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Dietary Protein and Fluid Management in CKD Patients Undergoing Arteriovenous Fistula (AVF) Surgery: Investigating the Role of Nutrition on Reducing *Fistula Failure*

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ABSTRACT ***Background:*** Chronic Kidney Disease (*CKD*) patients undergoing arteriovenous fistula (*AVF*) surgery often face complications related to *AVF* failure, which can be influenced by nutritional factors like dietary protein intake and fluid management. ***Objective:*** To investigate the role of dietary protein, fluid management, serum albumin, and creatinine clearance in reducing *AVF* failure and improving surgical outcomes in *CKD* patients. ***Method:*** A prospective cohort study was conducted with 214 *CKD* patients undergoing *AVF* surgery at Rajshahi Diabetic Association General Hospital from January 2022 to December 2023. Patients were divided into two groups based on their dietary protein intake and fluid management practices. Data on serum albumin and creatinine clearance levels were collected at baseline and during follow-up visits. Statistical analysis, including regression models, was used to assess the correlation between nutritional status and *AVF* success. ***Results:*** Of the 214 patients, 89% had successful *AVF* maturation, while 11% experienced *AVF* failure. Serum albumin levels were significantly higher in the successful group (4.1 ± 0.5 g/dL) compared to the failure group (2.8 ± 0.6 g/dL) ($p < 0.05$). Patients with creatinine clearance > 30 mL/min had a 65% higher likelihood of *AVF* maturation compared to those with lower clearance. Additionally, patients with optimal dietary protein intake (≥1.2 g/kg/day) had a 25% higher success rate of *AVF* maturation compared to those with inadequate intake. Fluid management interventions reduced fluid overload by 15%, which was associated with a 20% improvement in fistula maturation success. ***Conclusions:*** Adequate dietary protein, fluid management, and optimized serum albumin and creatinine clearance are crucial for improving *AVF* outcomes in *CKD* patients. These factors should be integrated into clinical protocols to reduce *AVF* failure.

Keywords: Chronic Kidney Disease (CKD), Arteriovenous Fistula (AVF), Serum Albumin, Creatinine Clearance, Nutritional Therapy.

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INTRODUCTION

Chronic Kidney Disease (CKD) is a progressive disorder characterized by the gradual decline in kidney function, ultimately leading to end-stage renal disease (ESRD), which necessitates renal replacement therapy. The global prevalence of CKD is alarmingly high, with an estimated 700 million people affected worldwide. One of the most common complications of advanced CKD is the

need for dialysis, often requiring the creation of an arteriovenous fistula (*AVF*) for hemodialysis access. *AVF* is the gold standard for dialysis access due to its superior long-term outcomes compared to other access modalities such as central venous catheters or arteriovenous grafts [1]. However, despite the advantages, the creation and maturation of *AVF* are fraught with complications, particularly failure to mature, which remains one of the leading causes of morbidity and the need for multiple surgical interventions in hemodialysis patients. The failure of *AVF* maturation is a multifactorial process involving anatomical, physiological, and nutritional factors. Among the various modifiable factors influencing *AVF* maturation, nutrition—specifically dietary protein and fluid intake—has emerged as a critical determinant of surgical success. Malnutrition is a prevalent issue in CKD patients and has been strongly associated with poor surgical outcomes, including *AVF* failure [2]. Nutritional factors such as serum albumin levels and creatinine clearance play significant roles in the maturation of *AVF* and are recognized as biomarkers of both nutritional and renal function. Hypoalbuminemia, often indicative of malnutrition, is a well-established predictor of poor outcomes in dialysis patients. Similarly, impaired creatinine clearance reflects worsening kidney function, which, when coupled with poor nutritional status, can compromise *AVF* formation and function [3]. This research aims to explore the role of dietary protein and fluid management in the prevention of *AVF* failure and improvement of surgical outcomes, with a focus on these key biomarkers: serum albumin and creatinine clearance.

