Surgical decompression via the unilateral intervertebral foraminal approach with local anesthesia for treating elderly patients with lumbar central canal stenosis

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OBJECTIVE Surgical decompression via a posterior interlaminar approach is widely used for treating lumbar central canal stenosis (LCCS). However, this surgical approach poses a challenge for elderly patients with comorbidities. Thus, the authors tried a new surgical decompression via the unilateral intervertebral foraminal approach with local anesthesia to treat such patients. The aim of this study was to evaluate the safety and effectiveness of surgical decompression via the unilateral intervertebral foraminal approach with local anesthesia for patients with LCCS.

METHODS Patients with LCCS who underwent surgical decompression, performed by a single surgeon, between January 2016 and March 2019 were retrospectively analyzed. All patients received decompression via the unilateral intervertebral foraminal approach with local anesthesia. Visual analog scale (VAS) scores, Oswestry Disability Index (ODI) scores, modified Macnab criteria, walking distance, and Schizas classification were used as outcome predictors. Additionally, a decompression evaluation method was designed for use after spinal endoscopic surgery.

RESULTS Overall, 23 patients with a mean age of 69 years were included in this study, with a mean follow-up of 28 months. Low-back and leg pain were significantly improved after decompression surgery. Postoperative ODI scores and walking distances were statistically significantly better than before surgery. Postoperatively, the Schizas classification for all patients was improved by at least 1 grade compared with the preoperative grade. No complications occurred during the follow-up period. According to the novel decompression evaluation method, all patients had at least achieved decompression in part 123+B.

CONCLUSIONS Surgical decompression via the unilateral intervertebral foraminal approach with local anesthesia showed promising outcomes in the treatment of elderly patients with LCCS. Additionally, a proposed postoperative decompression evaluation method can help guide surgical decompression.

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KEYWORDS lumbar central canal stenosis; LCCS; surgical decompression; intervertebral foraminal approach; local anesthesia

LUMBAR spinal stenosis (LSS) is one of the most common causes of low-back and leg pain among elderly patients.¹ With the degeneration of the lumbar spine, elderly patients will have bulging of the intervertebral disc, cohesive hyperplasia of facet joints, and hypertrophy of the ligamentum flavum, which leads to narrowing of the lumbar spinal canal and compression of the nerves and blood vessels in the spinal canal.² As well as having low-back and leg pain, such patients are usually unable to walk and stand for long periods of time.³

For patients for whom conservative treatment has failed, a variety of surgical decompression methods can achieve good results.⁴ Open surgery is traumatic, and the incidence of complications is as high as 4.8% to 8.8%.^{5,6} Additionally, elderly patients often have systemic diseases and poor tolerance to open surgery under general anesthesia. Therefore, minimally invasive surgery with local anesthesia is more suitable for elderly patients, especially for those with systemic diseases such as cardiopulmonary disease.

In recent years, spinal canal decompression under spi-

ABBREVIATIONS ASA = American Society of Anesthesiologists; LCCS = lumbar central canal stenosis; LSS = lumbar spinal stenosis; ODI = Oswestry Disability Index; VAS = visual analog scale.

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nal endoscopy has achieved good results in the treatment of elderly patients with LSS.⁷ Surgical decompression via the posterior interlaminar approach is mostly used for treating lumbar central canal stenosis (LCCS).⁸ Given that general anesthesia or epidural anesthesia is typically performed in the prone position, this surgical approach poses a challenge for patients with severe systemic diseases. Alternatively, surgery via the intervertebral foraminal approach can be done with local anesthesia in the lateral position,^{9,10} which is quite suitable for patients who cannot tolerate general anesthesia. However, previous studies have shown that the intervertebral foraminal approach is widely used for decompression of the intervertebral foramen and lateral recesses, and decompression of the lumbar central canal or central canal stenosis is considered to be a contraindication for this approach.^{11,12} Since 2016, we have used the lateral intervertebral foraminal approach with local anesthesia to decompress the central canal among elderly patients with LCCS and have achieved satisfactory results. In this study, we introduce the preliminary application effect of this surgical method.

