

## ORIGINAL ARTICLE

# The burden of costs on health services from patients with venous leg ulcers in Singapore

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## Abstract

Healthcare costs arising from venous leg ulcers (VLU) are expected to increase due to an aging population and increased prevalence of comorbidities. We aim to estimate the healthcare resources incurred by VLU patients, and to quantify the extent to which predictors explain variation in cost-related outcomes. Retrospective patient-level cohort data for VLU patients were analysed using generalised linear regression models. Data were extracted from a tertiary hospital registry in Singapore, between 2013 and 2017. The outcome variables were length of stay per admission; inpatient and outpatient bill per admission; whether a patient underwent a surgical treatment of the venous system; and, whether they visited the emergency department. Cost outcomes were reported in Singapore dollars (S\$). A total of 162 VLU patients were included with a mean age of 67.5 ( $\pm 14.4$ ). For the inpatient setting the mean length of stay was 8.1 days and the mean inpatient bill was S\$7886. For outpatients, the mean number of dressings was 29.4, and mean outpatient bill was S\$6962. Heart disease patients incurred longer hospital stays and larger inpatient bills per admission and females had greater odds of undergoing a surgical procedure on the venous system. Certain VLU patient groups were found to be associated with larger cost outcomes.

## KEYWORDS

chronic leg ulcer, chronic wound, economic burden, venous leg ulcer

## Key Messages

- this study provides insights into the use of healthcare resources by patients with venous leg ulcers (VLU)
- the cost of outpatient care was lower than inpatient care. An average VLU patient's outpatient bill was 12% less than the inpatient bill even though outpatient dressing sessions were 90% higher than inpatient dressing sessions
- patients with a medical history of ischemic heart disease or cardiomyopathy were associated with higher cost-related outcomes such as longer length of stay and larger inpatient bill per admission

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- female patients were more likely to undergo a venous system surgical procedure compared to males
- patients with comorbidities were more likely to make an emergency department visit compared to patients without

## 1 | INTRODUCTION

Venous leg ulcers (VLUs) are open lesions that occur between the knee and ankle, and coincide with venous disease.<sup>1</sup> They are common chronic wounds<sup>2</sup> and account for more than 90% of all leg ulcers.<sup>3</sup> The majority of the epidemiology studies of VLU report prevalence rather than incidence rates.<sup>4</sup> Studies estimate prevalence to range between 2.9%<sup>5</sup> and 53.1%<sup>6</sup> depending on the population, and an annual prevalence rate of 1.69% (95% confidence interval [CI]: 1.65-1.74) is seen among the elderly in the United Kingdom.<sup>7</sup> Data on incidence rates are scarce, with one recent Singapore study reporting a crude incidence of 15 per 100 000 persons (95% CI: 14-16) and age-specific rates to be greatest in patients aged  $\geq 80$  at 92 per 100 000 (95% CI: 74-112) in 2017.<sup>8</sup> Risk factors are advanced age, gender, obesity, trauma, immobility, deep vein thrombosis, and phlebitis.<sup>9-11</sup>

Chronic wounds, including VLUs, impose a substantial economic burden on individuals and health services. Chronic venous insufficiency remains undiagnosed till the development of a leg ulcer. Treatment at this stage becomes complicated, leading to wound recurrence and high utilisation of resources.<sup>12</sup> In Australia, the annual costs of VLUs to acute hospitals and residential aged care settings were estimated to be US\$785 million for 47 300 cases and US\$18 million for 1740 cases, respectively.<sup>13</sup> Medicare expenditures in the United States estimated US\$1.5 billion to have incurred in 2014 for venous wounds and related infections, which is approximately one-fifth of total care costs.<sup>14</sup> UK's National Health Service (NHS) study comparing data from 2012 to 2018 revealed a 71% increase in the annual prevalence of wounds, thereby resulting in patient management costs to rise by 48% in real terms.<sup>15</sup> These high costs are projected to multiply with an aging population and increasing comorbidities rates,<sup>16</sup> therefore it is crucial to understand the factors associated with high costs arising from VLUs.

