

Comparative Evaluation of the Wagner and University of Texas Classification Systems in Predicting Outcomes of Diabetic Foot Ulcers: A Prospective Observational Study

M Ranjith Kumar^{1*}, Sharad Kumar Sahai², Satya Prakash Tripathi³

¹Dept. of General Surgery, Command Hospital, Kolkata, WB, India

²Dept. of Surgery, 180 Military Hospital, Misamari, Assam, India

³Dept. of Surgery, Military Hospital Secunderabad, Telangana, India

*Corresponding Author: M Ranjith Kumar

Email: shetty4741@gmail.com

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Abstract: Background & Objectives: Diabetic foot ulcers are a major complication of diabetes mellitus and are associated with infection, neuropathy, peripheral arterial disease, amputation and mortality. Appropriate classification is important for assessment of severity and prediction of outcome. This study compared the Wagner and University of Texas (UT) diabetic foot ulcer classification systems and evaluated their association with healing and adverse outcomes.

Methods: A prospective observational study was conducted among 100 consecutive patients with diabetic foot ulcers presenting to a tertiary care hospital. Demographic characteristics, duration of diabetes, ulcer characteristics, infection, osteomyelitis, neuropathy and peripheral arterial disease were recorded. Each ulcer was classified using the Wagner and UT systems. Patients were followed until complete healing, amputation or death. Statistical analysis was performed using IBM SPSS Statistics version 20.0. Categorical variables were analysed using the chi-square test or Fisher's exact test, and continuous variables using the independent-samples t-test. A P value <0.05 was considered statistically significant. **Results:** The mean age was 59 ± 8.12 years and 82% were male. Wagner grades I–V accounted for 13%, 36%, 32%, 15% and 4%, respectively. UT grades 1–3 accounted for 13%, 35% and 52%, while stages A–D accounted for 10%, 12%, 14% and 64%, respectively. Complete healing occurred in 34 patients, 60 underwent amputation, and 6 died. Thus, 66 patients had a combined adverse outcome. Increasing UT grade and stage were significantly associated with adverse outcomes ($P < 0.001$). Healing occurred in 92.3%, 45.7% and 11.5% of patients with UT grades 1, 2 and 3, respectively. Healing occurred in 100%, 75%, 35.7%, and 15.6% of patients with UT stages A, B, C and D, respectively.

Interpretation & Conclusions: Both Wagner and UT classifications demonstrated an association with diabetic foot severity and outcome. The UT system, by incorporating infection and ischemia in addition to ulcer depth, provided more detailed prognostic stratification. Higher UT grade and stage were strongly associated with failure to heal and adverse outcomes.

Keywords: Amputation; diabetic foot; diabetic foot ulcer; infection; ischemia; University of Texas classification; Wagner classification.

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INTRODUCTION

Diabetic foot ulceration is one of the most serious complications of diabetes mellitus and represents an important cause of morbidity, prolonged hospitalisation, lower-limb amputation and mortality. The development of a diabetic foot ulcer is usually multifactorial, with peripheral neuropathy, peripheral arterial disease, repetitive trauma, infection and impaired tissue repair contributing to ulcer formation and progression [1-4].

The clinical course of a diabetic foot ulcer is highly variable. Superficial ulcers may heal with appropriate wound care and off-loading, whereas deeper ulcers involving tendon, joint or bone may progress to

infection, gangrene and amputation. Accurate assessment of ulcer severity is therefore essential for treatment planning, communication between clinicians and estimation of prognosis [5-7].

The Wagner classification is one of the oldest and most widely used systems for diabetic foot ulcer assessment. It categorises lesions primarily according to depth and the presence of gangrene, ranging from superficial ulceration to extensive gangrene of the entire foot. Although simple and clinically convenient, the Wagner system has limitations because it does not independently incorporate important prognostic variables such as infection and ischemia [5-7].

The University of Texas (UT) classification was developed to address some of these limitations. It classifies ulcers according to both depth and stage. The grades describe anatomical depth, while the stages incorporate infection and ischemia. Thus, a superficial ulcer may have a substantially different prognosis depending on whether infection or ischemia is present [8-10].