Methods

Study Population

This study was approved by the local ethics committee, and informed consent was obtained from each patient. This study retrospectively analyzed patients with LCCS treated by the percutaneous spinal endoscopic unilateral transforaminal approach with local anesthesia between January 2016 and March 2019. This study included patients 1) who had clear radicular pain and/or neurogenic intermittent claudication, 2) with a diagnosis of LCCS confirmed by CT and MRI, and 3) for whom conservative treatments had failed for > 3 months. The exclusion criteria included 1) low-back pain as the main symptom, or low-back pain greater than leg pain; 2) instability as shown by lumbar dynamic position radiography; 3) a grade of lumbar spondylolisthesis > Meyerding I; 4) patients with simple disc herniation; 5) degenerative scoliosis with a Cobb angle > 20°; 6) an obvious coagulation abnormality; and 7) skin infection in the surgical incision area.

Clinical Assessments

After surgery, patients were assessed at 3-month, 1-year, and 2-year follow-up visits. During each follow-up, lumbar spine radiographs, dynamic radiographs, lumbar CT, and lumbar MRI were performed.

The visual analog scale (VAS) was used to evaluate the degree of low-back and leg pain before and after surgery. The Oswestry Disability Index (ODI) was used to evaluate functional disability related to low-back pain.¹³ The ODI improvement rate was defined as (preoperative ODI – postoperative ODI)/preoperative ODI. An ODI improvement rate > 20% was considered effective. The modified Macnab criteria were also adopted to evaluate clinical efficacy.¹⁴ LSS was graded according to the Schizas classification, divided into grade A, B, C, and D based on the dural sac shape, cerebrospinal fluid signal, and epidural fat.¹⁵ In the case of disappearance of the cerebrospinal fluid signal in the dural sac, if there was still epidural fat, grade

C was indicated, and if epidural fat was absent, grade D was indicated.

Patient comorbidities were recorded according to the American Society of Anesthesiologists (ASA) classification of physical status. The operation time refers to the time from skin incision to skin closure. Perioperative complications were defined as complications during surgery or within 30 days after surgery. Late complications were defined as complications that occurred > 30 days after surgery. Recurrent pain was defined as recurrent low-back and/or leg pain during follow-up, with a VAS score ≥ 4 .

Since there is no recognized system for evaluating the range of decompression after spinal endoscopic surgery, we have designed an evaluation method to facilitate the objective and consistent description of the decompression range. This method is intended to help surgeons determine the minimum decompression range for effective decompression. We use the last layer of the intervertebral disc on transverse CT or MR images for horizontal decompression evaluation by dividing the spinal canal into 8 parts, numbered 1 through 8, as indicated in Fig. 1A. Sagittal decompression is evaluated based on sagittal CT or MR images of the dural sac edge (surgical approach side) by dividing it into 3 parts, lettered A, B, and C, as indicated in Fig. 1B. Thus, decompression to the corresponding area will be described accordingly as part 1234+BC decompression or part 123+B decompression.

Surgical Techniques

After patients are positioned lateral, we fold the operating table with the target segment as the apex to increase the surgical side clearance. On the lateral radiograph, we use the projection of the transverse process of adjacent vertebral bodies on the body surface as the safety line, and then mark the line between the apex of the upper articular process of the lower vertebral body and the posterior upper corner of the lower vertebral body. The line intersection point is used as the needle entry point (Video 1).

VIDEO 1. Video showing the surgical technique. Copyright Weibo Pan. Published with permission. [Click here to view.](#)

The surgical area is routinely disinfected and draped. Lidocaine is locally administered layer by layer, and a 2.5-mm K-wire is inserted along the puncture needle trajectory. After reaching the apex of the upper articular process of the lower vertebral body, the K-wire is pointed to the posterior upper corner of the vertebral body and tapped with a hammer into the bone. On the lateral radiograph, we advance the Kirschner needle tip to reach the posterior wall of the vertebral body or the posterior wall of the annulus fibrosis of the intervertebral disc. On the anterior radiograph, we guide the Kirschner needle tip close to the spinous process.

