

Effect of Mannitol on Renal Function during Cardiac Surgery and Immediate Post-Operative in Selected Private Hospitals in Nablus City/ Palestine

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ABSTRACT

Background: Cardiopulmonary bypass (CPB) is a common technique in cardiac surgery, however, it is associated with acute kidney injury. The type of solution in the CPB circuit can potentially affect surgery outcome through affecting several organs and body homeostasis. The optimal prime solution for the CPB circuit in adult cardiac surgery has not yet been defined. Mannitol is widely used in the priming solution for CPB even though there is no clear consensus on the role of mannitol in cardiac surgery.

Purpose: The purpose of this study was to investigate the effect of mannitol in the CPB prime solution on renal function during cardiac surgery and post-operative in selected private hospitals in Nablus City

Design and method: prospective cohort study design conducted at An-Najah National University Hospital and specialized Arab hospital. A sample of 120 patients was studied. The patients had cardiac surgery and they had preoperative normal renal function.

Results: The use of mannitol in the CPB prime solution was associated with a decrease in creatinine and BUN readings levels in the postoperative period (postoperative period mean = 0.7692 ± 0.26068 , and 18.3917 ± 7.56629 mg/dl, respectively; p-value<0.001) and an increase in GFR levels in the postoperative period (postoperative period mean = 112.27861 ± 1.43604 , p-value<0.001) indicating and improvement in renal function following cardiac surgery.

Keywords: Creatinine, mannitol, cardiopulmonary bypass, cardiac surgery, Renal function.

1. INTRODUCTION

Cardiopulmonary bypass (CPB) is a required circulatory support during cardiac surgery. CPB is (1). often associated with the risk of postoperative renal dysfunction, and thus it needs careful management strategies to recover this complication (2) especially to maintain acid-base balance and normal electrolyte levels. The CPB circuit prime solution can potentially affect post-

surgical outcomes through affecting various organ systems and homeostasis, such as the central nervous, renal systems, coagulation, osmolality, and electrolyte levels (1-6). previous studies examined the effect of using mannitol in the prime solution for CPB to protect renal system during and post cardiac surgery with the aim of preserving renal function during and after cardiac surgery (7).

However, the selection of CPB prime typically relies on individual preferences and practices (6). There is a debate within medical community on mannitol impact on renal function during cardiac surgery and immediate postoperative period (7). Recent surveys have revealed

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significant global disparities in CPB techniques and priming, yet the reasons behind such variations and their clinical ramifications remain vague (8). Currently, no standardized guidelines exist regarding the choice or customization of CPB prime solutions to suit specific patient characteristics or conditions.

CPB prime solutions commonly consist of crystalloid fluids, often supplemented with mannitol, a 6-carbon natural alditol. Mannitol serves as a volume expander with osmotic diuretic properties and thus has potential effects on various organ systems (1,8, 9). Several studies reported conflicting results regarding mannitol use. Some of these studies raised concerns about potential adverse effects on renal function, while others suggested a protective effect of mannitol (10-14).

Notably, one study found no significant clinical impact following the removal of mannitol from the priming solution, identifying only economic benefits (15). Consequently, consensus regarding mannitol's role during cardiac surgery remains elusive, with limited studies investigating its effects in CPB prime solutions (16).

2. MANNITOL AND RENAL FUNCTION

Emerging studies are exploring various renal protective strategies during cardiac surgery. These strategies include pharmacological interventions, modifications in surgical techniques, and advancements in perfusion strategies, aiming to optimize renal outcomes (25).

Mannitol, a well-established osmotic diuretic, has been a subject of significant interest in cardiac surgery field. It increases intratubular osmotic pressure, thus enhancing free water excretion. Furthermore, mannitol was reported to induce renal vasodilatation by decreasing renal vascular resistance and thus increasing renal blood flow although it may not affect glomerular filtration rates (GFR).

Research had focused on the possible effects of mannitol in cardiac surgery, focusing on its potential Reno-protective effects and implications for patient

outcomes. For instance, Mannitol is studied for its potential ability to alleviate renal ischemia and perfusion related injuries during cardiac surgery. In addition, as an osmotic diuresis, mannitol could protect renal function through maintaining renal blood flow and reducing tubular obstruction (24, 26).