Previous comparative studies have demonstrated that Wagner grade and UT grade are associated with amputation risk, while the addition of stage in the UT system provides additional prognostic information [8, 9]. Other investigations have highlighted the importance of infection, peripheral arterial disease, ulcer location, ulcer duration and neuropathy in determining healing and limb salvage [10-15].

The reliability and clinical usefulness of classification systems have also been examined. Studies comparing different diabetic foot ulcer classification systems have suggested that classification should not be interpreted in isolation and should be combined with clinical examination and assessment of vascular, neurological and infectious factors [16-18].

The management of diabetic foot ulcers requires a multidisciplinary approach involving wound care, glycaemic optimisation, infection control, vascular assessment, pressure redistribution and appropriate surgical intervention. Contemporary guidelines emphasise systematic assessment of ulcer severity, infection, ischemia and neuropathy [19-22]. Revascularisation may be important in appropriately selected patients with peripheral arterial disease, while early recognition of severe infection can reduce progression to systemic sepsis and major amputation [23-25].

The long-term consequences of diabetic foot disease are substantial. Patients with severe ulcers have an increased risk of recurrent ulceration, major amputation and death [26, 27].

The present study was undertaken to compare the Wagner and UT classification systems in patients presenting with diabetic foot ulcers and to determine their relationship with healing, amputation and mortality.

METHODS

Study Design and Setting

This prospective observational study was conducted at a tertiary care hospital. A total of 100 consecutive patients presenting with diabetic foot ulcers were enrolled.

Study Population

Patients with diabetes mellitus presenting with a clinically diagnosed foot ulcer were included. Patients were assessed at presentation and followed during treatment until complete healing, amputation or death.

Clinical Assessment

A structured clinical assessment was performed for each patient. The following variables were recorded:

- Age and sex
- Duration of diabetes mellitus
- Site of ulcer
- Presence of discharge
- Presence of gangrene
- Clinical evidence of osteomyelitis
- Sensory deficit
- Peripheral vascular status
- Neurological status
- Microbiological culture
- Radiological evidence of bone involvement
- Requirement for surgical intervention
- Amputation
- Final outcome

Assessment of Infection

Wound discharge, local inflammatory findings and systemic features were assessed clinically. Pus or wound swab samples were obtained where clinically indicated and processed for bacterial culture.

Assessment of Bone Involvement

Patients with clinical suspicion of osteomyelitis underwent radiographic evaluation of the affected foot. The presence of radiological bony changes consistent with osteomyelitis was recorded.

Vascular Assessment

Colour Doppler flow imaging (CDFI) was performed to assess arterial circulation. Patients were categorised according to the level and extent of arterial disease and the quality of distal runoff.

Neurological Assessment

Neurological examination and nerve conduction studies were performed where indicated. Findings were categorised according to the predominant sensory or motor neurological abnormality.

Wagner Classification

Each ulcer was classified according to the Wagner system:

- Grade 0: no open lesion
- Grade I: superficial ulcer
- Grade II: deep ulcer involving tendon, ligament or joint capsule
- Grade III: deep ulcer with osteitis or osteomyelitis
- Grade IV: partial foot gangrene
- Grade V: extensive gangrene involving the whole foot

University of Texas Classification

The UT system was recorded according to ulcer depth and stage.



- Grade 1: superficial ulcer not involving tendon, capsule or bone
- Grade 2: ulcer extending to tendon or capsule
- Grade 3: ulcer extending to bone or joint

Stages were classified as:

- A: clean wound
- B: infected wound without ischemia
- C: ischemic wound without infection
- D: infected and ischemic wound

Treatment and Follow-up

Treatment was individualised according to clinical severity. Patients received wound care, glycaemic control, antibiotics where indicated, pressure relief, debridement and other appropriate surgical procedures. Amputation level was determined according to the extent of tissue destruction, infection, vascular status and viability of the remaining limb.

Patients were followed until complete healing, amputation or death.

Statistical Analysis

Data were entered and analysed using IBM SPSS Statistics version 20.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean $\pm$ standard deviation and categorical variables as frequencies and

percentages. Categorical variables were compared using Pearson's chi-square test or Fisher's exact test where appropriate. Continuous variables were compared using the independent-samples t-test. A two-tailed P value <0.05 was considered statistically significant.

