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Comparison of two surgical strategies for fractures of the anterior process of the calcaneus with or without bridging plate fixation

Xi Hua[1,*], Junxin Zhang[1,*], Hao Liu[1,*], Yuehong Guan[2,*], Kangwu Chen[1] and Zhonglai Qian[1]

Abstract

Objective: To evaluate the therapeutic effects of applying internal fixation with a T-shaped locking plate that was used on the distal radius in fractures of the anterior process of the calcaneus (APC) with calcaneocuboid (CC) joint injury.

Methods: This retrospective study enrolled adult patients diagnosed with APC with CC joint injury that had received internal fixation with a T-shaped locking plate of the distal radius. Group NA underwent open reduction with 'not-across' CC joint plate fixation; and group A underwent open reduction with 'across' CC joint locking plate fixation. The outcomes were assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) score, a visual analogue scale (VAS) pain score and radiological evaluations.

Results: A total of 72 patients were enrolled in the study; 36 in each group. At 1 month after surgery, the outcomes of group NA were superior to group A in terms of AOFAS and VAS scores. Compared with group A, group NA showed significantly lower intraoperative blood loss, operation time and length of hospital stay. There were no significant differences in the postoperative improvement of Bolher's and Gissane's angles between the two groups.

Conclusion: Early functional recovery was faster in group NA than group A.

[1]Department of Orthopaedic Surgery, The First Affiliated Hospital of Soochow University, Suzhou, Jiangsu Province, China
[2]Department of Rehabilitation, Changshu No. 2 People's Hospital, Suzhou, Jiangsu Province, China

*These authors contributed equally to this work.

Corresponding author:
Zhonglai Qian, Department of Orthopaedic Surgery, The First Affiliated Hospital of Soochow University, 899 PingHai Road, Suzhou 215006, Jiangsu Province, China.
Email: qzldoctor@163.com

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Introduction

Calcaneus fractures are relatively common in clinical medicine and they account for approximately 2% of total fractures, with approximately 75% involving the subtalar joint and approximately 20–45% involving the calcaneocuboid (CC) joint.[1,2] At present, most studies on fracture classification and treatment methods emphasize the importance of anatomical reduction of the subtalar articular surface of the calcaneus, while ignoring the impact of anterior tuberosity fractures of the calcaneus and injury of the CC joint on foot function.[3–6]

The calcaneus anterior process is a saddle-shaped protuberance in front of the calcaneus, varying in length, width and shape. While stabilizing the lateral column of the foot, it articulates with the cuboid and navicular and forms the anterior part of the subtalar joint, the upper posterior part of the calcaneocuboid joint, and serves as the junction of the extensor digitalis brevis, the calcaneocuboid dorsal ligament and the split ligament. The bifurcated ligament is a type of elastic fibre bundle ligament that originates from the lateral side of calcaneus anterior process, which is divided into internal and external bands. The lateral band is the calcaneocuboid ligament, which arrives at the medial back side of the calcaneocuboid. The medial cord is the calcanavicular ligament, which is attached to the lateral surface of the scaphoid.

The most commonly used classification of the fracture of the anterior process calcaneus (APC) is the Degan Classification.[4] With increasing knowledge of the APC, almost all authors agree that surgery is not necessary for Degan type I and Degan type II fractures.[7,8] Surgical treatment by open reduction and internal fixation (ORIF) is mainly used for large dislocated APC (Degan type III).[3,8–10] ORIF is the most common method for achieving anatomic reduction and it allows for better functional activity and earlier return to normal walking. However, it has been reported that ORIF is more likely to result in wound complications.[10] APC involving the CC joint destroys the stability of the CC joint surface. Only by restoring the normal structure of the joint can a good prognosis be achieved. There is still much controversy as to whether fractures involving the CC joint require cross-articular fixation. Some scholars believe that comminuted fractures of the anterior calcaneus should be fixed across the calcaneocuboid joint to increase the stability of the fracture fixation.[12–14] However, others believe that, as the CC joint is part of linked joints around the calcaneus,[3,4,15,16] movement of the other joints, especially the subtalar joint, will be restricted after fixation and will cause the foot to lose its normal biomechanical properties, leading to joint problems and degenerative changes.[9,11,17–22] To reduce the incidence of complications, methods of ORIF with T-shaped locking plates that do not cross the CC joint have been developed.[12] There are increasing numbers of studies investigating the therapeutic effects of the use of open reduction and internal fixation with T-shaped locking plates in the repair of fractures of the APC.[12,14,23]

