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Jian Ebraheem

Radiological Techniques
Department, Health and Medical
Technology College-Baghdad,
Middle Technical University
(MTU), Iraq

Muhammed Mizher Radhi

Radiological Techniques
Department, Health and Medical
Technology College-Baghdad,
Middle Technical University
(MTU), Iraq

Asmaa Abdulsattar Obaid

Department of Physiotherapy
Techniques, College of Health
and Medical Techniques-
Baghdad, Middle Technical
University, Baghdad, Iraq

Study effect magnesium sulfate solution in rabbit's blood utilizing electrochemical

Jian Ebraheem, Muhammed Mizher Radhi and Asmaa Abdulsattar Obaid

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Abstract

Electrochemical sensors have gained significant importance due to their sensitivity, speed, and cost-effectiveness in detecting ions in biological fluids. Magnesium sulfate (MgSO_4), commonly used in therapeutic interventions, affects the electrolyte balance in blood. Understanding its electrochemical interactions, particularly on glassy carbon electrodes (GCEs), is crucial for developing diagnostic methodologies in animal models such as rabbits. This study investigates the electrochemical behavior of magnesium sulfate (MgSO_4) at the interfaces of glassy carbon electrodes (GCEs) within rabbit blood matrices, providing insights into the detection capabilities and performance of the electrodes. Glassy carbon electrode (GCE) was used to observe the chemical properties of magnesium sulfate solution in electrolyte of rabbit's blood medium by cyclic voltammetry. The study was aimed to find the electrochemical behavior of magnesium ions Mg(II) in the blood samples to find redox reaction. The study focused on the redox reaction of current peaks for magnesium ions in blood. The results were found one of reduction current peak appeared at -0.8 V. The research included different voltammetric study for the cathodic current peak of Mg ions, such as in different concentrations, scan rates, pH, and reliability in blood medium. A low detection limit was found of Mg(II) at 0.1 - 0.4 mM, with good linear of relationship of different scan rates and high sensitivity of 0.9914 . Also, the cathodic current peak of Mg ions was enhanced at alkaline blood solution of pH 8 - 10 . So, we can say that magnesium compound in blood medium act as anti-oxidative reagent, which can be used as a nutritional supplement, and causes its deficiency in the human body to serious health effects.

Keywords: Magnesium sulfate, anti-oxidative reagent, blood rabbit medium, cyclic voltammetry, electrochemical behavior

1. Introduction

There are many studies dealing with the electrochemistry of the different compounds in aqueous electrolytes such as blood medium [1-5].

The electrochemical behavior of Pb electrodes was examined with different wt. / vol. ratios of MgSO_4 at 0.0 , 0.5 , 1.0 , 2.0 , and 5.0 that added to the electrolyte. Cyclic voltammetric (CV) technique, linear sweep voltammetric (LSV) technique, and electrochemical resistance spectroscopy (EIS) were studied. The CV results showed better oxidation and reduction reaction of the Pb-electrode that attribute to the surface area of the Pb-electrode by increasing the activity [6].

When hydroxide ions and dissolved metals are added to a mixture of MgCl_2 , KCl, and NaCl salts, it has an effect on electrochemical analysis. Open cyclic voltammetric measurement indicated that the salt oxidation potential increased with the addition of hydroxide ions and decreased with the addition of molten magnesium metal. Cyclic voltammetry indicated the disappearance of the reduction peak associated with hydroxides with the addition of Mg. These results are of great importance and the mechanism of controlling the redox potential of this salt using dissolved Mg metal [7].

MgSO_4 solution has been developed as a drug that has different clinical uses. Mg (II) ions are the main cation in physiological reaction, and the balance of these ions is critical to the natural function of the different organs of the body. MgSO_4 is a pharmaceutical grade magnesium mineral that is used as a neuroprotective agent.

Corresponding Author:

Muhammed Mizher Radhi

Radiological Techniques
Department, Health and Medical
Technology College-Baghdad,
Middle Technical University
(MTU), Iraq

One reason for the frequent use of MgSO_4 for critical care is the high incidence of hypomagnesaemia in Intensive Care Unit (ICU) patients. Treatment of hypomagnesemia combined with the neuroprotective properties of MgSO_4 established a wide application of MgSO_4 in the intensive care unit [8]. In this work magnesium sulfate solution was studied in electrochemical analysis by cyclic voltammetry to determine the chemical behavior.