Many studies especially randomized controlled trials have been conducted to check and evaluate the effectiveness of mannitol in protecting the renal function during and after cardiac surgery. These studies often assess the special parameters and tests such as creatinine serum level, Blood urea nitrogen (BUN), and GFR (27).

Variable effects have been reported for the possible outcomes for mannitol use during cardiac surgery. These Conflicting findings highlight the need for a better understanding, taking into account factors such as patient populations, surgical techniques, and study designs (28).

In conclusion, mannitol holds promise as a reno-protective agent in the context of cardiac surgery. However, ongoing research is essential to address existing controversies and to refine guidelines for its optimal use. As cardiac surgery evolves, the role of mannitol and its potential synergies with emerging therapies will continue to shape the landscape of renal protection strategies.

3. METHODS

Study Design and Settings:

This study is an observational prospective cohort study that is designed to evaluate whether mannitol given during cardiac surgery are associated with the changes in renal functions among patients underwent cardiac surgery. The study was conducted in Palestine at An-Najah National University Hospital and specialized Arab hospital. A sample of 120 patients were studied. Data collection started in October 2023 and was completed by March 2024.

Ethical approval:

Ethical approval for our study entitled " Effect of Mannitol on renal function during cardiac surgery and immediate post-operative in selected private hospitals in

Nablus City/ Palestine" was obtained from An-Najah National University IRB committee on 9th of October 2023 (C.P.T. Oct. 2023/40) and all methods were carried out in accordance with relevant guidelines and regulations.

Patient Recruitment:

The study included adult patients scheduled for cardiac surgery. The Patients were recruited from the cardiac surgery unit, and informed consent was obtained prior to participation.

Inclusion and exclusion Criteria:

Patients aged 18 years and older undergoing elective cardiac surgery (e.g., CABG, valve replacement) and received intraoperative Mannitol administration and not complaining of renal failure were included in this study. .

Patients with pre-existing renal impairment (e.g., chronic kidney disease), undergoing emergency surgery, , patients weight less than 50 kg, patients with preoperative hematocrit less than 24% and previous history of cardiac surgery and patients who had contraindications to Mannitol were excluded from the study.

Study Tool:

Data were collected from the patients' medical records. The studied data includes demographic information (age, gender, BMI, smoking status), Preoperative medical history (e.g., hypertension, diabetes) and Laboratory results (creatinine, BUN, hemoglobin, GFR) measured preoperatively and postoperatively.

The study primary outcome variable was postoperative renal function, which was assessed through serum creatinine levels, blood urea nitrogen (BUN) levels. These variables were measured using standard laboratory procedures preoperatively and postoperatively. Glomerular filtration rate (GFR) was calculated based on serum creatinine levels.

Data Analysis:

Statistical analyses were performed using SPSS. Paired sample t-tests were used to compare preoperative and postoperative values for creatinine, BUN, hemoglobin, and GFR. A p value of 0.05 was adopted as a threshold for

significance.

Associations between demographic factors (e.g., age, gender) and postoperative renal function were analyzed through chi square and linear regression, with p-values reported to indicate statistical significance.

4. RESULTS

A sample of 120 patients who underwent cardiac surgery during the time period of the study were enrolled. All patients enrolled in the study used heart lung machine with mannitol used in the cardiopulmonary bypass. All of the enrolled patients had normal renal function in the preoperative period. Table 1 shows the demographic data of the participants.

