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Longitudinal Changes in Frailty Status After Cooled Radiofrequency Ablation and Rehabilitation in Knee Osteoarthritis: A Case Report

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Manuscript Preparation E
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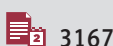
Patient: Female, 74-year-old
Final Diagnosis: Knee osteoarthritis
Symptoms: Right knee pain
Clinical Procedure: —
Specialty: Rehabilitation

Objective: Unusual clinical course
Background: Knee osteoarthritis (KOA) may contribute to physical frailty through chronic pain, reduced gait speed, and decreased activity. Cooled radiofrequency ablation (CRFA) is a minimally invasive treatment for chronic KOA pain, but longitudinal changes in pain, rehabilitation experience, and frailty after CRFA are not fully described.
Case Report: A 74-year-old woman with right KOA (Kellgren-Lawrence grade II) had experienced pain while walking for 5 years despite pharmacotherapy and intra-articular hyaluronic acid injections. Before CRFA, walking pain was 3.6 cm (visual analog scale score), gait speed was 0.92 m/s, and she was physically prefrail according to the revised Japanese version of the Cardiovascular Health Study criteria. CRFA was performed on the right superolateral, superomedial, and inferomedial genicular nerves; lifestyle guidance was initiated before treatment. At 1 month, walking pain decreased to 0.0 cm, gait speed improved to 1.11 m/s, and frailty status changed to robust. At 3 months, pain recurred after sitting in the seiza position, and reduced grip strength led to reclassification as physically prefrail. Seven 40-minute supervised outpatient rehabilitation sessions were provided once every 2 weeks from 3 to 6 months; they included multicomponent exercise, home exercise instruction, and reinforced lifestyle guidance. At 6 months, pain and grip strength improved. Robust status was restored and maintained at 12 months.

Conclusions: This case suggests that frailty status can change with pain relief, pain recurrence, and staged rehabilitation after CRFA. It generates the hypotheses that frailty monitoring may be a relevant longitudinal outcome after CRFA and that rehabilitation after pain relief may support sustained functional recovery in selected patients.

Keywords: Frailty • Knee • Rehabilitation

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Introduction

Frailty was defined in the 1990s as a state in which physiological reserve declines, increasing susceptibility to functional impairment; it is now regarded as an intermediate condition between robust health and dependency requiring long-term care, which arises from age-related declines in physical and mental function [1]. Physical frailty, a domain of frailty, increases the risk of falls and fractures through declines in muscle strength, gait speed, and physical activity. These changes impair mobility and reduce activities of daily living and instrumental activities of daily living, thereby increasing the likelihood of requiring long-term care [2]. Moreover, reduced physical activity has been associated with higher risks of hospitalization and complications, worse quality of life, social isolation, and increased mortality; therefore, reduced physical activity has attracted growing attention in recent years [3,4]. Although frailty is considered potentially reversible, pain or activity limitations in individuals with frailty often reduce physical activity, accelerating weight loss and declines in muscle strength, endurance, and walking ability. These changes can further reduce activity levels, leading to a “frailty cycle” [2]. Because implementation of adequate exercise can become more difficult as frailty progresses, early intervention—including at the prefrailty stage—is important [3].

Knee osteoarthritis (KOA) is a musculoskeletal disorder characterized by degenerative changes in articular cartilage and periarticular tissues, resulting in pain, stiffness, and functional impairment. The global burden of KOA continues to increase, such that approximately 370 million people worldwide were affected in 2021 [5]. KOA causes chronic pain and restricted joint movement, reducing activities of daily living and quality of life and increasing the risk of falls in middle-aged and older adults. As the population ages and the prevalence of obesity increases, the number of affected individuals and the associated societal burden are expected to grow. KOA-related chronic pain limits physical activity and can worsen frailty by slowing gait speed and reducing outings. Observational studies in older adults have demonstrated associations between KOA and frailty or prefrailty [6,7], suggesting that KOA-related pain can trigger the frailty cycle. Multiple international guidelines recommend conservative management of KOA centered on exercise therapy and weight management [8,9]. Similarly, multicomponent exercise interventions that include resistance training are recommended to manage frailty [3]. Thus, among patients with coexisting KOA and frailty, appropriate pain control is important to enable sustained participation in exercise. However, in clinical practice, concerns about pain exacerbation and pain-related avoidance behaviors often hinder engagement in and adherence to physical activity and exercise therapy; many patients are unable to achieve the amount of exercise needed to break the frailty cycle because of pain [10].

