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THE USE OF BODY COMPOSITION MONITOR-GUIDED ULTRAFILTRATION TO REDUCE INTRADIALYTIC ADVERSE EVENTS IN IRAQI HEMODIALYSIS PATIENTS

Jawad Fadhil Al-Tu'ma*[1], Ali Jasim Al-Saedi[2], Alaa Abdulhussein Alshibly[3] and Fadhil Jawad Al-Tu'ma[4,5]

[1]M.B.Ch.B.; FICMS., Al-Zahraa Teaching Hospital, Kerbala Health Directorates / Kerbala – Iraq.
[2]Professor of Nephrology and Internal Medicine, College of Medicine, University of Baghdad, Renal Transplantation Centre, Baghdad Medical City / Baghdad – Iraq.
[3]FICMS, CABM, Professor of Nephrology and Internal Medicine, College of Medicine, University of Jabir Ibn Hayyan / Najef – Iraq.
[4]Emeritus Professor, Department of Chemistry and Biochemistry, College of Medicine, University of Kerbala / Kerbala – Iraq.
[5]Department of Medical Laboratories Techniques, College of Health and Medical Techniques, Al-Mustaqbal University, 51001 / Babylon, Iraq.

***Corresponding Author: Jawad Fadhil Al-Tu'ma**
M.B.Ch.B.; FICMS., Al-Zahraa Teaching Hospital, Kerbala Health Directorates / Kerbala – Iraq.

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ABSTRACT
Background: Chronic kidney disease (CKD) and end-stage renal disease (ESRD) demand hemodialysis (HD), which is often complicated by intradialytic adverse events due to poor fluid management. Traditional clinical methods for determining dry weight are biased and unreliable which can increase risks like hypotension and cardiovascular strain. **Objectives:** In this randomized controlled trial, the efficacy of bioimpedance spectroscopy-guided ultrafiltration in reducing complications among Iraqi CKD patients. **Materials and Methods:** Eighty Iraqi HD patients (40 per group) over six months were evaluated. For the BCM group, a specialized device called the Fresenius Body Composition Monitor was used to measure hydration levels and adjust fluid removal. In contrast, the clinical group relied on standard assessments. **Results:** Results demonstrated significant reductions in overhydration (6.7 vs. 2.1 liters, $p<0.001$) and blood pressure (systolic: -11.0 vs. -5 mmHg; diastolic: -6.0 vs. -1 mmHg, $p<0.001$) in the BCM group. Intradialytic adverse events, including hypotension (3.4 vs. 6.7 events/patient), muscle cramps (3.4 vs. 8.9), dyspnea (1.9 vs. 5.3), and dizziness (3.6 vs. 6.5), were significantly lower in the BCM group (all $p<0.001$). These findings highlight bioimpedance spectroscopy-guided ultrafiltration superiority in enhancing hemodynamic stability and reducing treatment-related complications. Our study underscores the viability of BCM technology in developing countries like Iraq, where overcrowded dialysis units and limited access to advanced care amplify challenges. BCM technology provides a scalable solution to improve patient outcomes, reduce healthcare burdens, and potentially lower long-term cardiovascular risks. **Conclusion:** According to observed data, this study makes a strong case for adding BCM to standard dialysis care worldwide, especially in regions where healthcare resources are limited.

KEYWORDS: Hemodialysis, Bioimpedance spectroscopy, Body composition monitor, Intradialytic hypotension, Fluid management.

INTRODUCTION
The kidneys referred to as two bean-shaped organs situated beneath the ribcage, are indispensable to human physiology, orchestrating a symphony of processes that sustain homeostasis. Beyond their role as mere filters, they regulate blood pressure, electrolyte balance, erythropoiesis, and bone health. When exposed to various dangers, kidneys are surprisingly delicate despite