Table1. Demographic characteristics of the study sample

Variable	Frequency (%) N= 120
Age category (years)	
<30	3 (2.5)
30-45	10 (8.3)
45.1-60	58 (48.3)
>60	49 (40.8)
Age scale	Mean: 56 ± 0.06
Gender	
Male	80 (66.7)
Female	40 (33.3)
BMI category(kg/m²)	
<18.5 underweight	0
18.5-24.9 normal	43 (35.8)
25-29.9 overweight	53 (44.2)
30-34.9 obese	14 (11.7)
≥35 extremely obese	10 (8.3)
Smoking	
No	71(59.2)
Yes	49 (40.8)
past medical history	
Hypertension	79 (65.8)
Diabetes Meletus	70 (58.3)

4.1 preoperative measurements

The distribution of preoperative creatinine serum levels showed that the majority of patients (66.7%) had a

creatinine level within the normal range (0.7-1.2 mg/dL), while small proportion of patients have higher or lower levels (>1.2 mg/dL or <0.7 mg/dL). Similarly, the majority of patients (84%) had BUN levels within the normal range (7-30 mg/dL), with a smaller proportion exhibiting either lower (<7 mg/dL) or higher (>30 mg/dL) levels. Furthermore, the mean preoperative GFR was 84.64 ± 30.6 ml/min/1.73m² which reflects the overall renal function of the study population.

The distribution of preoperative hemoglobin levels showed that most patients had either mild anemia (8-11.9 g/dL) or normal levels (12-17 g/dL). In addition, most of the study participants (97.5%) did not receive blood transfusions preoperatively, indicating overall stable hemodynamics and adequate preoperative preparation.

4.2. intraoperative measurements

All participants enrolled in the study received mannitol intraoperatively. The majority of study participants (65%) underwent coronary artery bypass grafting (CABG), while a smaller number underwent valve replacement (17.5%) or other cardiac surgeries (17.5%)

In addition, the use of hemofiltration and intraoperative blood transfusion was studied. Our results showed that a small proportion of patients (1.7%) underwent hemofiltration intraoperatively, while 26.7% of patients received blood transfusions intraoperatively, either as whole blood or packed red blood cells (RBCs).

In order to evaluate the potentially mitigation effect of mannitol on renal ischemia-reperfusion injury, the volume of mannitol used intraoperatively were studied. The mean volume of mannitol administered intraoperatively was 156.17 ± 64.9 mL. This variability in volume suggests differences in clinical practice or patient-specific considerations.

Regarding the cross-clamp time; the mean duration of aortic cross-clamping was 102 ± 43.91 minutes with the mean duration of cardiopulmonary bypass (CPB) of 150.21 ± 67.736 minutes. During bypass temperature maintained as low as possible; the analyzed data showed

that the mean minimum intraoperative temperature was $33.17^\circ \pm 2.85$ C.

4.3. Post operation measurements

The majority of study participants (60%) had postoperative creatinine levels within the normal range (0.7-1.2 mg/dL), while smaller proportions had either lower (<0.7 mg/dL) or higher (>1.2 mg/dL) levels. The mean postoperative creatinine level was 0.76 ± 0.260 mg/dL. In addition, the majority of participants (90.8%) had postoperative BUN levels within the normal range (7-30 mg/dL), with a smaller proportion of participants had either lower (<7 mg/dL) or higher (>30 mg/dL) levels.

Postoperative hemoglobin level showed mild anemia (8-11.9 g/dL), for most of the patients (80%) while smaller proportions having either moderate (6-7 g/dL) or normal (12-17 g/dL) hemoglobin levels. The mean postoperative hemoglobin level was 10.7021 ± 1.436 g/dL, while the mean postoperative GFR was 112.27 ± 58.52 mL/min/1.73m². The mean postoperative GFR suggests preserved renal function overall. The analyzed data showed that the majority of patients (93.3%) did not receive blood transfusions postoperatively, while a smaller proportion (6.7%) received red blood cell (RBC) transfusions table 2.

4.4. Effect of mannitol administration on renal function (pre-op and post-op)

In order to study the effect of mannitol administration on renal function, creatinine and BUN levels were studied before and after cardiac surgery. Our study showed a significant difference ($p < 0.001$) between preoperative creatinine level (mean = 0.9365 ± 0.27097 mg/dL, Fig. 1A) postoperative creatinine level (mean = 0.7692 ± 0.26068 mg/dL, Fig. 1A). In addition, a significant difference ($p < 0.001$) was observed between preoperative and postoperative BUN levels (Fig. 1B).

