Original Article

Repair of spondylolysis using a pedicle screw U-shaped rod construct: A preliminary study of 25 young patients with a mean follow-up of 24 months

ABSTRACT

Study Design: Prospective case series, therapeutic Level IV.

Objectives: Functional and radiographic outcome evaluation of patients with spondylolysis treated with pars interarticularis defect repair with iliac bone grafting and application of a construct consisting of a pair of polyaxial pedicle screws connected by a U-shaped rod passing beneath the spinous process.

Methods: Twenty-five patients (27 operated lumbar levels) with an average of 20 months of follow-up (range 12–24 m) with spondylolysis who met our inclusion criteria were treated with the above-mentioned technique. Functional assessment was by the Visual Analog Score (VAS) for low back pain (LBP) and Oswestry Disability Index (ODI). Fusion was confirmed with plain x-rays and when indicated with computed tomography scan. Return to activities of daily living (ADL) was also assessed.

Results: There were 16 males (64%) and 9 females (36%), with a mean age of 18 ± 3 years at surgery, with a mean operating time of 79 ± 13 min and a mean blood loss of 186 ± 57 ml. ODI significantly improved from a mean of 63 ± 7 preoperatively to 10 ± 4 at 12 months postoperatively ($P < 0.001$). The mean preoperative LBP VAS score 8 ± 1 showed also a statistically significant decrease of values to 1 ± 1 at 12 months, ($P < 0.001$). At 12 m, all patients returned to unrestricted ADL. Pars healing was present in 19 patients (76%) at 6 months and in all patients at 12 months.

Conclusions: Polyaxial pedicular screws with a U-shaped rod offer an effective and reproducible treatment for spondylolysis with an appropriate fusion rate, predictable return to daily activities, and good pain relief in young adults.

Keywords: Pars defect, pars repair, pedicle screw rod construct, spondylolysis, U-shaped rod in spondylolysis

INTRODUCTION

Spondylolysis is usually an asymptomatic pars interarticularis defect caused by a stress fracture on one or both sides of the posterior lumbar vertebral arch. In adolescents incapacitating and persisting low back pain (LBP) can often be associated with lumbar spondylolysis.[1]

These pars fractures can lead to the stimulation of the nociceptive free nerve endings and cause significant back pain predominantly in adolescents aged 12–16 years.[2-4]

In addition, pain mediating neuropeptides have been described at the site of the defect by Eisenstein *et al*.[5]

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The exact prevalence of spondylolysis is unclear as it is asymptomatic in a large percentage of the population. Reports are based mainly on painful or symptomatic spondylolysis or cases associated with listhesis.[6]

In addition to developmental susceptibilities, certain activities constitute risk factors for spondylolysis owing to the nature of biomechanical stresses applied on the pars interarticularis. Biomechanical analyses have shown that hyperextension and persistent lordosis increase shear forces at the neural arch.[7]

Wiltse *et al*. hypothesized that most cases of isthmic spondylolysis should be considered fatigue fractures caused by repetitive load and stress as opposed to a single traumatic event, although a traumatic event may lead to the completion of a fracture already in evolution.[8]

Spondylolysis may be discovered incidentally or may manifest with LBP typically in the teenage years. Conventionally, symptoms consist of focal LBP which worsen with activity or on hyperextension of the spine and infrequently radiating to the gluteal region or posterior thigh.[9]

The goals of the treatment are the alleviation of pain and the restoration of stability. Initially, conservative management with activity restriction for pain control and bracing for 3–6 months are recommended.[10]

Based on kinematic studies and the principle of preserving motion segments, isolated repair of the pars interarticularis defect is the preferred treatment for symptomatic patients with no slip, same level disc degeneration, and relief from a prior diagnostic injection. Fusion is indicated if an attempt of pars repair was unsuccessful, the lamina is dysplastic, the defect is very large, or disc degeneration or listhesis is present.[11,12]

Indications for surgical repair besides failed conservative treatment include increasing pain, progressive listhesis, and deteriorating neurology.[13]

Preservation of the motion segment and retained compression of the bone graft epitomize the main principles on which various several surgical techniques are founded. Delayed or nonunion, material failure or loosening, and the need for extensive muscle dissection are well described with various techniques.[14,15]

This prospective study evaluates functionally and radiologically a pars repair technique with iliac bone grafting and pedicular screws connected to a U-shaped rod which is applied below the intraspinous ligaments.