We use the expansion rod to expand soft tissues along the K-wire, then place the working sleeve along the expansion rod before we take out the expansion rod and save the K-wire. Then we place the trephine along the working sleeve, saw the articular process in a clockwise direction, and closely observe the patient's reaction until there is a sense of loss of trephine resistance, indicating that the upper articular process has been cut off. We tap the working sleeve lightly to move it along the trephine to the target po-

FIG. 1. Decompression evaluation after spinal endoscopic surgery. **A:** Horizontal decompression is evaluated based on the last layer of the intervertebral disc on transverse CT or MR images. The anterior margin of the dural sac serves as the base edge. To divide the base part of the spinal canal into parts 2, 3, 4, and 5, vertical lines are drawn from the edges of the dural sac on both sides and the midpoint of the spinous process to the base edge. Then, using the facet joints on both sides of the spinal canal as the dividing point, the rest of the spinal canal is divided into parts 1, 6, 7, and 8. Starting from the upper articular process on the decompression side, the horizontal decompression area is divided into parts 1, 2, 3, 4, 5, 6, 7, and 8 in a clockwise or counter-clockwise direction, depending on the side of the surgical approach. **B:** Sagittal decompression is evaluated based on the sagittal CT scans or T2-weighted MR images of the dural sac edge (surgical approach side) by dividing it into parts A, B, and C. Part A is defined as an area from the lower edge of the pedicle of the upper vertebral body to the endplate below the upper vertebral body, which represents the nerve root exit area. Part B is defined as an area from the endplate below the upper vertebral body to the endplate above the lower vertebral body, which represents the intervertebral disc area. Part C is defined as an area from the endplate above the lower vertebral body to the upper edge of the pedicle of the lower vertebral body, which represents the area of the lateral recess or the area compressed by the degenerative sliding vertebral body in the upper back. Copyright Weibo Pan. Published with permission.

sition, remove the trephine and confirm that the working sleeve reaches the target position by C-arm machine. Under the endoscope, basket punches, laminectomy forceps, and various types of nucleus pulposus forceps are used to remove the hyperplastic superior articular process and the hypertrophic ligamentum flavum, in turn, to decompress the dorsal side of the nerve root. Then, we decompress the outer and ventral sides of the nerve root and gradually advance to the opposite side until there is no obvious compression on the ventral side of the nerve. In most patients, we have achieved decompression on the ventral side of the contralateral nerve root, allowing us to see the contralateral nerve root directly while observing whether there is active bleeding on the channel. For patients with Meyerding grade I lumbar spondylolisthesis, the posterior upper corner of the lower vertebra needs to be removed until the nerves are fully released. Finally, a radiofrequency scalpel is used to ablate and shrink the rough, soft-tissue surface and completely stop the bleeding.

During the operation, it is necessary to observe whether the nerve root is loose and whether pulsation is obvious. A straight leg elevation test is performed to observe whether the nerve root slips well and whether the patient's leg pain and numbness improve significantly, which can be used as a reference for judging whether the decompression is adequate. After confirming that there is no bleeding or residual debris in the visual field, we exit the working sleeve, while observing whether there is active bleeding on the channel.

For 3 weeks after surgery, it is recommended that pa-

tients stay in bed, rest, and wear back brace before getting out of bed. Patients should be encouraged to actively exercise their back muscles after surgery. Patients should avoid bending and twisting movements that increase the shearing force of the intervertebral disc for 1 year after surgery.

Statistical Analysis

Continuous variables were expressed as mean $\pm$ standard deviation. Categorical variables were expressed in counts and percentages. The differences between ODI and VAS scores at the four time points were compared by using repeated analysis of variance. Statistical analysis was performed with IBM SPSS Statistics version 22.0 (IBM Corp.), and $p < 0.05$ indicated statistical significance.

Results

Clinical Characteristics and Outcomes

Surgery was performed in 25 patients; 2 patients died during the follow-up period. One patient died half a year after the operation due to an unknown cause. His symptoms had significantly improved at the 3-month follow-up. Another patient died of stroke 11 months after surgery. The patient's waist and leg symptoms had improved significantly before his death. A total of 23 patients were included for final analysis, with a mean follow-up of 28 months (range 24–42 months). There were 12 males (52.2%) and 11 females (47.8%), with a mean age of 69 ± 10 years (range 53–86 years). Regarding ASA class, 2

TABLE 1. Clinical outcomes of the 23 patients with LCCS who underwent surgical decompression

