A new technique of percutaneous minimally invasive surgery assisted by magnetic resonance neurography

a retrospective analysis of 30 adults with moderate-to-severe gluteal muscle contracture

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Aims

In order to release the contracture band completely without damaging normal tissues (such as the sciatic nerve) in the surgical treatment of gluteal muscle contracture (GMC), we tried to display the relationship between normal tissue and contracture bands by magnetic resonance neurography (MRN) images, and to predesign a minimally invasive surgery based on the MRN images in advance.

Methods

A total of 30 patients (60 hips) were included in this study. MRN scans of the pelvis were performed before surgery. The contracture band shape and external rotation angle (ERA) of the proximal femur were also analyzed. Then, the minimally invasive GMC releasing surgery was performed based on the images and measurements, and during the operation, incision lengths, surgery duration, intraoperative bleeding, and complications were recorded; the time of the first postoperative off-bed activity was also recorded. Furthermore, the patients' clinical functions were evaluated by means of Hip Outcome Score (HOS) and Ye et al's objective assessments, respectively.

Results

The contracture bands exhibited three typical types of shape – feather-like, striped, and mixed shapes – in MR images. Guided by MRN images, we designed minimally invasive approaches directed to each hip. These approaches resulted in a shortened incision length in each hip (0.3 cm (SD 0.1)), shorter surgery duration (25.3 minutes (SD 5.8)), less intraoperative bleeding (8.0 ml (SD 3.6)), and shorter time between the end of the operation and the patient's first off-bed activity (17.2 hours (SD 2.0)) in each patient. Meanwhile, no serious postoperative complications occurred in all patients. The mean HOS-Sports subscale of patients increased from 71.0 (SD 5.3) to 94.83 (SD 4.24) at six months postoperatively ($p < 0.001$). The follow-up outcomes from all patients were "good" and "excellent", based on objective assessments.

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Conclusion

Preoperative MRN analysis can be used to facilitate the determination of the relationship between contracture band and normal tissues. The minimally invasive surgical design via MRN can avoid nerve damage and improve the release effect.

Take home message

- Our research used the visualized magnetic resonance neurography to assist minimally invasive release surgery in the treatment of gluteal muscle contracture (GMC), which not only provides an important reference for further research on the morphological classification and pathological mechanism of GMC, but also improves the effect of minimally invasive surgery in the treatment of GMC and patient satisfaction.

Introduction

Gluteal muscle contracture (GMC), i.e. gluteal fibrotic contracture, is a clinical syndrome characterized by contracture, fibrosis, and even degeneration of the gluteal muscles, iliotibial band (ITB), and their associated fascia,[1] which was first described in 1981.[2] GMC distributes around the world in Asia, Europe, Africa, and North America, and its prevalence rate is estimated to be between 1% and 2.5%.[3] GMC is mostly associated with repeated intramuscular injections into the buttocks, resulting in fibrosis and contracture.[1,4] Other causes of acquired GMC are injuries and surgeries around hips.[5]

Patients with GMC typically complain of the inability to squat with knees together and sit with legs crossed.[6] The treatment of GMC covers non-surgical management, different types of surgical management, and programmed rehabilitation and physiotherapy.[7-11] When a patient is suffering from GMC, nonoperative treatment seldom plays an effective role.[1,6,12] Different surgical methods have been applied for removing or dividing fibrous bands to obtain normal function and movement, including techniques of conventional open surgery, endoscopic release, and minimally invasive release.[3,6,13,14]

The conventional open surgery for GMC usually produces haematoma formation, wound complications, slow postoperative recovery, and unsightly skin scarring.[13-15] Such hypertrophic or keloid scars (averaging 7 cm in width) in the buttocks and thighs often have a negative psychological effect on patients.[6]