The paired sample t-test demonstrated a statistically significant difference ($p < 0.001$) between preoperative and postoperative hemoglobin levels, also, there was a statistically significant difference ($p < 0.001$) between

preoperative and postoperative hemoglobin levels (fig.1C). The means and standard deviations for

preoperative and postoperative levels of creatinine, BUN and hemoglobin are presented in table 2.

Table 5: the differences between preoperative and postoperative lab results according to the paired sample t test.

Variable	N	Mean	Standard deviation	P value
Creatinine				
Pre op	120	.9365	.27097	<0.001
Post op	120	.7692	.26068	
BUN				
Pre op	120	22.5000	7.80971	<0.001
Post op	120	18.3917	7.56629	
HGB				
Pre op	120	11.8978	30.68077	<0.001
Post op	120	10.7021	58.52910	
GFR				
Pre op	120	84.6463	2.14284	<0.001
Post op	120	112.2786	1.43604	

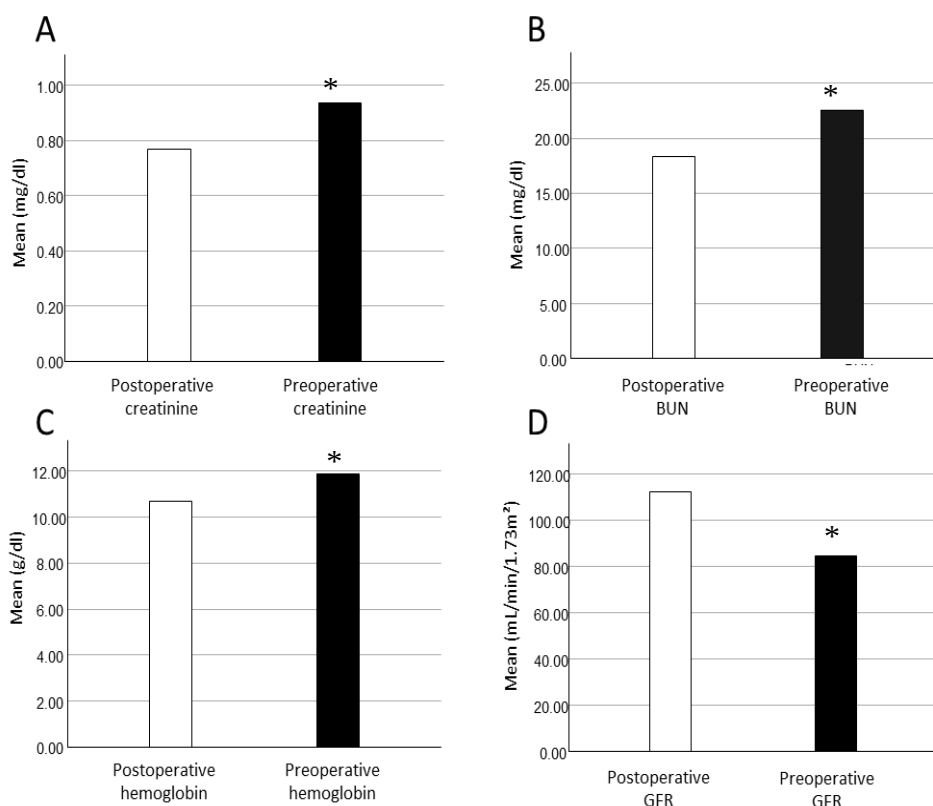


Figure 1: preoperative and post-operative levels of creatinine, BUN, hemoglobin and GFR. Black columns represent the preoperative levels of creatinine (A), BUN (B), hemoglobin (C) and GFR (D). White columns represent the postoperative levels of creatinine (A), BUN (B), hemoglobin (C) and GFR (D). * represents a p-value less than 0.05

4.5. Effect of mannitol volume on renal function

The effect of mannitol volume on renal function was also studied through the measured postoperative levels of creatinine, BUN and GFR. Our results showed that there was no significant effect for mannitol volume on postoperative creatinine level (0.769 ± 0.0260 mg/dl). In addition, no significant effect was observed for the mannitol volume on postoperative BUN levels (18.39 ± 7.566 mg/dl) and postoperative GFR (112.27 ± 58.529 mL/min/1.73m², Table 3).

