Effect of an Educational Program of the Monitoring Fluid and Electrolyte Balance on Nurses' Performance among Cardiac Surgery Patients

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Abstract

Background: Cardiac surgeries greatly influence the physiologic status of fluid and electrolytes in the body, patients can experience a many of fluid and electrolyte disorders. So, fluid and electrolyte stabilization is one of the corner stones of patient's nursing care. **The aim of the study:** Evaluated the effect of implementing an educational program of the monitoring fluid and electrolyte balance on nurses' performance among cardiac surgery patients. **Research design:** Quasi experimental research design was used to conduct the aim of this study. **Setting:** The study was conducted in the ICU of Cardiothoracic Surgery Unit at Benha University Hospital , Qalyubia Governorate, Egypt. **Subjects:** Purposive sample of 40 nurses who are working in the ICU of Cardiothoracic Surgery Unit at Benha University Hospital were taken from both sexes , their age ranged from 30- <40 years old during six months . **Tools:** two tools were used; (1) : Self- administered questionnaire, it involved the nurses' socio demographic characteristics and nurses' knowledge assessment regarding fluid and electrolyte balance monitoring in cardiac surgery patients, (2) nurses' practice observational checklist. **Results:** the result of this study revealed that, total mean score of nurses' knowledge regarding fluid and electrolyte balance was 36.00 ± 4.52 pre program implementation, then improved to 69.70 ± 4.30immediate post and had slightly declined to 66.55 ± 5.51post 2 months of program implementation, respectively and the total mean score of nurses' practice regarding maintaining fluid and electrolyte balance was69.00 ± 4.79pre program implementation, then improved to 100.1 ± 4.40immediate post and had slightly declined to 91.10 ± 5.23post 2 months of program implementation was with high significant differences (p= <0.001*) **Conclusion:** The level of knowledge and practice among nurses regarding fluid and electrolyte balance monitoring in cardiac surgery patients significantly improved post program implementation. **Recommendations:** Ongoing educational and training programs are needed for nurses regarding fluid and electrolyte balance monitoring in cardiac surgery patients in the ICU of Cardiothoracic Surgery Unit at Benha University Hospital using educational program booklets.

Key words: Disability, Low back pain, Lumbar flexion exercise, pain, Patients' program

Introduction

Cardiac surgery or cardiovascular surgery is surgery on the heart or great vessels performed by cardiac surgeons. It is often used to treat complications of ischemic heart disease, correct congenital heart disease and it also includes heart transplantation. Cardiac surgeries greatly influence the physiologic status of fluid and electrolytes in the body, patients can experience a many of fluid and electrolyte disorders. So, fluid and electrolyte stabilization is one of the corner stones of patient's nursing care ***(Gregory & Bett, 2025).***

Deterioration following cardiac surgery often occurs in the immediate postoperative hours and can cause multiple physiologic alterations, including electrolyte disturbances, acid-base imbalances, atelectasis, diminished pulmonary compliance, hemolysis, and thromboembolism***(del Nido, Kaza & Hoganson, 2025).***

Water is essential for life, and maintaining the correct balance of fluid in the body is crucial to health fluid balance is a term used to describe the balance of the input and output of fluids in the body to allow metabolic processes to function correctly. Around 52% of total body weight in women and 60% in men is fluid. This consist of water and molecules containing, for example, sodium, chloride and potassium ***(Horikawa et al.,2025).***

Body fluid is located in two fluid compartments; the intracellular space (fluid in the cells) and the extracellular space (fluid outside the cells). Approximately two thirds of body fluid are in the intracellular fluid (ICF) compartment and

are located primarily in the skeletal muscle mass. The extracellular fluid (ECF) compartment is further divided into the intravascular, interstitial, and Trans- cellular fluid spaces **(GOYAL et al.,2025) .**

. Fluids and electrolytes and acid base balance are fundamental to the process of life. They are necessary to maintain health and function of all body system. Fluids are vital to all forms of life, they help maintain body temperature and cell shape, and they help transport nutrients, gases, and wastes. Electrolytes play a vital role in maintaining homeostasis within the body **(Daniels, Criddle & McDonald, 2025).**

In cardiac surgery patients, crystalloids solution is infused to restore the circulating volume. After cardiac surgery, the patient will pass a large amount of diluted urine within the first 2-6 hours and will excrete the large amount of potassium. Cardiac surgery patients frequently required potassium supplementation to maintain the S/K+ (serum potassium) and its normal range is 3.5 - 4.5 mEq/l ***(Ellekjaer et al., 2025).***

Hemodynamic stability is considered the major nursing role for the management of cardiac surgical patients, the crystalloid solution is infused to restore the circulating volume, and potassium supplementation is required to maintain the serum potassium and its normal range is 3.5 - 4.5 mEq/l ***(Kontar et al., 2023).***

The nurse is a vital member in the health care team who assess and identifies changes in fluid and electrolytes balance. Understanding the basic principles of fluid and electrolyte imbalance in the body is essential in assessing the patient, planning interventions, and evaluates the effects of care. Knowledge of which electrolytes can be affected by various disorders and an ability to quickly identify the signs and symptoms of electrolyte imbalance can ensure prompt treatment, thereby circumventing more serious complication ***(Mahmoud, Ammar & Mohamed, 2023).***

Significance of the study

More than 2 million people around the world have open-heart surgery to treat various heart problems, and approximately 500,000 people undergo open-heart surgery each year in the United States to correct various cardiovascular problems, In Iran, 30,000 heart surgeries are performed annually, approximately 50 to 60 percent are for coronary artery bypass surgery (CABG) ***(Rahimi et al., 2023).***

In developing countries like Egypt, approximately 11% of cardiac diseased patients undergo cardiac operation; the average annual case volume of adult cardiac surgery is 300-350 cases. (***Vervoort et al, 2020).*** The number of patients undergoing cardiac surgeries in the cardiothoracic surgery unit at Benha University Hospital in 2022 was about 96 patients ***(Benha University Hospital Statistical Office, 2022).***

Electrolyte disorders following cardiac surgery are common occurrences leading to complications. Studies revealed that hypokalemia has been reported in 34% of patients, hypomagnesemia in 46%, hypophosphatemia in 83%, and hypocalcemia in 7.8%. Correction of intraoperative hypomagnesemia in cardiac surgery patients undergoing extracorporeal circulation has been reported to reduce the incidence of ventricular tachyarrhythmia ***(Gebregzabher, Gebretensaye& Alemu2023).***Therefore, this research was carried out in an attempt to promote the nurses' performance regarding their assessing, and monitoring fluid, and electrolyte balance and imbalance for cardiac surgery patients ***(Mahmoud, Ammar& Mohamed,2023) .***

Aim of the study

This study aimed to evaluate the effect of implementing an educational program of the monitoring fluid and electrolyte balance on nurses' performance among cardiac surgery patients.