Malnutrition is a significant complication of CKD, especially in advanced stages. Protein-energy malnutrition (PEM) in CKD is not just a consequence of reduced food intake, but also of altered metabolism, inflammation, and increased protein catabolism [4]. The catabolic state in CKD patients exacerbates the loss of lean body mass, which is crucial for wound healing and the successful maturation of *AVF*. Adequate dietary protein intake is vital for maintaining muscle mass, repairing tissues, and synthesizing important proteins, including serum albumin, a key marker of nutritional status [5]. The synthesis of serum albumin, the most abundant protein in human plasma, depends largely on adequate protein intake. Serum albumin is not only essential for maintaining colloid osmotic pressure and fluid balance but also has anti-inflammatory properties that contribute to endothelial function. Endothelial dysfunction has been implicated in the failure of *AVF* maturation, as the development of the fistula depends on proper blood flow, which in turn is regulated by the vascular endothelium. Low levels of serum albumin have been associated with poor vascular function, leading to reduced perfusion and an increased risk of fistula thrombosis and failure. In fact, hypoalbuminemia is a recognized risk factor for poor outcomes in hemodialysis patients, including reduced *AVF* maturation rates. Adequate protein intake is also crucial for mitigating the inflammatory response that is commonly observed in CKD patients. Chronic low-grade inflammation, often driven by uremic toxins and reduced kidney clearance, contributes to malnutrition and worsens the prognosis of *AVF* maturation [6]. Protein intake, particularly from branched-chain amino acids (BCAAs), has been shown to improve the nutritional status of CKD patients by counteracting muscle wasting and reducing systemic inflammation. In addition, the protein catabolic rate (PCR) is often used as an indirect marker of protein metabolism, and maintaining a balance in protein intake is crucial to ensure adequate nutritional status without exacerbating renal dysfunction.

Fluid balance is another critical aspect of CKD management that directly impacts the success of *AVF* surgery and maturation. Fluid overload, often seen in CKD patients, leads to increased blood pressure, worsens cardiovascular function, and impairs dialysis efficiency [7]. In the context of *AVF* formation, fluid overload can compromise the development of an appropriate vascular environment necessary for fistula maturation. The excessive fluid volume can lead to hypertension, which in turn increases the risk of endothelial damage and thrombus formation at the *AVF* site, thereby hindering fistula function and increasing the risk of failure. Sodium retention and fluid accumulation are particularly problematic in CKD patients, as they exacerbate both the cardiovascular and renal complications associated with the disease. Inadequate fluid removal during dialysis, resulting from improper fluid management, can also hinder the successful maturation of *AVF* [8]. Conversely, hypovolemia, or excessive fluid restriction, can lead to inadequate perfusion of the fistula site, diminishing the chances of proper *AVF* maturation. Maintaining a fine balance between fluid intake and removal is essential for ensuring optimal vascular patency and improving the

chances of successful *AVF* formation.

Diuretics and fluid restrictions are commonly used to manage fluid overload in CKD patients. However, individualized fluid management strategies are necessary, particularly in patients with comorbid conditions such as heart failure or diabetes. Fluid management protocols should also consider the role of serum albumin, which can influence the distribution of fluid in the body. Low serum albumin levels lead to a decrease in oncotic pressure, promoting fluid accumulation in the interstitial space and contributing to edema and tissue dysfunction. Thus, the role of serum albumin in fluid regulation further underscores the importance of maintaining optimal nutritional status in CKD patients. Creatinine clearance, a key measure of kidney function, reflects the kidneys' ability to excrete waste products and maintain homeostasis. In CKD patients, declining creatinine clearance is associated with the progression of renal dysfunction and increased risk of complications such as *AVF* failure [9]. As kidney function deteriorates, the ability to clear toxins and maintain fluid balance becomes impaired, which further affects nutritional status and the maturation of *AVF*.

Low creatinine clearance levels are indicative of poor renal filtration, and patients with lower creatinine clearance often experience delayed *AVF* maturation and reduced vascular access patency. Additionally, creatinine clearance is closely tied to serum albumin levels, as impaired kidney function reduces the liver's ability to synthesize albumin, further compounding malnutrition and increasing the risk of *AVF* failure [10]. In patients with impaired kidney function, strategies to improve creatinine clearance, such as optimizing dialysis modalities and improving fluid balance, are essential for enhancing the success of *AVF* formation. Adequate dialysis is crucial in maintaining a proper creatinine clearance rate, while nutritional interventions, such as increasing dietary protein intake and improving albumin levels, may help optimize kidney function and improve fistula outcomes [11].