Compared with conventional open surgery, arthroscopic release has the advantage of small skin wounds (2 to 3 cm), earlier rehabilitation, and minimal complications.[1,6,16,17] However, there are three main limitations to the technique itself. First, it is difficult to manipulate arthroscopes within the narrow artificial space close to the greater trochanter when the affected hip is gradually passively flexed, adducted, and internally rotated during surgery.[6] Second, not only is the arthroscope hard to access effectively,[16] but it is also easy to damage the sciatic nerve due to the existence of blind spot when the GMC involves the external rotators of the hips or joint capsules. ccopic operation, which can result in side effects on the healthy soft-tissues.[6]

One minimally invasive release method for GMC was introduced by Ye et al[6] in 2012. By using a specially designed scalpel via several small incisions (usually 3 mm), the contracture bands were divided into different anatomical points around the greater trochanter in a supine position.[1,6] This method has the advantage of small surgical incision, cosmetic benefits, and short operating time. Compared with arthroscopic surgery, it is more effective when deeper structures are involved.[1,6] Similar to Ye et al's method, our group has also established a novel minimally invasive method for the treatment of GMC. The contracture band could be released through one to three small incisions inferior to the tip of greater trochanter. Since 2010, we have used the method to treat more than 400 GMC patients. Although Ye et al's method and ours appear simple and easy to do operatively, both methods demand much more attention because of the high risk of accidental injury during surgery,[1] especially when the relationship between contracture bands and normal tissues (such as the sciatic nerve) cannot be accurately identified under minimal incisions in patients with severe external rotation of the hips.

MRI is an efficient imaging modality for evaluating the pathological conditions of GMC.[11] Muscle atrophy and intramuscular fibrotic bands, as a low-intensity signal in all sequences, are two major MRI features of GMC.[18] By suppressing the signal from adjacent tissue, magnetic resonance neurography (MRN) is more effective for showing nerves. Furthermore, the path of the sciatic nerve was visualized

Table I. Parameters of magnetic resonance NerveVIEW.

Parameters	NerveVIEW
Orientation	Coronal
Acquired voxel (mm)	1.1 × 1.1 × 2.0
Field of view (mm)	250 × 324 × 150
Slices	150
TR (ms)	2,300
TEequiv (ms)	176
TSE factor	51
Refocusing pulses	Tissue-specific (nerve)
Min angle (°)	25
Max angle (°)	110
Fat suppression	STIR
Inversion recovery delay (ms)	280
Pulse type	OIT broad adiabatic
MSDE	
Refocusing type	OIT broad adiabatic
VENC (cm/s)	2
TEprep pulse	23.7
Time	6 mins 33 s

MSDE, motion-sensitive driven equilibrium; OIT, offset independent trapezoid; SPAIR, SPectral Attenuated Inversion Recovery; STIR, short TI inversion recovery; TEequiv, echo time equivalent; TEprep, echo time preparation; TR, repetition time; TSE, turbo spin echo; VENC, velocity encoding.