The first aim of this study is to analyse existing data from Singapore's health services to estimate the costs and resources arising from patients with VLUs. The second aim is to quantify the extent to which modifiable and non-modifiable factors explain variation in selected cost-related outcomes. It is expected that these results form a baseline information and will be useful for judging the

economic value of novel interventions or improved models of care.

## 2 | METHODS

### 2.1 | Study data

This study is a retrospective analysis of a cohort of patients extracted from the National University Hospital of Singapore (NUH) data registry. Patients were included if they were 21 years and above, and were admitted into NUH with the principle clinical diagnosis of VLU using International Classification of Disease codes I822 and I830. Patients' retrievable electronic data from 1 January 2013 to 31 October 2017 were extracted for this study. Data on socio-demographic characteristics, lifestyle behaviour, medical history, and information on outpatient and inpatient treatment of wound were available. Socio-demographic characteristics were age, gender, and race. Lifestyle behaviour variables included obesity and smoking (current). Patient's medical history included diabetes mellitus, ischemic heart disease/cardiomyopathy, hypertension, hyperlipidemia, and chronic kidney disease/end-stage renal failure. Data on inpatient stays included number of admissions, length of stay of each admission, number of podiatrist and nurse dressing sessions, and type of surgical procedures. Surgical treatment of ulcer comprised of debridement and skin grafting, and surgical treatment of the venous system included open surgical interventions (ie, ligation and stripping) and endovenous surgical procedures (ie, radiofrequency ablation and sclerotherapy). Data on outpatient treatment of wound included number of outpatient visits, number of emergency department (ED) visits, and number of outpatient podiatrist dressing sessions. The outpatient visits included vascular surgery clinic, diabetic clinic, and podiatrist clinic visits. The total inpatient and total outpatient bill was the gross amount incurred by patients before government subsidy, and was provided in Singapore dollars (S\$).

### 2.2 | Ethics

The study was approved by the NHG Domain Specific Review Board (DSRB 2019/00917).

## 2.3 | Study outcomes

For the first aim of this study, we included costs incurred between the first and last inpatient admission or outpatient visit. The majority of patients were found to have a maximum follow-up period of 2 years of inpatient treatment. For the second aim, all outcomes were adjusted for the length of follow-up. The outcomes used were: mean length of stay per admission; mean inpatient bill per admission; and mean outpatient bill per visit, not inclusive of ED charges. Other outcomes were if a patient underwent a surgical treatment of the venous system, and if a patient had ED visit(s), no or yes. All costs are reported in Singapore dollars (S\$).

## 2.4 | Statistical methods

The characteristics of patients are summarised using frequencies and percentages for categorical variables, and means and SDs for normally distributed continuous variables or medians and first quartile-third quartile ranges for skewed variables. A generalised linear model (GLM) approach was used that employs maximum-likelihood estimation and allows for different distributions for outcome variables, to investigate the association between explanatory variables and cost outcomes. The continuous outcomes were heavily positively skewed, thus gamma distribution was chosen in GLM settings to characterise the outcome and a log link function to specify the relationship between the outcome mean and explanatory variables.<sup>17</sup> Results of GLM were reported as beta coefficients and 95% CI along with *P*-values. Coefficients were transformed to the original units of length of stay (days) and costs (S\$), by multiplying to the mean of the outcome variable. For binary outcomes including venous system surgery and ED visit, multivariable logistic regression models with a logit link function were used, and the results were reported as odds ratios (OR) and 95% CIs.

The variable selection process was done based on clinical knowledge<sup>18</sup> and then statistical significance was used for a stepwise selection approach where all candidate variables were included as explanatory terms. Different permutations of a variable were explored, such as age categorised vs continuous variable. Multi-collinearity was checked via variance inflation factor and no major violation was observed.

Model performances were checked using quantile-quantile (Q-Q) plots of the residuals and those that yielded the best residuals and lowest Akaike information criterion were preferred. All statistical analysis was performed using R Statistical software (R Core Team [2020]).