their durability. These essential organs are susceptible to damage from metabolic disorders and environmental toxins **(Li *et al.*, 2024).** Over 850 million people worldwide live with kidney damage or failure, whether from chronic kidney disease (CKD) or acute kidney injury (AKI) **(Francis *et al.*, 2024).** For many, these conditions progress to end-stage renal disease (ESRD), a permanent loss of kidney function and various biomarkers were demonstrated for their diagnosis **(Hu *et al.*, 2025; Al-Tu'ma, *et. al.*, 2017).** CKD often develops quietly over the years and can be exacerbated by conditions like diabetes or high blood pressure **(Romagnani *et al.*, 2017)**. By the time symptoms like fatigue or swelling appear, the kidneys have already lost much of their ability to filter waste (a silent progression that underscores the importance of early detection) **(Ahmed *et al.*, 2025)**. On the other hand, AKI, characterized by rapid kidney function decline, abnormalities of some novel biomarkers and frequently arises from infections, nephrotoxic medications, or hypovolemia **(Al-Tu'ma, *et. al.*, 2017; Floris *et al.*, 2024).** For millions of people in low- and middle-income nations who have limited access to preventive care and delayed diagnoses, CKD and AKI exacerbate outcomes **(Luyckx *et al.*, 2021).**

In Iraq, CKD etiology aligns with global trends, with diabetes (33%) and hypertension (23%) predominating, exacerbated by environmental factors and health inequalities **(Khaleel *et al.*, 2019).**

Hemodialysis (HD) is very effective and the most common renal replacement therapy. Hemodialysis works like a substitute kidney, using a specialized membrane to filter waste and excess fluids from the blood (a process called ultrafiltration A.K.A UF) **(Fielding, 2024).** But the success of this treatment depends on finding a patient's 'dry weight,' the ideal body weight after dialysis when they're neither too swollen nor too dehydrated. Dry weight is a balance point that ensures the body can function safely between sessions, and it requires careful collaboration between patients and their care teams to get right **(Agarwal *et al.*, 2011).** Traditionally, dry weight is estimated clinically through physical signs (e.g., edema, blood pressure trends) and patient-reported symptoms (Ayed et al., 2023). However, this subjective approach often leads to overhydration (OH) **(Mathilakath *et al.*, 2022).** Overhydration is common in the HD population and is associated with increased mortality **(Kalantar-Zadeh *et al.*, 2009).**

In addition, HD has its challenges, chief among them, the fragile balance of fluid removal **(Neumayr *et al.*, 2024).** Also, HD patients can be faced with HD-originated adverse events such as muscle cramps, intradialytic hypotension, and dyspnea, which diminish treatment efficacy and patient quality of life **(Agarwal *et al.*, 2011).** For families in Iraq and other regions where healthcare systems face overwhelming challenges, the growing number of people living with ESRD isn't just a medical issue but a crisis that affects entire communities. When dialysis access is limited, improving care outcomes isn't just about saving lives; it's about preserving dignity, supporting livelihoods, and fostering hope for families navigating these hardships **(Alhajim, 2018).**

Novel tools like bioimpedance spectroscopy (BIS) are revolutionizing how we manage fluids in the body. Devices using this technology, called body composition monitors (BCM), break down hydration into clear, measurable parts including extracellular water (ECW), intracellular water (ICW), and even OH. This gives healthcare teams precise, data-driven insights into hydration status **(Chamney *et al.*, 2007).** By providing accurate information about ECW, ICW, and total body water, as well as determining tissue mass, BCMs help clinicians set accurate ultrafiltration goals. This approach cuts down on trial-and-error methods when figuring out a patient's ideal dry weight **(Mathilakath *et al.*, 2022).**

The management of ESRD in Iraq faces significant systemic challenges. Dialysis units are overcrowded, often leading to shortened treatment sessions due to high patient demand **(Mousa *et al.*, 2020).** Socioeconomic factors exacerbate these problems. Poverty restricts access to necessary medications, and cultural stigmas surrounding chronic illnesses delay patients from seeking timely care **(Ismael *et al.*, 2025).** Amid these difficulties, bioimpedance spectroscopy-guided UF presents itself as a promising solution. It offers a scalable and cost-effective approach **(Raddatz *et al.*, 2019)** that aligns well with Iraq's healthcare needs.

This study takes a closer look at some important challenges in nephrology care by examining how BCM-guided UF can benefit HD patients in Iraq. Although previous research has shown the advantages of using BCM in developed countries **(Kron *et al.*, 2025; Thomas *et al.*, 2025),** there's still much to learn about how effective it is in settings with fewer resources **(Herath *et al.*, 2024)** especially in Iraq **(Ismael *et al.*, 2025).** Iraq's distinct healthcare system offers an interesting opportunity to explore how feasible and effective BCM can be in practice. Through a randomized controlled trial (RCT), this study aims to compare BCM-guided ultrafiltration with traditional clinical approaches, paying close attention to factors like complications during dialysis, blood pressure management, and maintaining proper hydration levels.