The functional recovery of the foot benefits from the anatomical reduction and stable internal fixation of APC with CC joint injury.[20] With open reduction and internal fixation, T-locking plates that do not across the calcaneocuboid joint may be sufficient to provide considerable clinical benefit. The aim of this current study was to objectively evaluate the therapeutic effects of applying internal fixation with a T-shaped locking plate that was used on the distal radius in fractures of the APC with CC joint injury.

Patients and methods

Patient population

This retrospective study enrolled consecutive adult patients diagnosed with APC with CC joint injury in the Department of Orthopaedic Surgery, The First Affiliated Hospital of Soochow University, Suzhou, Jiangsu Province, China between January 2015 and December 2020. The inclusion criteria for these patients were as follows: (i) aged $\geq$18 years; (ii) a Degan type III injury; (iii) surgery involving ORIF with T-shaped locking plates; (iv) follow-up $>$12 months. The exclusion criteria were as follows: (i) patients with open wounds; (ii) patients with fractures combined with other tarsal fractures; (iii) patients treated with multiple plates. The patients were retrospectively divided into two groups: group A contained patients with fractures involving the articular surface of the calcaneocuboid or with articular surface collapse that underwent an 'across' CC joint locking plate fixation; and group NA contained patients that had larger fractures without displacement that underwent a 'not-across' joint plate fixation.

Ethical approval from the Medical Ethics Committee of the First Affiliated Hospital of Soochow University was obtained for this study (no. SZS2022017). All methods were carried out in accordance with the relevant guidelines and regulations. Written informed consent was obtained from all participants. All patient details have been de-identified. The reporting of this study conforms to STROBE guidelines.[24]

Surgical procedures

Treatment plans were formulated based on preoperative X-ray and three-dimensional computed tomography (3D-CT) examinations. For group NA (Figure 1), open reduction and a 'not-across' CC joint plate was used. For group A (Figure 2), open reduction and 'across' CC joint locking plate fixation was used. Before surgery, ice was applied to the ankle and an intravenous drip of mannitol was used to alleviate swelling in the foot. During the operation, general anaesthesia was used and the patient was placed in a lying position on the contralateral side with a balloon tourniquet on the lower extremity. The calcaneocuboid articular surface and subtalar articular surface bone masses were then reduced under direct vision, using multiple Kirschner wires to temporarily fix the fractured bone masses. The prepared T-shaped plate of the distal radius was then fitted to the calcaneus.

For group NA, a locking plate 'not-across' the CC joint was used. After confirming the incision, a full-thickness skin incision was cut and the skin flaps were quickly peeled from the lateral wall. Care should be taken to protect the peroneus brevis tendon beneath the incision. Two or three Kirschner wires were then placed in the talus and cuboid as traction to expose the calcaneus cuboid, articular surface and lateral wall. The front fracture of the calcaneus was then reduced under direct vision, restoring the flat joint surface of the CC and was temporarily fixed with Kirschner wires. The distal radius T-shaped locking plate was then attached to the front of the calcaneus, confirming the placement of the CC joint and the anterior bone mass of the