Variable	Preop	3 Mos Postop	1 Yr Postop	2 Yrs Postop
Mean VAS score, low-back pain	3.8 ± 0.6 (3–5)	3.4 ± 0.6 (3–5)	2.3 ± 0.8 (1–5)	1.6 ± 1.0 (0–3)
Mean VAS score, leg pain	7.7 ± 0.8 (6–9)	1.8 ± 1.0 (0–3)	0.3 ± 0.5 (0–1)	0.5 ± 0.8 (0–3)
Mean ODI score	69.7 ± 21.4 (20–100)	11.8 ± 15.1 (0–62)	10.2 ± 13.2 (0–58)	8.0 ± 13.3 (0–53)
Mean walking distance, m	77.5 ± 100.7 (0–500)	817.4 ± 331.2 (100–1000)	1708.7 ± 850.1 (100–3000)	NA
Modified Macnab criteria, n (%)				
Excellent	NA	19 (82.6)	22 (95.7)	22 (95.7)
Good	NA	4 (17.4)	1 (4.3)	1 (4.3)

NA = not available.

Mean values are presented as the mean ± SD (range).

patients were in class IV, 5 patients were in class III, 13 patients were in class II, and 3 patients were in class I. Twenty-one patients received surgery at L4–5 and 2 patients received surgery at L3–4. The mean procedure time was 100 ± 16 minutes (range 60–120 minutes). No perioperative complications occurred.

In terms of low-back pain, the mean VAS scores before surgery and 3 months, 1 year, and 2 years after surgery were 3.8, 3.4, 2.3, and 1.6, respectively. In terms of leg pain, the mean VAS scores before surgery and 3 months, 1 year, and 2 years after surgery were 7.7, 1.8, 0.3, and 0.5, respectively. The mean ODI scores before surgery and 3 months, 1 year, and 2 years after surgery were 69.7, 11.8, 10.2, and 8.0, respectively (Table 1). We found that VAS scores and ODI scores at all postoperative time points (3 months, 1 year, and 2 years after surgery) were better than those scores before surgery, with a significant difference (all $p < 0.05$).

The modified Macnab criteria at 3 months after surgery were excellent in 19 patients (82.6%) and good in 4 patients (17.4%). The modified Macnab outcomes at 1 year and 2 years after surgery were roughly the same: excellent in 22 patients (95.7%) and good in 1 patient (4.3%) (Table 1).

Preoperative Schizas classification of all patients included 1 patient in grade B, 12 patients in grade C, and 10 patients in grade D. Postoperatively, Schizas classification of all patients was improved by at least 1 grade compared with the preoperative level.

All patients had intermittent claudication before surgery, with a mean walking distance of 77 m. At 3 months after surgery, the mean walking distance of all patients was 817 m, which was significantly greater than before surgery (Table 1). One patient with Parkinson's disease could only walk 10 m before surgery; however, he could walk 100 m at the 3-month follow-up and 200 m at the 1-year follow-up.

Assessment of Decompression

According to our novel evaluation method of decompression range, 4 patients (17.4%) underwent horizontal decompression of part 123 (part 123 group), and 19 patients (82.6%) underwent horizontal decompression of part 1234 and other parts (part 1234 group). Sagittal decompression of part B was achieved in 4 patients (17.4%), of part BC in 18 patients (78.3%), and of part ABC in 1

patient (4.3%). In all patients, decompression was achieved at least in part 123+B.

There was no statistical difference in VAS scores, ODI scores, and walking distances between the part 123 and part 1234 decompression groups at each time point (Fig. 2). VAS scores and ODI scores at 3 months after surgery, 1 year after surgery, and 2 years after surgery were better than those measurements before surgery, with a significant difference (all $p < 0.05$) between the 2 groups (Fig. 2). Additionally, no significant difference was observed in the ODI improvement rate between the part 123 and part 1234 decompression groups at each follow-up time point (Table 2).

Figures 3 and 4 show images obtained in 2 representative patients who received surgical decompression via the unilateral intervertebral foraminal approach with local anesthesia in whom satisfactory clinical results were achieved. Effective decompression was evaluated according to our proposed method.