In recent years, cooled radiofrequency ablation (CRFA) has gained attention as a novel treatment option for chronic pain associated with KOA. In June 2023, CRFA became eligible for coverage within the Japanese national health insurance system [11]. CRFA is indicated for patients with KOA who have an inadequate response to conventional conservative therapies. It delivers radiofrequency energy to 3 peripheral nerves—the superolateral, superomedial, and inferomedial genicular nerves—to thermally ablate the targeted nerve tissue. CRFA reportedly provides greater pain relief than conservative treatments such as intra-articular corticosteroid [12] and hyaluronic acid [13] injections. It also is less invasive than conventional surgical treatments, including total knee arthroplasty. Improvements in physical function (eg, gait speed) and pain have been reported after CRFA [11].

In addition to continuous measures such as gait speed and muscle strength, frailty-state classification provides an integrated clinical framework for evaluating changes across multiple physical domains. Among patients with KOA, pain-related activity limitations may contribute to the development or progression of physical frailty [7]. Therefore, transitions among frail, prefrail, and robust states may represent clinically meaningful changes in vulnerability and physical reserve that are not fully captured by a single continuous outcome. Accordingly, when KOA-related pain contributes to frailty through reduced physical activity and decreased gait speed, it may be clinically meaningful to evaluate the effects of CRFA for pain relief along with subsequent lifestyle guidance and rehabilitation over time. Thus far, few case reports have extensively described longitudinal changes in pain, physical function, daily activity, and frailty-related indices after CRFA. This case report describes the 1-year course of pain, physical function, daily activity, and frailty status before and after CRFA in an older patient with KOA and physical prefrailty; particular attention is given to changes in frailty status during periods of pain relief, pain recurrence, and rehabilitation.

Case Report

A 74-year-old woman presented with a 5-year history of right knee pain. She had previously received conservative treatments, including pharmacotherapy and intra-articular hyaluronic acid injections, without adequate symptom relief. She was referred to our orthopedic department for further evaluation and treatment. At the initial visit, she was independently ambulatory and able to perform activities of daily living without assistance. Before CRFA, she had not received formal rehabilitation or physical therapy from a physical therapist. She attended an exercise class once per week and had previously walked for exercise but discontinued walking because of knee pain. She hoped that pain relief would make household