2. Experimental

2.1 Materials: Magnesium sulfate (MgSO_4) received from Galen Ilac San. Co. (german), and healthy Blood samples of the rabbit. The blood was diluted with deionized water by 1

blood: 9 deionized water.

2.2 Devices

Cyclic Voltmetric Technology: NuVant Systems EZstat (Potentiostat / Glvanostat) series from USA is used. The voltametric cell was connected to a voltage state monitor and monitored by software installed on the PC to performing the cyclic voltammetry (CV) measurement. The Ag electrode contains Ag/AgCl in 3 Molar of KCl as reference electrode, using a 1 mm diameter of platinum wire as a counter electrode. It was used Glassy Carbon Electrode (GCE) as a working electrode after performing by polishing and cleaning the surface of the electrode as show in Figure 1.

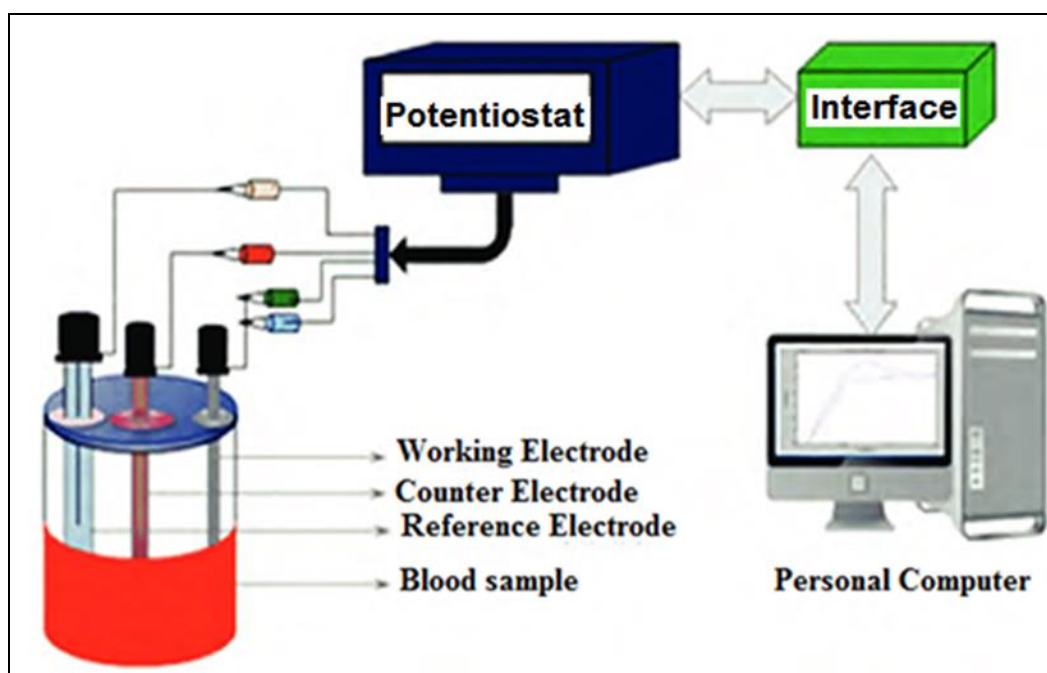


Fig 1: Scheme of cyclic voltammetry parts

3. Results and Discussion

Scientists have recently focused on studying the effect of the chemical compound on the composition of the blood. Where

the electrochemical properties of magnesium sulfate (MgSO_4) in the blood medium were studied from the side of oxidation and reduction in various fields of medicine [9].

