Two-stage Revision of Infected Total Knee Arthroplasty Using an Antibiotic-impregnated Static Cement-spacer

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Background: Static antibiotic-impregnated cement spacers have been used widely to treat chronically infected total knee arthroplasties with a high success result. However, difficulty in surgical exposure during revision has been encountered. The purpose of this study was to evaluate the clinical results of two-stage reimplantation of an infected total knee arthroplasty using a static antibiotic-impregnated cement spacer.

Methods: Thirty-one patients (32 knees) with infected total knee arthroplasty had a two-stage reimplantation using a static antibiotic-impregnated cement spacer. Twelve (37.5%) of 32 knees required a V-Y quadricepsplasty and five (15.6%) required a quadriceps snip for surgical exposure at revision. One patient was lost to follow-up and three patients died of unrelated causes. The remaining 27 patients (28 knees) returned at a mean of 68.3 months (8-197 months) for clinical evaluation.

Results: Four knees (14%) had recurrent infection. The mean Knee Society score improved from 40 points preoperatively to 82 points postoperatively. The mean functional score improved from 10 points preoperatively to 60 points postoperatively. The mean range of knee motion improved from 57° preoperatively to 88° at the latest follow-up. Three knees with V-Y quadricepsplasty developed an extension lag from 20° to 45° and three knees had a patella baja postoperatively.

Conclusion: Two-stage reimplantation of an infected total knee arthroplasty using a static antibiotic-cement spacer achieved an infection control rate of 86% and improvement in the clinical results. However, weakness of the extensor mechanism of the knee associated with a V-Y quadricepsplasty, which was required in a high percentage of patients during revision surgery in our series, is of great concern.

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Key words: static antibiotic-impregnated cement spacer, infected total knee arthroplasty, V-Y quadricepsplasty

Infection after total knee arthroplasty (TKA) is a devastating complication. The reported incidence ranges from 1.1% to 12.4%.[1,2] The treatment options include antibiotic suppression only, debridement and

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retention of the prosthesis,[3] resection arthroplasty,[4] arthrodesis[5,6] and two-stage exchange arthroplasty.[7-9] Two-stage reimplantation was first advocated by Insall et al. for chronically infected TKA.[7] In their report, ten of 11 knees had eradication of infection. Later investigators used antibiotic-impregnated cement spacers to achieve an infection control rate up to 90%.[8-12] The technique of using an antibiotic-cement spacer block after first-stage debridement and removal of the knee prosthesis was first described by Cohen et al.[13] Subsequently, Booth and Lotke reported their experience using a spacer block in 25 infected TKAs.[14] Only one patient developed a recurrent infection, and knee flexion averaged 100° at the final follow-up. However, later reports on this technique mentioned difficulty in exposure of the knee at reimplantation because of scar contracture of the quadriceps and the ultimate range of knee motion was less than expected from a revision TKA because of aseptic loosening.[15-17] The purpose of this study was to evaluate the clinical results of two-stage reimplantation of an infected TKA using a static antibiotic-impregnated cement spacer.

METHODS

From March 1991 to August 2001, 31 patients with 32 knees with a diagnosis of infected total knee arthroplasty were treated with two-stage reimplantation in our institution.

There were 8 men (9 knees) and 23 women (23 knees) with an average age of 66 years (range, from 50 to 78 years). The diagnoses of disease on the index total knee arthroplasty were osteoarthritis in 28, rheumatoid arthritis in one, gouty arthritis in one, and post-traumatic arthritis in two knees. There were 19 right knees and 13 left knees. Co-morbidity was common and included diabetes mellitus in eight, rheumatoid arthritis in one, and chronic steroid abuse in one.

Infection of the knee was defined if an aspiration culture or deep tissue culture obtained during the operation yielded microorganisms, if there was gross purulence during removal of the prosthesis, if histological examination of the periarticular tissue showed acute inflammation, or if there were clinical symptoms with an elevated erythrocyte sedimentation rate (ESR), elevated C-reactive protein (CRP) level and a progressive radiolucent line around the knee prosthesis on radiographic examination.