METHODS

This prospective case series was done at Cairo University Hospitals, Cairo, Egypt and Haram Hospital, Giza, Egypt between June 2014 and March 2018 comprising 25 patients (27 lumbar levels) with spondylolysis treated with iliac bone grafting and a direct repair of the pars stabilized with a construct consisting of a pair of polyaxial pedicle screws connected by a U-shaped rod passing beneath the spinous process. Tightening the rod to the screws buttresses the iliac bone graft to the defect. The study included 16 males and 9 females with the youngest patient 13 and the eldest patient being 25 years old at surgery (mean 19 years). The average follow-up period was 24 m and ranged between 18 and 32 months.

After Ethical Committee approval, all patients or their caregivers signed an informed and detailed consent describing the procedure, alternative treatment methods, and possible complications.

Inclusion criteria

Age 12–25 years, radiologically confirmed spondylolysis with or without Grade I spondylolisthesis, chronic, disabling low-back pain, no neurological symptoms unresponsive to conservative treatment for at least 6 months and normal disc and facet joints without signs of disk degeneration at the lytic or adjacent levels confirmed by MRI.

Exclusion criteria

Grade II or higher spondylolisthesis, dysplastic lamina, disc degeneration at the level of the lysis, facet arthritis, and radicular pain.

The complete medical history was recorded, and comprehensive general and neurological examinations were done.

An Arabic version of the Oswestry LBP disability Oswestry Disability Index (ODI) questionnaire was applied preoperatively and at each follow-up. The Visual Analog Score (VAS) for LBP preoperatively and at 1, 6, and 12 months postoperatively. Similarly, restrictions of activities of daily living (ADLs) were assessed and complete unrestricted return to ADL was considered as an outcome measure. Moreover, intra-and postoperative complications occurring during the study period were recorded.

Preoperatively, plain x-rays of the lumbar spine included anteroposterior, lateral, oblique and dynamic flexion/extension views and a lumbosacral MRI. In some cases, preoperative lumbosacral computed tomography (CT) was done to confirm the diagnosis.

Postoperatively, plain x-rays of the lumbosacral spine were done at 1, 6, and 12 months. CT lumbosacral spine was done when indicated not before 9 months.

Surgical technique

Patient positioning and anesthesia

All patients were operated by the same surgeon and under general anesthesia on an appropriately sized spine frame in the prone position after cushioning pressure sensible areas and ensuring a freely hanging abdomen. All patients received 1.5 g of cefuroxime intravenous 30 min before skin incision. Biplanar fluoroscopy was utilized to locate the affected level.

A midline incision was made, and the paraspinal musculature laterally elevated to expose the lamina, the pars and the base of the transverse process. Care was taken not to damage the capsule of the facet joints.

The defect in the pars was exposed and the fibrocartilaginous tissue was curetted with an electrical burr and sharp curettes to bleeding bone while the thick fibrous tissue was removed with pituitary rongeurs. Care was taken to avoid enlargement of the defect.

Anatomical landmarks and fluoroscopy were then used to determine the starting point for the pedicle screw. A starting hole was done, and a pedicle finder used to identify the pedicle. The walls and floor were assessed with a ball-tipped probe, and the hole was tapped and prepared for a 6.5 mm polyaxial titanium pedicle screw of appropriate length.

Cancellous bone graft was harvested through a 3-cm window from the iliac crest and placed in the defect and impacted. It was placed as an onlay graft at the pars defect with care taken not to place the graft ventral to the defect, to obviate exiting nerve root compromise.