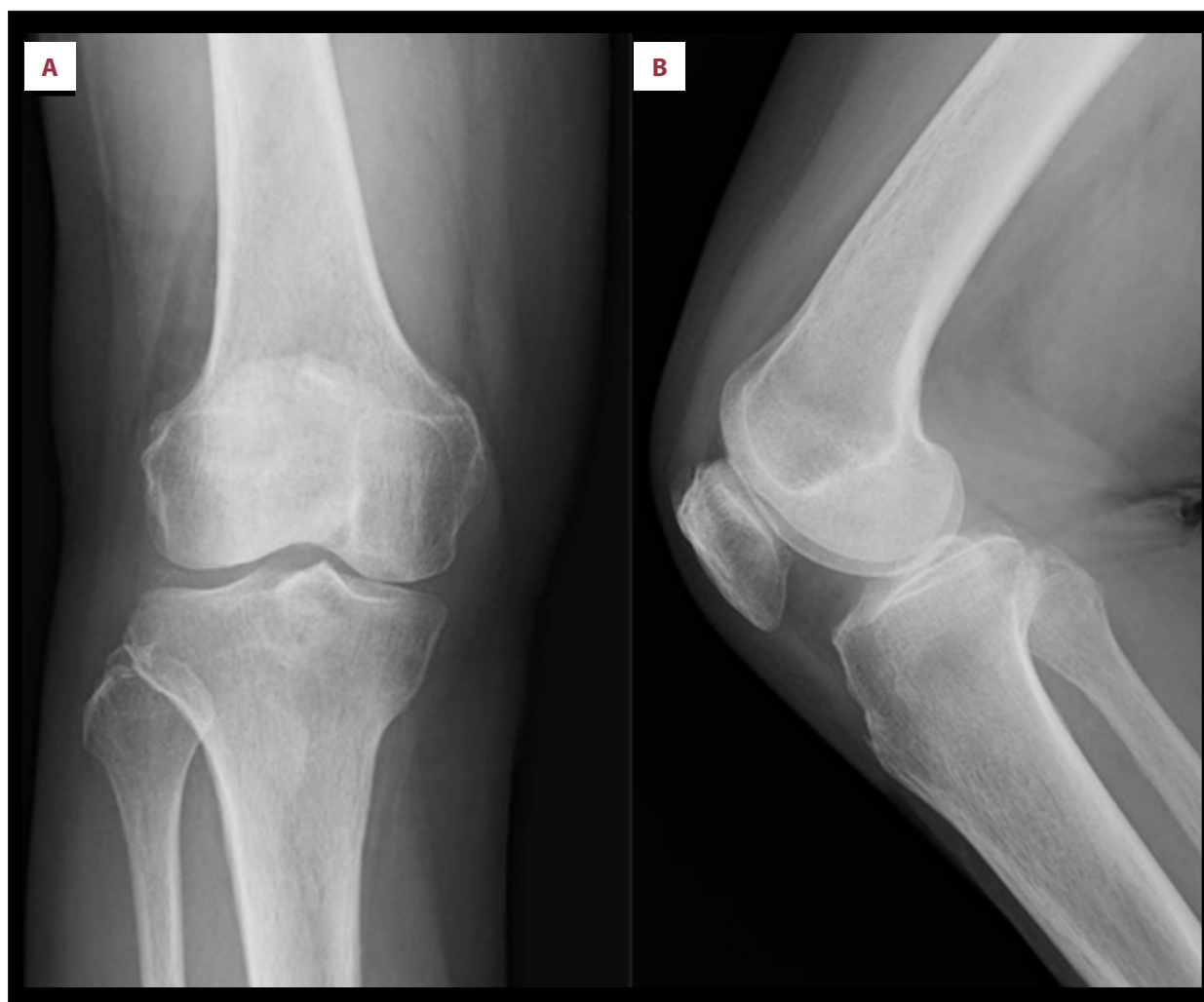


Figure 1. Preprocedural radiographs of the right knee. (A) Anteroposterior view. (B) Lateral view.

tasks easier and allow her to resume walking. Her medical history included breast cancer and uterine cancer. She had been diagnosed with breast cancer at age 43 and uterine cancer at age 50. Although treatment duration and recurrence status could not be confirmed for either condition, she did not require active treatment during the intervention period. She had no history of stroke, neurological disease, severe cardiopulmonary disease, or other musculoskeletal disorders affecting her ability to walk.

Her height was 154.0 cm, and her weight was 46.0 kg (body mass index, 19.4 kg/m²). No joint effusion was observed. Knee range of motion was 0° in extension and 130° in flexion. Pain was present during knee movement and walking, and tenderness was noted along the medial joint line. No local warmth or skin changes were observed. Radiography revealed right KOA classified as Kellgren-Lawrence grade II (**Figure 1**).

Pain intensity was assessed using a 10-cm visual analog scale (VAS), which ranged from 0 cm (no pain) to 10 cm (worst imaginable pain). Before CRFA, the VAS score was 0.0 cm at rest and 3.6 cm during walking. The patient reported persistent concern about knee pain and avoided pain-provoking activities, such as deep knee flexion and squatting. Grip strength was 19.4 kg (maximum of both hands). Gait speed was 0.92 m/s; knee extensor strength, expressed as the weight-bearing index (ie, knee extension strength [kgf]/body weight [kg] × 100), was 26.3% on the right and 32.8% on the left. Physical frailty was evaluated using the revised Japanese version of the Cardiovascular Health Study criteria (J-CHS) [14]. Because her gait speed met the frailty criterion, the patient was classified as physically prefrail.