Research Hypothesis:

H1- The nurses will have a higher knowledge score after implementing an educational program regarding fluid and electrolyte balance for cardiac surgery patients than before.

H2- The nurses will have a higher practice score after implementing an educational program regarding fluid and electrolyte balance for cardiac surgery patients than before.

II. Subjects and Method

Research design

A quasi-experimental design study was used to conduct the study (pre- and post-test design).

Study setting

The study was conducted in the ICU of the Cardiothoracic Surgery Unit at Benha University Hospital, Qalyubia Governorate, Egypt. When entering the ICU in the first floor of medical building, there is main door, doors, one for Cardiothoracic Surgery Unit and the other for ICU of Cardiothoracic Surgery Unit , there are four

beds for receiving the patients after cardiac surgery that are surrounded by a curtain to preserve the privacy of patients, cardiac surgery performed two days a week, Sunday and Wednesday, included two cases per day. The Cardiothoracic unit on the second floor of the medical building receives patients before the day of surgery for preparation, while the ICU of the Cardiothoracic Surgery Unit receives patients after surgery for care. Follow-up is done after discharge every Tuesday in the Cardiothoracic Outpatient Clinics.

Subjects

A purposive sample of 40 nurses from the aforementioned setting was recruited within 6 months.

Inclusion Criteria

-Who assigned for direct patient care and willing to participate in the study.

Exclusion criteria:

-Nurses have working experience of not less than six months in the ICU of the Cardiothoracic Surgery Unit.

Tools of data collection

Two tools for data collection were used as follows:

Tool I: Self- Self-administered questionnaire: (Appendix I)

This tool was designed by researchers and translated into Arabic after reviewing recent relevant literature and scientific references. It involved the following two parts as follows:

Part 1: Nurses' demographic characteristics: This part concerned with the assessment of nurses' personal data related to their age, sex, marital status and educational qualification, as well as their years of experience in the ICU of Cardiothoracic Surgery Unit, workshops was taken before the program regarding monitoring of the fluid and electrolytes or cardiac surgery patients.

Part 2: **Nurses**' **Knowledge Assessment:** It was developed by the researcher through a review of related literature and adapted from ***(Ouda, Said & Mohamed, 2020) & (Hassan, 2021)***. It aimed to assess knowledge about the monitoring of fluid and electrolyte balance and imbalance for cardiac surgery patients. It consisted of 32 questions divided into six sections as follows:

Section 1: It was concerned with assessing nurses' knowledge regarding fluid and electrolyte balance monitoring in cardiac surgery patients and included 7 questions.

Section 2: It was concerned with assess nurses' knowledge regarding the normal levels and values of fluids and electrolytes in the body and included 8 questions.

Section 3: It was concerned with assess nurses' knowledge regarding the features of various fluid and electrolytes disorders and problems in the body and included 9questions.

Section 4: It was concerned with assess nurses' knowledge regarding the fluid and electrolytes assessment after open heart surgery and included 11questions.

Section 5: It was concerned with assessing nurses' knowledge regarding the types of solutions used before and after open-heart surgery and included 4questions.

Scoring system:

For all items related to knowledge, each question was scored from 0 -2 scores where two scores were given for each correct, complete answer, one score for an incomplete answer, and zero for an incorrect answer. The total knowledge questions were 39 points, and the total score of knowledge was calculated and converted into percent and categories as follows:

- Knowledge scores > 80 % good knowledge. (> 62grades)
-Knowledge score 60 - ≥80 % average knowledge. (47 ≥ 62grades)
- Knowledge score <60 % poor knowledge. (<47 grades)

Tool II: Nurses' practice observational checklist: (Appendix I)

It aimed to assess nurses' practice for assessing and monitoring fluid balance and clinical parameters of imbalance post-cardiac surgery patients. It was developed by the researcher after reviewing related literature and adapted from **(Hosny, Sherief, & Mohamed, 2022).** And divided into seven sections as follows:

Section 1: It was concerned with assessing nurses' practice regarding the measurements of the patients' fluid and electrolyte intake (input). It included 21 steps**.**

Section 2: It was concerned with assessing nurses' practice regarding the measurements of the patients' fluid and electrolyte output. It included 14steps.

Section 3: It was concerned with assessing nurses' practice regarding the central venous pressure measurement. It included 12 steps.

Section 4: It was concerned with assessing nurses' practice regarding capillary refill time measurement. It included 10 steps.

Section 5: It was concerned with assessing nurses' practice regarding arterial blood gases measurement. It included 26steps.

Section 6: It was concerned with assessing nurses' practice regarding the Glasgow Coma Scale tool to measure the degree of consciousness. It included 11steps.

Section 7: It was concerned with assessing nurses' practice regarding height and weight measurement. It included 11steps.

Scoring system:

Each procedure was scored from 0 -1. One score for each completed step and zero for the not-done step. The total practice steps were 105 steps, and the total score of practice was calculated and converted into percentages and categories as follows:

- A practice score of ≥ 85% is considered a competent level. (≥89grades)
- A practice score of < 85% is considered an incompetent level. (<89grades)

Ethical considerations:

The ethical research considerations include the following:

- The research approval was obtained from the ethical committee in the faculty of nursing before starting the study.
- The researcher clarified the objectives and aim of the study to nurses' included in the study and assured maintaining anonymity and confidentiality of subjects.
- Nurses' were informed that they are allowed to choose to participate or not in the study and they have the right to withdraw from the study at any time without any consequences.
- Verbal consent was obtained from each participants enrolled into the study.
- All information was gathered used only for their benefit of data and for the purpose of the study.

II. Preparatory phase: This phase included reviewing of literature of various aspects for this study in order to develop the appropriate tools for data collection according to supervisors' guidance and experts' opinions. The researcher translated the knowledge program in Arabic language. During this phase, the researcher also visited the study setting to be acquainted with the personnel and the setting.

Content validity:

The face and content validity were ascertained by a group of (3) experts, three assistant professors from medical surgical nursing department, faculty of nursing, Benha University. The experts reviewed the tools to check the relevancy, simplicity, clarity, comprehensiveness, and applicability of the questions. Their opinions elicited regarding the content, format, consistency, accuracy and relevancy of the tools, necessary modification were done accordingly and the final form of the tools was used for data collection.

Tools reliability:

All tools of the study were tested statistically for its reliability, and it was evaluated using test-retest method by the Cronbach's alpha test which is used to measure the internal consistency. The reliability score of knowledge **tool I** was (0.946) and the reliability score of practices **tool II** was (0.672).