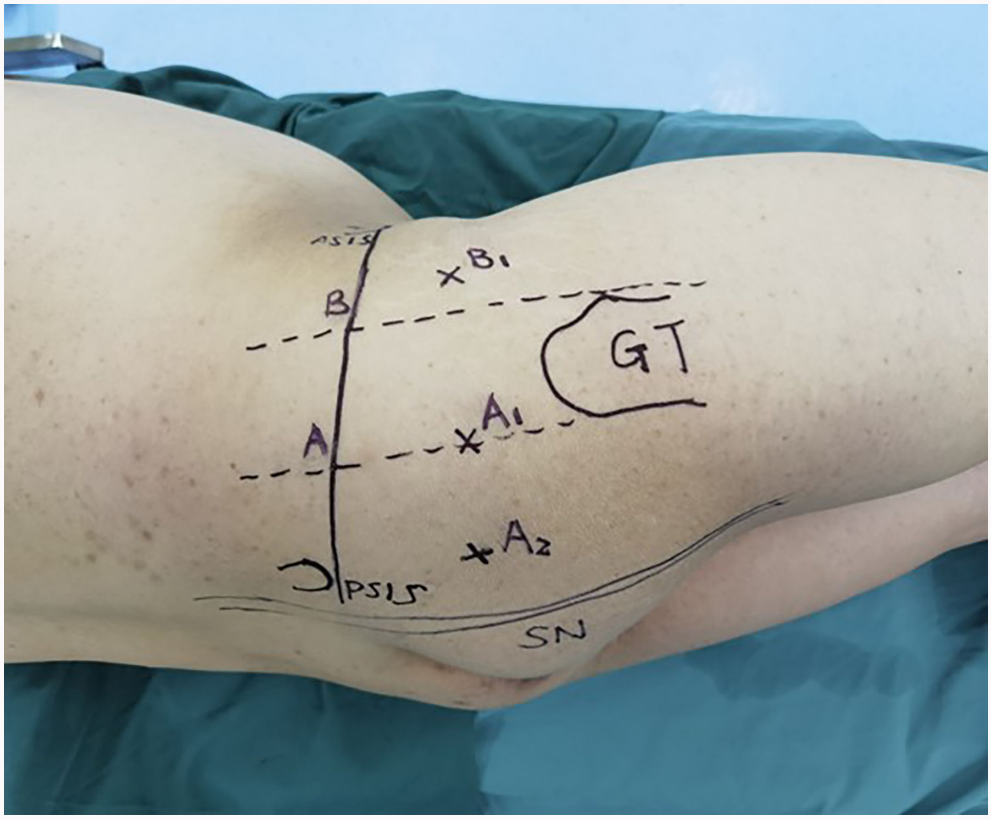

Fig. 1
Photograph showing confirmation of points A1 and A2 for skin markers. ASIS, anterior superior iliac spine; GT, greater trochanter; PSIS, posterior superior iliac spine; SN, sciatic nerve.

a b

Fig. 2
a) Contracture release surgery was performed with a special scalpel though the preoperative designed incision (first at point A2, then at point A1 if required). b) The incision was wiped dry and sealed by a beauty pull tape.

by using a modified 3D image NerveVIEW sequence (Philips Healthcare, UK).[19] Therefore, in this study, we intended to introduce visual MRN to minimally invasive surgery to create a novel MRN-guided minimally invasive technique for GMC releasing in adults.

Methods

Study design

The present study was approved by the ethics committee of hospital in accordance with the Declaration of Helsinki.[20] All patients signed consent forms to participate in the study. From January to December 2022, 44 patients with bilateral GMC who had failed to improve by means of nonoperative treatment underwent minimally invasive release in our hospital (Xijing Hospital, China). The inclusion criteria were: 1) moderate-to-severe GMC diagnosed through medical history, symptoms, and physical examination according to Zhao et al's[7] classification system; 2) no response to conservative treatment for at least six months, and their daily lives were disrupted by