The intervention protocol is shown in **Figure 2**. One week before CRFA, an ultrasound-guided diagnostic block was performed by injecting 1 mL of 1% lidocaine at each of the superolateral, superomedial, and inferomedial genicular nerve

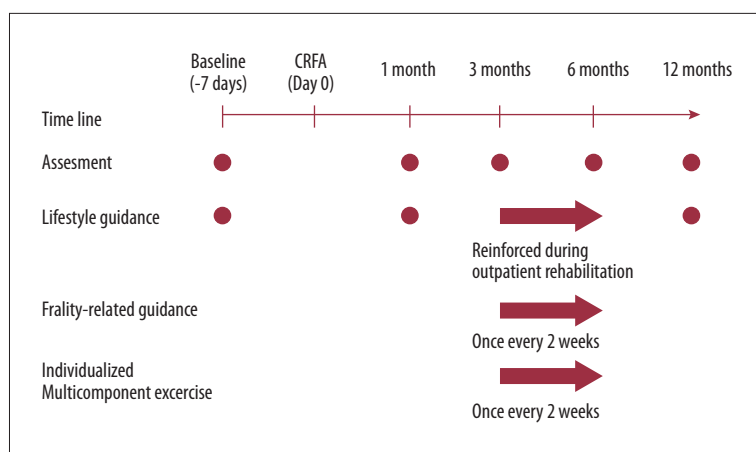


Figure 2. Timeline of assessments and interventions in this case. Baseline assessment and initial lifestyle guidance were provided 7 days before cooled radiofrequency ablation (CRFA). Follow-up assessments were conducted at 1, 3, 6, and 12 months after CRFA. Frailty-related guidance and individualized multicomponent outpatient rehabilitation were provided once every 2 weeks between 3 and 6 months after CRFA. Lifestyle guidance was reinforced during outpatient rehabilitation.

Table 1. Changes in pain, physical function, and frailty assessments.

	Baseline	1 month	3 months	6 months	12 months
Visual analog scale score at rest (cm)	0	0	0	0	0
Visual analog scale score during walking (cm)	3.6	0	3.9	1.3	1.7
Body mass index (kg/m ²)	19.40	19.40	20.25	19.82	19.82
Grip strength (kg)	19.40	19.40	17.60	20.70	20.30
Right knee extensor strength, WBI (%)	26.3	24.8	20.8	27.9	22.3
Left knee extensor strength, WBI (%)	32.8	27	21.7	31.1	29.1
Usual gait speed (m/s)	0.92	1.11	1.19	1.18	1.20
Maximum gait speed (m/s)	1.46	1.80	1.46	1.91	1.68
Revised Japanese version of the Cardiovascular Health Study criteria (points) [items meeting the frailty criterion]	1 [Gaitspeed]	0	1 [Gripstrength]	0	0

Abbreviation: WBI, weight-bearing index (ie, knee extension strength [kgf]/body weight [kg] × 100).

targets. Because the block reduced pain by at least 50% and the patient wished to undergo CRFA, CRFA was subsequently scheduled. At the same visit, the patient was informed that excessive knee loading after pain relief could lead to symptom recurrence. Her daily activities were reviewed; she was advised to avoid high-load activities such as running, rapid stair ascent or descent, squatting, deep knee flexion in the seiza position, and kneeling activities (eg, assuming a quadruped position).