Pilot study:

Pilot study was conducted on 10 % of studied sample (10 nurses) in order to test the clarity and applicability of the study tools and the program, also to estimate the time required for each tool to be filled by the researcher as well as to identify any possible obstacles that may hinder data collection. Based on the results of the pilot study the necessary modifications were done for more applicable tools to collect data. The nurses selected for the pilot study were excluded from the study subjects.

III. Field work:

Data collection of the study was carried out through six months, from the beginning of April, 2024 at the end of October, 2024, the researcher attended the study setting two days (Tuesday and Thursday) per week. The precautionary practice measures for infection control to prevent wound infection as wearing facemask, gloves and using alcohol aseptic solution for both the researcher and the nurses included in the study. The study was conducted through four phases:

Assessment Phase (baseline data)

Once the aim of the study was explained to the participant of nurses in simple words, each participant was individually interviewed using the structured questionnaire concerning nurses' demographic characteristics, then the studied nurses were assessed for their knowledge concerning fluid and electrolyte monitoring for cardiac surgery patients using **(tool I)** and observe the nurses' practice regarding fluid and electrolyte monitoring for cardiac surgery patients using (**tool II).** The tools were collected by the researcher preprogram implementation for each nurse individually.

Planning phase:

Once the initial assessment finished, an

educational program was planned and designed based on individual nurses' condition needs. The researcher set up sessions plan covering general and specific objectives. This program was developed from recent literatures, revised and modified based on the experts' comments, in order to be implemented using various methods. The program resources and facilities were allocated (printed material and location or site of session that best serve the learner). The researcher determined the timetable of sessions with the nurses for starting program sessions.

Educational program :

The booklet was designed by the researcher under the guidance of the supervisors after reviewing the recent literature related to the study and adapted from Jones (2024) and Rasmussen (2024). It was written in simple Arabic Language with different illustrated colored pictures, it consists of theoretical part that included general information and instruction concerning parts of the heart and their functions, heart surgeries, their types and risks, normal rate of water and the importance of fluids for the body system, definition of electrolytes, , causes of fluid and electrolyte disorders in the body and how to diagnose them, examples of the most important minerals in the body and some disorders that occur in heart surgery patients and nursing care for them and diagnose fluid disorders and practical part that included uses and types of intravenous solutions for cardiac surgery patients, nursing steps for replacing therapeutic fluids and salts for cardiac surgery patients and nursing steps followed to calculate the number of drops per minute for gravity infusion .Based on the nurses' needs obtained by the analysis data from the tools yielded by the researcher, the general aim and specific objective were stated.It divided into two parts as follows:

Part I: The theoretical part; it aimed to improve nurses' knowledge related to monitoring fluid and electrolyte balance for cardiac surgery patients as (define parts of the heart and their functions , mention types of heart surgeries and their risks , recognize the normal rate of water and the importance of fluids for the body , define electrolytes, their importance and their normal rate, list causes of electrolyte disorders in the body and how to diagnose them, mention the examples of the most important minerals in the body and some disorders that occur in heart surgery patients and nursing care for them and mention diagnose fluid disorders, uses and types of intravenous solutions for cardiac surgery patients .

Part II: The practical part; it aimed to improve nurses' practices related to monitoring fluid and electrolyte balance for cardiac surgery patients as (demonstrate nursing steps for replacing therapeutic fluids and electrolyte for cardiac surgery patients and demonstrate nursing steps followed to calculate the number of drops per minute for gravity infusion).

Implementation phase:

Nurses' program sessions were implemented in the form of five sessions. The duration of each session was take time 30 minutes and sometimes 45 minutes for 3 or 4 nurses included in each session. The researcher was available 2 days per week in the ICU of cardiothoracic surgery in the morning at Benha University Hospital. Motivation, problem solving and reinforcement techniques were used to enhance an active participation of the nurse in the educational sessions.

Total numbers of sessions were (5) sessions divided as follow :-

1st session: (introductory session) Recognize & identify all objectives for implementation of an educational program regarding fluid and electrolyte balance for cardiac surgery patients.

2nd session: Include recognize & identify all objectives for implementation of an educational program regarding fluid and electrolyte balance for cardiac surgery patients such as define normal rate of water in human body, know the importance of fluids for the human body , recognize causes of electrolyte disorders in the human body Know the most important minerals in the human body and Recognize minerals disorders that occur to cardiac surgery patients.

3rd session: Include identify uses , types of intravenous solutions for cardiac surgery patients, apply steps of nursing care for correct minerals disorders that occur to cardiac surgery patients and apply steps for replacing therapeutic fluids and salts for cardiac surgery patients.

4th session: Include perform of the patients' fluid and electrolyte intake measurements, the patients' fluid and electrolyte output measurements, central

venous pressure measurement, capillary refill time measurement and arterial blood gases measurement.

5th session: Include perform Glasgow Coma Scale measurements and hight and weight measurement .

- Different teaching and learning methods were used during the sessions which included; discussion, demonstration and re-demonstration. The instructional media included mobile videos and printed handout with pictures, which was presented in clear and concise form to enhance nurses' performance regarding monitoring fluid and electrolyte balance among cardiac surgery patients . The program colored booklet was given to each studied nurse in order to help them for reviewing and support teaching.

- At the beginning of the first session, nurses were oriented regarding the program contents, its purpose and impact on his condition and expected outcomes. Second session, include applying observational checklist steps. At the end of all sessions, each nurse was asked about their ability to perform observational checklist steps. The researcher informed each nurses that they would be evaluated by the researcher after two month post implementing the program.

- Each session was started by a summary about what has been discussed in the previous session and the objectives of the new session, using simple Arabic language, also the session ended by a summary of its contents and feedback was obtained from the nurses to ensure that the nurses got the maximum benefit.
- At the end of all sessions, I asked them about their opinion on the program and their benefits from the subject. The researcher informed the nurses patients that they will be evaluated by the researcher.

Evaluation phase

It aimed to evaluate the effect of implementing an educational program of assessing and monitoring fluid and electrolytes balance on the nurses' knowledge, practice performance. It was based on the finding of differences between pre and post program implementation. The evaluation was done by the researchers on Immediate and two month post implementing the program using the tools **(tool I) (part II) and Tool II).**

Results

Table (1): Shows the distribution of studied nurse's personal information , it was noticed 70.0% of nurses were in the age category of 30- <40 years old, with mean age 31.93 ± 4.83. Females were more prevalent and constituted 55.0% of the studied nurses and 100.0% of them were married. As regards the educational qualification, 75.0 % of them had diploma from the nursing institute with 10 years or more experience in nursing field, adding to one year -< 5 years of experience in the intensive care unit of the cardiothoracic surgery.