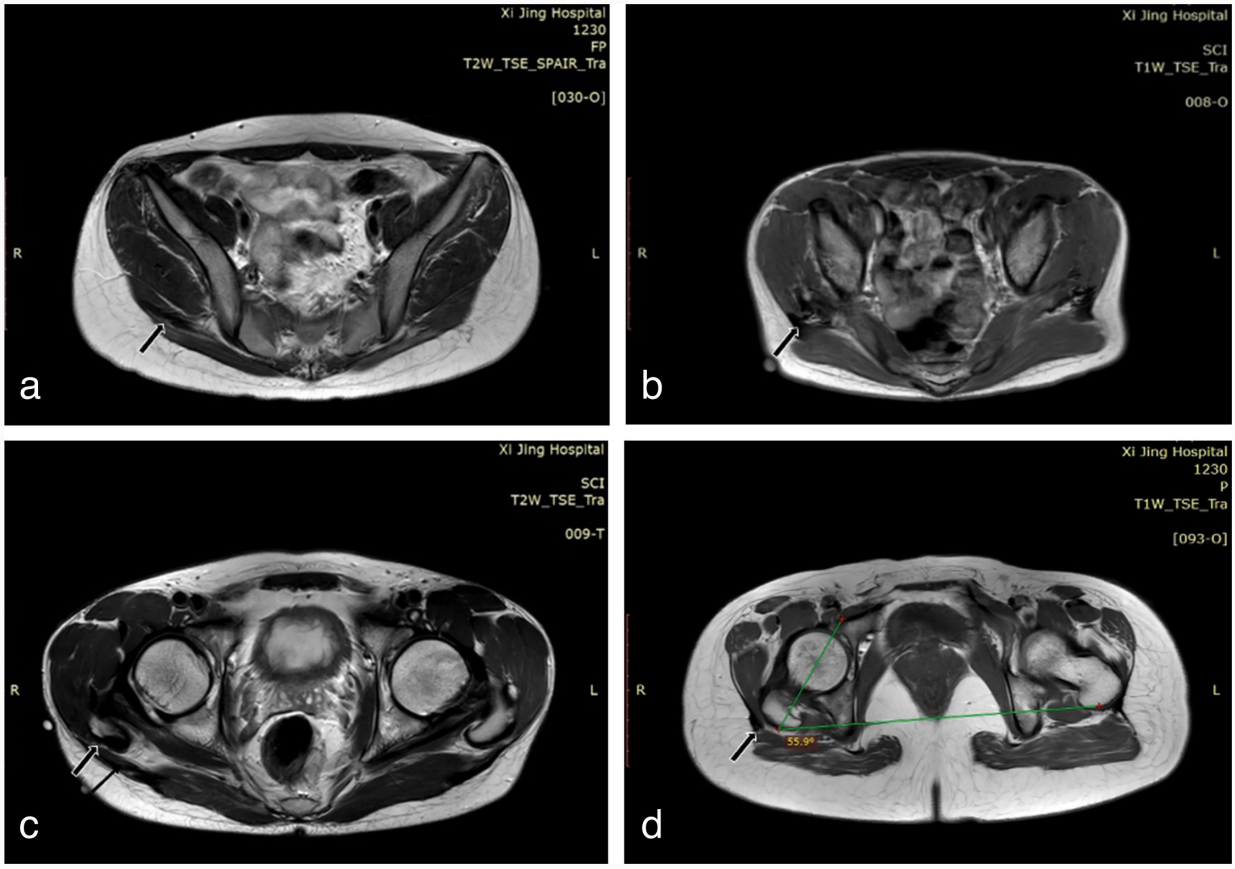

Fig. 3
Contracture bands mostly displayed three types of MR morphology: a) feather shapes, b) strip shapes, and c) mixed shapes. d) In some cases, the thicker fibrotic contracture caused medial retraction of the affected muscles, resulting in the external rotation of proximal femur. Arrow indicates contracture bands.

Table II. Contracture band morphology and symptom severity.

Symptom severity	Feather-like shape	Striped shape	Mixed shape	Total
Moderate	36	8	0	44
Severe	2	8	6	16
Total	38	16	6	60

Table III. Measurements in different shapes of gluteal muscle contracture (n = 30).

Shape	Mean D_{fs}, cm (SD)	Mean external rotation angle, ° (SD)
Feather	5.34 (0.82)	25.09 (5.92)
Striped	3.41 (0.23)	34.54 (1.69)
Mixed	2.22 (0.38)	45.95 (2.97)
p-value	p < 0.001*	p < 0.001*

*Analysis of variance (F test).

this disease; 3) their hips had been scanned by MRN preoperatively; and 4) had undergone minimally invasive release.

Furthermore, patients with the following presentations were excluded: 1) clinical or radiological evidence of spinal or lower limb neurological problems; 2) clinical or radiological evidence of hip dysplasia or subluxation; 3) medically unfit for surgery under general anaesthesia or spinal anaesthesia; and 4) coagulopathy. Additionally, those with a follow-up time < six months were excluded. Thus, a total of 30 patients (with 60 hips) were included in this study.