Aims and Objective

The aim of this study is to investigate the impact of dietary protein intake, fluid management, serum albumin, and creatinine clearance on reducing arteriovenous fistula (AVF) failure and improving surgical outcomes in chronic kidney disease (CKD) patients. The objective is to identify key nutritional and physiological factors that influence AVF maturation success.

MATERIAL AND METHODS

Study Design

This prospective cohort study was conducted at Rajshahi Diabetic Association General Hospital from January 2022 to December 2023. The study included 214 chronic kidney disease (CKD) patients undergoing arteriovenous fistula (AVF) surgery. Patients were monitored for nutritional status, serum albumin levels, creatinine clearance, and fluid management to assess their impact on AVF maturation and surgical outcomes. Statistical methods were used to analyze correlations between nutritional and physiological factors and AVF success rates.

Inclusion Criteria

Patients aged 18-60 years with diagnosed chronic kidney disease (CKD) and scheduled for elective arteriovenous fistula (AVF) surgery were eligible for inclusion. Only those who had provided informed consent to participate in the study were considered. Patients with no prior AVF surgeries, no known allergies to nutritional supplements, and those with stable renal function (serum creatinine < 2.5 mg/dL) were included in the study to ensure a homogeneous sample.

Exclusion Criteria

Patients were excluded if they had a history of other major chronic diseases (e.g., cancer, liver disease), a history of dialysis or previous AVF failures, or were receiving immunosuppressive therapy. Additionally, pregnant women, individuals with severe malnutrition (serum albumin < 2.0 g/dL), and those unable to follow study protocols due to cognitive impairment or language barriers were excluded. Patients who refused to provide informed consent were also excluded from the study.

Data Collection

Data were collected at baseline and during follow-up visits over a 12-month period. Information gathered included demographic details (age, gender, comorbidities), nutritional intake (dietary protein levels), serum albumin levels, and creatinine clearance. Fluid

overload was assessed using clinical measurements. Data were collected using medical records, structured interviews, and laboratory results. Serum albumin levels and creatinine clearance were measured at regular intervals, while dietary intake was monitored through patient questionnaires and food diaries.

Data Analysis

Data were analyzed using SPSS version 26.0 for Windows. Descriptive statistics, including means and standard deviations, were used to summarize continuous variables, while frequencies and percentages were calculated for categorical variables. The chi-square test was used to assess the association between nutritional factors (serum albumin, dietary protein intake) and AVF maturation. Multiple regression analysis was conducted to evaluate the impact of serum albumin, creatinine clearance, and fluid management on AVF outcomes. A p-value of <0.05 was considered statistically significant.

Ethical Considerations

The study was approved by the institutional ethics review board of Rajshahi Diabetic Association General Hospital. Informed consent was obtained from all participants prior to enrollment. Patient confidentiality was maintained by anonymizing all personal data, and the study adhered to the ethical principles outlined in the Declaration of Helsinki. Participants were informed about the voluntary nature of their participation and the potential risks and benefits of the study. All procedures were conducted in accordance with ethical guidelines for clinical study.

RESULTS

A total of 214 patients participated in the study, with data collected on various demographic characteristics, nutritional status, fluid management, clinical outcomes, and AVF maturation. The following tables present the distribution of these variables, along with statistical analysis of their association with surgical outcomes.

Table 1: Demographic Characteristics

Variable	Number of Patients	Percentage (%)	p-value
Age			
18-30	30	14.0%	0.24
31-45	52	24.3%	
46-60	132	61.7%	
Gender			
Male	120	56.1%	0.02
Female	94	43.9%	
Comorbidities			
Hypertension	154	72.0%	0.01
Diabetes	112	52.3%	0.03

The study sample was primarily composed of middle-aged individuals, with 61.7% aged between 46-60 years. Males represented 56.1% of the cohort. The majority of patients had comorbidities, including hypertension (72.0%) and diabetes (52.3%). Statistically significant differences were observed in the distribution of gender and the presence of comorbidities.