TABLE 1 Characteristics of the study cohort

Variable	n = 162
Socio-demographic characteristics	
Age (years)	67.5 (±14.4)
Gender	
Male	93 (57.4)
Female	69 (42.6)
Race	
Chinese	83 (51.2)
Malay	33 (20.4)
Indian	33 (20.4)
Others	13 (8.0)
Medical history	
Presence of comorbidities <sup>a</sup>	81 (50)
Diabetes mellitus	20 (12.3)
Ischemic heart disease/ cardiomyopathy	35 (21.6)
Hypertension	65 (40.1)
Hyperlipidaemia	34 (21.0)
Chronic kidney disease/end-stage renal failure	39 (24.1)
Lifestyle factors	
Obesity	12 (7.4)
Smoking (current)	41 (25.3)
Treatment of wound	
Surgical treatment of ulcer <sup>b</sup>	5 (0.02)
Surgical treatment of venous system <sup>c</sup>	38 (23.5)
Emergency department visits	86 (53.1)
Variables adjusted for length of follow-up	
Number of inpatient dressing sessions <sup>d</sup> per admission	1.0 (0.8-3.0)
Length of stay per admission (days)	4.0 (1.0-7.0)
Inpatient bill per admission (S\$)	4654.0 (2575.0-7486.0)
Number of outpatient podiatrist dressing sessions per visit	0.5 (0.0-1.1)
Outpatient bill per visit (S\$)	199.5 (134.4-295.6)

Note: Data presented as n (%) for categorical variables, mean (±SD) for normally distributed continuous variables, or as median (Q1 – Q3) for non-normally distributed continuous variables.

<sup>a</sup>Includes diabetes mellitus, ischemic heart disease/cardiomyopathy, hypertension, hyperlipidemia, or chronic kidney disease/end-stage renal failure.

<sup>b</sup>Includes debridement and skin grafting.

<sup>c</sup>Includes radiofrequency ablation, sapheno-femoral ligation and stripping, and sclerotherapy.

<sup>d</sup>Includes podiatrist and nurse dressing sessions.

R: A language and environment for statistical computing. R. Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>).

### 3 | RESULTS

#### 3.1 | Cohort characteristics

Data on 168 VLU patients were available for review. Patients who incurred excessive resources and large bills were considered irrelevant to the analysis due to two primary reasons: (a) excessive utilisation of resources could be due to reasons unrelated to the outcomes of interest; (b) extreme values could skew results that represent the majority. With the advice from a wound care specialist, it was deemed that a patient who incurs 40 days or more of inpatient days is likely caused by other medical conditions that co-exist with a VLU wound. Therefore, five patients who had a length of stay per admission of 40 days or more, and one patient who had a mean inpatient bill per admission that was more than S \$50 000 were excluded from this study. A total of 162 patients were included in the analysis. The statistical distributions of the outcomes analysed are presented in Appendix A.

In Table 1 the characteristics of patients are shown. Mean age was 67.5 ( $\pm 14.4$ ), and 57.4% were male. Most were Chinese (51.2%), followed by the other ethnicities. Hypertension was prevalent, followed by chronic kidney disease or end-stage renal failure, and ischemic heart disease or cardiomyopathy. Close to one-quarter of patients (23.5%) underwent a surgical treatment of the venous system. Approximately half the cohort (53.1%) had at least 1 ED visit due to VLU.

#### 3.2 | Healthcare costs and resources consumed

Approximately 90% of patients who had their initial inpatient admission in years 2013, 2014 or 2015, had their final follow-up admission within 2 years. The sum of inpatient dressing sessions were 305 (95% CI: 2.23-3.75), length of stay was 825 days (95% CI: 6.26-9.91) and inpatient bill amounted to S\$804 412 (95% CI: 6142.86-9629.93), for 102 patients. For an average patient, inpatient dressing sessions was 3.0, length of stay was 8.1 days and inpatient bill was S\$7886.

The duration of outpatient treatment follow-ups varied greatly across the cohort. Therefore, the data for patients who had an outpatient visit in 2013, the first year of the cohort data, was used to estimate the consumption of outpatient resources. The total number of outpatient

TABLE 2 Factors associated with length of stay per inpatient admission: multivariable generalised linear model

Variable	Coefficient (95% CI)	P value
Age (year)	1.01 (1.00-1.02)	.116
Female gender	1.08 (0.83-1.40)	.561
Race		
Malay vs Chinese	0.96 (0.70-1.32)	.781
Indian vs Chinese	1.14 (0.84-1.58)	.397
Others vs Chinese	0.76 (0.49-1.25)	.255
Ischemic heart disease/ cardiomyopathy	1.63 (1.22-2.22)	.002
Surgical treatment of venous system <sup>a</sup>	0.46 (0.34-0.63)	<.001
Number of inpatient dressing sessions per admission <sup>b</sup>	1.19 (1.13-1.27)	<.001

Abbreviation: CI, confidence interval.