Based on clinical manifestations,[7] 44 hips were classified as moderate (ten males with both hips and 11 females with both hips, two females with one right hip) and 16 as severe patients (two males with both hips and five females with both hips, two females with left hip). The Hip Outcome Score (HOS)[21] was used for subjective evaluation, which contains two subscales: the Activities of Daily Living (HOS-ADL) and Sports subscales (HOS-Sports).[13] All the operations were performed by the authors of this article (JG, TW, LB).

Image viewer

MRN was used for preoperative evaluation of GMC in each patient. Prior to MRN scan, two oily capsules were placed on the skin surface of the affected hip to act as the marker. First, a line was drawn from the anterior superior iliac spine (ASIS) to the posterior superior iliac spine (PSIS), which was defined as the iliac spine line (ISL). Next, two lines were drawn

a b

Fig. 4
a) In the strong T2-Weighting axial image, the distance from oily capsules to fibrotic contractures was measured. R: oily capsule; arrow: fibrotic contracture. b) The distance from the oily capsule to the sciatic nerve was measured in the 3D images. Arrow: sciatic nerve.

Fig. 5
An example of patient-reported cosmetic satisfaction at six months postoperatively.

Table IV. Preoperative and postoperative patient characteristics.

Characteristic	Value
Mean age, yrs (SD)	27.3 (4.8)
Male/female, n	12/18
Zhao's GMC classification,[7] number of hips	
Mild	0
Moderate	44
Severe	16
Mean incision length per hip, cm (SD)	0.3 (0.1)
Mean operating time, mins (SD)	25.3 (5.8)
Mean intraoperative bleeding volume, ml (SD)	8.0 (3.6)
Mean time until postoperative off-bed activity, hrs (SD)	17.2 (2.0)
Analgesia required on the first postop day, n (%)	
No	18 (60)
Yes	12 (40)
VAS on the third postop day, n (%)	
0	28 (93)
1	2 (7)

GMC, gluteal muscle contracture; VAS, visual analogue scale.

from either the anterior or posterior margin of the greater trochanter to meet ISL at points A and B. Then, point A1 was obtained by extending about 4 cm from point A to distal limb, along the posterior margin of the greater trochanter. Point A2 was determined by extending 5 cm from point A1 parallel to ISL. Two oily capsules were placed at the aforementioned two points by tapes (Figure 1). MRN scans of pelvis including the buttocks and hips were performed in a supine position via a 3.0 T system (Ingenia 3.0 T CX; Philips Healthcare), with a 32-channel torso array coil. Specific scan parameters referred to in De Paepe et al[19] with modifications are detailed in Table I.

Image measurement and analysis

From the native images, the distance between oily capsules and the fibrotic contractures was measured and was defined as d_1. Similarly, the distance from oily capsules to the sciatic nerve was measured in the 3D images and was defined as d_2.

Table V. Clinical outcomes.

Outcome	Preop	6 mths postop	p-value
Mean HOS-ADL (SD)	78.2 (4.9)	96.5 (3.7) *	< 0.001*
Mean HOS-Sports (SD)	71.0 (5.3)	94.8 (4.2) *	< 0.001*
Ye et al[6] evaluation criteria, n (%)			< 0.001†
Excellent		27 (90)	
Good		3 (10)	
Poor		0	
Patient-reported cosmetic satisfaction, n (%)		30 (100)	< 0.001†
Patient-reported functional satisfaction, n (%)		29 (96)	< 0.001†
Recurrence, n (%)			< 0.001†
No		30 (100)	
Yes		0	

*Independent-samples *t*-test.
†Fisher's exact test.
HOS-ADL, Hip Outcome Score-Activities of Daily Living subscale; HOS-Sports, Hip Outcome Score-Sports subscale.

The distance from fibrotic contracture to sciatic nerve named as d_{fs} was calculated by d_2 minus d_1. The contracture band shape and external rotation angle (ERA) of proximal femur were also analyzed according to references.[18,22] The minimally invasive GMC releasing surgery was then performed based on the images and measurement results. The above mentioned measurements were performed by RadiAnt DICOM Viewer software (Medixant, Poland).