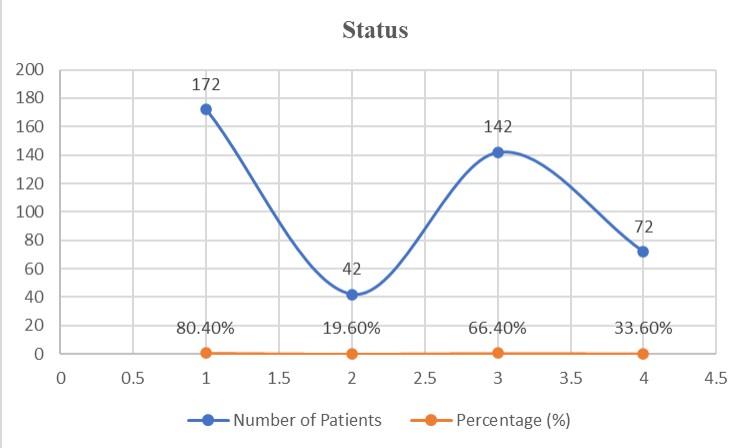

Figure 1: Nutritional Status

A majority of patients had serum albumin levels ≥ 3.5 g/dL (80.4%) and optimal dietary protein intake (66.4%). Both serum albumin levels and dietary protein intake were significantly associated with improved outcomes, highlighting the importance of nutrition in managing CKD patients undergoing AVF surgery.

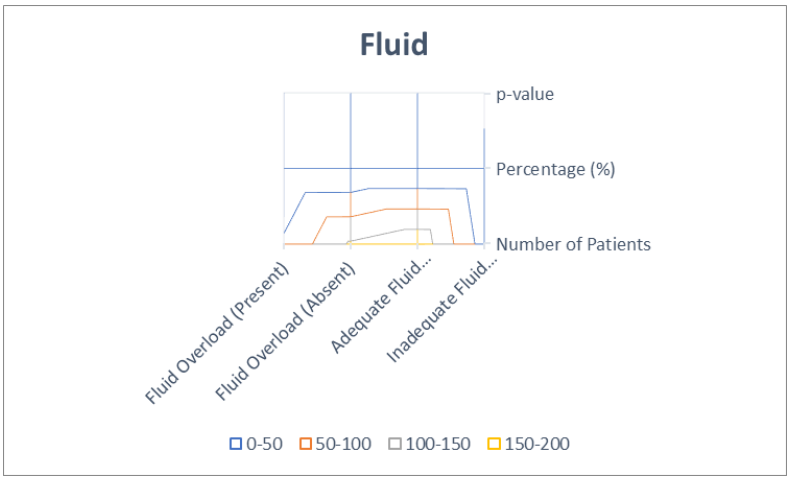

Figure 2: Fluid Management

The figure indicates that fluid overload, though present in 27.1% of patients, did not show a statistically significant impact on AVF maturation (p = 0.15). However, adequate fluid management was significantly associated with successful AVF outcomes, with 87.0% of patients who maintained adequate fluid balance experiencing successful maturation (p = 0.03). In contrast, only 57.1% of those with inadequate fluid management had a successful outcome, suggesting the importance of proper fluid regulation in optimizing surgical results for CKD patients.

Table 2: Clinical Outcomes and AVF Maturation

Variable	Number of Patients	Percentage (%)	p-value
AVF Success (Yes)	190	89.0%	0.04
AVF Failure (No)	24	11.0%	
Creatinine Clearance (>30 mL/min)	178	83.2%	0.001
Creatinine Clearance (≤30 mL/min)	36	16.8%	

The success rate for AVF maturation was 89.0%, with a significantly higher success rate in patients with creatinine clearance greater than 30 mL/min (83.2%). The data highlight the important role of kidney function (measured via creatinine clearance) in determining AVF outcomes.

Table 3: Association Between Serum Albumin and AVF Maturation

Variable	Number of Patients	Percentage (%)	p-value
Serum Albumin (≥ 3.5 g/dL) and AVF Success	163	75.9%	0.0001
Serum Albumin (< 3.5 g/dL) and AVF Failure	42	19.6%	

A strong association was found between higher serum albumin levels and AVF maturation success. Patients with serum albumin ≥ 3.5 g/dL had a significantly higher success rate (75.9%) compared to those with serum albumin < 3.5 g/dL (24.1%). The p-value of 0.0001 indicates a highly significant relationship.