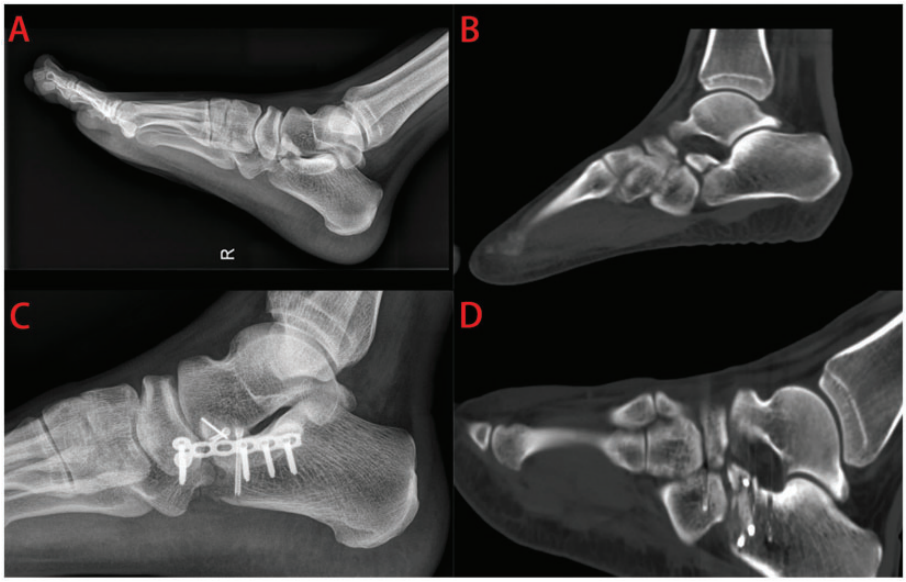

Figure 1. Preoperative and postoperative lateral calcaneus X-rays and three-dimensional computed tomography (3D-CT) scans of a 55-year-old female patient with a fracture of the anterior process of the calcaneus that received open reduction and 'across' calcaneocuboid joint locking plate fixation (group A): (a) preoperative lateral X-ray image; (b) preoperative 3D-CT image; (c) postoperative lateral X-ray image at 1 month after surgery and (d) postoperative 3D-CT image at 6 months after surgery.

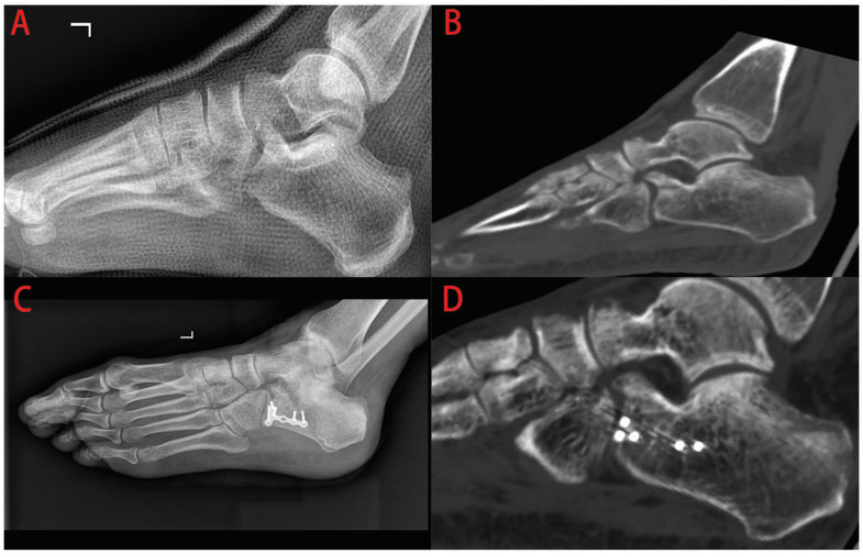

Figure 2. Preoperative and postoperative lateral calcaneus X-rays and three-dimensional computed tomography (3D-CT) scans of a 31-year-old male patient with a fracture of the anterior process of the calcaneus that received open reduction and 'not-across' calcaneocuboid joint plate fixation (group NA): (a) preoperative lateral X-ray image; (b) preoperative 3D-CT image; (c) postoperative lateral X-ray image at 1 month after surgery and (d) postoperative 3D-CT image at 6 months after surgery.

calcaneus under direct vision. A C-arm X-ray machine and fluoroscopy were then used from the side to check the axis of the calcaneus. The articular surface of the calcaneus was checked. Finally, the front and body of the calcaneus were fixed with screws. For group A, a locking plate across the CC joint was selected.

Data collection

Data were collected from patients aged $\geq$18 years old who had both radiographic and 3D-CT images of the ankle and foot taken between the initial emergency and the final follow-up from a retrospective search of the hospital image database using the search terms 'calcaneocuboid joint' and 'the anterior process fracture of calcaneus' in the radiographic reports.

Radiographic evaluation

Two designated surgeons (Z.L.Q and K.W.C) measured all imaging parameters including Bohler's angle and Gissane's angle for each study participant from the radiographic reports.