Surgical methods

After general anaesthesia or spinal anaesthesia, the patient was placed in a lateral position with the affected limb upside. One of the authors of this article (JC) faced the patient and fixed the pelvis and torso to avoid movement, while assistant (TW) stood behind the patient and placed the affected limb in a hip flexion and knee flexion adduction position to keep the contracture band tension. After skin disinfection, the surgeon stood behind the patient and performed the contracture release surgery with a special scalpel through the preoperative designed incision (first at point A2, then at point A1 if required). Points A1 and A2 were commonly used minimally invasive entrances (Figure 2a). The length and direction of scalpel were controlled according to the predesigned scheme.

The contraction bands were gradually released from superficial to deep. Assistant B repeatedly performed passive hip joint movements to check for residual contracture structures. To improve releasing effects, an additional surgical entrance point (point B) was sometimes used ahead the extension of greater trochanter posterior margin. Due to being far from important tissues, this point was not marked (Figure 1).

The surgery was deemed finished when an audible snapping sound or palpable movement of the contraction bands could no longer be detected. After the wound was irrigated with iced saline solution three times, the incision was wiped dry and sealed by a beauty pull tape followed by wrapping with sterile dressing (Figure 2b). The release of other side was operated similarly. Finally, both wounds were compressed by a pelvic strap to minimize the possibility of haematoma formation postoperatively.

Postoperative rehabilitation

Rehabilitation exercises started from the day of surgery or from the first day after surgery. The duration of each exercise was determined by the patient's tolerance, usually no less than ten minutes. The beauty pull tapes were removed within two weeks.

Patient evaluation

Incision lengths, operating time, intraoperative bleeding volume, the time of the first postoperative off-bed activity, complications, and recurrence were recorded. Additionally, the visual analogue scale (VAS) was applied for pain evaluation.[21] At six months postoperatively, the patients' clinical functions were also evaluated subjectively and objectively according to reference.[13] The postoperative subjective evaluation was carried out using HOS, while the objective clinical evaluation was performed by using the assessment criteria Ye et al[6] and Rai et al[13] set as references. All 30 patients were followed up at a mean of 6.63 months (SD 0.24, 6.2 to 7.3) postoperatively.

Statistical analysis

Incision lengths, operating time, intraoperative bleeding, off-bed activity time, ERA, and HOS are presented as means and SDs. The d_{fs} and ERA were analyzed with analysis of variance (ANOVA) (F test) and non-parametric tests (Kruskal-Wallis H test). HOS was analyzed with independent-samples *t*-test. Ye et al's[6] evaluation criteria and patient-reported satisfaction were analyzed with Fisher's exact test. p 0.05 was considered as a statistically significant difference. Data analysis was performed using SPSS v. 17.0 software (SPSS, USA).

Image results

MR images of the patients showed marked atrophy of gluteus maximus in the presence of fibrotic bands, which are contiguous to the iliotibial tract.[23] The fibrotic bands showed low signal intensity on all sequences, and were most visible on fat-suppressed images. The contracture bands mostly displayed three types of MR morphology, which are feather-like, striped, and mixed shapes (Figure 3a to 3c). The feather-like contracture bands were mainly formed in the superficial part of gluteus maximus muscle and seldom involved its deep tissues. It usually started from the posterior upper part of greater trochanter and gradually extended to the upper thirds of gluteus maximus muscle (Figure 3a). By contrast, the striped contracture band affected the full thickness of the gluteus maximus muscle, and even reached the gluteus meius, gluteus minimus, and piriformis. Although the width of the striped contracture band was not as wide as the feather-like one, it looked thicker and tighter. A depressed groove could be found at the muscle-tendon junction (Figure 3b). As for the mixed GMC, both striped and feather-like contracture could be found on MRI, and the involved fibrotic tissues became wider and thicker (Figure 3c). In some striped or mixed-shaped

Table VI. Criteria for objective clinical evaluation.