Discussion

There are various surgical decompression methods for LSS, including open surgical decompression, spinal canal decompression under the microscope, spinal canal decompression under the microendoscopic discectomy channel, and decompression of both sides of the spinal canal with a single dorsal approach under full endoscopy.^{16–18} These surgical methods can achieve satisfactory decompression results, and the amount of surgical trauma is becoming less and less;¹⁹ however, these surgical methods cannot be performed with local anesthesia. For elderly patients with complications, especially those with poor cardiopulmonary function, local anesthesia has certain advantages such as less impact on the whole body, easy communication with patients, and timely understanding of the decompression effect. In addition, the aforementioned surgical approaches are all posterior approaches, which cause more or less damage to the posterior tension band.

Spinal endoscopy via the transforaminal approach can be performed with local anesthesia. This surgical method can clearly show the compression on the ventral side of the nerve without damaging the posterior tension band. After years of development, the indications of spinal endoscopy via the transforaminal approach have gradually expanded

FIG. 2. Comparison of functional outcomes between the part 123 (blue) and part 1234 (green) decompression groups at each time point. A: VAS scores of low-back pain. B: VAS scores of leg pain. C: ODI scores. D: Walking distance.

from the initial simple disc herniation to LSS. The transforaminal approach is mostly suitable for foraminal stenosis and lateral recess stenosis. However, central canal stenosis is considered a contraindication to the transforaminal approach.¹² Yeung et al.¹¹ suggested that severe

central canal stenosis with a spinal canal area < 100 mm² was a contraindication for surgery via the transforaminal approach. Bao et al.²⁰ reported decompression of central canal stenosis through the transforaminal approach and, notably, they defined central spinal stenosis as the antero-

TABLE 2. Comparison of the postoperative ODI improvement rate between the part 123 and part 1234 groups

Median Postop ODI Improvement	Part 123 Group (n = 4)	Part 1234 Group (n = 19)	Z Score	p Value
3 mos	0.967 (0.8, 1.0)	0.904 (0.8, 0.9)	-1.623	0.105
1 yr	0.987 (0.7, 1.0)	0.904 (0.8, 1.0)	-1.223	0.221
2 yrs	0.987 (0.9, 1.0)	0.957 (0.8, 1.0)	-1.119	0.263

Values are presented as the median (first quartile, third quartile).

FIG. 3. An 84-year-old male presented with numbness and weakness in both lower extremities, which he had been experiencing for 5 years, and left lower-extremity pain that had started 1 month prior. He walked no more than 20 m before surgery. **A:** Preoperative sagittal T1-weighted MR image showing L4–5 Meyerding grade I spondylolisthesis. **B:** Preoperative transverse T2-weighted MR image showing a grade D Schizas classification. Before surgery, the VAS score for low-back pain was 3, left lower-limb pain score was 9, and ODI score was 94. In 2017, the patient underwent the unilateral intervertebral foramina approach (L4–5) for spinal canal expansion and nerve decompression with local anesthesia. **C and D:** Intraoperative fluorescent images showing the position of the working sleeve when the final decompression was completed. **E and F:** Postoperative sagittal T1-weighted MR image showing that the upper edge of the L5 vertebral body was excised (E), and a postoperative transverse T2-weighted MR image showing a grade B Schizas classification (F). **G:** Postoperative CT scan showing that the surgical decompression area was part 812345+BC. Three months after surgery, the patient had no obvious symptoms of pain and numbness in either lower extremity and could walk more than 1000 meters. At that time, the VAS score for low-back pain was 3, VAS score for left lower-extremity pain was 1, ODI score was 8, and modified Macnab criteria classification was excellent.

posterior diameter of the central canal < 10 mm. The degree of stenosis was not described in detail. Postoperative horizontal MRI showed that the decompression area was mainly located in parts 2 and 3. Sagittal decompression was not evaluated.

Among the 23 patients in this study, 22 patients had severe central spinal stenosis, including 12 patients classified as grade C and 10 patients as grade D, according to the Schizas classification. We performed surgical decompression via the unilateral intervertebral foramina approach with local anesthesia on the side with severe symptoms. All patients had significant improvement in leg pain after surgery. Thus, this surgical method can achieve effective decompression of the nerve tissue in patients with LCCS and effectively improve the nerve symptoms of the lower limbs. The low-back pain of all patients at 1 and 2 years after surgery was significantly reduced compared with before surgery. Thus, the partially resecting the upper articular process has no obvious adverse effect on the stability of the lumbar spine and will not increase the patient's symptoms, such as low-back pain. In addition, this may also be related to our conservative postoperative rehabilitation treatment. Postoperative Schizas classifications of

all patients improved by at least 1 grade compared with the preoperative grades, of which 11 patients improved by more than 2 grades and 1 patient improved by 3 grades.