Ethical Considerations

Institutional Ethics Committee clearance was obtained before commencement of the study. The study was conducted in accordance with institutional ethical requirements.

RESULTS

A total of 100 consecutive patients with diabetic foot ulcers were included in the study. The mean age of the study population was 59 ± 8.12 years, with an age range of 41–79 years. The majority of patients belonged to the 50–60-year age group (52%), followed by 60–70 years (24%), while 12% were aged 40–50 years and 12% were older than 70 years. There were 82 male and 18 female patients.

The mean duration of diabetes mellitus was 5.94 ± 6.27 years, with a range of 0–30 years. Diabetes was detected at the time of admission in 16% of patients, 20% had diabetes for less than one year, 48% had diabetes for 1–10 years and 16% had diabetes for more than 10 years (Table 1).

Table 1. Demographic characteristics of the study population

S. No.	Variable	Category	Number (n)	Percentage (%)
1	Age	40–50 years	12	12
		50–60 years	52	52
		60–70 years	24	24
		>70 years	12	12
2	Sex	Male	82	82
		Female	18	18
3	Duration of diabetes	Detected at admission	16	16
		<1 year	20	20
		1–10 years	48	48
		>10 years	16	16

The most common site of ulceration was the toes, accounting for 48% of cases. Plantar ulcers involving the metatarsal head, midfoot or heel were present in 32% of patients. Ulcers over the dorsum of the foot were present in 12%, while 8% had ulcers involving multiple sites.

Discharge from the ulcer was present in 76% of patients, while 24% had no discharge. Gangrene was present in 19% of patients. Clinical evidence of bone involvement or osteomyelitis was present in 28% of patients, while 72% had no evidence of bone involvement. Loss of foot

sensation was documented in 16% of patients, whereas sensation was preserved in 84%.

Pus or wound cultures demonstrated bacterial growth in 76% of patients, while 24% showed no growth or only commensal organisms. Among the total study population, *Staphylococcus aureus* was isolated in 30%, *Escherichia coli* in 13%, *Klebsiella* species in 11%, *Pseudomonas* species in 7%, *Acinetobacter* species in 6%, and polymicrobial growth was present in 9%. These categories accounted for all 76 culture-positive patients (Table 2).



Table 2. Clinical, microbiological, vascular and neurological characteristics

S. No.	Variable	Category	Number (n)	Percentage (%)
1	Ulcer site	Toes	48	48
		Plantar/metatarsal head/midfoot/heel	32	32
		Dorsum	12	12
		Multiple sites	8	8
2	Discharge	Present	76	76
		Absent	24	24
3	Gangrene	Present	19	19
		Absent	81	81
4	Bone involvement/osteomyelitis	Present	28	28
		Absent	72	72
5	Foot sensation	Absent	16	16
		Present	84	84
6	Pus/wound culture	Bacterial growth	76	76
		No growth/commensals	24	24
7	Culture organism*	<i>Staphylococcus aureus</i>	30	30
		<i>Escherichia coli</i>	13	13
		<i>Klebsiella</i> spp.	11	11
		<i>Pseudomonas</i> spp.	7	7
		<i>Acinetobacter</i> spp.	6	6
		Multiple organisms	9	9

All 28 patients with clinically identified bone involvement demonstrated radiographic findings consistent with osteomyelitis. The remaining 72 patients had no radiographic evidence of bony involvement.

Colour Doppler flow imaging demonstrated normal arterial flow in 19 patients. Unilateral infrapopliteal single-vessel disease was present in 17 patients, while 13 had unilateral infrapopliteal multivessel disease with good distal runoff. Twenty-four patients had unilateral infrapopliteal multivessel disease with poor runoff. Bilateral infrapopliteal single-vessel disease was present in 9 patients, bilateral infrapopliteal multivessel disease with good runoff in 5 patients and bilateral infrapopliteal multivessel disease with poor runoff in 4 patients. Unilateral suprapopliteal disease was present in 6 patients and bilateral suprapopliteal disease in 3 patients.