The causative organisms were *Methicillin-sensitive Staphylococcus aureus* in four, *Methicillin-resistant Staphylococcus aureus* in three, *Staphylococcus epidermidis* in five, *Pseudomonas aeruginosa* in one, *Escherichia coli* in one, *Enterobacter cloacae* in one, *Peptostreptococcus* species in one, *Corynebacterium* species in one, *Campylobacter* species in one, *Staphylococcus* species in one, *Enterococcus* species in one and Gram positive cocci in one knee. Two knees had mixed infection. Negative aspiration or deep tissue culture results were noted in 9 of 32 knees (Table 1). Of the 9 knees with negative culture results, the diagnoses of infection were based on clinical symptoms and signs and positive histological diagnosis of acute inflammation in four, gross purulent discharge during surgery in two, and positive clinical symptoms and signs with marked elevation of ESR and CRP in three knees.

Surgical procedures

The first stage operation included surgical debridement, total synovectomy, and removal of all knee prosthesis and cement. An antibiotic-impregnated cement block with a short intramedullary

Table 1. Micro-organisms Isolated in the First Stage Procedure

Micro-organisms	N = 32
Staphylococcus epidermidis	5
MSSA	4
MRSA	3
Escherichia coli	1
Enterococcus cloacae	1
Pseudomonas aeruginosa	1
Staphylococcus spp.	1
Peptostreptococcus spp.	1
Corynebacterium spp.	1
Campylobacter spp.	1
Enterococcus spp.	1
Gram positive cocci	1
Mixed	2
Negative	9

Abbreviations: MRSA: *Methicillin-resistant Staphylococcus aureus*; MSSA: *Methicillin-sensitive Staphylococcus aureus*.

cement stem was inserted into the femoral or tibial canal (Figs 1 and 2). The antibiotics were selected empirically or according to culture results. Three grams of vancomycin and four grams of piperacillin were used in one pack of bone cement. Deep tissues, including synovial tissue and membrane around the bone-prosthesis interface, were obtained for bacterial culture and pathologic examination. Post-operative intravenous antibiotics were given according to the sensitivity test of the culture or empirically. Intravenous antibiotics were used for 2-4 weeks until the serum CRP value returned to the normal limits and the patient was free of infection signs clinically. Additional oral antibiotics were given for another 4 weeks. A recurrent infection was defined if there was an elevated ESR and CRP and recurrent signs of infection of the knee clinically after the first-stage operation. Ten knees needed a second debridement