Table 3: Effect of mannitol volume on renal function

Variable	N	Mean	Standard deviation	P value
Mannitol volume	120	156.17	64.900	0.809
Post op creatinine	120	0.769	0.260	
Mannitol volume	120	156.17	64.900	0.149
Post op BUN	120	18.39	7.566	
Mannitol volume	120	156.17	64.900	0.255
Post op GFR	120	112.27	58.529	

4.6. Association between socio-demographic data and post operation renal function

The association Between different socio-demographic variable and postoperational renal function was studied using the postoperative levels of creatinine and GFR using linear regression analysis. Different postoperative creatinine levels were obtained for variable age groups. The mean postoperative creatinine levels were 0.5400 ± 0.052 , 0.7200 ± 0.204 , 0.7047 ± 0.241 and 0.8698 ± 0.268 mg/dl for patients aged 30, 30-45, 45-60 and >60 years, respectively. These results shows that there is a statistically significant association between age and postoperative creatinine levels ($p = 0.002$). Specifically, older age (>60) is associated with higher postoperative creatinine levels.

Furthermore, GFR levels were 96.6272 ± 19.41 , 101.0786 ± 32.50 , 91.8801 ± 30.004 and 71.9969 ± 27.54 for patients aged below 30, 30-45, 45-60 and patients

above 60 years old, respectively. The analyzed data revealed that there is a statistically significant association between age and postoperative GFR ($p < 0.001$). Specifically, older age (>60) is associated with lower postoperative GFR.

The association Between Surgery Type and Postoperative Renal Function was also evaluated in this study. The results showed that for patients undergoing CABG surgery, the mean postoperative creatinine level was 0.7442 ± 0.232 , and for patients undergoing valve replacement, the mean postoperative creatinine level was 0.6862 ± 0.266 . Patients undergoing other types of surgery had a mean postoperative creatinine level of 0.9452 ± 0.288 . These results showed that there is a statistically significant association between surgery type and postoperative creatinine levels ($p = 0.005$). Specifically, patients undergoing other types of surgery had higher postoperative creatinine levels compared to those undergoing CABG or valve replacement.

In addition, the association between postoperative GFR and the type of surgery was analyzed. Our results showed that the mean postoperative GFR was 87.6369 ± 30.6 for patient undergoing CABG surgery, while the mean postoperative GFR was 83.1737 ± 26.12 for patients undergoing valve replacement and 75.0112 ± 34.21 for patients undergoing other type of surgery. Our analysis showed a statistically significant association between surgery type and postoperative GFR ($p = 0.034$). Specifically, patients undergoing other types of surgery had lower postoperative GFR compared to those undergoing CABG or valve replacement.

Finally, the association between smoking and postoperative GFR was analyzed. The analyzed data showed that the mean postoperative GFR was 77.9104 ± 29.5 for non-smokers, while the mean postoperative GFR was 94.4066 ± 29.9 for smokers indicating that smokers had higher postoperative GFR ($p = 0.003$, Table 4).

Table 4: Association between socio-demographic data and post operation renal function

Independent Variable	Dependent variable	P value
Age	Post op Creatinine mean	
<30	.5400 ± 0.052	0.002
(30-45)	.7200 ± 0.204	
(45.1-60)	.7047 ± 0.241	
>60	.8698 ± 0.268	
Surgery type	Post op creatinine mean	0.005
CABG	.7442 ± 0.232	
valve replacement	.6862 ± 0.266	
Other	.9452 ± 0.288	
Age	Post op GFR	<0.001
<30	96.6272 ± 19.41	
(30-45)	101.0786 ± 32.50	
(45.1-60)	91.8801 ± 30.004	
>60	71.9969 ± 27.54	0.003
Smoking	Post op GFR	
No	77.9104 ± 29.5	
Yes	94.4066 ± 29.9	
Surgery type	Post op GFR	0.034
CABG	87.6369 ± 30.6	
valve replacement	83.1737 ± 26.12	
Other	75.0112 ± 34.21	

5. DISCUSSION

The best solution for the CPB circuit during cardiac surgery is still under evaluation. Our study focused on the beneficial effects of using mannitol in the prime solution for CPB. The results showed a decrease in creatinine and BUN levels and an increase in GFR in the postoperative period, indicating an improvement in renal function following cardiac surgery (48). Additionally, our results showed a decrease in hemoglobin postoperatively, indicating a decline in red blood cell mass, potentially due to surgical blood loss or hemodilution (42).

