papathanasiou et al[24] reported that the colonization with multidrug-resistant bacteria including MRSA is a highly prevalent risk factor for infection-associated death in LVAD patients. Given the high prevalence of MRSA in patients with uptake, Ga-SPECT-CT might be able to detect persisting, invasive, and refractory infections, and be useful to classify the severity of driveline infection.

LVAD-related bacterial infections and sepsis often start as a superficial driveline infection.[25] Without appropriate treatment, driveline infections may progress to infect the deep tissue and components of the device, leading to poor prognosis.[6,7,25] Given the significant consequences of these infections, the ISHLT guidelines recommend reinforcing patient education and immobilization technique, and treatment with intravenous or oral antibiotics for a minimum of 2 weeks or until the infection has resolved in terms of superficial driveline infection.[6] Additionally, intravenous antibiotics are recommended until the clinical condition stabilizes and the infection improves (usually 6−8 weeks) in the setting of deep driveline infection.[6] If the driveline infection worsens or recurs, then surgical intervention should be considered.[6] However, appropriate duration of antibiotic therapy and timing of surgical intervention remain controversial. In the present study, the prolonged duration of antibiotic therapy reduced the risk of surgical

Table 5. Univariate Analysis of the Risk Factors Associated With Surgical Intervention and Readmission for Driveline Infection

Factors	Surgical Intervention		Readmission	
	OR (95%CI)	*P* = value	OR (95%CI)	*P* = value
Age (per 1 year)	1.01 (0.96−1.08)	0.62	1.00 (0.95−1.05)	0.96
Diabetes mellitus	0.61 (0.03−4.89)	0.67	0.63 (0.07−4.28)	0.63
Maximum body temperature (per 1°C)	0.46 (0.14−1.21)	0.13	0.83 (0.30−2.12)	0.69
Wound pain	4.76 (0.72−95.01)	0.11	0.57 (0.46−2.48)	0.46
Bleeding	2.72 (0.61−14.88)	0.19	1.96 (0.53−7.69)	0.32
Swelling	0.96 (0.17−4.53)	0.96	1.30 (0.31−5.61)	0.72
WBC (per 1 /μL)	1.00 (1.00−1.00)	0.74	1.00 (0.99−1.00)	0.53
CRP (per 1 mg/dL)	0.67 (0.39−1.00)	0.079	1.09 (0.75−1.67)	0.65
SOFA score (per 1 point)	1.68 (0.52−10.49)	0.47	1.00 (0.35−2.85)	1.00
Positive skin culture at DLES	n/a	0.15	n/a	0.035
MRSA cultured at DLES	5.50 (1.10−30.74)	0.038	0.4 (0.007−1.85)	0.24
Uptake on Ga-SPECT-CT	9.00 (1.39−178.33)	0.018	7.86 (1.81−43.86)	0.0051
Deep driveline infection	1.26 (0.26−5.64)	0.76	2.08 (0.53−8.82)	0.30
Duration of antibiotic therapy (per 1 day)	0.95 (0.89−0.99)	0.0018	1.00 (0.99−1.01)	0.99

n/a, not available; WBC, white blood cell.

intervention. An inappropriate short duration of antibiotic therapy could lead to surgical intervention. Therefore, it may be important to continue antibiotic therapy for a certain period, even if clinical findings have stabilized and driveline infection has improved. Furthermore, driveline infection patients with uptake on Ga-SPECT-CT had higher rates of surgical intervention and readmission compared with no-uptake patients. Based on these results, these patients should be treated with long-term antibiotics for >2 weeks, with consideration of early surgical debridement and translocation of DLES, despite superficial driveline infection. Furthermore, Ga-SPECT-CT provides information about the region, depth, and range of the driveline infection. These data are extremely valuable in helping clinicians to decide whether surgical interventions are indicated. Therefore, Ga-SPECT-CT could be one of the clinical modalities for guiding the treatment of driveline infection in patients with a LVAD.

This study has several key limitations that should be discussed. First, this was a retrospective observational study and the final decision of treatment strategy depended on the attending doctor. The difference in attending doctor might affect the selection of treatment and therefore patient outcomes. Second, it is possible that clinical decisions regarding surgical intervention were influenced by initial Ga-SPECT-CT findings. However; in 5 of 10 patients, surgical interventions were performed >3 months after the initial Ga-SPECT-CT examinations (range: 103−544 days), indicating that the decision of surgical intervention was mainly influenced by comprehensive clinical findings. Initial Ga-SPECT-CT findings may therefore only represent one aspect of the decision-making process for surgical intervention. Finally, the sample size and the number of events were relatively small. For this reason, we could not perform multivariate analysis for risk factors associated with clinical outcomes and could not eliminate the effects of confounding factors, such as bleeding, MRSA, and duration of antibiotic therapy. Therefore, prospective registries with larger numbers of cases are needed to determine the usefulness of Ga-SPECT-CT in LVAD patients with driveline infection.

In conclusion, the sensitivity of Ga-SPECT-CT in detecting driveline infection was not sufficiently high to justify its use as a screening tool for driveline infection. However, uptake on Ga-SPECT-CT was a risk factor for surgical intervention and readmission for driveline infection. We should decide the treatment strategies for implantable LVAD patients with driveline infection by referring to uptake on Ga-SPECT-CT in addition to the results of culture at DLES.

Disclosures

The authors have no conflict of interest.

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