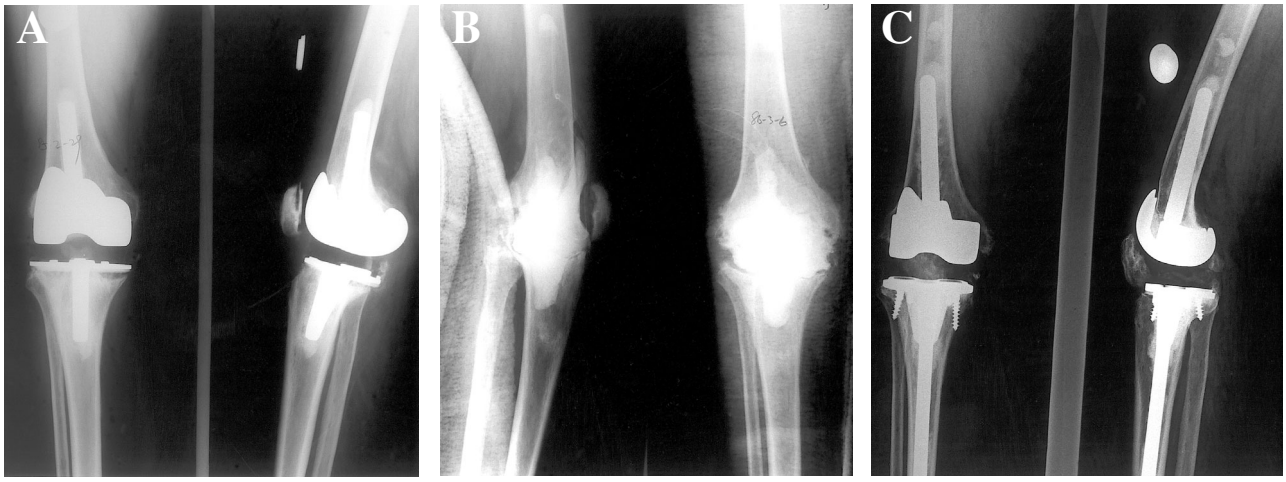

Fig. 1 A 65-year-old man with septic loosening of a right revision TKA. (A) Preoperative anteroposterior and lateral radiographs of the right knee. (B) Postoperative anteroposterior and lateral radiographs after debridement, removal of the knee prosthesis and insertion of a static antibiotic-impregnated cement block. (C) Anteroposterior and lateral radiographs taken nine years after second stage reimplantation via a V-Y quadricepsplasty. Patella baja was obvious. His range of knee motion at that time was from 0° to 90°.

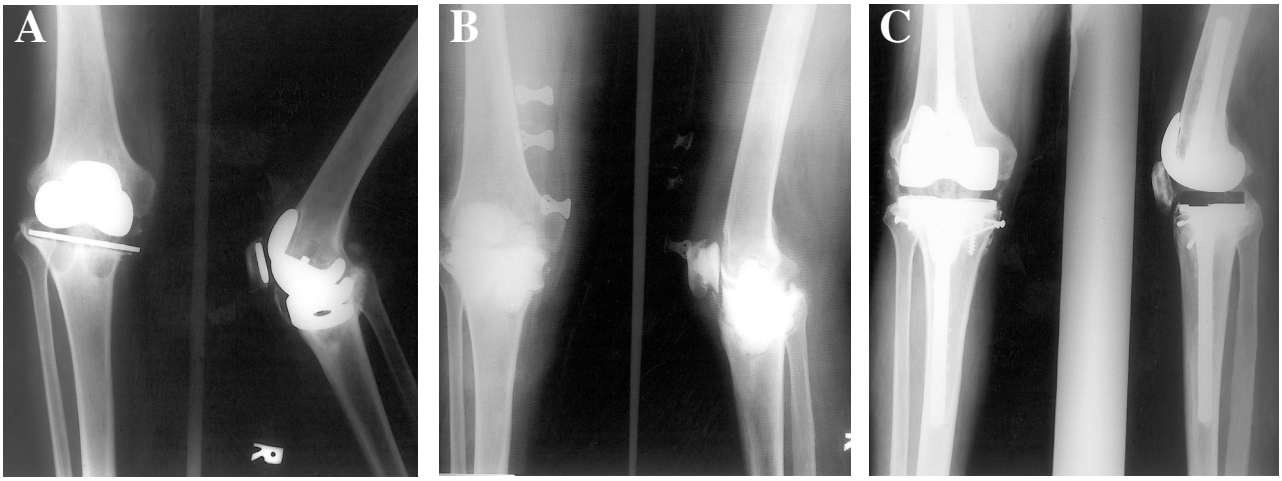

Fig. 2 A 59-year-old man with a chronic discharging sinus of the right knee for three years (A) Preoperative anteroposterior and lateral radiographs of the right knee. (B) Postoperative anteroposterior and lateral radiographs after debridement, removal of the knee prosthesis and insertion of a static antibiotic-impregnated cement block. (C) Anteroposterior and lateral radiographs taken 10 years after second stage reimplantation using a structural allograft via a V-Y quadricepsplasty. Note patella baja on the lateral view. His range of knee motion at that time was from 5° to 105°.

before the second stage operation because of recurrent infection. Post-operatively a long leg splint was applied for 2 weeks followed by long leg casting for 4 weeks. The patients were then allowed ambulation with walker support.

The reimplantation surgery was not undertaken until the knees were free of any signs of clinical infection and the patient had normal ESR and CRP values. The cement spacer blocks were removed and the knee joint was further debrided. Intra-operative deep tissues were again obtained for bacterial culture and pathologic examination. The implants used for revision TKA were the Advantim posterior-stabilized total knee prosthesis (Dow-Coring Wright, Arlington, Tennessee, U.S.A.) in 26, and the porous-coated anatomic (PCA) revision total knee system (Howmedica, Rutherford, NJ, U.S.A.) in 6 knees. A medial parapatellar approach was used with additional V-Y quadricepsplasty or quadriceps snips if difficult surgical exposure was encountered. Twelve knees (37.5%) required VY quadricepsplasty (Figures 1 and 2) and five knees (15.6%) required a quadriceps snip procedure. The tibial or femoral bone defects were grafted with antibiotics-impregnated morsellized allografts (Fig. 1). A structural allograft was required if there was a structural defect in the femoral or tibial condyles (Fig. 2). Stemmed prostheses with cement were used in all knees. The patella was not resurfaced in 12 knees due to poor bone stock.