Our study also evaluated the effects of using different volumes of mannitol in the prime solution for CPB. There was no significant effect of mannitol volume on

postoperative creatinine levels, BUN levels, or GFR. Furthermore, the association between socio-demographic data and postoperative renal function was studied. There was a statistically significant association between age and postoperative creatinine levels and GFR: older age was associated with higher postoperative creatinine levels and lower GFR.

Finally, our results showed that different types of surgery affect postoperative renal function. For instance, patients undergoing other types of surgery had higher postoperative creatinine levels and lower GFR compared to those undergoing CABG or valve replacement.

Findings concerning the relationship between mannitol and socio-demographic characteristics are limited and inconsistent. The gender distribution in the sample population showed a significant skew towards males, with 66.6% being male and 33.3% female. Some previous studies have also noted gender differences in health research (49–51). The gender imbalance in our study may have implications for understanding health outcomes within the population. For instance, a study found a similar trend of male predominance in their sample of cardiovascular disease patients, suggesting a need for gender-sensitive approaches in healthcare research.

While gender distribution might not directly relate to the effect of mannitol on renal function, it is essential to consider potential gender differences in response to treatments (34). Other studies have highlighted gender-specific differences in renal outcomes post-cardiac surgery, suggesting the need for gender-stratified analyses in future research (13, 34).

In our study, the notable gender imbalance within the sample may influence how mannitol affects renal function post-cardiac surgery. While there is limited direct research on gender-specific responses to mannitol in this context, some studies have suggested that gender differences may influence renal outcomes following cardiac surgery, possibly due to variations in renal physiology and response to medications (35).

In addition, in our study older age was associated with higher postoperative creatinine levels and lower GFR. The age-distribution in the sample was skewed towards older individuals, with a predominant presence of middle-aged to elderly individuals, and thus, may impact how mannitol affects renal function post-cardiac surgery. Elderly patients are often more susceptible to renal complications post-surgery (35). Studies have shown that advanced age is a significant risk factor for acute kidney injury (AKI) after cardiac surgery, potentially affecting the efficacy and safety of mannitol administration (36).

On the other hand, the varied BMI distribution, with a substantial proportion of individuals classified as overweight, obese, or extremely obese, may also influence the impact of mannitol on renal function post-cardiac surgery (36). Obesity is a known risk factor for postoperative complications, including AKI. While specific studies on the interaction between BMI and mannitol in cardiac surgery are scarce; research has highlighted the increased risk of AKI in obese patients undergoing cardiac surgery (37).

The high prevalence of smoking within the sample population (40.8%) may also be a factor to consider in assessing the effects of mannitol on renal function post-cardiac surgery. Smoking is associated with various cardiovascular and renal complications, which may interact with mannitol's effects. While direct studies on the interaction between smoking and mannitol in this context are limited, research has demonstrated the adverse effects of smoking on postoperative renal function in cardiac surgery patients (38). In addition, the high prevalence of hypertension (65.8%) and diabetes mellitus (58.3%) within the sample population underscores the importance of considering comorbidities when assessing the effects of mannitol on renal function post-cardiac surgery. Both hypertension and diabetes are risk factors for AKI and may interact with mannitol's renal effects. While direct studies on the interaction between these comorbidities and mannitol in cardiac surgery are limited, research has

demonstrated the impact of hypertension and diabetes on postoperative renal outcomes (39).

We observed a decrease in creatinine levels in the postoperative period indicating an improvement in renal function or clearance of creatinine following cardiac surgery (48). Also, we found a decrease in hemoglobin postoperatively indicating a decline in red blood cell mass, potentially due to surgical blood loss or hemodilution (42).