Table (2): Shows the distribution of studied nurse's regarding to their total of knowledge about fluid and electrolyte balance pre and post program implementation, it showed that 85% of the studied nurses had poor total knowledge level pre program while immediately post implementation and post 2 months of program (90% & 77.5%, respectively) of them had good knowledge level. Also, 80.0% of the studied nurses had poor knowledge level regarding the role of nurses in evaluating fluids and electrolyte after cardiac surgery preprogram, while immediately post and post 2 months period (75.0% and 62.5%, respectively) had a good level of knowledge.

Figure (1): Illustrates nurses' total knowledge level among cardiac surgery patients pre and post program implementation, where 85 % had a poor level of knowledge pre program implementation to be improved to reach a good level immediately post program among 90 % and slightly declined to 77.5 % post 2 months of program.

Table (3): Shows the distribution of studied nurse's regarding to their levels of practices among cardiac surgery patients pre and post program implementation revealing a significant difference between the study periods. Where, 90% of the studied nurses had average total practice level pre program while immediately post implementation and post 2 months of program (100% & 90%, respectively) of them had good practice level. Also, 60.0% of the studied nurses had poor practice level regarding clinical parameters assessment (capillary refill) preprogram, while immediately post and post 2 months period

(85.0% and 70.0%, respectively) had a good level of practice.

Figure (2): Illustrates nurses' total practice level among cardiac surgery patients pre and post program implementation, where 90 % had an average level of practice pre program implementation to be improved to reach a good level immediately post program among 100 % and slightly declined to 90 % post 2 months of program.

Table (4): Shows the distribution of studied nurse's regarding to relationship between nurse' total score for knowledge and their socio demographic characteristics. It was noticed that there was highly statistically difference between total knowledge and nurses' age, years of experience in nursing field and years of experience in the intensive care unit of the cardiothoracic surgery unit at P <0.05 preprogram implementation as well as with educational qualification and attendance of training courses on fluid and electrolyte monitoring for cardiac surgery patients, moreover with sex after 2 months period of program implementation.

Table (5): Shows the distribution of studied nurse's regarding to relationship between nurse' total score for practice and their socio demographic characteristics It was noticed that there was highly statistically difference between total practice and nurses' age, years of experience in nursing field, years of experience in the intensive care unit of the cardiothoracic surgery unit as well as attendance of training courses or workshops on fluid and electrolyte monitoring for heart surgery patients at P <0.05 preprogram implementation as well as with educational qualification and attendance of training courses on fluid and electrolyte monitoring for cardiac surgery patients after 2 months period of program implementation.

Table (6): Shows correlation between total nurses ' knowledge and their practice level about fluid and electrolyte balance among cardiac surgical patients pre and post program implementation. It was noticed that there was a positive and significant correlation between total knowledge, and total practice post program periods p value <0.001**, while not significant during preprogram period p value >0.050.

Table (1): Frequency distribution of studied nurses according to their socio demographic characteristics (n =40)

The nurse's socio demographic data	Total (n = 40)	
	No.	%
Age (Years)		
• 20>- 30	12	30.0
• 30>- 40	28	70.0
• 40-50	0	0.0
Mean ± SD.	31.93 ± 4.83	
Sex		
• Male	18	45.0
• Female	22	55.0
Marital status		
• Single	0	0.0
• Married	40	100.0
• Widow	0	0.0
• Divorced	0	0.0
Educational qualification		
• Diploma from the Nursing Institute	30	75.0
• Bachelor of Nursing	10	25.0
• Master's degree	0	0.0
• Doctorate degree	0	0.0
Years of experience in the field of nursing:		
• Less than one year	0	0.0
• From one year to less than 5 years	3	7.5
• From 5 years to less than 10 years	10	25.0
• From 10 years or more	27	67.5
Years of experience in the intensive care unit of the cardiothoracic surgery unit:		
• Less than one year	0	0.0
• From one year to less than 5 years	16	40.0
• From 5 years to less than 10 years	13	32.5
• From 10 years or more	11	27.5
Attending previous training courses :		
• No	38	95.0
• Yes	2	5.0

Table (2): Frequency distribution of studied nurses regarding their total of knowledge about fluid and electrolyte balance among cardiac surgical patients pre and post program implementation (n =40).

Total nurses' knowledge regarding fluid and electrolyte balance	Pre - program implementation						Post program implementation												Fr (p)	p_1	p_2
							Immediately post program implementation						After two moths post program implementation								
	Poor (<60%)		Average (60%-80%)		Good (> 80%)		Poor (<60%)		Average (60%-80%)		Good (> 80%)		Poor (<60%)		Average (60%-80%)		Good (> 80%)				
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%			
- Fluids and electrolyte balance among cardiac surgery patients	32	80.0	8	20.0	0	0.0	0	0.0	11	27.5	29	72.5	0	0.0	17	42.5	23	57.5	69.879* (<0.001*)	<0.001*	<0.001*
-Normal rates and values of fluids and electrolytes in the body	30	75.0	10	25.0	0	0.0	0	0.0	17	42.5	23	57.5	0	0.0	19	47.5	21	52.5	69.333* (<0.001*)	<0.001*	0.001*
-Fluid and electrolyte disorders in cardiac surgery patients	24	60.0	16	40.0	0	0.0	0	0.0	4	10.0	36	90.0	0	0.0	8	20.0	32	80.0	61.474* (<0.001*)	<0.001*	<0.001*
- Types of solutions used after cardiac surgery	22	55.0	18	45.0	0	0.0	0	0.0	6	15.0	34	85.0	0	0.0	12	30.0	28	70.0	70.806* (<0.001*)	<0.001*	<0.001*
- Role of nurses in evaluating fluids and electrolyte after cardiac surgery	22	55.0	18	45.0	0	0.0	0	0.0	6	15.0	34	85.0	0	0.0	12	30.0	28	70.0	70.806* (<0.001*)	<0.001*	<0.001*
Overall	**34**	**85.0**	**6**	**15.0**	**0**	**0.0**	**0**	**0.0**	**4**	**10.0**	**36**	**90.0**	**0**	**0.0**	**9**	**22.5**	**31**	**77.5**	75.984* (<0.001*)	<0.001*	<0.001*

Figure (1): Frequency distribution of studied nurses regarding their total of knowledge about fluid and electrolyte balance among cardiac surgical patients pre and post program implementation.