Functional evaluation

Visual analogue scale (VAS) scores were used to assess subjective pain perception prior to surgery, 1 month after surgery and at 6 months after surgery (0–10 scale, with 0 being painless and 10 being the most painful). In addition, the American College of Foot and Ankle Surgery (AOFAS) scores were used to determine improvements in the quality of functional outcomes prior to surgery, 1 month after surgery and at 6 months after surgery.

Statistical analyses

All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA). Continuous data are presented as mean $\pm$ SD. Categorical data are presented as n of patients (%). Paired-sample t-test was used to compare continuous data and χ^2-test was used to compare categorical data. A P-value <0.05 was considered statistically significant.

Results

This retrospective study enrolled 72 patients with fractures of the APC: 36 patients in group A and 36 patients in group NA. The clinical and demographic characteristics of the two groups are presented in Table 1. There were no significant differences between the two groups in the clinical and demographic characteristics.

The functional and radiological parameters of both groups are summarized in Table 2. Except for Gissane's angle at 1 and 6 months after surgery, all other parameters were significantly different at these two timepoints compared with the preoperative values in both groups ($P < 0.05$ for all comparisons). There were no significant differences in the preoperative parameters between the two groups. At 1 month after surgery, the AOFAS and VAS scores of group NA were significantly better than those of group A ($P < 0.05$ for both comparisons).

Surgical parameters and related complications of the two groups are presented in Table 3. Intraoperative blood loss, operation time and length of hospital stay were significantly lower in group NA compared with group A ($P < 0.05$ for all comparisons). Surgical complications occurred in 10 patients during hospitalization and there was no significant difference between the two groups. Three patients developed superficial wound infection on the third day after surgery. Cephalosporin was injected intravenously for 3 days and the wound was cleaned with iodine wet compress. All patients were discharged after complete resolution of symptoms.

Table 1. Demographic and clinical characteristics of patients with a fracture of the anterior process of the calcaneus that received either 'across' calcaneocuboid joint locking plate fixation (group A) or 'not-across' calcaneocuboid joint plate fixation (group NA).

Characteristic	Group NA $n = 36$	Group A $n = 36$
Age, years	43.53 ± 9.71	46.00 ± 12.29
Sex, male/female	11/25	9/27
Body mass index, kg/m^2	23.67 ± 3.92	23.11 ± 3.58
High work loading[a]	5 (13.89%)	6 (16.67%)
Follow-up, months	19.86 ± 4.20	20.47 ± 3.92
Cause of fractures		
High altitude falling	26 (72.22%)	29 (80.56%)
Sports sprain	10 (27.78%)	7 (19.44%)

Data presented as mean $\pm$ SD or *n* of patients (%).
[a]Standing for long periods and having a high level of exercise at work.
No significant between-group differences ($P \geq 0.05$); paired-sample *t*-test was used to compare continuous data and χ^2-test was used to compare categorical data.

Table 2. Functional and radiological results of patients with a fracture of the anterior process of the calcaneus that received either 'across' calcaneocuboid joint locking plate fixation (group A) or 'not-across' calcaneocuboid joint plate fixation (group NA).

Characteristic	Group NA $n = 36$	Group A $n = 36$	Statistical analysis[a]
AOFAS score			
Preoperative	39.94 ± 3.34	41.19 ± 4.34	NS
1 month after surgery	81.28 ± 4.89*	76.42 ± 4.37*	$P < 0.01$**
6 months after surgery	83.22 ± 4.86*	82.39 ± 6.12*	NS
VAS pain score			
Preoperative	8.00 ± 0.68	7.83 ± 0.70	NS
1 month after surgery	1.58 ± 0.65*	2.14 ± 0.68*	$P < 0.01$**
6 months after surgery	1.39 ± 0.49*	1.44 ± 0.61*	NS
Bohler's angle,			
Preoperative	20.44 ± 3.10	20.50 ± 3.49	NS
1 month after surgery	28.17 ± 2.55*	27.17 ± 2.90*	NS
6 months after surgery	28.56 ± 2.47*	27.78 ± 2.44*	NS
Gissane's angle,			
Preoperative	122.00 ± 6.30	124.06 ± 5.78	NS
1 month after surgery	122.17 ± 3.61	121.69 ± 4.10	NS
6 months after surgery	122.28 ± 3.72	121.56 ± 4.07	NS

Data presented as mean $\pm$ SD.
[a]Paired-sample *t*-test was used to compare continuous data; *significant difference compared with the preoperative value, $P < 0.05$; **significant difference between the two groups, $P < 0.05$; NS, no significant between-group difference ($P \geq 0.05$).
AOFAS, American Orthopaedic Foot and Ankle Society; VAS, visual analogue scale.