CRFA was performed according to a previously reported method [11] by a board-certified orthopedic surgeon who had completed a training program certified by the Japanese Society for Joint Diseases. Using the Coolief® Pain Management System (Avanos Medical, Inc., Alpharetta, GA, USA), ablation was applied to the superolateral, superomedial, and inferomedial genicular nerves at 60 °C for 2 minutes and 30 seconds each. No adverse events or complications occurred, and the patient was discharged the same day. After CRFA, oral loxoprofen sodium

was administered for 3 days, followed by topical loxoprofen sodium as needed. No additional analgesic medication was administered during the intervention period.

Changes before and after treatment are shown in **Table 1**. At 1 month after CRFA, pain improved to a VAS score of 0.0 cm both at rest and during walking. Gait speed also improved, and frailty status changed from physical prefrailty to robust. Regarding daily activity, the patient resumed walking for approximately 20 minutes per day, an activity she had previously discontinued because of knee pain. At this time point, the revised J-CHS classification changed to robust, associated with pain relief and improved gait speed; however, body weight and knee extensor strength did not improve. Thus, the change in frailty status was mainly attributable to improved gait speed.

At 3 months after CRFA, right knee pain during walking recurred after the patient sat in the seiza position, and the VAS score

Table 2. FITT principles and progression/adjustment criteria for exercise therapy and lifestyle guidance implemented after CRFA.

Item	Description
Frequency	Outpatient rehabilitation: 40-minute sessions every 2 weeks for 3 months (3-6 months after CRFA) Home exercise: ≥ 3 days/week, scheduled twice daily (morning and evening)
Intensity	Resistance training: 60%-70% of 1-repetition maximum Aerobic exercise: ≤ 60% heart rate reserve (Karvonen formula) Perceived exertion: Borg scale ≤ 13
Time	Resistance training: 10-20 repetitions × 1 set per exercise, progressed to 2 sets Aerobic exercise: 10-15 min/session; after resuming walking, approximately 20 min once daily
Type	Resistance training: quadriceps (isometric knee extension), gluteus medius (hip abduction), and upper-extremity band exercises Balance training: tandem stance and single-leg stance (≤ 60 s) Aerobic exercise: cycle ergometer and walking
Progression	Exercise volume was increased if pain during exercise or on the following day (NRS) did not exceed that experienced during daily activities
Pain management	Exercise volume was reduced in consultation with a physical therapist. Progression was paused until pain stabilized, and daily activities were reassessed
Criteria	Persistent pain during exercise or on the following day, or pain interfering with activities of daily living
Adherence monitoring	Home exercise adherence was assessed by patient self-report (sessions/week, duration, and interruptions)
Lifestyle counseling	Seiza: cushion between the buttocks and heels to reduce knee load Floor activities: towel under the knee Deep squatting: replaced with sitting on a chair

Abbreviations: CRFA, cooled radiofrequency ablation; FITT, frequency, intensity, time, and type; NRS, numerical rating scale.

Note: A visual analog scale was used for scheduled pain outcome assessments; an NRS was used during rehabilitation to monitor exercise-related and next-day pain and to guide exercise progression.

during walking increased to 3.9 cm. Although gait speed was maintained, grip strength decreased, and she was classified as physically prefrail according to the revised J-CHS criteria. After pain recurrence, she became reluctant to walk outdoors and participate in exercise classes, suggesting reduced physical activity. Therefore, from 3 to 6 months after CRFA, 40-minute outpatient rehabilitation sessions were provided by a physical therapist once every 2 weeks (7 sessions in total). During outpatient rehabilitation, frailty assessment results were presented to the patient, and information was provided to increase her awareness of frailty. An individualized multicomponent exercise program was implemented, primarily consisting of resistance exercises targeting the quadriceps and gluteus medius, combined with standing balance training and aerobic exercise. Exercises that could be performed at home were prescribed as a home exercise program. Participation in the home exercise program was confirmed by interviewing the patient at each rehabilitation session; however, adherence was not recorded using a standardized exercise diary or monitoring device. Additionally, lifestyle guidance initiated before treatment was reinforced at each session; information about daily activities was also collected. To improve reproducibility, the exercise therapy and lifestyle guidance used in this case were organized according to the frequency, intensity, time, and type

(FITT) principle and progression criteria, and the exercise load was gradually increased after confirmation that pain had not worsened (Table 2).