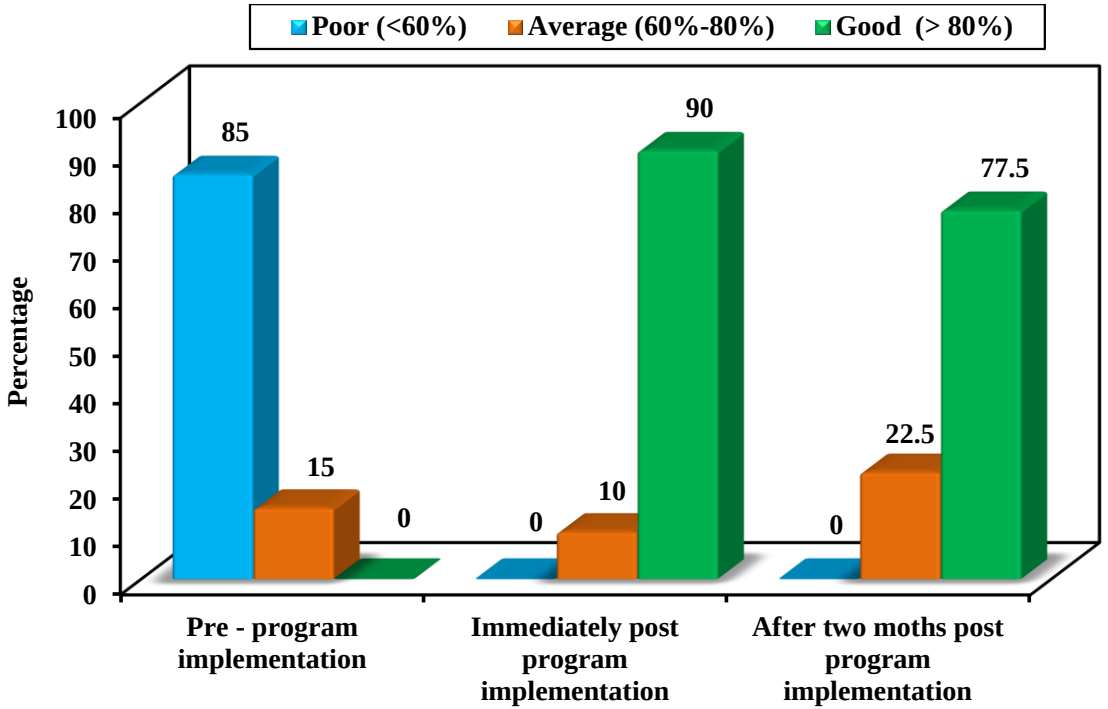

Table (3): Frequency distribution of studied nurses according to their levels of practices among cardiac surgery patients pre and post program implementation (n =40).

Nurses' practices levels regarding fluid and electrolyte balance	Pre - program implementation						Post program implementation												Fr (p)	p_1	p_2
							Immediately post program implementation						After two moths post program implementation								
	Poor (<60%)		Average (60%-80%)		Good (> 80%)		Poor (<60%)		Average (60%-80%)		Good (> 80%)		Poor (<60%)		Average (60%-80%)		Good (> 80%)				
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%			
-Measurements of fluid and electrolyte intake	20	50.0	20	50.0	0	0.0	0	0.0	7	17.5	33	82.5	2	5.0	7	17.5	31	77.5	75.786* (<0.001*)	<0.001*	<0.001*
-Measurements of fluid and electrolyte output	23	57.5	17	42.5	0	0.0	0	0.0	8	20.0	32	80.0	0	0.0	10	25.0	30	75.0	76.355* (<0.001*)	<0.001*	<0.001*
-Clinical parameters assessment (CVP	20	50.0	20	50.0	0	0.0	0	0.0	6	15.0	34	85.0	0	0.0	9	22.5	31	77.5	66.966* (<0.001*)	<0.001*	<0.001*
Clinical parameters assessment (capillary refill)	24	60.0	16	40.0	0	0.0	0	0.0	6	15.0	34	85.0	0	0.0	12	30.0	28	70.0	78.154* (<0.001*)	<0.001*	<0.001*
-Clinical parameters assessment (ABG)	12	30.0	28	70.0	0	0.0	0	0.0	5	12.5	35	87.5	0	0.0	6	15.0	34	85.0	74.667* (<0.001*)	<0.001*	<0.001*
-Clinical parameters assessment (GCS)	32	80.0	8	20.0	0	0.0	0	0.0	4	10.0	36	90.0	0	0.0	12	30.0	28	70.0	76.000* (<0.001*)	<0.001*	<0.001*
-Clinical parameters assessment (height and weight)	12	30.0	20	50.0	8	20.0	0	0.0	7	17.5	33	82.5	0	0.0	8	20.0	32	80.0	58.118* (<0.001*)	<0.001*	<0.001*
Overall	**4**	**10.0**	**36**	**90.0**	**0**	**0.0**	**0**	**0.0**	**0**	**0.0**	**40**	**100.0**	**0**	**0.0**	**4**	**10.0**	**36**	**90.0**	**72.800* (<0.001*)**	**<0.001***	**<0.001***

Figure (2): Frequency distribution of studied nurses according to their levels of practices among cardiac surgery patients pre and post program implementation.