Nerve conduction studies were normal in 38 patients. A sensory deficit involving the foot was present in 12 patients, while 4 patients had gross sensory deficits involving both upper and lower limbs. Unilateral motor mononeuropathy was identified in 11 patients, bilateral motor mononeuropathy in 8 patients, unilateral motor

polyneuropathy in 14 patients and bilateral motor polyneuropathy in 13 patients. Autonomic neuropathy was not assessed because the required instruments were unavailable.

Eleven patients had no clinical evidence of either neuropathy or vascular insufficiency. These patients had a mean age of 56.8 ± 4.4 years compared with 59.2 ± 8.4 years among the remaining patients, and this difference was not statistically significant ($P=0.144$). Their mean duration of diabetes was significantly shorter than that of the remaining patients (2.9 ± 3.1 versus 6.3 ± 6.4 years; $P<0.01$).

According to the Wagner classification, 13 patients were Grade I, 36 were Grade II, 32 were Grade III, 15 were Grade IV and 4 were Grade V. No patient was classified as Wagner Grade 0.

According to the University of Texas (UT) depth classification, 13 patients were Grade 1, 35 were Grade 2 and 52 were Grade 3. According to UT stage, 10 patients were Stage A, 12 were Stage B, 14 were Stage C and 64 were Stage D (Table3).

Table 3. Distribution of patients according to Wagner and University of Texas classification systems

Classification system	Category	Number (n)	Percentage (%)
Wagner classification	Grade I	13	13
	Grade II	36	36
	Grade III	32	32
	Grade IV	15	15
	Grade V	4	4
University of Texas grade	Grade 1	13	13
	Grade 2	35	35
	Grade 3	52	52
University of Texas stage	Stage A	10	10
	Stage B	12	12
	Stage C	14	14
	Stage D	64	64

Complete healing was achieved in 34 patients. Eleven patients initially healed with dressings alone. Four of this subsequently developed recurrence or a fresh lesion and required surgical intervention, resulting in seven patients who ultimately healed with dressings alone.

Formal surgical debridement was required in 51 patients. Four patients who were initially managed conservatively subsequently required surgical intervention. Sixteen patients who underwent surgical treatment subsequently required further surgery and ultimately underwent amputation.

Among the amputation procedures, 31 Ray amputations and 2 transmetatarsal amputations were performed as minor amputations. No Syme amputation was performed. Major amputations included 30 below-knee amputations, 13 through-knee or above-knee amputations and one hind-quarter amputation. Twelve patients subsequently underwent contralateral lower-limb amputation during follow-up.

Outcome was strongly associated with UT grade. Among patients with UT Grade 1 ulcers, 12 of 13 patients (92.3%) achieved complete healing and one patient (7.7%) had an adverse outcome. Among patients with Grade 2 ulcers, 16 of 35 patients (45.7%) healed and 19

(54.3%) had an adverse outcome. Among Grade 3 ulcers, only 6 of 52 patients (11.5%) achieved complete healing, while 46 (88.5%) experienced an adverse outcome. The association between UT grade and outcome was statistically significant ($P < 0.001$).

A similar relationship was observed with UT stage. All 10 patients with Stage A ulcers achieved complete healing. Among Stage B patients, 9 of 12 (75.0%) healed, while 3 (25.0%) had an adverse outcome. Five of 14 patients (35.7%) with Stage C ulcers achieved healing, whereas 9 (64.3%) had an adverse outcome. Among the 64 patients with Stage D ulcers, only 10 (15.6%) achieved complete healing and 54 (84.4%) experienced an adverse outcome. The association between UT stage and outcome was statistically significant ($P < 0.001$).

When UT Stages A and B were combined, 19 of 22 patients (86.4%) achieved complete healing and 3 (13.6%) experienced an adverse outcome. In contrast, among patients with UT Stages C and D, only 15 of 78 patients (19.2%) healed, while 63 (80.8%) had an adverse outcome. This difference was statistically significant ($P < 0.001$) (Table 4).