At 6 months after CRFA, pain during walking improved to a VAS score of 1.3 cm. Gait speed was maintained, grip strength improved, and frailty status again changed to robust. Regarding daily activities, the patient continued to follow instructions to reduce local mechanical stress on the knee joint, such as placing a cushion between the buttocks and heels when sitting in the seiza position and a towel between the knees and the floor when assuming a quadruped position. In addition to walking and attending exercise classes, she planned to compete in a municipal e-sports event after being invited by a friend.

At 12 months after CRFA, walking pain was 1.7 cm (VAS score), indicating that pain relief was maintained compared with the pre-CRFA level. Grip strength and gait speed were also maintained, and the patient remained robust. Because the exercise classes and local events had ended, she maintained her exercise routine by following televised exercise programs at home. During follow-up, her body mass index remained within the normal range, and no change in Kellgren-Lawrence grade was observed.

Discussion

This case report describes the 1-year course of a patient with KOA and physical prefrailty, including improvement in gait speed and frailty status after pain relief following CRFA, recurrence of pain after sitting in the seiza position with subsequent worsening of frailty status, and restoration of robust status after structured outpatient rehabilitation and reinforced lifestyle guidance. Although previous studies have demonstrated improvements in pain and physical function after CRFA, longitudinal evaluations of frailty-related indices remain limited. The present case provides hypothesis-generating clinical implications for a multidisciplinary management approach combining pain control and rehabilitation in patients with KOA.

At 1 month after CRFA, pain relief, improved gait speed, and resumption of walking were observed, and the revised J-CHS classification changed from physical prefrailty to robust. As previously reported [11], pain relief may have reduced pain-related compensatory gait patterns and contributed to improved gait speed. However, because body weight and knee extensor strength did not clearly improve, the change in frailty classification at this time point appeared to be primarily associated with improved gait speed. The clinical course showed that pain relief after CRFA coincided with improved gait speed, resumption of walking, and transition to robust status according to the revised J-CHS criteria. These findings support the hypothesis that pain relief is associated with resumption of activity and improved walking ability. However, it cannot be concluded that CRFA alone improved frailty status or interrupted the frailty cycle.

At 3 months after CRFA, right knee pain during walking recurred after the patient sat in the seiza position, and she was reclassified as physically prefrail because of reduced grip strength. Central pain mechanisms are reportedly associated with muscle weakness not only around the knee joint but also at distal sites [15]; chronic pain has been associated with systemic inflammatory responses and changes in the autonomic nervous and endocrine systems [16-18]. Based on these findings, knee pain recurrence may have affected not only local responses around the knee joint but also systemic muscle strength. However, because pain recurrence, reduced activity, and decreased grip strength occurred during the same period in the present case, it cannot be determined whether knee pain recurrence directly caused the reduction in grip strength. Nevertheless, given that the patient restricted walking and participation in exercise classes after pain recurrence, the pain recurrence and reduced physical activity may have been associated with her reclassification as physically prefrail.

Unlike surgical treatment such as total knee arthroplasty, CRFA is characterized by early improvements in pain and gait speed

without directly correcting the underlying joint deformity. Therefore, post-treatment management may benefit from including not only supervised exercise therapy but also comprehensive interventions, such as early and continuous guidance on daily activities to avoid excessive joint loading that may exacerbate pain or increase mechanical stress on the joint. Arthritis education and exercise therapy for patients with KOA reportedly improve pain and physical function [8,9,19]. Additionally, multicomponent exercise therapy is recommended to prevent the progression of frailty and frailty-related decline [3]. Based on these considerations, outpatient rehabilitation from 3 to 6 months in the present case included repeated education concerning frailty, multicomponent exercise primarily focused on lower-limb strengthening, home exercise instruction, and guidance on daily activities. Exercise load was gradually increased using case-specific progression criteria only after confirmation that exercise did not exacerbate pain. At 6 months, pain during walking decreased, grip strength improved, and the patient returned to robust status, which was maintained at 12 months. Furthermore, pain relief, improved grip strength, and return to robust status occurred during the same period following individualized outpatient rehabilitation and reinforced lifestyle guidance. This course suggests that, in addition to pain relief after CRFA, guidance to avoid pain-provoking daily movements and exercise intervention may have been associated with increased activity. However, the independent effects of rehabilitation and lifestyle guidance cannot be determined from the present single case.