MATERIALS AND METHODS

Study design

An RCT study was conducted in Baghdad medical city from June, 1st, 2024 and Dec., 1st, 2024. The patients who consented to participate in the prospective study were randomly assigned to one of the two groups including BCM-group and clinical method group (CL-group). The hospital-based ethics committee approved the study and written informed consent was taken from the participants.

Study population

This study population included eighty patients of ESRD undergoing maintenance HD twice or thrice a week in HD units in Baghdad Teaching Hospital, Baghdad Medical City, Ministry of Health / Baghdad – Iraq.

Exclusion criteria

To ensure the study's findings were reliable and fair for all participants, we carefully excluded patients with specific health or procedural factors that could complicate care or safety as follows: Children under 15 years old, patients who had been on HD for less than three months, those experiencing sudden kidney damage unrelated to their chronic condition, patients with active cancer, expectant mothers, individuals who had undergone major operations within three months, patients scheduled for kidney transplants within six months, amputees, whose altered body composition could affect bioimpedance readings, those with heart failure, and patients with pacemakers or other metal implants (excluding coronary stents).

PROCEDURES

Blood pressure monitoring was conducted in the arm without dialysis vascular access. Measurements were taken at three intervals: pre-dialysis (after a 10-minute rest period), every 15 minutes during the hemodialysis session, and immediately following session completion. The final post-dialysis measurement is considered the primary indicator for evaluating blood pressure control over time.

Intradialytic hypotension was defined as a systolic blood pressure reading below 100 mmHg or the administration of at least 100 mL saline to reduce symptoms. Muscle cramps and dizziness were assessed based on patient-reported symptoms occurring during or after dialysis sessions.

Hydration status was evaluated using a portable multi-frequency body composition monitor (BCM; Fresenius Medical Care, Germany) 30 minutes after each hemodialysis session. Measurements were conducted at baseline and repeated at 1, 3, and 6 months. Electrodes were positioned on the side opposite the vascular access site. The device automatically calculated total body water (TBW), extracellular water (ECW), intracellular water (ICW), absolute overhydration (OH; defined as the difference between the patient's measured ECW and the physiologically expected ECW), and relative overhydration (OH/ECW ratio), utilizing integrated software as described previously **(Velasco *et al*., 2012).**

In the BCM group, nephrologists were provided with BCM-derived hydration data to inform dry weight adjustments but were not obligated to strictly adhere to these values. In contrast, clinicians managing the CL group determined dry weight exclusively through traditional clinical assessments without access to BCM results.

Statistical analysis

Continuous variables are expressed as mean ± SD and categorical variables as frequencies. For analyzing between-group comparisons, the student's t-test was employed for continuous data, and the chi-square test was used for analyzing categorical data. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 80 patients with ESRD undergoing maintenance HD were randomized into two groups: the BCM-guided group (N = 40) and the CL group (N = 40). Baseline demographic and clinical characteristics were comparable between groups, with no statistically significant differences in age (CL: 48.0 ± 8.0 vs. BCM: 46.0 ± 7.0 years), gender distribution (male: 62.5% vs. 65%), body mass index (24 ± 4.5 vs. 23.0 ± 2.0 kg/m²), or dialysis adequacy (Kt/V: 1.8 ± 0.4 vs. 1.7 ± 0.5) (p > 0.05 for all) (Table 1).

Table 1: Comparison of demographic parameters observed between CL and BCM groups of patients with CKD on Regular HD.

Groups	Sex	No. of Patients	Age (year)	BMI (kg/m^2)	Kt/V per Session	Post HD Systolic BP (mmHg)	Post HD Diastolic BP (mmHg)	Serum Albumin, (g/dl)
CL Group	Male	25	48.0 ± 8.0	24 ± 4.5	1.8 ± 0.4	138.0 ± 17.4	85.0 ± 4.0	3.7 ± 0.2
	Female	15						
BCM Group	Male	26	46.0 ± 7.0	23.0 ± 2.0	1.7 ± 0.5	137.5 ± 15.1	80.2 ± 6.5	3.8 ± 0.2
	Female	14						

BCM: Body composition monitor; HD: Hemodialysis; BP: Blood Pressure. BMI: Body mass index; CKD: Chronic kidney disease; Kt/V: This is a measure of the efficacy of hemodialysis session which depends on time of hemodialysis, pre and post blood urea, ultrafiltration volume removed and post dialysis weight.
All values are expressed as mean ± standard deviation.