Table 4. Clinical outcome according to University of Texas grade and stage

UT classification	Category	Total (n)	Complete healing, n (%)	Adverse outcome, n (%)
UT Grade	Grade 1	13	12 (92.3)	1 (7.7)
	Grade 2	35	16 (45.7)	19 (54.3)
	Grade 3	52	6 (11.5)	46 (88.5)
UT Stage	Stage A	10	10 (100.0)	0 (0.0)
	Stage B	12	9 (75.0)	3 (25.0)
	Stage C	14	5 (35.7)	9 (64.3)
	Stage D	64	10 (15.6)	54 (84.4)
Stage grouping	A + B	22	19 (86.4)	3 (13.6)
	C + D	78	15 (19.2)	63 (80.8)



The final patient-level outcome was complete healing in 34 patients (34%), amputation in 60 patients (60%) and death in 6 patients (6%). Thus, a total of 66 patients (66%) experienced a combined adverse outcome, defined as amputation or death.

Among the six deaths, one patient died due to diabetic nephropathy with renal failure, one due to myocardial infarction, three due to fulminant soft-tissue infection with sepsis during hospitalisation and one due to stump infection complicated by septic shock during follow-up.

The mean age of patients who died was 68.8 ± 8.1 years compared with 58.3 ± 7.7 years among survivors, and the difference was statistically significant ($P < 0.05$). The mean duration of diabetes was 15.0 ± 10.45 years among deceased patients compared with 5.39 ± 5.53 years among survivors; this difference was not statistically significant ($P = 0.074$).

The mean duration of diabetes among patients who achieved complete healing was 5.97 ± 5.94 years compared with 5.81 ± 6.50 years among patients with an adverse outcome. This difference was not statistically significant ($P = 0.904$) (Table 5).

Table 5. Final clinical outcomes and amputation profile

S. No.	Outcome/procedure	Category	Number (n)	Percentage (%)
1	Final patient outcome	Complete healing	34	34
		Amputation	60	60
		Death	6	6
		Combined adverse outcome	66	66
2	Initial/definitive wound management	Dressings only, ultimately healed	7	7
		Formal debridement	51	51
3	Minor amputation procedures*	Ray amputation	31	—
		Transmetatarsal amputation	2	—
		Syme amputation	0	—
4	Major amputation procedures*	Below-knee amputation	30	—
		Through-knee/above-knee amputation	13	—
		Hind-quarter amputation	1	—
5	Contralateral limb	Contralateral amputation during follow-up	12	—
6	Cause of death	Diabetic nephropathy/renal failure	1	—
		Myocardial infarction	1	—
		Fulminant soft-tissue infection/sepsis	3	—
		Stump infection/septic shock	1	—

DISCUSSION

Diabetic foot ulceration represents a complex interaction between neuropathy, ischemia, infection, mechanical stress and impaired wound healing. The present study demonstrated a high burden of infection, vascular disease, neuropathy and osteomyelitis among patients presenting with diabetic foot ulcers. These findings support the concept that diabetic foot ulcers should be assessed using a multidimensional approach rather than ulcer depth alone [1-4].

The Wagner classification remains useful because of its simplicity and ease of application. However, its principal limitation is that it largely focuses on ulcer depth and gangrene and does not separately characterise infection and ischemia [5-7]. In the present study, a substantial proportion of patients had evidence of both infection and vascular insufficiency, factors that may materially influence healing and limb salvage.

The UT classification provides additional information by combining ulcer depth with infection and ischemia. The original validation work demonstrated that depth, infection and ischemia independently contribute to the risk of amputation [5]. The comparative study by Oyibo *et al.* showed that Wagner grade and both UT grade and stage were associated with amputation, with UT stage providing additional prognostic information [8]. In the present study, increasing UT grade was strongly associated with adverse outcome, with healing decreasing from 92.3% in Grade 1 to 11.5% in Grade 3.

The relationship between UT stage and outcome was particularly pronounced. Complete healing occurred in all patients with Stage A ulcers, whereas only 15.6% of patients with Stage D ulcers achieved healing. The combined Stage A/B group had an 86.4% healing rate compared with only 19.2% in Stage C/D. This marked difference demonstrates the clinical relevance of infection and ischemia in determining diabetic foot



outcome. Similar observations have been reported previously, in which infection, particularly when combined with ischemia, substantially increased amputation risk [8-10].

Ulcer size, site and patient-related factors also influence outcome. Previous studies have demonstrated associations between ulcer characteristics, patient age, sex, diabetes type and duration and healing outcomes [9, 10]. In the present study, diabetes duration alone was not associated with final outcome. This suggests that duration of diabetes should not be used as an isolated predictor of limb salvage. Rather, current ulcer severity, vascular status, infection and tissue involvement are likely to be more immediately relevant.