Items	Criteria	Scores
Closing knees together while squatting and standing	Squatting and standing freely	3
	Squatting and standing partly with help	2
	Squatting and standing wholly with help	1
	Unable to squat or stand	0
Crossing and overlapping the legs with 90° flexion of the hip and knee joint	Crossing and overlapping the legs freely	3
	Crossing and overlapping the legs partly with help	2
	Crossing and overlapping the legs wholly with help	1
	Unable to cross and overlap the legs	0
Ambulation	No waddling gait involuntarily	2
	No waddling gait consciously	1
	Waddling gait consciously	0
Gliding of fibrotic band in the iliotibial tract	No gliding of fibrotic band and no resistance	2
	Gliding of fibrotic band, and no resistance felt	1
	No gliding of fibrotic band, but resistance felt	0

Total scores: excellent 9 to 10, good 7 to 8, poor 0 to 6.

cases, the thicker fibrotic contracture caused medial retraction of affected muscles, resulting to the external rotation of proximal femur (Figure 3d). The correspondence between imaging findings and clinical symptoms is displayed in Table II. Patients with feather-like contracture band predominantly present with moderate symptoms, while those with striped or mixed fibrotic bands often showed severe symptoms.

Measurement results

As the largest nerve bundle in the pelvis, images of the sciatic nerve were clearly visible in MRN images. The oily capsules at the affected hips displayed high signal intensity on all sequences. High-quality images of each case were acquired, which were defined as at least five individual nerve roots combined with the sciatic nerve.[19] In the sT2W axial image (Figure 4a), the mean distance between oily capsules and fibrotic contractures was 4.64 cm (SD 0.99), while that from the oily capsule to the sciatic nerve was 9.15 cm (SD 1.13) in the 3D images (Figure 4b). Based on the measurements of each case, when the d_{fs} in different shapes of contracture bands was compared (Table III), the mean value of the feather-like group was 5.34 cm (SD 0.82), which was much higher than that of the other groups ($p < 0.001$, ANOVA). Moreover, the minimum d_{sf} in the mixed group was 1.74 cm, and the ERA in both striped and mixed groups was higher than that of the feather-like group ($p < 0.001$, ANOVA).

Feasibility and surgical outcomes

The basic surgical outcomes of patients are illustrated in Table IV. The length of incision in each affected hip, the duration of releasing procedure, the intraoperative bleeding volume, and the time of postoperative off-bed activity were shorter, fewer or less than references.[6,15] In total, 18 patients (60.0%) required postoperative analgesia, while 12 (40.0%) did not at the day of surgery. Three days after operation, 28 patients (93.3%) complained of pain, as measured by VAS score.

Clinical results

Table V summarizes the clinical outcomes of patients at six-month follow-up. All the patients could squat with knees together and sit with legs crossed. The mean HOS-ADL score had increased from 78.2 (SD 4.9) to 96.5 (SD 3.7) and the HOS-Sports score increased from 71.0 (SD 5.3) to 94.8 (SD 4.2). According to the criteria of Table VI, the objective clinical function was "excellent" in 27 patients (90%), and "good" in three (10.0%). Moreover, all patients expressed cosmetic satisfaction (Figure 5). There was no recurrence of GMC.

Complications

There were no wound infections and no sciatic nerve injuries in any of the patients. Postoperative bruising was observed in three patients as an early complication, which took two weeks to be cured after continuous compression and bandaging. A total of 16 patients experienced mild waddling gait after the surgery; 14 patients returned to normal within four weeks, and two returned to normal within six weeks.

Discussion

Compared with arthroscopic release, the minimally invasive release technique used in this study does not need much operating space, and is not affected by the movement of joints during surgery. Only a specially designed scalpel, in which the blade was attached to the handle via 1 to 3 small approach (average 0.3 cm), is needed in operation. Moreover, the surgical instrument (scalpel) can enter deeper into the tissues and obtain a greater releasing effect.