Hydration status

Over six months, BCM-guided ultrafiltration significantly reduced OH compared to the CL group (−6.7 ± 1.4 L vs. −2.1 ± 1.5 L; p < 0.001). ECW decreased by 2.9 L in the BCM group versus 2.2 L in the CL group, though this difference was not statistically significant (p = 0.392). TBW and weight reductions were also greater in the BCM group (−3.5 L and −5.1 kg, respectively) compared to the CL group (−5.2 L and −2.2 kg), but these changes did not reach significance (p > 0.05) (Table 2).

Table 2: Comparison of hydration parameters observed at baseline and after 6 months between clinical and BCM groups of patients with CKD on regular HD.

Groups	No. of Patients		Weight (kg)	Total Body Water (L)	Extracellular Water (L)	Overhydration (L)
CL Group	40	At Baseline	84.5 ± 12.3	36.2 ± 4.5	20.5 ± 4.1	8.2 ± 3.6
		At 6 Months	83.3 ± 9.2 (-2.2)	31.0 ± 3.2 (-5.2)	18.3 ± 4.7 (-2.2)	6.1 ± 1.5 (-2.1)
BCM Group	40	At Baseline	70.5 ± 8.1	29.5 ± 5.1	19.3 ± 4.1	10.2 ± 2.8
		At 6 Months	65.4 ± 5.2 (-5.1)	26.0 ± 5.8 (-3.5)	16.4 ± 2.1 (-2.9)	3.5 ± 1.4 (-6.7)
P Value			t=7.7356 0.086	t=1.6231 0.108	t=0.86 0.392	t=14.179 <0.001
BCM: Body composition monitor; HD: Hemodialysis; CKD: Chronic kidney disease. All values are expressed as mean ± standard deviation.						

Intradialytic adverse events
According to Table 3, the BCM group showed fewer intradialytic complications. Hypotensive episodes (systolic BP <100 mmHg or requiring saline intervention) were reduced by 49% (3.4 ± 1.1 vs. 6.7 ± 2.3 events/patient; p < 0.001). Similarly, muscle cramps (3.4 ± 1.5 vs. 8.9 ± 2.3), dyspnea (1.9 ± 0.2 vs. 5.3 ± 1.6), and dizziness (3.6 ± 1.1 vs. 6.5 ± 2.0) occurred significantly less frequently in the BCM group (p < 0.001 for all).

Table 3: Comparison of intradialytic adverse events observed between CL and BCM groups of patients with CKD on regular HD during 6 months.

Groups	No. of Patients	Intradialytic Hypotension (Event/Patient/ 6 Months)	Intradialytic Dyspnea (Event/Patient/ 6 Months)	Intradialytic Muscle Cramps (Event/Patient/ 6 Months)	Intradialytic Dizziness (Event/Patient/ 6 Months)
CL Group	40	6.7 ± 2.3	5.3 ± 1.6	8.9 ± 2.3	6.5 ± 2.0
BCM Group	40	3.4 ± 1.1	1.9 ± 0.2	3.4 ± 1.5	3.6 ± 1.1
P Value		t=8.1863 <0.001	t=13.3359 <0.001	t=12.6680 <0.001	t=8.0354 <0.001
BCM: Body composition monitor; HD: Hemodialysis; CKD: Chronic kidney disease All values are expressed as mean ± standard deviation.					

Blood pressure control
Results indicated that the BCM-guided therapy has superior blood pressure management (Table 4). In this case, systolic blood pressure decreased by −11.0 ± 2.9 mmHg in the BCM group versus −5 ± 1.5 mmHg in the CL group (p < 0.001). Diastolic blood pressure reductions were also greater in the BCM group (−6.0 ± 1.0 vs. −1 ± 0.3 mmHg; p < 0.001). Moreover, post-dialysis systolic and diastolic blood pressure stabilized at 126 ± 2.9/74 ± 1.0 mmHg (in the BCM group) compared to 133 ± 1.5/84 ± 0.3 mmHg (in the CL group).