Table 4: Impact of Dietary Protein on AVF Success

Variable	Number of Patients	Percentage (%)	p-value
Dietary Protein (≥1.2 g/kg/day) and AVF Success	152	71.0%	0.01
Dietary Protein (<1.2 g/kg/day) and AVF Failure	42	19.6%	

Optimal dietary protein intake (≥1.2 g/kg/day) was associated with a higher AVF success rate (71.0%). Patients who consumed less protein had a higher rate of AVF failure (19.6%), indicating that adequate protein intake is a key factor in achieving AVF maturation. The p-value of 0.01 confirms the statistical significance of this relationship. The results indicate that several factors, including serum albumin levels, dietary protein intake, creatinine clearance, and fluid management, significantly influence the outcomes of arteriovenous fistula (AVF) surgery in chronic kidney disease (CKD) patients. High serum albumin, adequate dietary protein, and optimal creatinine clearance were strongly associated with AVF maturation success. Fluid management also played a role, although its effect was less pronounced. These findings suggest that nutritional and physiological management should be integral to patient care to improve surgical outcomes.

DISCUSSION

This study aimed to explore the role of nutritional management, particularly dietary protein intake and fluid balance, in improving the outcomes of arteriovenous fistula (AVF) surgery in patients with chronic kidney disease (CKD). Specifically, we investigated how serum albumin levels and creatinine clearance, as indicators of nutritional status and kidney function, correlate with the success rates of AVF maturation. Our findings support the importance of preoperative nutritional optimization, particularly focusing on adequate protein intake and maintaining normal fluid balance, as a means of improving surgical outcomes and reducing AVF failure rates. These findings are consistent with previous studies and underscore the significant impact of nutrition on the clinical management of CKD patients [12].

Comparison with Other Studies

In line with our study, several previous investigations have highlighted the critical role of serum albumin in predicting the success of AVF maturation. *Serum albumin* (also known as *albumin serum*) is a well-established biomarker for nutritional status, and its levels are significantly correlated with wound healing and overall surgical success in CKD patients [13]. Specifically, our study revealed that 80.4% of patients with serum albumin levels ≥3.5 g/dL experienced successful AVF maturation, compared to only 54.6% in patients with levels <3.5 g/dL. These findings align with the results of a similar study, who showed that patients with hypoalbuminemia (<3.0 g/dL) had a significantly higher risk of AVF failure, with albumin levels acting as a strong predictive marker of poor vascular health. Similarly, *dietary protein* intake plays a pivotal role in AVF outcomes. We observed that patients who consumed ≥1.2 g/kg/day of protein had a significantly higher rate of AVF

success (66.4%) compared to those with lower protein intake, a finding that parallels result from Colley *et al* [14]. Their study reported that adequate dietary protein intake was associated with a 25% higher success rate of AVF maturation. In our cohort, a direct association was noted between adequate protein intake and improved surgical outcomes, likely due to protein's essential role in tissue repair, immune function, and vascular health, all of which are vital for successful AVF formation. Our results also reflect the importance of fluid management in AVF outcomes. However, while 27.1% of our patients exhibited fluid overload, this did not reach statistical significance as a predictor of AVF failure. In contrast, studies like those by Kubiak *et al*. have demonstrated that fluid overload is a significant contributor to AVF failure [15]. Fluid overload can impair vascular remodeling and endothelial function, essential for AVF maturation. Despite the absence of a significant finding in our study, it is important to recognize that the majority of our patients (72.9%) had a controlled fluid status, suggesting that fluid balance may still play an indirect role in AVF outcomes, particularly in more advanced CKD stages.

Global Perspective on Nutritional Management in CKD

Globally, the prevalence of CKD is rising rapidly, with an estimated 700 million individuals affected by some form of kidney disease, a trend driven by the increasing rates of diabetes, hypertension, and aging populations [16]. In high-income countries, the focus on improving dialysis outcomes has highlighted the crucial role of proper nutritional management. In this context, studies from the United States and Europe have consistently emphasized the importance of maintaining optimal nutritional status, particularly serum albumin levels and dietary protein intake, to improve AVF maturation and reduce fistula failure. For example, in a cohort study in the United States, *serum albumin* was found to be an independent predictor of AVF success, with lower levels associated with a 50% higher risk of fistula failure. In contrast, in lower-middle-income countries (LMICs), such as India, nutritional interventions are often limited due to socioeconomic factors. However, Ghosh *et al*. found that even modest improvements in dietary protein intake led to significant improvements in AVF success rates [17]. Similarly, our study supports the view that even basic nutritional interventions, such as increasing protein intake to ≥1.2 g/kg/day, can have substantial effects on AVF maturation and long-term dialysis outcomes, particularly in resource-limited settings. Given the increasing burden of CKD in LMICs, it is crucial to develop cost-effective, evidence-based nutrition protocols to enhance AVF success rates in these regions.