After placement of the pedicle screws, a stiff titanium rod was contoured to a U-shape configuration and placed through a small defect made in the deep part of the interspinous ligament to pass below the spinous process of the affected level. The rod was provisionally fixed loosely to each of the two pedicle screws. Care was taken to preserve the remaining interspinous ligamentous complex [Figure 1]. Thereafter, the pars defect was cautiously compressed by applying a rod compressor across the ipsilateral pedicle screw and the rod at the contralateral side of the

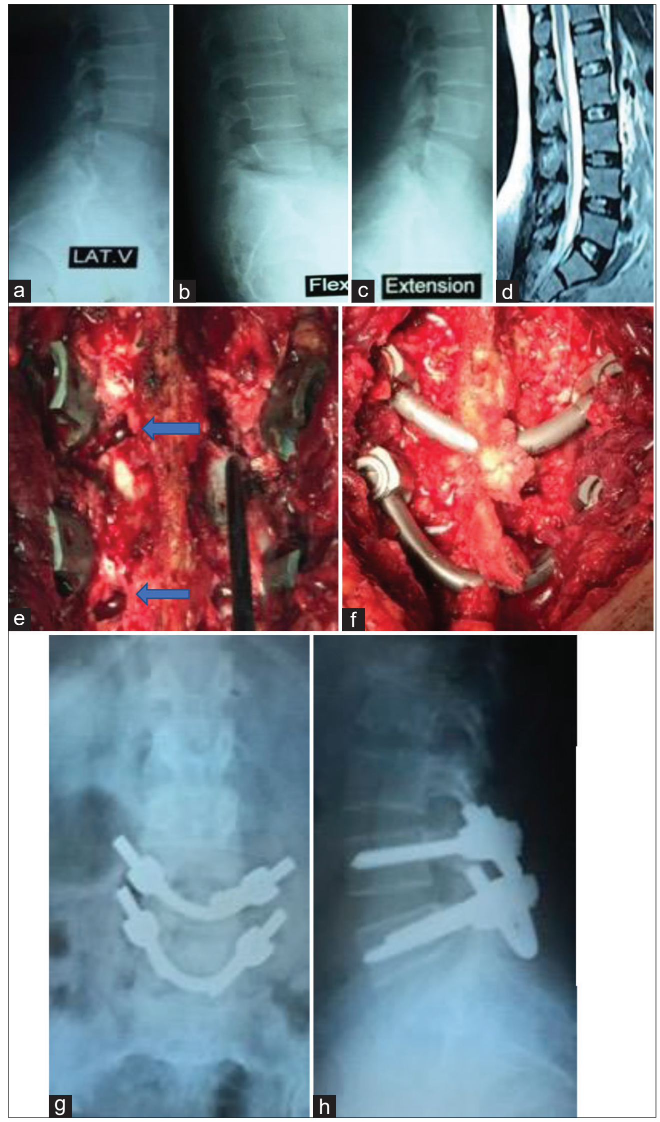

Figure 1: (a-d) 20-year-old female patient with unrelenting back pain for more than 1 year, x-ray showed double level pars defect at L4, L5. Intraoperative view (e) with an instrument pointing to the pars defect and (f) before and after application of the titanium rods. Visual Analog Score back pain score improved from 10 to 2 at last follow-up, Oswestry Disability Index score improved from 85 to 18 at last follow-up at 12 months. (g and h) showing complete bony healing

corresponding spinous process followed by tightening of the ipsilateral nut. This procedure was repeated on the other side. Hence, the rod was firmly fixed against the spinous process and the laminae thereby buttressing and compressing the graft to the defect and stabilizing the posterior arch.

Finally, graft stability at the pars defect was ensured by a McDonalds elevator and correct implant placement was confirmed by biplanar fluoroscopy. The patient was mobilized on the first postoperative day with a lumbosacral support for 3 weeks.

Postoperative care and follow up

In the first 3 months, heavy lifting and strenuous activities were avoided, and patients were discouraged from trunk hyperextension or flexion movements.

Plain radiographs for fusion or attenuation of pars fractures were assessed after 1, 3, 6, and 12 months from surgery.

Radiographic outcome was assessed by an independent observer who determined the presence of adequate bone healing by fusion of 3 out of 4 cortices. In equivocal cases, or for patients experiencing back pain, CT scans were taken to evaluate for possible pseudarthrosis. This was necessary in 10 patients (40%).

Statistical analysis

SPSS version 22 (IBM, Armonk, NY, USA) was used to analyze the anonymized data. It was summarized using the descriptive analysis for quantitative variables and frequencies (number of cases) and relative frequencies (percentages) for categorical variables. Comparisons between groups were done using the unpaired *t*-test. The Chi-square and Friedmann tests were performed for comparing the categorical data. Exact test was used when the expected frequency was <5. $P < 0.05$ was considered statistically significant.