<sup>a</sup>Includes radiofrequency ablation, sapheno-femoral ligation and stripping, and sclerotherapy.

<sup>b</sup>Includes podiatrist and nurse dressing sessions.

TABLE 3 Factors associated with inpatient bill per admission: multivariable generalised linear model

Variable	Coefficient (95% CI)	P value
Age (year)	1.00 (0.99-1.01)	.633
Female gender	0.98 (0.74-1.30)	.888
Race		
Malay vs Chinese	0.95 (0.68-1.34)	.757
Indian vs Chinese	1.24 (0.89-1.75)	.206
Others vs Chinese	0.95 (0.58-1.62)	.828
Ischemic heart disease/ cardiomyopathy	1.81 (1.26-2.64)	.001
Chronic kidney disease/end- stage renal failure	1.36 (0.95-1.95)	.075
Surgical treatment of venous system <sup>a</sup>	1.27 (0.91-1.79)	.160
Number of inpatient dressings per admission <sup>b</sup>	1.11 (1.05-1.17)	<.001

Abbreviation: CI, confidence interval.

<sup>a</sup>Includes radiofrequency ablation, sapheno-femoral ligation and stripping, and sclerotherapy.

<sup>b</sup>Includes podiatrist and nurse dressing sessions.

podiatrist dressing sessions and outpatient bill amounted to 2260 (95% CI: 18.46-40.24) and S\$536 068 (95% CI: 5119.08-8804.75), respectively, for 77 patients. Mean dressing sessions per patient and outpatient bill per patient was 29.4 and S\$6962.

**TABLE 4** Factors associated venous system surgical procedure (no or yes): multivariable logistic regression model

Variable	Odds ratio (95% CI)	P value
Age (year)	0.95 (0.90-0.98)	.004
Female gender	3.01 (1.20-8.08)	.022
Race		
Malay vs Chinese	0.97 (0.29-3.03)	.957
Indian vs Chinese	0.97 (0.29-2.99)	.963
Others vs Chinese	2.26 (0.44-12.31)	.327
Diabetes mellitus	0.13 (0.01-0.85)	.073
Ischemic heart disease/ cardiomyopathy	0.19 (0.01-1.06)	.120
Chronic kidney disease/end- stage renal failure	0.15 (0.01-0.86)	.081

Abbreviation: CI, confidence interval.

### 3.3 | Inpatient services

The GLM results—that inform the second aim of this study—are presented in Tables 2 and 3. In Table 2 we see that patients with a history of ischemic heart disease or cardiomyopathy, patients who had a venous system surgical procedure, and the number of inpatient dressing sessions per admission were significantly associated with length of stay. The presence of ischemic heart disease or cardiomyopathy results in a 63% increase in the length of stay ( $\beta$ : 1.63, 95% CI: 1.22-2.22), which converts to these patients incurring an additional 3.6 inpatient days per admission compared to their counterparts. Patients who underwent a surgical procedure on the venous system use fewer bed days by 3.1 days ( $\beta$ : 0.46, 95% CI: 0.34-0.63) compared to patients who did not. A unit increase in the number of inpatient dressing sessions causes an additional 1.09 bed days ( $\beta$ : 1.19, 95% CI: 1.13-1.27).

In Table 3 we see the presence of heart disease or cardiomyopathy and number of inpatient dressing sessions were significantly associated with higher inpatient bill. Patients with heart disease incur an additional inpatient bill amount average of S\$5088 ( $\beta$ : 1.81, 95% CI: 1.26-2.64) per admission compared to patients without. Similarly, patients with a history of chronic kidney disease incur higher inpatient bill compared to patients without ( $\beta$ : 1.36, 95% CI: 0.95-1.95), though this was less precisely estimated. A unit increase in the number of dressing sessions per admission increases inpatient bill by S\$691 ( $\beta$ : 1.11, 95% CI: 1.05-1.17).