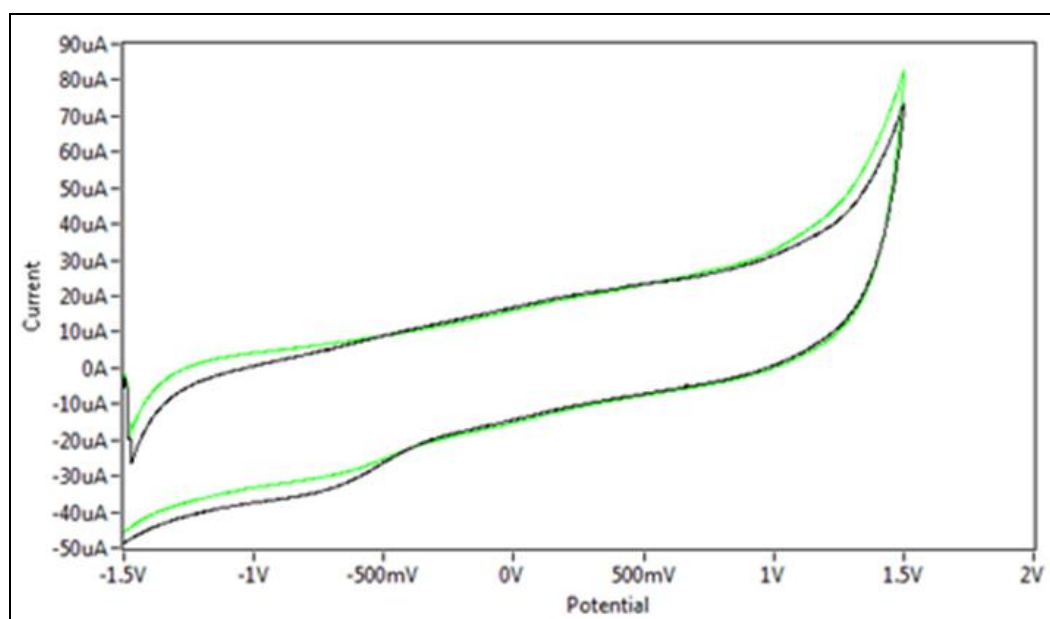


Fig 2: Cyclic voltammogram of 0.5 M MgSO_4 solution in blood media at different concentration (green line 0.1 mM and black line 0.4 mM) using GCE as working electrode

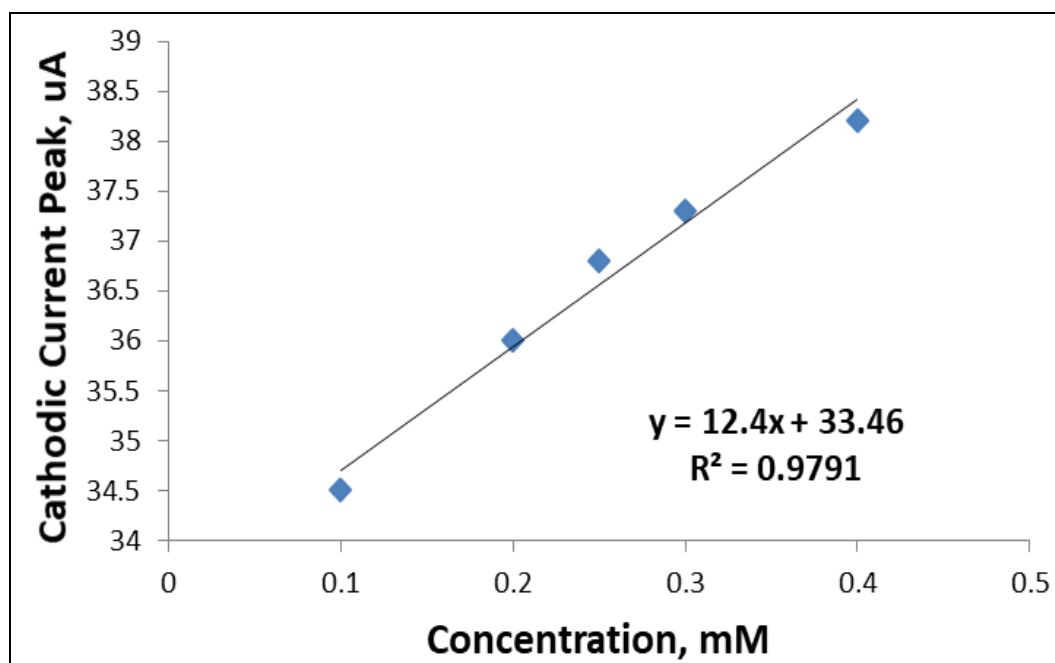


Fig 3: Calibration curve of cathodic peak current of 0.5 M MgSO_4 solution in blood media at 0.8 V against to different concentrations (0.1-0.4 mM).