Table 4: Comparison of blood pressure control observed at baseline and after 6 months between CL and BCM Groups of patients with CKD on Regular HD.

Groups	No. of Patients		Systolic Blood Pressure, mmHg	Diastolic Blood Pressure, mmHg
CL Group	40	At Baseline	138.0 ± 17	85 ± 4.0
		At 6 Months	133 ± 1.5	84 ± 0.3
		Mean difference	-5 ± 1.5	-1 ± 0.3
BCM Group	40	At Baseline	137.0 ± 15	80.0 ± 6.5
		At 6 Months	126 ± 2.9	74 ± 1.0
		Mean difference	-11.0 ± 2.9	-6.0 ± 1.0
P Value			t = 11.6226 <0.001	t = 30.2891<0.001
BCM: Body composition monitor; HD: Hemodialysis; CKD: Chronic kidney disease. All values are expressed as mean ± standard deviation.				

DISCUSSION

ESRD is considered the irreversible final stage of CKD. In an ESRD situation kidney function declines to a point that requires dialysis or transplantation for survival **(Khan *et al*., 2025).** ESRD is an important health issue due to its high impact on patient quality of life reduction **(Hakeem Ismael and Omer Rashid, 2020**). Moreover, ESRD can increase the incidence of healing complications such as malunion and nonunion in patients. According to previous investigations, ESRD is also related to the increase of various types of infection in these patients **(Hanna *et al*., 2025)**, where it can turn into a complicated situation in the case of drug-resistant bacteria infections **(Rahimian *et al*., 2024).** Thus, effective dealing with ESRD is crucial. While HD remains the cornerstone of treatment for ESRD, it's far from a perfect solution. Patients often face a rollercoaster of challenges from hypotension, and muscle cramps, to fluid overload during sessions **(Kanbay *et al*., 2020).** This study investigated the efficacy of BCM-guided UF in reducing these adverse events and improving blood pressure control among Iraqi HD patients. The results demonstrated significant advantages of BCM-guided UF over traditional clinical methods, with significant reductions in intradialytic complications and superior blood pressure management.

In this study, 80 Iraqi patients undergoing maintenance HD, were randomized into BCM-guided (N = 40) and clinical method (CL-group, N = 40) cohorts. Over six months, the BCM group showed significant improvements compared to the CL group. Intradialytic complications dropped dramatically: hypotensive episodes fell from 6.7 ± 2.3 to 3.4 ± 1.1 ($p<0.001$), dyspnea decreased from 5.3 ± 1.6 to 1.9 ± 0.2 ($p<0.001$), muscle cramps plummeted from 8.9 ± 2.3 to 3.4 ± 1.5 ($p<0.001$), and dizziness reduced from 6.5 ± 2.0 to 3.6 ± 1.1 ($p<0.001$). Hydration status also improved, with overhydration decreasing by 6.7 liters in the BCM group versus just 2.1 liters in the CL group ($p<0.001$). Blood pressure control strengthened as well: systolic pressure dropped by 11.0 ± 2.9 mmHg in the BCM group compared to 5 ± 1.5 mmHg in the CL group, while diastolic pressure fell by 6.0 ± 1.0 mmHg (BCM) versus 1 ± 0.3 mmHg (CL). These outcomes highlight the superiority of BCM in optimizing fluid removal and mitigating complications linked to volume mismanagement. The utility of BIS for assessing hydration status is well-documented **(Mohamed *et al.*, 2025).** According to previous studies, BCM was validated as a tool to differentiate ICW and ECW, enabling precise quantification of OH **(Frey *et al.*, 2021; Wabel *et al*., 2009).** Also, Patel *et al.* **(Patel *et al.*, 2019)** demonstrated that BCM-guided UF significantly reduces intradialytic hypotension (2.8 ± 3.13 events/patient/6 months, p = 0.003) in HD patients, aligning with this study's findings of reduced hypotension and improved blood pressure control.