According to our own design of the decompression evaluation method, surgery for all patients had at least achieved decompression in part 123+B. Both the part 123 and part 1234 decompression groups achieved effective decompression and satisfactory clinical results. There was no statistical difference in VAS score, ODI score, ODI improvement rate, walking distance, and Schizas classification between the groups. We speculate that this may be due to most patients being able to tolerate severe spinal stenosis (as observed on imaging) for a long time. Only when the patient's pain is intolerable will surgery be chosen. Decompression of the posterolateral and anterior sides of the ipsilateral nerve roots, the anterior side of the contralateral nerve roots, or even only decompression of the posterolateral and anterior sides of the ipsilateral nerve roots and the ventral side of the dural sac (part 123+B), can achieve satisfactory decompression results. Our surgical technique does not require extensive decompression as does traditional surgery. Of course, during the operation, we still need to fully decompress the compressed nerve

FIG. 4. A 72-year-old female had recurrent low-back and left leg pain for 3 years. Waist movement was restricted, and the straight leg-raising test and enhanced test were positive. **A and B:** Preoperative MR images showing a grade C Schizas classification (A) and L4–5 Meyerding grade I spondylolisthesis (B). Before surgery, the patient's low-back pain VAS score was 4, left leg pain VAS score was 7, ODI score was 76, and walking distance was 100 m. **C and D:** Postoperative MR images showing a grade B Schizas classification (C) with decompression of part 1234+ABC (D). After 3 months of follow-up, the low-back pain VAS score was 4, left leg pain VAS score was 2, ODI score was 13, walking distance was > 1000 m, and modified Macnab criteria classification was good. The ODI scores 1 year and 2 years after surgery were 7 and 2, respectively.

tissues seen under the endoscopy as much as possible, to ensure that there is no obvious compression of the nerves in part 1234+BC. When the degeneration of the lumbar spine worsens and secondary spinal stenosis occurs again, adequate decompression will also leave enough decompression space to ensure that the decompression effect lasts long enough.

The mean age of patients in this cohort was 69 years, with 5 patients older than 80 years and the oldest patient aged 86 years. There were 2 patients in ASA class IV and 5 patients in ASA class III. The use of local anesthesia for this surgical method has obvious advantages for elderly patients, especially those with comorbidities, and the operation time is short. In addition, patients with abnormal cardiopulmonary function can also tolerate the operation because of the lateral position. The patient's abdominal pressure is lower during lateral surgery, which can reduce intraoperative bleeding. Compared with the prone position, the lateral position can make the affected limb bend the hips and knees and relax the nerve tissue, which is conducive to straight leg elevation and other evaluations. At the same time, we can ask the patients whether their symptoms (e.g., numbness of the lower limbs) are relieved in order to judge whether the nerve decompression is sufficient.

This study has certain flaws. First, the follow-up time of this study is only 2 years and it is necessary to extend the follow-up to determine how long the decompression effect can last. Second, this study mainly used postoperative CT scanning to evaluate the decompression, which is not as effective as MRI for soft-tissue imaging.

Conclusions

Surgical decompression via the unilateral intervertebral foraminal approach with local anesthesia is an effective treatment for elderly patients with LCCS, especially for those who have comorbidities and cannot tolerate general anesthesia. Additionally, our proposed postoperative decompression evaluation method is conducive to objectively and accurately understanding the decompression range after spinal endoscopy, and facilitates peer communication.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Pan. Acquisition of data: both authors. Analysis and interpretation of data: both authors. Drafting the article: Pan. Critically revising the article: Ruan. Reviewed submitted version of manuscript: Pan. Approved the final version of the manuscript on behalf of both authors: Pan. Statistical analysis: both authors. Administrative/technical/material support: both authors. Study supervision: Pan.

Supplemental Information

Videos

Video 1. <https://vimeo.com/624394293>.

Video Abstract. <https://vimeo.com/641119698>.

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