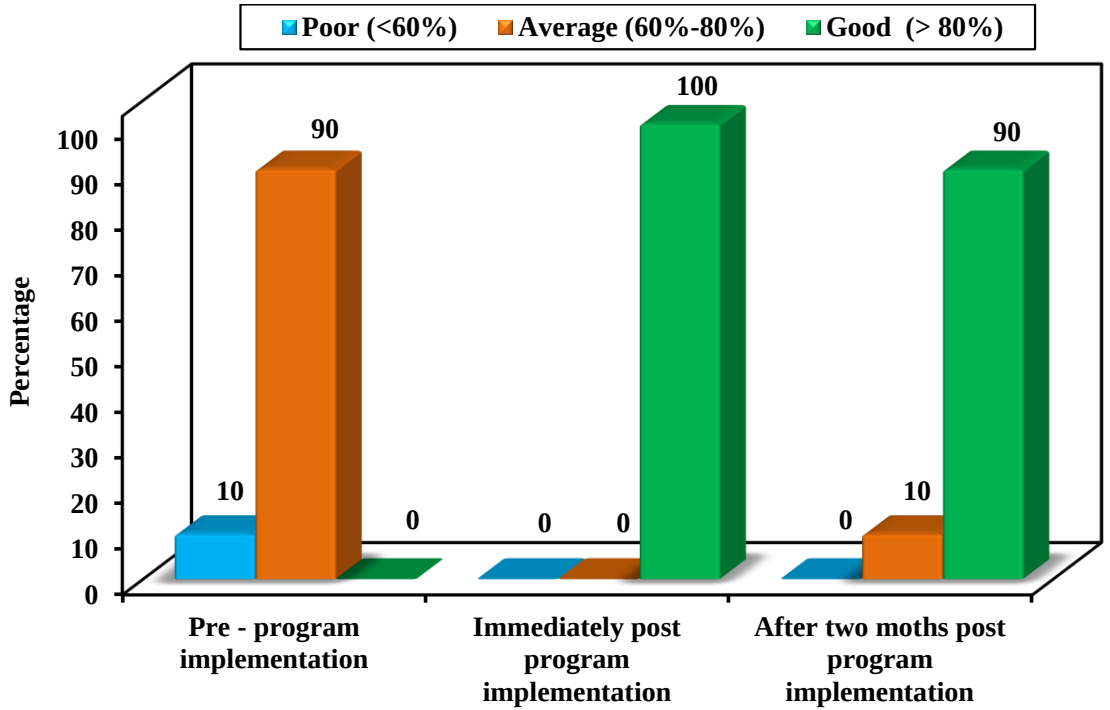

Table (4): Relationship between nurse' total score for knowledge and their socio demographic characteristics (n =40)

The nurse's socio demographic characteristics	N	Total score for knowledge		
		Pre - program implementation	Post program implementation	
			Immediately post program implementation	After two moths post program implementation
		Mean ± SD.	Mean ± SD.	Mean ± SD.
Age (Years)				
• 20- <30	**12**	31.66 ± 3.93	71.16 ± 3.88	67.58 ± 7.31
• 30- <40	**28**	37.85 ± 3.37	69.07 ± 4.39	66.10 ± 4.63
t (p)		**5.058* (<0.001*)**	**1.428 (0.162)**	**0.771 (0.445)**
Sex				
• Male	**18**	36.11 ± 5.70	69.61 ± 4.86	68.72 ± 4.96
• Female	**22**	35.90 ± 3.42	69.77± 3.91	64.77 ± 5.40
t (p)		**0.139 (0.891)**	**0.116 (0.908)**	**2.383* (0.022*)**
Educational qualification				
• Diploma from the Nursing Institute	**30**	35.90 ± 3.33	68.66 ± 4.12	64.63 ± 4.66
• Bachelor of Nursing	**10**	36.30 ± 7.27	72.80 ± 3.39	72.30 ± 3.59
t (p)		**0.057 (0.812)**	**8.166 (0.007)**	**22.423 (0<0.001*)**
Years of experience in the field of nursing:				
• From one year to less than 5 years	**3**	29.00 ± 0.00	73.66 ± 0.57	72.33 ± 2.88
• From 5 years to less than 10 years	**10**	33.70 ± 5.37	70.80 ± 4.21	66.90 ± 7.85
• From 10 years or more	**27**	37.62 ± 3.21	68.85 ± 4.32	65.77 ± 4.37
F (p)		**9.509* (<0.001*)**	**2.256 (0.119)**	**2.034 (0.145)**
Years of experience in the intensive care unit of the cardiothoracic surgery unit:				
• From one year to less than 5 years	**16**	33.00 ± 4.13	69.43 ± 4.61	65.81 ± 7.14
• From 5 years to less than 10 years	**13**	37.07 ± 2.98	70.07 ± 3.42	67.38 ± 2.78
• From 10 years or more	**11**	39.09 ± 4.15	69.63 ± 5.10	66.63 ± 5.57
F (p)		**9.121* (0.001*)**	**0.077 (0.926)**	**0.282 (0.756)**
Have you taken training courses or workshops on fluid and salt monitoring for heart surgery patients:				
• No	**20**	36.80 ± 2.62	66.35 ± 3.31	62.30 ± 3.43
• Yes	**20**	35.20 ± 5.81	73.05 ± 1.87	70.80 ± 3.56
t (p)		**1.121 (0.269)**	**7.869* (<0.001*)**	**7.681* (<0.001*)**

Table (5): Relationship between nurse' total score for practice and their socio demographic characteristics (n =40)

The nurse's socio demographic characteristics	N	Total score for practice		
		Pre - program implementation	Post program implementation	
			Immediately post program implementation	After two moths post program implementation
		Mean ± SD.	Mean ± SD.	Mean ± SD.
Age (Years)				
• 20>- 30	**12**	65.0 ± 3.91	102.0 ± 4.43	93.33 ± 5.48
• 30>- 40	**28**	70.71 ± 4.10	99.29 ± 4.21	90.14 ± 4.91
t (p)		**4.094* (<0.001*)**	**1.841 (0.073)**	**1.819 (0.077)**
Sex				
• Male	**18**	70.44 ± 3.97	101.11 ± 3.64	92.89 ± 4.76
• Female	**22**	67.82 ± 5.16	99.27 ± 4.86	89.64 ± 5.24
t (p)		**1.771 (0.085)**	**1.327 (0.192)**	**2.033* (0.049*)**
Educational qualification				
• Diploma from the Nursing Institute	**30**	68.67 ± 5.39	98.93 ± 4.21	89.40 ± 4.52
• Bachelor of Nursing	**10**	70.0 ± 2.11	103.60 ± 2.95	96.20 ± 3.79
t (p)		**1.122 (0.269)**	**3.237* (0.003*)**	**4.276* (<0.001*)**
Years of experience in the field of nursing:				
• From one year to less than 5 years	**3**	69.0 ± 0.0	105.0 ± 0.0	98.0 ± 0.0
• From 5 years to less than 10 years	**10**	64.20 ± 3.79	101.40 ± 4.65	92.40 ± 5.56
• From 10 years or more	**27**	70.78 ± 4.16	99.07 ± 4.13	89.85 ± 4.75
F (p)		**10.066* (<0.001*)**	**3.401* (0.044*)**	**4.312* (0.021*)**
Years of experience in the intensive care unit of the cardiothoracic surgery unit:				
• From one year to less than 5 years	**16**	67.25 ± 5.23	100.50 ± 4.65	91.0 ± 6.28
• From 5 years to less than 10 years	**13**	68.08 ± 4.33	101.31 ± 3.15	92.15 ± 3.56
• From 10 years or more	**11**	72.64 ± 2.34	98.09 ± 4.97	90.0 ± 5.44
F (p)		**5.507* (0.008*)**	**1.768 (0.185)**	**0.497 (0.613)**
Have you taken training courses or workshops on fluid and salt monitoring for heart surgery patients:				
• No	**20**	71.20 ± 5.75	96.20 ± 1.88	86.60 ± 2.11
• Yes	**20**	66.80 ± 1.99	104.0 ± 2.05	95.60 ± 3.02
t (p)		**3.236* (0.004*)**	**12.532* (<0.001*)**	**10.931* (<0.001*)**