The deep tissue culture during the second stage operation yielded no bacterial growth in all knees. No residual infection or acute inflammation were found in the histologic examination of the periarticular tissue during reimplantation surgery.

All patients received one week of intravenous antibiotics, followed by one week of oral antibiotics. Postoperatively, patients started continuous passive motion of the knee after drains were removed. Full weight bearing on the operative limb was not allowed until 3 months later. Patients were followed 6 weeks, 12 weeks, and 24 weeks postoperatively and then annually for clinical evaluation and radiographic examination of the knee. Blood tests including ESR and CRP were obtained at each visit.

Clinical evaluation

The Knee Society score and functional score[18] were obtained for clinical evaluation before the operation and at the final follow-up. Standing anteroposterior and lateral radiographs of the knee were made at each visit. The patients were classified as free of infection if they had no clinical symptoms of infection, normal ESR and CRP values, and no progressive radiolucent line around the prostheses. A paired *t* test was used to compare the differences between preoperative and postoperative clinical and functional outcomes as well as range of knee motion.

RESULTS

One patient was lost to follow-up and three patients died of unrelated causes. The remaining 27 patients (28 knees) returned to follow-up at a mean of 68.3 months (ranging from 8 to 197 months). The average interval between the first stage resection and second-stage reimplantation was 7.4 months ranging from 2.3 to 29.7 months. Most patients underwent reimplantation surgery less than 6 months after resection surgery. Ten patients underwent reimplantation surgery longer than 6 months after the first-stage operation due to persistent infection and multiple debridements.

Infection control

Four knees (14%) had recurrent infection from 2.5 to 7 months after reimplantation surgery. Among them, two had recurrent infection with the same organism, one changed from *Pseudomonas aeruginosa* to *Entercoccus*, and one changed from no growth of bacteria to *Staphylococcus hemolytica*. Three of them were successfully treated with removal of the prosthesis and arthrodesis. The remaining patient underwent an above knee amputation for recurrent infection. The other 24 knees were free of infection with an overall infection control rate of 86%.

Clinical evaluation

Among the surviving 24 knees, the mean Knee Society knee score improved from 40 points preoperatively (range, 2-62 points) to 82 points postoperatively (range, 33-99 points) ($p = 0.000$). The mean functional score improved from 10 points preoperatively (range, 0-25 points) to 60 points postoperatively (range, 0-90 points) ($p = 0.000$) (Table 2).

The mean range of motion of the knee improved from 57 degrees preoperatively (range, 10-110

Table 2. Clinical Results of Surviving 24 Knees with Two-stage Revision Total Knee Arthroplasty (TKA)

	Preoperative	Postoperative	*p* value
Knee score (mean ± SD)	40 ± 15	82 ± 14	0.000
Functional score (mean ± SD)	10 ± 9	60 ± 23	0.000
Range of knee motion (mean ± SD)	57 ± 24°	88 ± 19°	0.000

Abbreviation: SD: standard deviation.

degrees) to 88 degrees (range, 30-120 degrees) at the latest follow-up. The difference was statistically significant (Table 2). However, there were still nine knees with an unsatisfactory range of knee motion (< 90 degrees) postoperatively ranging from 30 to 85 degrees due to preoperative stiffness of the knee (range, 10-60 degrees) and poor rehabilitation.