Discussion

The purpose of this current study was to compare the clinical efficacy of two different approaches to the surgical repair of Degan type III fractures of the APC. To date, a variety of surgical and conservative treatment options have been described in a few studies, which were dominated by case reports.[15,16,23,25,26] Case numbers were low

Table 3. Surgical parameters of patients with a fracture of the anterior process of the calcaneus that received either 'across' calcaneocuboid joint locking plate fixation (group A) or 'not-across' calcaneocuboid joint plate fixation (group NA).

Characteristic	Group NA $n = 36$	Group A $n = 36$	Statistical analysis[a]
Intraoperative blood loss, ml	84.36 ± 10.86	100.86 ± 13.05	$P < 0.01$
Operative time, min	74.53 ± 8.37	84.36 ± 10.86	$P < 0.01$
Length of hospital stay, days	6.64 ± 1.27	7.83 ± 1.95	$P < 0.01$
Complications			
Incision infection	2	1	NS
Delayed wound healing	2	3	NS
Screw breakage	0	2	NS

Data presented as mean $\pm$ SD or *n* of patients.
[a]Paired-sample *t*-test was used to compare continuous data and χ^2-test was used to compare categorical data; NS, no significant between-group difference ($P \geq 0.05$).

and there was often no uniform classification or treatment consensus.[12] Most classifications of calcaneus fractures, such as the AO classification,[27] Essex-Lopresti classification[28] and the Sanders classification,[29] do not or only partially describe APC. The most commonly used classification of APC is that of the Degan classification.[13] According to radiographs, fractures of the APC can be classified into three different types as follows: (i) type I represents undisplaced avulsion fractures outside the joint; (ii) type II represents displaced extrarticular fractures; and (iii) type III represents large intrarticular calcaneal process fractures.[13]

Since the APC was first described in 1931,[30] only a few case reports and case series have been published, suggesting a variety of treatment recommendations.[7,13,14,25] Treatment methods include the following non-surgical treatments: fixed calf cast, forearm crutches to relieve pressure on the foot used for 2–10 weeks and the use of elastic bandages and early functional treatment of the whole body to adapt to the symptoms.[31] Others have recommended open reduction and internal fixation or open arthroscopic resection for surgical treatment.[12,15,32] Open reduction and stable internal fixation have since been established as the standard treatment for most fractures of the APC.[7] In a series of clinical studies, more than two-thirds of patients obtained good-to-excellent results.[5,10,22,33–36] Conservative treatments resulted in fracture consolidation after almost 2.5 years, especially in patients that had delayed treatment.[10] To some extent, treatment is not satisfactory in terms of the long-term prognosis, as ankylosis and disturbances in bone union may occur and may require surgery.[26] Patients that receive more invasive surgery may experience postoperative incision exudation and wound infection requiring lengthy hospital stays.[37]Although more surgeons are tending to use a minimal incision lateral approach and percutaneous fixation with wires and screws or sinus tarsi that reduces the wound size and soft tissue damage of the lateral approach, the operation is not only more difficult and often longer, but also may not result in anatomical reduction.[12,32] As described in a previous study, six of 20 patients experienced complications such as malunion or screw positioning deviation and one patient had delayed wound healing.[11] Nevertheless, this approach improves the geometry of the calcaneus and reduces the wound infection rate. Displaced APC with joint involvement may benefit from acute open reduction and internal fixation to restore the anatomy and reduce the

risk of post-traumatic arthritis.[12] A series of cases described injuries extending to the calcaneal joints, indicating that they are often not combined with separate fixation, resulting in persistent symptoms requiring surgical removal of bone debris or delayed fixation.[7,14] Therefore, the best treatment for displaced or large acute fractures with calcaneal joint involvement or displacement is open reduction and internal fixation.[7,12,14] In a review of APC fracture management, a total of 17 fractures received acute surgical treatment.[38] These procedures include removal of fracture fragments, open reduction with a single cancellous screw or other fixation.[1,3,8] A previous study demonstrated that isolated APC can be fixed using locking plates and screws in patients with effective functional recovery 6 months after surgery.[12] In summary, while these surgical techniques have been shown to be effective in treating calcaneal intra-articular fractures, there is no evidence that any of them is superior.[10,20,22,35,39]