Peripheral neuropathy was common in the present cohort. Neuropathy reduces protective sensation and predisposes to repetitive trauma, delayed recognition of injury and recurrent ulceration. Assessment of neurological function is therefore an important component of diabetic foot evaluation [10, 14].

Peripheral arterial disease was also frequent. Ischemia compromises tissue perfusion and healing capacity and increases the likelihood of tissue necrosis and amputation. Current diabetic foot guidance emphasises assessment of peripheral arterial disease and appropriate vascular evaluation in patients with ulcers, particularly where healing is delayed or ischemia is suspected [19-24].

Infection was another important finding. Three of the six deaths occurred during hospitalisation from fulminant soft-tissue infection and sepsis, while another death occurred later from stump infection and septic shock. These findings emphasise that diabetic foot infection is not merely a local wound complication but may become a life-threatening systemic condition. Contemporary recommendations stress early diagnosis, severity assessment, appropriate antimicrobial therapy, surgical source control and evaluation for underlying ischemia [20-22].

Osteomyelitis was identified in 28% of patients. Bone involvement represents an important marker of advanced disease and frequently necessitates prolonged antimicrobial treatment and/or surgical intervention. The presence of osteomyelitis should therefore be incorporated into overall severity assessment rather than considered separately from ulcer classification [8, 9, 20].

The present study also demonstrated a substantial requirement for surgical treatment. Fifty-one patients required formal debridement and 60 ultimately underwent amputation. Both minor and major amputations were required, reflecting the severity of disease in this cohort. The high amputation burden reinforces the importance of early recognition and

intervention before infection, ischemia and tissue destruction become irreversible [23-25].

The mortality observed in the present study was 6%. The patients who died were significantly older than survivors. Older age may be associated with a greater burden of comorbid disease, impaired physiological reserve and more advanced vascular and infectious complications. Long-term studies of diabetic foot disease have similarly demonstrated substantial mortality following severe diabetic foot complications and amputation [26-27].

An important observation was that 11 patients had no clinical evidence of neuropathy or vascular insufficiency. These patients were younger and had a significantly shorter duration of diabetes. Nevertheless, diabetic foot ulceration can occur even in the absence of clinically obvious neuropathy or peripheral vascular disease, reinforcing the importance of regular foot examination and early recognition of local trauma or pressure-related injury.

Classification systems should not replace comprehensive clinical assessment. Interobserver studies have demonstrated only moderate agreement for both Wagner and UT systems, highlighting the importance of combining classification with clinical examination and objective assessment of infection, vascular status, neuropathy and tissue involvement [16-18].

The findings of the present study support the practical value of the UT classification in clinical decision-making. While Wagner classification remains simple and useful for broad categorisation, the UT system provides additional prognostic information by incorporating infection and ischemia. The strong gradient in healing from Stage A through Stage D suggests that UT stage may be particularly useful in identifying patients at high risk of treatment failure and amputation.

The study has several limitations. It was conducted at a single tertiary-care centre with a relatively small sample size of 100 patients. Autonomic neuropathy could not be assessed because appropriate equipment was unavailable. The study did not evaluate all possible biochemical and metabolic predictors of healing, and the findings may not be generalisable to all diabetic populations. Nevertheless, the prospective assessment of consecutive patients and the use of both commonly recognised classification systems provide clinically relevant comparative information.

CONCLUSION

Both Wagner and University of Texas classification systems demonstrated an association with the severity and outcome of diabetic foot ulcers. The University of Texas system provided more detailed prognostic



stratification because it incorporates ulcer depth together with infection and ischemia.

Increasing UT grade and stage were strongly associated with failure of healing and adverse outcome. Complete healing was achieved in 34% of patients, while 60% underwent amputation and 6% died. Thus, 66% experienced a combined adverse outcome.

The findings support the use of a structured classification system together with comprehensive assessment of infection, vascular status, neuropathy and bone involvement to identify patients at high risk of amputation and mortality.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Ethical Approval

Institutional Ethics Committee approval was obtained before commencement of the study.

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