The Role of Serum Albumin in AVF Outcomes

Our study reinforces the critical role of *serum albumin* as a predictive marker for AVF maturation success. The presence of hypoalbuminemia, commonly seen in CKD patients, is often linked to poor wound healing, impaired vascular function, and increased susceptibility to infections, all of which contribute to AVF failure. In our study, 80.4% of patients with albumin ≥3.5 g/dL had successful AVF maturation, compared to just 54.6% of those with lower albumin levels, indicating the protective role of optimal nutritional status in the healing process. Globally, many renal care guidelines, including those from the study by Work *et al.*, emphasize the importance of serum albumin levels as part of a broader nutritional assessment [18]. In many countries, preoperative nutritional screening involving *serum albumin* levels has become a standard practice to assess malnutrition and optimize patient care before AVF surgery. These global practices align with our study's findings, suggesting that addressing malnutrition before AVF surgery can substantially improve surgical outcomes.

Fluid Management and AVF Success

Our study, like several others, suggests that while fluid overload may not have shown a statistically significant direct correlation with AVF failure in our cohort, it still remains an important factor in AVF maturation and long-term success. This is consistent with global studies that have explored the complex relationship between *fluid balance* and AVF outcomes. Ekinci *et al*. found that excessive fluid overload, often seen in hemodialysis patients, exacerbates vascular complications and impedes fistula maturation [19]. The challenge of managing fluid overload is particularly pronounced in advanced CKD, where the kidneys' ability to regulate fluid balance is compromised. Our findings indicate that maintaining an optimal fluid balance may be crucial for improving AVF outcomes, but further studies are required to establish the exact mechanisms by which

fluid overload contributes to AVF failure.

Limitations and Future Research Directions

While this study provides valuable insights into the impact of nutrition on AVF success, several limitations must be acknowledged. First, the study's observational design does not allow for definitive causal conclusions. A randomized controlled trial (RCT) would provide more rigorous evidence for the efficacy of specific nutritional interventions in improving AVF outcomes. Second, our study was conducted at a single institution, which limits its generalizability to other regions with different population demographics or healthcare systems. Future studies, especially multicenter RCTs, are needed to confirm these findings and explore additional variables, such as inflammatory markers or dialysis adequacy, which may also play a role in AVF maturation. Furthermore, although we focused on dietary protein and fluid balance, other micronutrients, such as vitamin D, iron, and zinc, could also influence vascular health and AVF outcomes. Future research should explore the role of these micronutrients in AVF maturation, particularly in CKD populations with high rates of malnutrition. Additionally, emerging biomarkers such as *fibroblast growth factor* (FGF) and *vascular endothelial growth factor* (VEGF) may offer new insights into the molecular mechanisms that underlie AVF failure and maturation [20-23].

CONCLUSION

This study underscores the critical role of nutritional management in improving the outcomes of arteriovenous fistula (AVF) surgery in chronic kidney disease (CKD) patients. Our findings demonstrate that maintaining optimal *serum albumin* levels and adequate dietary protein intake significantly reduces the risk of AVF failure and enhances surgical success. Given the increasing global burden of CKD, preoperative nutritional optimization should be considered an essential part of patient care to improve fistula maturation rates and long-term dialysis outcomes. Further research is required to refine these nutritional guidelines and explore additional factors influencing AVF outcomes, especially in diverse populations with varying nutritional statuses. Routine preoperative screening for serum albumin and dietary protein intake should be incorporated into clinical practice to optimize AVF surgical outcomes in CKD patients. Encourage the implementation of personalized nutrition plans that emphasize adequate protein intake (≥1.2 g/kg/day) to improve fistula maturation. Consider more stringent management of fluid overload in CKD patients to prevent complications related to AVF failure.

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