The results from GLM regression for venous system surgical procedure are presented in Table 4. Age and gender were statistically significant with surgical procedures

**TABLE 5** Factors associated with outpatient bill per visit: multivariable generalised linear model

Variable	Coefficient (95% CI)	P value
Age (year)	1.00 (0.99-1.01)	.798
Female gender	1.14 (0.91-1.45)	.262
Race		
Malay vs Chinese	1.16 (0.87-1.57)	.329
Indian vs Chinese	0.84 (0.63-1.13)	.235
Others vs Chinese	0.93 (0.61-1.46)	.728
Diabetes mellitus	0.68 (0.48-0.97)	.031
Chronic kidney disease/end- stage renal failure	1.18 (0.90-1.57)	.247

Abbreviation: CI, confidence interval.

of the venous system. A unit increase in age decreased the odds of a patient going through the procedure by 5% (95% CI: 0.90-0.98). Also, females had thrice the odds of undergoing this form of treatment compared to males (OR: 3.01, 95% CI: 1.20-8.08). Although imprecisely estimated, the associations of several factors were found to be close to the accepted threshold of statistical significance with the outcome variable. The odds of going through the surgical procedure were found to be lower in patients with a history of diabetes mellitus, heart disease, and kidney disease, by 87% (95% CI: 0.01-0.85), 81% (95% CI: 0.01-1.06), and 85% (95% CI: 0.01-0.86), respectively, compared to those without.

### 3.4 | Outpatient services

GLM results for outpatient bill per visit and ED visit are presented in Tables 5 and 6, respectively. Patients with a history of diabetes mellitus incur a lower outpatient bill by \$74 ( $\beta$ : 0.68, 95% CI: 0.48-0.97) per visit compared to patients without, and this association was found to be significant. Though imprecisely estimated, females had a higher outpatient bill by 14% ( $\beta$ : 1.14, 95% CI: 0.91-1.45), which converts to S\$32 more per visit incurred by females vs males. In Table 6, the association between the incurrence of an ED visit and presence of comorbidities was found to be statistically significant. Patients with one or more comorbidities had greater odds by 5-fold (OR: 5.06, 95% CI: 1.29-25.85), compared to patients without any. Less precisely estimated, however, a notable association would be that patients with heart disease or cardiomyopathy had more than twice the odds of incurring an ED visit (OR: 2.39, 95% CI: 0.86-7.22) for ED visit.

**TABLE 6** Factors associated with emergency department visit (no or yes): Multivariable generalised linear model

Variable	Odds ratio (95% CI)	P value
Age (year)	1.01 (0.99-1.04)	.324
Female gender	0.65 (0.31-1.32)	.229
Race		
Malay vs Chinese	1.36 (0.55-3.44)	.510
Indian vs Chinese	1.14 (0.47-2.76)	.778
Others vs Chinese	0.51 (0.11-2.11)	.368
Presence of comorbidities <sup>a</sup>	5.06 (1.29-25.85)	.029
Ischemic heart disease/ cardiomyopathy	2.39 (0.86-7.22)	.106
Hypertension	0.38 (0.08-1.44)	.186

Abbreviation: CI, confidence interval.

<sup>a</sup>Includes diabetes mellitus, ischemic heart disease/cardiomyopathy, hypertension, hyperlipidemia, or chronic kidney disease/end-stage renal failure.

## 4 | DISCUSSION

This study reveals that treating VLU is costly, and, how the consumption of healthcare resources varies among VLU patients. Patients with a medical history of ischemic heart disease or cardiomyopathy were significantly associated with higher cost-related outcomes such as longer length of stay and higher inpatient bill per admission. Moreover, female patients were more likely to undergo a venous system surgical procedure compared to males, and patients with comorbidities were more likely to incur an ED visit compared to patients without.