3.1 Study of MgSO_4 in blood medium in different concentration

Evaluating the electrochemical behavior of magnesium sulfate in blood at different concentrations is essential for understanding its impact on electrode performance and biological interactions. Concentration-dependent studies provide insights into sensitivity, detection limits, ion uptake dynamics, and potential biological effects. MgSO_4 solution is a compound with stimulant activity in blood medium and heavy metal function with hemoglobin which causes reduction of current peak at -0.8 V. Figure 2 shows the cyclic voltammogram of different concentration of MgSO_4 solution in blood medium that enhanced the peak reduction current versus increased the MgSO_4 concentration^[10].

The relationship between cathodic current peak of 0.5 M MgSO_4 solution in blood media at -0.8 V against to different concentrations with low detection limit of (0.1-0.4 mM) which mentioned a good Straight line with equation of $Y=12.4X+33.46$ and sensitivity of $R^2=0.9791$ as shown in Figure 3.

The electrochemical behavior of magnesium sulfate in rabbit blood shows a concentration-dependent increase in capacitive signals up to about 3.0 mM, which is exceeded by matrix effects. For practical sensing, calibration within the physiological and moderately elevated magnesium ranges is ideal for accuracy and reproducibility.

3.2 Study of Different Scan Rates (SR)

The study of different scan rates was used the cyclic voltmmetric technique to electrochemical characterization of the properties of MgSO_4 solution in blood medium. Figure 4 shows the results that determine the increasing the assay rate leads to an enhancement of the peak current reduction of MgSO_4 in the blood medium.

The relationship between the peak reduction current (I_{pc}) at the different scanning rate (SR) has a straight line as shown in Figure 5. The results indicated that the reduction mechanism is controlled by the diffusion of Mg (II) ions in the blood

medium^[11]. The Randles-Sevick equation that used for the relationship between the peak cathodic current and scan rate which gives straight lines as shown in Fig. 5. In this sense, it indicates that the redox process is reversible and the diffusion reaction^[12, 13].

Randles-Sevick equation which is used for the relationship between peak cathodic current and scan rate that get a good linear lines as shown in Figure 5. In this sense, it has the oxidation-reduction reaction a reversible relationship and the diffusion reaction^[12, 13].

Also, the diffusion coefficient for the reduction of MgSO_4 in the blood medium can be determined from the Randles-Sevick equation^[14]

$$I_p = (2.69 \times 10^5) n^{3/2} A C D_f^{1/2} V^{1/2}$$

Where,

D_f : is the diffusion coefficient (cm^2/sec),

I_p : is the current peak (μA),

N : is the number of moles of electrons transferred in the reaction,

A : is the area of the electrode (cm^2), and V : the scan rate (Vsec^{-1}).

3.3 Study Different pH

Different acidity at different pH was studied of MgSO_4 solution in the blood medium is one of the most important studies that can be obtained from the best scientific facts, especially the MgSO_4 solution in these conditions. It was found that Mg(II) ions cause oxidative stress in the acidic medium of blood at pH = 3 by enhancing the cathodic current peak of 625 mV with the anodic current peak of -500 mV as shown in Figure 6. While Mg(II) Ions in normal blood medium at pH = 7 have only one cathode peak at -500 mV which served as an antioxidant reagent^[15].

In pH = 13 as alkaline medium that the reaction of Mg (II) ions in blood is different from that in acid, and the oxidation current peaks of Mg (II) disappeared and the cathodic peak was enhanced compared to acidic medium as shown in Figure 6^[16, 17].