Outcome of V-Y quadricepsplasty

The clinical outcomes of 12 knees that underwent a V-Y quadricepsplasty for surgical exposure at the time of revision TKA are listed in Table 3. Among the 12 knees, two had recurrent infection which resulted in arthrodesis in one and above knee amputation in the other; two other patients (two knees) died of unrelated causes. At the last follow-up before their death, both patients had developed extension lags of 45° and 20°. In the remaining eight knees, the mean knee score improved significantly from 34.6 points preoperatively to 81.1 points at the latest follow-up, the mean functional score improved significantly from 9.4 points preoperatively to 55.6 points at the latest follow-up and the mean range of the knee motion improved significantly from 51.2° preoperatively to 91.1° at the latest follow-up. However, one patient developed an extension lag of

Table 3. Clinical Data of 12 Knees with V-Y Quadricepsplasty

Age	Gender	Preoperatvie				Postoperative					
		Knee score	Functiona score	ROM of knee (degree)		Knee score	Functional score	ROM of knee (degree)		Extension lag (degree)	Clinical remarks
				Extension	Flexion			Extension	Flexion		
57	M	5	0	0	10	83	80	0	90	0	
61	M	42	0	0	60	63	15	30	120	30	
59	M	47	15	0	60	88	40	5	105	0	Patella baja
65	M	36	0	0	30	93	80	0	90	0	Patella baja
72	F	52	20	0	80	99	90	0	100	0	Patella baja
72	F	11	0	0	30	87	70	5	90	0	
68	M	44	20	0	70	68	35	0	95	0	
68	M	40	20	0	70	68	35	5	90	0	
75	F	Recurrent infection, knee arthrodesis									
75	M	Recurrent infection, above knee amputation									
								ROM of knee at last visit before death			
53	F	Died of unrelated cause						45	85	45	
71	F	Died of unrelated cause						20	90	20	

Abbreviations: M: Male; F: Female; ROM: Range of motion.

30 degrees; three other patients had a patella baja postoperatively (Figs 1 and 2).

Radiographic evaluation

There were no radiolucencies around the revised knee prostheses in the follow-up radiographs of the 24 surviving knees.

Complications

In addition to the four knees (14%) with recurrent infection, the complications included partial avulsion of the patellar tendon in two, extension lag of the knee in two and flexion contracture of the knee in one. The two partial avulsions of the patellar tendon were both successfully repaired with heavy suture. An extension lag of the knee of 30 degrees developed postoperatively in one knee with a V-Y quadricepsplasty. Another knee without a quadricepsplasty at exposure developed a 40 degree extension lag postoperatively. The cause of the extension lag was unknown. A 68-year-old woman developed a flexion contracture of 30 degrees on the knee postoperatively due to preoperative stiffness of the knee (ROM, from 30 to 60) and poor general health which made aggressive rehabilitation difficult.

DISCUSSION

Two-stage reimplantation remains the most effective and common treatment for eradication of infection in a chronically infected TKA. The success rate of infection eradication after the two-stage procedure is between 85% and 95%.[8-12] However, the modalities that manage the space after removal of the knee prosthesis vary, including no spacer,[7,9,19] use of antibiotic-impregnated cement beads,[20] and static[13,14] or articulating spacers.[17,21,22] Cohen et al. reported three cases of two-stage reimplantation of an infected TKA using an antibiotic-loaded cement spacer block in 1988.[13] They reported that the antibiotic-loaded cement block has following advantages: it provides mechanical stability to the knee, it acts as a mechanical spacer for ligament and soft tissue tension and it serves as a local antibiotic-delivery system. One of their patients could ambulate with a cane by wearing a knee immobilizer and kept the cement spacer in place for six months before reimplantation.

Theoretically, the knee spacer maintains soft tissue tension and lessens capsular contracture around the knee joint during the interim period. However, in cases of static spacers which keep the knee in an extension position for a prolonged period, problems may occur, including quadriceps scarring and shortening, obliteration of the medial and lateral gutters and fusion of the patella to the anterior femur.[17] Booth and Lotke stated that the knees are usually painful and stiff as result of resection of the prosthesis and subsequent immobilization, making reimplantation surgery arduous.[14] Because of quadriceps scarring from a prolonged period of immobilization, surgeons are faced with difficult surgical exposure and occasionally quadriceps snip, V-Y turn down, or a tibial tubercle osteotomy is required.[17] In the current report, a V-Y quadricepsplasty was required in 12 knees and a quadriceps snip in five knees because of quadriceps contracture and difficulty in surgical exposure.

Another drawback of the static spacer is bone loss attributed to migration of the spacer blocks. In the report by Calton et al., a 40% tibial bone loss and 44% femoral bone loss were associated with the use of spacer blocks.[23] Bone loss was common when spacer blocks were undersized and made without a small intramedullary stem. Our cement spacer blocks were made with a femoral and tibial stem, therefore, no obvious bone loss on the femoral or tibial bone was observed.