The contracture bands in 63% of cases (38 hips) were formed in the upper and middle third of the gluteus maximus,

and were contiguous to the iliotibial tract as evidenced by horizontal and coronal images described in literature.[23] This may be due to the fact that in order to avoid injury to the sciatic nerve, the outer upper muscle attached to region of the buttocks is often chosen as the site of intramuscular injection. In some cases, the contracture bands became thicker and further involved deeper tissues, such as the gluteus medius and piriformis, in addition to the gluteus maximus. To achieve a complete release effect, the surgical instrument needs to be inserted deeply. In the present study, we found that the shortest distance from the contracture band to the sciatic nerve was 1.7 cm. If the angle of entry or the direction of release were not well controlled, there would be a higher risk of nerve damage.[3]

Based on MRN images, distances between skin marker and both contracture bands and sciatic nerve were firstly measured and analyzed in this study. Since the approach point, contracture band, and sciatic nerve cannot all be displayed in a 2D image, we determined the safe distance by comparing the difference (d_{fs}) between the two distances. If the value of the former is much larger than that of the latter (e.g. more than 3 cm), we believe that the sciatic nerve is in a safe range. As long as the depth of knife access is restricted, the sciatic nerve will not be affected. If the value is less than 3 cm, we will further judge the position relationship between contracture band and sciatic nerve in the 3D image. If the two are still close to each other in the 3D images, we will reduce the risk by adjusting the angle of the scalpel and the direction of release. Since we actually determine the safe distance by comparing the difference between the two distances (d_{fs}), rather than directly relying on the absolute value of the distance between the contracture belt and the sciatic nerve to determine the surgical method, this can avoid the impact of changes in the position of the sciatic nerve due to changes in the patient's position.

We found that the thickening band not only caused the medial retraction of gluteus muscles, which can lead to internal rotation of the proximal femur, but also formed a significant depressed groove on the muscle surface on MRI. Patients often present with small buttocks or cone-shaped buttock, and Ober's sign was strongly positive.[3] Since the contracture band retracted backwards and was closer to the sciatic nerve, it was more prone to result in accidental injury when released.

Additionally, we found that although the striped contracture band is thicker and deeper, its involvement was narrower and could generally be completed through one minimally invasive approach (about 0.2 cm length). By contrast, although the feather-like contracture band is located on the surface of the gluteal muscle, due to its wide distribution it often required two or three approaches (0.4 to 0.6 cm) to complete the release. However, once a mixed contracture band was encountered, the releasing depth and width would increase. In order to reduce the damage to the gluteus medius and decrease the occurrence of gait instability (such as Trendelenburg gait), we first chose one or two approaches (point A2 and A1) at the posterior edge of the gluteus medius for releasing. If the contracture belt was very extensive and the above method could not be used to loosen the contracture belt, we would add another approach (point B) to the proximal extension of trochanteric anterior margin.

There are some limitations in the present study. First, the sample size is relatively small and the follow-up duration relatively short. In order to determine the relationship between imaging findings and clinical symptoms, more clinical cases will be needed. Although each patient received a follow-up period of more than six months, we believe that if the follow-up period is increased, the patient's hip function will be better restored. Second, there is no postoperative MRI for further evaluation of contracture bands. Due to good functional recovery, no patient was willing to undergo a postoperative MRN scan. Third, we only assessed the sciatic nerves in relation to the contracture band. In fact, other nerves and blood vessels, such as the superior gluteal artery, superior gluteal nerve, inferior gluteal artery, and inferior gluteal nerve can also be found on MRI, which are not assessed in this study due to the limited quality of typical pictures. Finally, the study is only restricted to use of the minimally invasive surgical approach; histological evidence was not obtained.

In summary, we investigated the anatomical relationship between the sciatic nerves and contracture bands in GMC patients through the use of 3D MRN images. We determined a safe procedure before minimally invasive release based on the patients' MRN imaging. By using this safe procedure and preoperative planning, complications could be reduced during minimally invasive surgery.

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Data sharing

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Ethical review statement

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