This case report has 3 principal limitations. First, because it describes a single case, the generalizability of the findings is limited. The patient had relatively mild-to-moderate KOA (Kellgren-Lawrence grade II), was independent in activities of daily living, and exhibited physical prefrailty rather than physical frailty. Moreover, pain recurrence was precipitated by sitting in the seiza position, a high-load knee posture associated with the Japanese lifestyle. Accordingly, the observed clinical course may be most applicable to older adults with mild-to-moderate KOA whose physical activity is limited by pain and who have prefrailty or early signs of frailty. It remains uncertain whether a similar course would occur in patients with more advanced joint deformity, established physical frailty, severe comorbidities, or different lifestyles and pain-provoking activities. Additionally, the patient's preserved independence in activities of daily living, pre-existing exercise habits, and physical and cognitive capacity to participate in supervised and home-based exercise may have facilitated the observed recovery. Therefore, the clinical course observed in the present case may not be generalizable to individuals with greater functional impairment, lower motivation to exercise, cognitive impairment, or limited social support.

Second, this case does not allow the independent contributions of CRFA, lifestyle guidance, the natural course, changes in physical activity, and outpatient rehabilitation to changes in pain, physical function, or frailty status to be determined. Pain relief after CRFA may have facilitated the resumption of walking and exercise; however, subsequent pain recurrence, reduced physical activity, lifestyle guidance, and exercise therapy may have interacted over time to influence the clinical course. Thus, the improvements in frailty status and physical function observed in the present case cannot be exclusively attributed to either CRFA or rehabilitation.

Finally, changes in frailty status should be interpreted cautiously because the revised J-CHS criteria are based on pre-defined thresholds. When gait speed or grip strength is close to a cutoff value, even a small change in the measured value may alter frailty classification despite only a modest underlying physiological change. Natural temporal variation, measurement variability, and regression to the mean also may have contributed to the observed transitions between prefrail and robust states. Accordingly, changes in frailty classification should not be solely attributed to CRFA or rehabilitation. Future prospective studies involving larger numbers of patients are needed to examine the longitudinal relationships among pain, physical activity, exercise therapy, and frailty-related indices after CRFA.

Conclusions

In our patient with KOA and physical prefrailty, gait speed improved during the same period as pain relief after CRFA, and the revised J-CHS classification changed to robust. Subsequently, pain recurrence triggered by sitting in the seiza position and reduced activity were accompanied by reclassification as physically prefrail. After structured outpatient rehabilitation and reinforced lifestyle guidance, the patient returned to robust

status at 6 months, which was maintained through 12 months. This report does not establish the effectiveness of CRFA or rehabilitation for improving frailty; however, it generates 2 hypotheses for future research. First, frailty status may be a relevant longitudinal outcome after CRFA. Second, rehabilitation initiated after pain relief may help selected patients translate symptomatic improvement into sustained functional recovery. This clinical course is a hypothesis-generating observation that suggests the clinical importance of evaluating changes in frailty status among prefrail patients with KOA whose activity is limited by pain, particularly in relation to pain relief after CRFA, pain recurrence, reinforced lifestyle guidance, and staged rehabilitation. The independent effects of CRFA, lifestyle guidance, and rehabilitation should be examined in future case series or prospective studies.

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Institution Where Work Was Done

Himi Municipal Hospital, Himi, Toyama, Japan.

Patient Consent

Written informed consent was obtained from the patient for publication of this case report and any accompanying images. All procedures performed in this study were conducted in accordance with the ethical standards of the authors' institution.

Declaration of Figures' Authenticity

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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