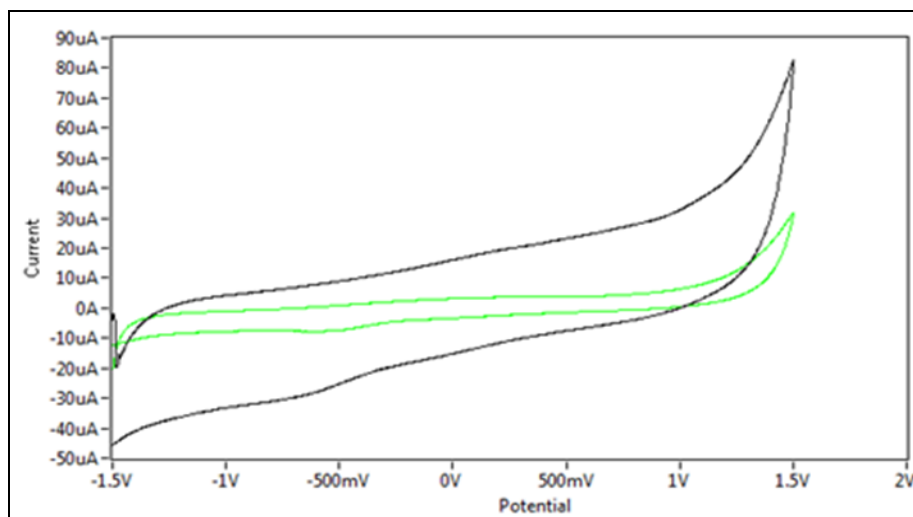


Fig 4: Cyclic voltammogram 0.5 M MgSO_4 solution in blood medium at various scan rates (green line 100 mVsec^{-1} and black line 100 mVsec^{-1})

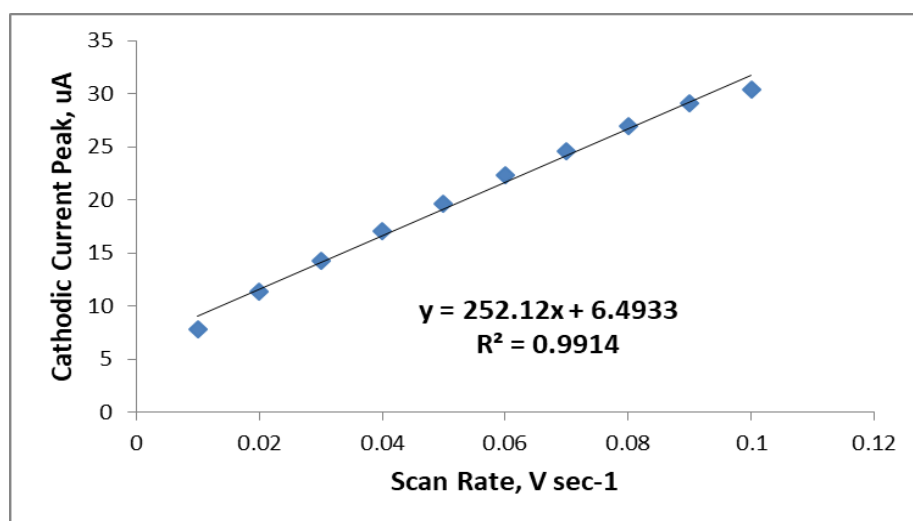


Fig 5: Calibration curve of reduction peak current of 0.4 mM MgSO_4 solution in blood medium at 0.8 V versus to scan rates of (0.01-0.01 Vsec^{-1})

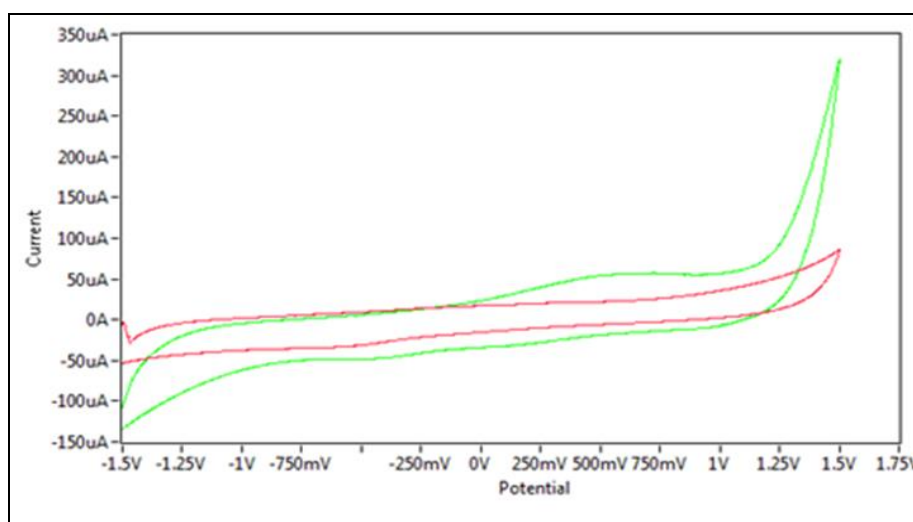


Fig 6: Cyclic voltammogram of 0.5 M MgSO_4 solution in blood media at different pH (green line in acidic pH and black line in alkaline pH) using GCE as working electrode.