Longer plate fixation may also result in traumatic arthritis and ankylosis as patients are only able to perform functional exercise later.[7,12] Because the tibiotalar joint, subtalar, talar navicular and calcaneocuboid joints are linked, crossing the CC joint is likely to seriously affect the normal mechanical function of the middle tarsal joint, the subtalar joint, and valgus, and will adversely affect normal walking.[3,11] Good joint mobility is necessary for early postoperative functional exercise. Patients often delay weight-bearing rehabilitation due to poor joint mobility and postoperative pain. In addition, according to mechanical principles, the steel plate and loose screws might be broken by mechanical force in patients treated with the 'across' the CC joint approach. The use of ORIF with the 'across' the CC joint approach can provide good fracture visualization, but it does more damage to the soft tissues, thereby increasing the risk of wound dehiscence, flap devascularization, injury to the sural nerve and infection.[9,11,20,22]

This current study compared the therapeutic effectiveness of two surgical fixation methods for APC fractures with CC joint injury (Degan type III) that involved fixation 'across' or 'not-across' the CC joint. Based on the evidence obtained, the 'not-across' approach (group NA) was more effective than the 'across' approach (group A) for the restoration of joint function in terms of clinical outcomes and radiological evaluations, as assessed by the improvement in the AOFAS score, Bohler's angle and Gissane's angle, although differences between the two groups did not reach statistical significance for all measures. It is generally accepted that AOFAS verification alone is insufficient.[40] Most of the published studies on APC fractures have only reported subjective results with 'satisfactory' clinical outcomes, describing the healing process as 'smooth or only illustrating radiological results'.[5,13] Most previous studies on Degan type III fractures have insufficient sample sizes and lack objective data collection.[4,7] This current study, therefore, has some reference value for the treatment of Degan type III fractures of the APC using relatively objective parameters.

The high incidence of calcaneal fracture complications has always been a challenge for surgeons. In terms of complications, the present study demonstrated a greater rate of broken screws in group A that was treated with plate fixation 'across' the CC joint compared with the 'not-across' approach (group NA), but the difference between the two groups did not reach statistical significance. A slower postoperative recovery of function and a greater tendency toward soft tissue damage can lead to complications such as necrosis, dehiscence, tendinitis or nerve damage.[21,41] Full weight-bearing walking can only be done after the fracture has healed, as faulty bone union and plate

fracture may result. Clinical studies have also shown that early postoperative weight-bearing is associated with better functional outcomes.[1,2] If reliable fixation can be achieved, the sooner the patient begins weight-bearing activities, the better the functional results.[42,43] The current results showed that, in terms of the functional outcome as measured by AOFAS and VAS pain scores, the 'not-across' approach (group NA) was superior to that of the 'across' approach (group A) at 1 month postoperatively.

This current study had several limitations. First, the number of patients included in the study was small because APC fractures are rare. Secondly, these fractures are intra-articular fractures, but the quality of the anterior articular surface cartilage was not evaluated by magnetic resonance imaging during long-term follow-up. Fractures of the APC are more common in young adults that exercise. If the sample size could be further increased, the recovery of function could be specifically evaluated. Thirdly, the study could have lacked objective outcome scores because of the differences in the recovery methods used by patients.

In conclusion, good clinical efficacy was demonstrated for the use of a T-shaped plate in the surgical treatment of Degan type III fractures of the APC. It was further shown that, the short-term postoperative functional recovery of the 'not-across' approach was significantly better than that of the 'across' approach, which might accelerate the initiation of rehabilitation exercises and help patients return to normal life as soon as possible.

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Author contributions

K.W.C. and Z.L.Q. designed the study and performed the clinical diagnosis and treatment; X.H. wrote the manuscript; J.X.Z., H.L. and X.H. collected the patient information; Y.H.G. provided help in writing the manuscript.

Declaration of conflicting interests

The authors declare that there are no conflicts of interest.

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ORCID iD

Xi Hua https://orcid.org/0000-0002-3659-1688

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