RESULTS

There were 16 males (64%) and 9 females (36%) with a mean age of 18 ± 3 years (range 13 to 25 years). Twelve patients had spondylolysis at L5 (12/25) 48%, 11 patients at L4 (11/25) 44%, one patient had a double level involving L3/L4 (4%), and one patient had double level encompassing L4/L5 (4%). Operating time averaged 79 ± 13 min and blood loss averaged 186 ± 57 ml [Tables 1 and 2].

There was a statistically significant decrease in ODI score over time with statistical significance on pairwise comparison. The ODI for all patients showed significant improvement from a mean of 63 ± 7 preoperatively to 51 ± 8 at 1 months postoperatively, 30 ± 10 at 6 months, and 10 ± 4 at 12 months postoperatively ($P < 0.001$) [Table 2 and Figure 2].

There was a statistically significant decrease in VAS back pain over time with statistical significance on pairwise comparison. The preoperative LBP VAS score was 8 ± 1 and showed a statistically significant decrease of values to 6 ± 1 immediately postoperative, 3 ± 1 at 1 month postoperatively, 2 ± 1 at 6 months and 1 ± 1 at 12 months, ($P < 0.001$), respectively [Table 2 and Figure 3].

Table 1: Demographics

	n	Percentage
Male	16	64
Female	9	36
Total	25	100
Level		
L3/L4	1 (2)	4
L4/L5	1 (2)	4
L4	11	44
L5	12	48
Total	25 (27)	100

Brackets indicate double level affection

Table 2: Statistical analysis

	Mean±SD	Median (IQR)	*P*
Age years	18±3	18 (16-20)	
Operative duration (min)	79±13	80 (70-90)	
ODI preoperative	63±7	62 (58-70)	<0.001
ODI 1 month postoperative	51±8	50 (46-55)	
ODI 6 months	30±10	30 (22-34)	
ODI 1 year	10±4	10 (7-12)	
VAS back pain preoperative	8±1	8 (7-9)	<0.001
Postoperative	6±1	6 (5-6)	
1 month postoperative	3±1	3 (2-4)	
6 months postoperative	2±1	1 (1-2)	
12 months postoperative	1±1	1 (0-1)	
Blood loss (ml)	186±57	200 (100-300)	

IQR - Interquartile range; ODI - Oswestry Disability Index; SD - Standard deviation; VAS - Visual Analog Score

The Friedman nonparametric test conducted to compare VAS back pain score over time, revealed that there was a statistically significant decrease over time of the VAS back pain score.

At 12 months, all patients reported that they were able to participate unrestrictedly in ADL.

Pars healing was evaluated after 3, 6, 9, and 12 months using X-rays and when indicated using CT scan at 9 or 12 months.

Healing was present in 19 of 25 patients (76%) by 6 months and at 9 months healing was verified in 23 of 25 cases (92%). Nevertheless, complete radiographic healing of the spondylolytic defect was seen in all patients 100% after 1 year ($P < 0.001$). Delayed bony healing in this patient cohort was not found to be age dependent.

Complications:

Postoperative complications included one superficial wound hematoma which did not require intervention, and two superficial wound infections which responded to antibiotic treatment. Delayed healing of the bone defect which was defined as union occurring after 9 months occurred in 2 of the 25 patients (8%) [Table 3].

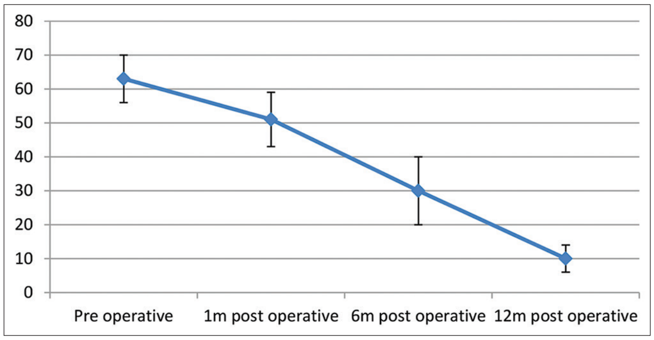

Figure 2: Mean Oswestry Disability Index scores preoperatively and at postoperative follow-up