3.4 Biological effects of magnesium sulfate in blood

3.4.1 Electrolyte Homeostasis

Magnesium is a vital electrolyte that regulates many physiological processes

In blood plasma, magnesium ions

Stabilize cell membranes, regulate ion channels (especially for potassium and calcium). Act as a cofactor for more than

300 enzymatic reactions, including those involving ATP metabolism. In rabbits, as in humans, normal plasma magnesium concentrations typically range between 0.7 and 1.1 mM. Magnesium sulfate intake can raise these levels, potentially affecting cardiovascular, muscular, and nervous system function.

3.4.2 Effects on Blood Chemistry

- **Calcium Antagonist:** High magnesium concentrations compete with calcium, potentially reducing calcium-dependent processes such as coagulation and neuromuscular excitability [18]
- **PH Changes:** Magnesium sulfate solutions may be slightly acidic; infusion may result in a slight decrease in blood pH, affecting electrochemical measurements.
- **Protein Binding:** Approximately 20-30% of plasma magnesium is bound to proteins (especially albumin), which may affect the activity of free ions on the electrode surface.

3.5 Study of reducibility and stability

A good reducibility and stability of the cyclic voltammetric analysis of Mg(II) in blood medium which is shown in Fig. 7 was found in ten scanning times overlap of the cyclic voltammogram with low RSD from the peak current limiting of Mg(II) by GCE as the sensitive working electrode [19]. Magnesium sulfate exhibits high chemical and electrochemical stability in rabbit blood under typical voltammetric conditions. Direct reduction of Mg^{2+} is not preferred, but subtle sorption effects influence the electrochemical double-layer properties, which can be accurately examined using modified GCEs.

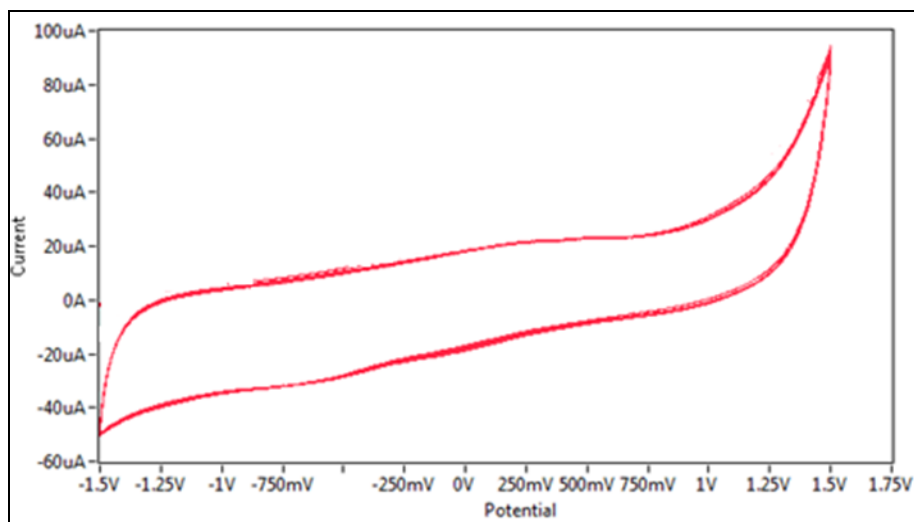


Fig 7: Cyclic voltammogram 0.5 M, MgSO_4 solution in blood medium in ten times on GCE.

4. Conclusions

Studying the effect of Mg(II) on hematopoiesis can be concluded that the effect of these ions on blood components is an antioxidative reagent, especially in the neutral and alkaline medium, which enhanced the current limiting peak of Mg(II), so it can be used as an antioxidant reagent in a supplement food because of its benefit to the body, and to stay away from various diseases. The magnesium sulfate-doped glassy carbon electrode shows promising electrochemical activity in rabbit blood samples, with appropriate surface modifications significantly improving sensitivity and stability. Future modifications could focus on reducing biocontamination and improving selectivity in clinical diagnostics and healthcare applications.

Conflict of Interest

Not available

Financial Support

Not available

5. Reference

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