Our study showed that the amount of mannitol administered intraoperatively did not have a statistically significant effect on postoperative renal function, as assessed by creatinine levels, BUN levels, or GFR. These findings indicate that factors other than mannitol volume may have a greater influence on postoperative renal outcomes in patients undergoing cardiac surgery. Studies suggest that mannitol is commonly used as a renal protective agent during cardiac surgery, its impact on postoperative renal function may be influenced by various patient-specific factors and surgical variables beyond the volume administered (46).

We found significant differences between preoperative and postoperative levels of creatinine, BUN, hemoglobin, and GFR. The decrease in creatinine and BUN levels and the increase in GFR postoperatively indicate improvements in renal function following cardiac surgery. Also, the decrease in hemoglobin levels postoperatively may reflect surgical blood loss or hemodilution, which is commonly observed after cardiac surgery (39). Overall, these findings suggest favorable outcomes in terms of renal function and hemodynamic stability following cardiac surgery, as evidenced by the changes in laboratory parameters from preoperative to postoperative measurements.

6. LIMITATIONS OF THE STUDY

The application of our results is limited to two private hospitals, which may reduce the generalizability of the study. In addition, the sample size was 120 participants, and broader generalizability may require a larger sample size.

7. CONCLUSIONS

This prospective cohort study revealed no effect of the volume of mannitol administered during cardiac surgery on postoperative renal function in patients with normal preoperative renal function. However, the use of mannitol

in the prime solution resulted in a significant decrease in creatinine and BUN levels in the postoperative period. We therefore conclude that the role of mannitol and the effect of its volume in cardiac surgery require further research to support the generalizability of these findings.

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تأثير المانيتول على وظائف الكلى أثناء جراحة القلب وبعدها مباشرة في مستشفيات خاصة مختارة في مدينة نابلس/ فلسطين.

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ملخص

الخلفية: تُعد مجازة القلب والرئة (CPB) تقنية شائعة في جراحة القلب، إلا أنها ترتبط بإصابة كلوية حادة. يمكن أن يؤثر نوع المحلول في دائرة مجازة القلب والرئة على نتائج الجراحة من خلال التأثير على العديد من الأعضاء وتوازن الجسم. لم يُحدد بعد المحلول الأولي الأمثل لدائرة مجازة القلب والرئة في جراحة القلب للبالغين. يُستخدم المانيتول على نطاق واسع في محلول التحضير لمجازة القلب والرئة، على الرغم من عدم وجود إجماع واضح على دوره في جراحة القلب.

الغرض: هدفت هذه الدراسة إلى دراسة تأثير المانيتول في محلول مجازة القلب والرئة الأولي على وظائف الكلى أثناء جراحة القلب وبعدها في مستشفيات خاصة مختارة في مدينة نابلس.

التصميم والمنهجية: تصميم دراسة أترابية مستقبلية أُجريت في مستشفى النجاح الوطني الجامعي ومستشفى العربي التخصصي. تُرست عينة من 120 مريضاً. خضع المرضى لجراحة قلب، وكانت وظائف الكلى لديهم طبيعية قبل الجراحة. **النتائج:** ارتبط استخدام المانيتول في محلول CPB الرئيسي بانخفاض مستويات قراءات الكرياتينين والنيتروجين في الدم خلال فترة ما بعد الجراحة (متوسط فترة ما بعد الجراحة = 0.7692 ± 0.26068 ، و 18.3917 ± 7.56629 ملغ/ديسيلتر، على التوالي؛ قيمة $p < 0.001$) وزيادة في مستويات معدل الترشيح الكبيبي خلال فترة ما بعد الجراحة (متوسط فترة ما بعد الجراحة = 112.27861 ± 1.43604 ، قيمة $p > 0.001$) مما يشير إلى تحسن في وظائف الكلى بعد جراحة القلب.

الكلمات الدالة: الكرياتينين، المانيتول، مجازة القلب والرئة، جراحة القلب، وظائف الكلى.

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