Table (6): Correlation between total nurses ' knowledge and their practice level about fluid and electrolyte balance among cardiac surgical patients pre and post program implementation (n = 40)

Knowledge vs. practices	Pre - program implementation	Post program implementation	
		Immediately post program implementation	After two moths post program implementation
R	0.154	0.630*	0.606*
P	0.342	<0.001*	<0.001*

Discussion

Fluid balance monitoring is an essential part of the process of care in ICU of cardiothoracic surgery unit. Fluid balance is the balancing of intake and output of fluid to allow metabolic processes to function correctly. Maintaining fluid balance plays an important role in the managing cardiac surgery patients, the accurate monitoring of fluid balance activities is a vital part of patients' baseline information, which guides medical and nursing interventions to achieve physiological stability***(Rasmussen et al., 2024).***

Regarding age, the current study revealed that more than two thirds of studied nurses, were recorded within age group of thirty to forty years old. .This result in the same line with ***Mohammed, Roshdy & Mokhtar, (2020).*** Whose study titled " Effect of Safe Hydration Management Educational Program on Nurses' Performance and Patients' Outcomes in Minia University Hospitals. " , and reported that the age of most of the studied nurses were recorded within age group of thirty to forty years old.

But the present study findings incongruent with ***Hosny, Sherief & Mohamed , (2022).*** about " Prevalence of Assessment of Nurses' knowledge and Performance Regarding Fluid and Electrolyte Management for Cardiac Surgery Patients at the cardio-thoracic surgery department affiliated to Mansoura University Hospital. " , and reported that the age of most of the studied nurses were recorded between twenty six to less than thirty years.

Regarding to sex, the current study results showed that more than half of the studied nurses were female. From researcher point of view this results may be explained by the fact that nursing is a universal feminine profession especially in Egyptian society culture as well as the enrolment of the male students in this profession was started in the late decades.

This finding is in line with ***Abd Elalem, & Fouad, (2020).*** Whose study about " Effect of an instruction intervention about body fluid balance assessment on knowledge and practice among nurses in Intensive Care Unit in intensive care unit at Menoufia university hospital. " showed that the majority of the studied nurses were female.

Regarding to educational qualification, the current study showed that three quarter of the studied nurses had diploma from the Nursing Institute. From the researcher's point of view these results explained by a little number of faculty′s graduates had employed in the university hospital and other work in schools or ministry of health hospital. This result in the same line with ***Mohamed, Mohammed & Taha, (2018)*** . showed that three quarter of the study sample graduated from a technical institute.

On the other hand, the present study findings incongruent with ***Hosny, Sherief & Mohamed, (2022),***titled "Assessment of Nurses' knowledge and Performance Regarding Fluid and Electrolyte Management for Cardiac Surgery Patient in cardio-thoracic surgery department of Mansoura University Hospitals. " showed that almost two third of the studied nurses had bachelor degree.

Concerning years of experience in the field of nursing, the current study findings revealed that two third of studied nurses had ten years in the field of nursing. From the researcher's point of view, governmental hospitals often tend to have a nursing workforce composed mainly of experienced staff. This may be due to the fact that the number of newly graduated nurses is insufficient to meet the growing healthcare

demands. As a result, the nursing staff in these institutions is largely made up of nurses with long years of experience, who have remained in service to fill the gap caused by the shortage of new recruits. This finding is consistent with a study was done by ***Michelsen, et al., (2022)*** entitled "A study on accuracy and precision of fluid volume measurements by nurses, patients and healthy persons in a clinical setting in university Hospital in Denmark. " which reported that the more than half of studied nurses had ten years in the field of nursing.

Conversely, in a study carried out by ***Mohammed, Roshdy & Mokhtar , (2020)*** about " Effect of Safe Hydration Management Educational Program on Nurses' Performance and Patients' Outcomes at Minia University Hospitals. " they mentioned that the slightly less than three fifth of studied nurses had more than five years in the field of nursing.

Concerning their years of experience in the intensive care unit of the cardiothoracic surgery unit, the result revealed that two fifth of the studied nurses had experience in the intensive care unit of the cardiothoracic surgery unit from one year to less than 5 years. From the researcher's point of view, this may be due to that the hospitals are increasingly recruiting new nurses into specialized units to meet the growing needs of cardiothoracic surgical care, especially given advancements in surgical procedures and rising patient numbers .This result is dis agreement with a study by ***Mansour, (2020).*** about " Developing Nursing Standards for Maintaining Fluid and Electrolyte Balance for Critically Ill Patients in Intensive Care Units in ICUs of Mansoura University Emergency Hospital. " and found that most of the sample were had experience in the intensive care unit of the cardiothoracic surgery unit for more than 20 years.

Concerning their marital status, the result revealed that all of them married. It may attributed to that the Egyptian females prefer to be married in young age according to Egyptian society culture . This finding is in line with a study supported *by* ***Hafez et al., (2022)*** about " Effect of Implementing Fluid and Electrolyte Resuscitation Educational Package on Nurses' Performance and Outcomes of Patients with Burn at Mansoura University Hospitals. " and found that most of the sample were married.

Regarding training courses or workshops on fluid and electrolyte monitoring for cardiac surgery patients, the findings of the current study revealed that most of the studied nurses didn't participate on fluid and electrolyte monitoring workshops for cardiac surgery patients. From the researcher's point of view, this could be attributed to several factors such as limited availability of specialized training programs, lack of institutional support, or workload pressures that prevent nurses from attending such educational activities.

This finding is in line with a study supported *by* ***Abd Elalem & Fouad, (2020).*** Found that majority of the sample weren't participate on fluid and electrolyte monitoring workshops for cardiac surgery patients.

Concerning nurses' total knowledge level about fluid and electrolyte balance among cardiac surgery patients pre and post program implementation, the finding of the present study revealed that majority of studied nurses had a poor level of knowledge preprogram implementation ,while improved to become the majority had good level immediately post program , then slightly declined to become only three quarter of studied nurses had good level post 2 months of program implementation .From the researcher's point of view, this suggests that structured educational programs can lead to immediate and significant improvements in nurses' knowledge. However, the slight decline observed after two months also emphasizes the need for ongoing reinforcement and periodic refresher training to maintain knowledge retention over time.

This finding congruent with study carried out by ***Eta et al.,(2024)*** which entitled" Nurses' practices of input and output monitoring of patients on intravenous fluid therapy in hospitals within Fako Division, Cameroon. " they indicated that majority of the studied nurses had unsatisfactory total knowledge about fluid and electrolyte monitoring .