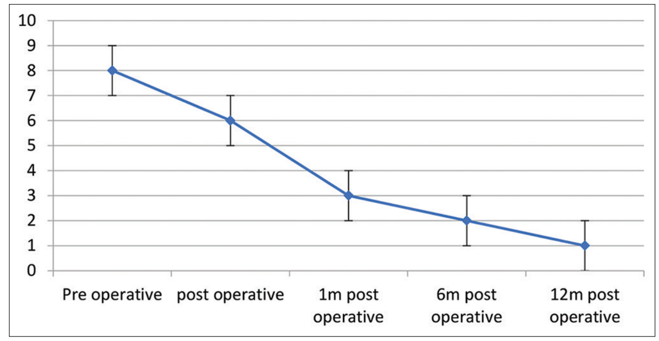

Figure 3: Visual Analog Score back pain preoperatively and at postoperative follow-up

Two male patients had persistent back pain with minimal improvement in outcome (ODI and VAS scores). One of them was a manual worker, and lumbar MRI at 12 months postoperatively unveiled a degenerated disc. Nevertheless, the back pain improved after epidural injection. The other patient was a heavy and noncompliant smoker and back pain improved after intensive physiotherapy and medical treatment.

No breakage or loosening of the hardware was encountered, and none was removed. No patients had sciatica, motor deficit, or sensory loss at follow-up.

DISCUSSION

Numerous surgical techniques have been designated for symptomatic spondylolysis repair and up to Grade I spondylolisthesis refractory to conservative management.

In the direct pars defect repair by screws described by Buck, the loose lamina and pars defects are exposed, and the pars defects are debrided and decorticated. The defect is crossed by a cortical bone screw.[11]

The Scott wiring technique involves decorticating the transverse process, the lateral aspect of the superior facet, and the lamina on each side.

Kakiuchi reported that 100% of pars defects united when the pars defect was bridged with a rod attached by a cephalic pedicle screw and a caudal laminar hook in combination with bone grafting.[16]

Other authors have reported the usage of pedicle screws to secure the lamina with either a rod-hook construct or a V-shaped rod under the spinous process.

Direct surgical repair of spondylolysis has mainly been targeted patients younger than 30 years since their discs are less degenerative and hence are more suitable for direct repair.[11,17] Due to the limited number of 25 patients and only 6 patients (24%) exceeding the age of 18 years, we cannot make a solid conclusion about the effect of age on fusion rates.

Table 3: Complications encountered in this series

Complication	Cases	Percentage
Back pain	2	8
Need for transfusion	1	4
Wound related	2	8
Postoperative hematoma	1	4
Delayed union (9 months)	2	8

However, several authors have demonstrated that patients below 20 years fair better than older patients. Ivanic *et al*. in their retrospective study employing a hook screw system and involving 113 patients with 10.9 years follow-up reported that more than 90% had excellent outcomes.

Twenty patients were older than 20 years and 35% of them developed pseudarthroses, whereas of the 93 patients younger than 20 years a mere of 8.6% had pseudoarthroses.[18]

Nozawa *et al*. used a Scott wiring technique in 20 athletes with 13 being younger than 20 years. Excellent clinical outcome was reported in 86% of patients being younger than 20 years, whereas in only 70% in those being older than 20 years.[19]

A modified Scott technique was adopted by Johnson and Thompson and they testified in 2 of 3 patients older than 25 years a poor, whereas in all 19 patients younger than 25 years a satisfactory result.[20]

Using a laminar hook equipped with a spring placed beside a screw placed in the articular process, Morscher *et al*. reported the union rates of 56%–82%.[21]

A pedicle screw hook system was applied by Debusscher and Troussel in 12 patients 30 years of age or younger and in 11 patients older than 30 years. Only 73% of the elder patient group showed an excellent outcome which however was achieved by all younger patients.[22]

Using the Scott wiring technique, Bradford and Iza reported osseous union in 90% and good to excellent functional outcome in 80%, despite requiring a greater surgical exposure and the increased incidence of complications as wire breakage.[2]