The use of static spacers in two-stage revision TKA because of infection has been associated with less satisfactory knee motion. Barrack et al. reported that the range of knee motion was 89° in patients with septic revision compared to 99° in patients with aseptic revision TKA.[15] A similar result was reported by Wang et al.[16] In both studies, a static cement-spacer was used in the interim period after debridement and removal of the knee prosthesis. In the current study, the ultimate range of knee motion was 88° which was comparable with previous reports. Decreased knee flexion of 93.7° in patients with static spacers compared with 107.8° in patients with mobile spacers was reported by Emerson et al.[21] Fehring et al. reported improvement in knee motion from 98° to 105° if the static spacer was changed to a mobile spacer.[17] However, the difference was not statistically significant.

In primary or revision TKA procedures, a modified V-Y quadricepsplasty is occasionally required because of severe extensor mechanism contracture.[24-

[26] Another option is an osteotomy of the tibial tubercle.[27] If there is severe osteoporosis and a stemmed tibial component is required, osteotomizing the tibial tubercle may be associated with a higher complication rate.[27,28] A V-Y quadricepsplasty is a better choice if lengthening of the quadriceps tendon is desirable.[24,25,28] However, this procedure is associated with a higher degree of extension lag and weakness of the quadriceps while increasing the knee motion.[28] In one study, the reported improvement of knee motion was 49° with an average extension lag of 8° after modified V-Y quadricepsplasty for a difficult exposure during TKA.[29] In the current study, 12 knees (37.5%) underwent a V-Y quadricepsplasty after a static spacer was used for 2.3 to 29.7 months. The postoperative knee motion improved significantly from 51.2° to 91.9°. However, three patients developed an extension lag from 20° to 45° (Table 3). Two of these patients died of unrelated causes. Three other patients had a patella baja postoperatively.

In conclusion, two-stage reimplantation of an infected TKA using a static antibiotic-impregnated cement spacer achieved an infection control rate of 86% and improvement in the clinical results. However, because 37.5% of the knees required a V-Y quadricepsplasty for surgical exposure during the second- stage procedure, weakness of the extensor mechanism was noted in some patients.

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使用含抗生素的固定式骨水泥填充物來進行全人工膝關節感染兩階段再置換

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背 景： 含抗生素的固定式骨水泥填充物已經廣泛被使用來治療慢性全人工膝關節感染且有高比例的成功結果，然而在再置換的手術過程是相當困難的。這項研究的目的在於使用兩階段的方式進行人工膝關節感染的再置換，且使用含抗生素的固定式骨水泥填充物並評估其最後臨床結果。

方 法： 總共有 31 名患者 (32 個膝關節) 使用兩階段的方式再置換其感染的全人工膝關節，且使用含抗生素的固定式骨水泥填充物。在 32 個膝關節中有 12 個膝關節 (37.5%) 需要 VY 股四頭肌成形術，5 個膝關節 (15.6%) 需要股四頭肌切開術來得到較好的手術顯露。一名患者失去追蹤，且有三名患者因爲其他因素死亡，剩下的 27 名患者 (28 個膝關節) 總共追蹤了 68.3 個月 (8 到 197 個月)。

結 果： 4 個膝關節 (14%) 有再發感染，24 個膝關節 (86%) 沒有感染復發的情形。平均膝關節評分由術前 40 分改善到術後 82 分，平均膝關節功能性評分由術前 10 分改善到術後 60 分。平均膝關節活動角度在最後追蹤時，由術前 57 度改善到術後 88 度。3 個膝關節接受了 VY 股四肌成形術後產生了 20-45 度的伸直遲緩，其他的 3 個膝關節在術後產生的髕骨低位。

結 論： 使用含抗生素的固定式骨水泥填充物來進行人工膝關節感染的再置換可以得到 86% 的感染控制率及改善臨床結果。然而高比例的病患在再置換的過程中需要進行 VY 股四頭肌成形術，且造成膝蓋的伸直機制無力是這項研究中值得注意的。

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關鍵詞： 含抗生素的固定式骨水泥填充物，人工膝關節感染，VY 股四頭肌成形術

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