The cost of outpatient care was found to be lower than inpatient care. Outpatient bill was 12% lesser than inpatient bill per patient even though outpatient dressing sessions were 90% higher than inpatient dressing sessions per patient. Outpatient care is vital to the treatment of VLU as it maintains mobility, prevents complications that arise from continuous bed rest, and is less costly.<sup>19</sup> Likewise, a study<sup>20</sup> conducted in a wound centre with 84 patients and a 6-month follow-up period reported that total cost for VLU was significantly lower in outpatients compared to inpatients, US\$10 851 vs US\$33 629. In contrast, an economic evaluation of wound care in US for Medicare beneficiaries reported highest costs in hospital outpatient care, US\$9.9-US\$35.8 billion, compared to other sites of service,<sup>14</sup> possibly due to increased availability of outpatient treatments.<sup>21</sup> In a more recent UK study on VLU treatment costs, direct costs to the Welsh NHS made up 1.2% of the annual budget and it was also identified that nurse visits, dressings, and compression bandages were major cost drivers.<sup>12</sup> Although high costs

are incurred, a review of chronic venous leg ulceration found that the quality of life for patients could be further improved.<sup>22</sup> This evidence shows opportunities for research on the cost-effectiveness of prevention programmes and improved management targeted at specific patient groups with VLUs.<sup>20,23</sup> The additional costs of optimal care should be balanced against the potential savings from shorter lengths of stay, fewer consumables, and fewer re-admissions.

VLU patients with one or more comorbidities were five times more likely to incur an ED visit compared to patients without. This is an important find as higher risk of comorbidities that affect wound healing potential is expected of a growing aging population.<sup>24</sup> Furthermore, care in EDs is costly, resulting from on-demand services, trained personnel, and the provision of specialised medical devices to handle crises.<sup>25</sup> This study also found VLU patients with ischemic heart disease or cardiomyopathy to be significantly associated with higher cost outcomes such as longer length of stay and higher inpatient bill. This supports existing literature stating cardiovascular disease as an important factor in wound healing.<sup>26</sup> Interestingly, patients with existing heart conditions were less likely to undergo surgical procedures of the venous system, though this was not statistically significant. A similar pattern was observed in VLU patients with chronic kidney disease or end-stage renal failure, where they were associated with higher inpatient bill per visit, but was less likely to incur a venous system surgery. It is plausible that physicians do not recommend such procedures as a priority treatment for VLU patients with existing comorbid conditions due to potential risks involved. This could consequently lead to high utilisation of resources, such as more hospital bed days and dressing sessions. Although cost outcomes vary among VLU patients depending on wound sizes and severity,<sup>13</sup> this study highlights the importance of targeting optimal care on specific VLU patient groups, so as to reduce costs arising from VLU cases.

Guideline-based care or optimal care is often held up as a sensible policy goal. And the economic arguments for this are strong with a prospective study of changes to costs and quality of life strongly favouring the adoption of optimal care.<sup>27</sup> A 2018 systematic review on economic evaluations of interventions aimed at chronic wound prevention and management deduced that a guide-lined based care was most likely to be a cost-effective or cost-saving alternative.<sup>23</sup> If the change to total costs from implementation is favourable when compared to changes to health benefits, then economic arguments can be made to support an adoption decision.<sup>28,29</sup>

There are several limitations to this study. The length of inpatient stay is underestimated for VLU patients with

surgeries, as a majority of patients who had done VLU-related surgeries during non-wound-related admissions were excluded from this analysis. This resulted in patients with surgery being significantly associated with shorter length of stay compared to those without surgeries. Second, we analysed factors associated with direct costs, and did not incorporate indirect costs such as time away from productive activity. Hence the total societal costs involved in VLU patient treatment and management are underestimated in this study. Finally, there was no data on the nature of the wound, such as wound size, severity, and if the wound was healed. This could have provided more insight into factors contributing to cost-related outcomes.

## 5 | CONCLUSION

The cost of VLU outpatient care was lower than inpatient care for the average patient, and VLU patients with specific characteristics were associated with higher cost-related outcomes. Heart disease patients incurred longer length of stay per admission and higher inpatient bill per admission, female patients were more likely to undergo a venous system surgical procedure, and patients with comorbidities were more likely to incur an ED visit. Important information on cost can provide some insights on the direction of wound treatment so as to mitigate costs.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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