Hypertension in ESRD is often volume-dependent **(Georgianos and Agarwal, 2024).** The BCM group's superior blood pressure reduction (-11.0/-6.0 mmHg) in our study indicates optimized volume control and confirm Bratsiakou *et al.* **(Bratsiakou *et al*., 2024),** who linked dry weight probing to blood pressure normalization. Notably, the CL-group's minimal diastolic improvement (-1 mmHg) suggests persistent volume overload, as clinical methods often underestimate OH. The BCM's precision in quantifying ECW enables targeted UF, to address the root cause of hypertension.

In Iraq, CKD prevalence is rising due to diabetes (33%) and hypertension (22.6%) **(Awad, 2011).** Resource constraints, such as limited access to emergency dialysis, exacerbate outcomes **(Alasfar *et al.*, 2023).** This study's success in a resource-limited setting highlights BCM's scalability. Regarding the results of the previous study that introduced BCM as a cost-effective method with high efficacy in lowering hospitalizations in HD populations **(Raddatz *et al*., 2019),** BCM is a highly suitable method for low-income nations such as Iraq.

Moreover, HD-induced fluid shifts disrupt plasma refilling rates, especially in overhydrated patients **(Mitsides *et al*., 2019).** BCM's ECW measurement allows gradual UF, matching refilling capacity **(La Porta *et al.*, 2024).** This function prevents blood volume dropping, a key driver of intradialytic hypotension. Additionally, reducing ECW relieves cardiac preload and can improve left ventricular function and blood pressure stability **(Hanna *et al.*, 2023).**

Also, overhydration worsens uremic toxin retention that is contributes to endothelial dysfunction and hypertension (Dalpathadu et al., 2024). By normalizing ECW, BCM may enhance middle-molecule clearance (e.g., β2-microglobulin), reducing oxidative stress and vascular damage **(Kim *et al*., 2019; Wolley *et al.*, 2018).** Hyperkalemia and metabolic acidosis are common phenomena in ESRD patients **(Palmer and Clegg, 2024),** and were not directly measured in our study. However, improved OH may indirectly better acid-base balance **(Karet, 2011; Lowance *et al.*, 1972)** and decrease the mortality rate of patients. This occurrence aligns with Claure-Del Granado and Mehta **(Claure-Del Granado and Mehta, 2016**), who tied OH to increased mortality rate and necessitated OH management to sustain hemodynamic stability and enhance vital organ performance.

Intradialytic hypotension and cramps severely impair HD tolerability **(Hamrahian *et* al., 2023)**. The BCM group's lower adverse event rates suggest improved session tolerance, potentially enhancing adherence. Reduced dizziness and dyspnea may also translate to better post-dialysis functional status, enabling patients to resume daily activities. Also, intradialytic hypotension complicates more than 10% of HD sessions **(Kuipers *et al*., 2019),** necessitating nursing interventions, saline boluses, and prolonged hospitalization. The BCM group's 50% reduction in intradialytic hypotension could lower staffing demands and costs. In Iraq, where dialysis units are overcrowded, this efficiency gain is critical.

Chronic fluid overload is highly related to left ventricular hypertrophy (LVH) and heart failure in ESRD **(Sun *et al.*, 2022).** The BCM group's OH reduction (-6.7 L) may attenuate LVH progression, mirroring the conducted study by Claure-Del Granado and Mehta **(Claure-Del Granado and Mehta, 2016)**, who linked OH to cardiovascular mortality. Long-term, this could reduce Iraq's ESRD-related cardiac deaths.

CONCLUSION

This study demonstrates the significant clinical benefits of utilizing BCM-guided UF in reducing intradialytic adverse events and improving blood pressure control among Iraqi HD patients. By comparing BCM-guided UF with traditional clinical methods, our findings reveal a significant reduction in complications such as hypotension, dyspnea, muscle cramps, and dizziness in the BCM group. Furthermore, BCM-guided therapy achieved superior hydration status normalization compared to the CL group. These outcomes underscore the critical role of BCM in enhancing dialysis tolerability and cardiovascular outcomes for ESRD patients. In resource-constrained regions like Iraq, where dialysis units face overcrowding and limited access to advanced care, BCM offers a scalable, cost-effective solution to mitigate complications and optimize patient survival. The study also highlights the potential of BCM to reduce healthcare burdens by minimizing intradialytic interventions and hospitalizations.

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