Salib and Pettine modified the Scott wiring technique by passing a wire around the cortical screws introduced into both pedicles and tightened it beneath the spinous process. Nonetheless, fixation of the wire to the pedicle screw did not increase the stiffness of the construct when biomechanical testing was done.[23]

In 1998, Songer and Rovin were the first to report on pedicular screw-based constructs as they secured a cable to the screw and passed it around on the contralateral lamina. Osseous union were reported in all seven patients, whereas an excellent outcome was reported in 5 out of 7 patients.[24]

Subsequent variations included the combination of a pedicle screw to a laminar hook or to a curved rod which is passed underneath the spinous process to provide stability of the pars defect.[18,22,25]

The "V-rod method" was soon coined smiley face rod method as the screw head and rod on the anterior-posterior plain radiograph resembled a smiley face.[25]

It was attested excellent biomechanical properties by Ulibarri *et al*. when compared to other direct repair modalities.[26]

In 2005, a new pedicle screw hook construct system was introduced by Roca *et al*. which provided in 92% an excellent outcome, although its usage in patients older than 20 years was not recommended by the authors.[27]

Using a variable-angle pedicle screw in combination with a laminar hook and a rod to provide more rigidity, Kakiuchi reported fusion in all 16 patients and improvement of the symptomatology in 13 patients.[16]

Nevertheless, Gillet and Petit achieved an excellent outcome in 6 patients only (60%) when using a pedicle screw-V-shaped rod construct.[25]

An excellent outcome was reported in 18 patients (90%) by Altaf *et al*. Radiological union was confirmed in 16 patients (80%).

The effect of nonunion on functional outcome is still controversial,[28] and several authors believe[12,29,30] that patients winding up with a pseudarthrosis have a poor or fair outcome. However, others do not ratify this relationship.[20,31,32]

Screw breakage, wire and cable failures, and wire slippage from the transverse process are possible but infrequent failures in pars repair techniques.[22,25]

Besides, there is possibly an increased risk of neural damage during blind passage of wires underneath the transverse process.[25,33]

Pseudarthroses has been described not infrequently. It occurred in 15 out of 113 patients (13.3%) in the series of Ivanic *et al*.[18] utilizing the Morscher technique. Less frequently, persistent low-back pain after surgery has been reported.[25]

It was found that 15% of the screws used in Buck's technique were misplaced by penetrating the inferior articular process due to an erroneous technique constituting the main difficulty of this repair. Subsequently, nonunion ensues due to screw breakage or loosening.[31]

In a biomechanical study comparing several pars repair techniques by

Deguchi *et al*., it was found that the most rigid stabilization with the smallest amount of motion was obtained by screw-rod-hook fixation.[34]

There are few studies reporting on operative time and blood loss. Our operating time (mean ± standard deviation [SD], 79 ± 13 min) and blood loss (mean ± SD, 186 ± 57 ml) were comparable to other authors. Rajasekaran *et al*.[35] using Buck's method reported that the mean operative time was 58 min (range 45–75 min) and the mean blood loss was 98 ml (range 50–140 ml).

The underlying technique used readily available instrumentation to provide a strong rigid construct. The bone graft in the pars defect was not stalled by screws, permitting high rates of union. Postoperative recovery is made easier as the strength of the construct bypasses the need for postoperative immobilization.

Confounding factors in the underlying study are the single surgeon, single center nature, limited number of patients, and lack of a control group. Most importantly, the oldest patient was 25 years, whereas most patients were below 20 years. Therefore, the efficacy of this technique in patients elder than 25 years cannot be verified. However, this study should serve as a stimulus for further larger multi-centric comparative randomized control trials to verify its efficacy in pars defect repair.

CONCLUSIONS

Polyaxial pedicular screws with a U-shaped rod-based direct repair for spondylosis with or without low-grade spondylolisthesis are a reliable choice with an appropriate fusion rate, predictable return to daily activities, and good pain relief in young adults.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients or their legal caregivers have given their consent for their images and other clinical information to be reported in the journal. The patients or their legal caregivers understand that their names and initials will not be published, and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Compliance with ethical standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants or their respective caregivers included in the study.

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Conflicts of interest

There are no conflicts of interest.

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