In addition, there were high statistically significant differences in their total knowledge level pre and post program implementation. From the researcher's perspective, this finding provides strong evidence that the program had a meaningful impact on enhancing nurses' understanding of fluid and electrolyte balance among cardiac surgery patients.

This finding is also congruent with ***Da Silva, (2024)***, about " Understanding body fluid balance, dehydration and intravenous fluid therapy in London General Hospital. " reported that there was significant positive differences between nurses' total knowledge level about fluid and electrolyte balance pre and post program implementation.

This finding is also congruent with ***Abd Elalem & Fouad, (2020).*** about " Effect of an instruction intervention about body fluid balance assessment on knowledge and practice among nurses in Intensive Care Unit *at Menoufia university hospital*. " reported that there was a high statistically significant improvement of nurse's knowledge related to fluid input and output post intervention than pre intervention for all items of knowledge. In addition to more than half of the nurses have poor knowledge pre intervention, while the majority of nurses had good knowledge at post intervention.

Regarding nurses' total practice level among cardiac surgery patients pre and post program implementation, the finding of the present study revealed that majority of studied nurses had an average level of practice preprogram implementation ,while improved to become all of studied nurses had good level of practice immediately post program, then slightly declined to become the majority of them had good level post 2 months of program implementation. From the researcher's point of view, this reflects not only the effectiveness of the intervention in enhancing practical skills, but also the potential for knowledge translation into actual clinical practice when supported by structured and targeted training. However, the slight decline over time highlights the need for continuous follow-up, supervision, and refresher sessions to sustain high practice standards, particularly in critical care areas such as ICU of cardiothoracic surgery unit.

This finding is in agreement with a study by ***Audet et al.,(2024)*** . about" Inter professional teams with and without nurse practitioners and the level of adherence to best practice guidelines in cardiac surgery: A retrospective study in a cardiac surgery unit of a university hospital in Québec (Canada). " They mentioned that their nurses teams have a higher level of adherence to best-practice post guidelines implementation compared pre guidelines implementation.

Conversely, in a study carried out by ***El Desouky, N., Taha, N. & Hafez, G. , (2020)*** which entitled" Factors affecting Nurses' performance regarding the care for patients underwent coronary artery bypass graft n cardiothorathic Intensive Care Unit and intermediate intensive care unit At Zagazig University Hospitals. " they indicated that more than half of the studied nurses had unsatisfactory total knowledge and inadequate total practice regarding the care for patients underwent CABG and need educational training program to improve nurses 'performance regarding care for cardiac surgery patient. In addition, there were high statistically significant positive differences in their total practice level pre and post program implementation.

Relations and correlations between the studied variables.

Concerning relation between total knowledge of the studied nurses and their socio demographic characteristics . The finding of the present study showed that there was highly statistically difference between total knowledge and nurses' age, years of experience in nursing field and years of experience in the intensive care unit of the cardiothoracic surgery unit at $P<0.05$ preprogram implementation as well as with educational qualification and attendance of training courses on fluid and electrolyte monitoring for cardiac surgery patients, moreover with sex after 2 months period of program implementation. From the researcher's point of view, this suggests that older and more experienced nurses, as well as those with higher qualifications, tend to have stronger foundational knowledge. Additionally, the significant association with prior attendance of training courses highlights the effectiveness of continuous education in enhancing knowledge.

The result is in the same line with study supported by ***Abu Farah, H., & Khleif, M. ,(2024)*** about " Knowledge, attitude, and practice of Palestinian critical care nurses about hemodynamic instability in patients with cardiovascular diseases in Palestinian critical hospital. " reported that there was highly statistically significant difference between total knowledge and nurses' age, years of experience in the nursing field and years of experience in the intensive care unit of the cardiothoracic surgery unit.

Conversely, in a study carried out by ***Farooq, N. & John, S., (2022).*** which entitled" Evaluation of the parameters influencing nurses' effectiveness in the treatment of patients after coronary artery bypass graft surgery in ICU of pakistan general hospital . " they shows that there is no strong relationship among nurses' education and skills scores and variables influencing nurse performance and there was no significant relationship between total awareness and education among the nurses

investigated in caring for patients after coronary artery bypass graft surgery in ICU.

Concerning relation between total practice of the studied nurses and their socio demographic characteristics. The finding of the present study showed that there was highly statistically significant difference between total practice and nurses' age, years of experience in nursing field, years of experience in the intensive care unit of the cardiothoracic surgery unit as well as attendance of training courses or workshops on fluid and electrolyte monitoring for heart surgery patients at P <0.05 preprogram implementation as well as with educational qualification and attendance of training courses on fluid and electrolyte monitoring for cardiac surgery patients after 2 months period of program implementation. From the researcher's point of view, these results suggest that more experienced nurses and those who have participated in relevant workshops or courses are better equipped with practical skills necessary for the care of cardiac surgery patients. Additionally, the continued significance of educational qualification and training attendance even after two months further reinforces the long-term impact of formal education and ongoing training.

The result is in the same line with study done by ***Hassan, A. (2021)***. entitled" Effect of applying guidelines on nurses performance regarding fluid and electrolyte imbalance in intensive care unit in Damietta General Hospital. " they shows that there were statistically significant relation regarding scores of nurses' practice regarding fluid& electrolyte imbalances monitor and management pre, immediately after and follow up after guidelines applications in area of fluid and electrolyte monitor score, fluid and electrolyte management score and total practice .

Pertaining to correlation between total nurses ' knowledge and their practice level about fluid and electrolyte balance among cardiac surgical patients pre and post program implementation, it showed that there was a positive and significant correlation between total knowledge, and total practice post program periods p value <0.001**, while not significant during preprogram period p value >0.050. From the researcher's point of view, this result means that the training program was very effective. Before the program, nurses might have had some knowledge, but it didn't really affect how they worked. After the program, their knowledge clearly helped improve their practice. This shows that when nurses receive proper training, they are more able to apply what they learn in real situations.

The result is in the same line with the study by ***Doruker, N., Oden, T., & Korkmaz, F.,(2023).*** Entitled" Determination of knowledge and attitudes of cardiac surgery nurses regarding the enhanced recovery after surgery protocol in the cardiovascular surgery unit of a university hospital in the province of Izmir, Turkey. they show that there was a positive and statistically significant correlation between the mean knowledge level score and total practice level score.

Conclusions

The study concluded that the nurses' knowledge and practice levels in monitoring fluid and electrolyte among cardiac surgery patients significantly improved after implementing the program. This indicates that the educational program booklet was highly effective in enhancing nurses' knowledge and practices, showing statistically significant differences and supporting the research hypotheses.

Recommendations

This study was recommended as the following:

- Improving unlicensed staff and nurses' knowledge, attitudes, and practices associated with fluid status monitoring by the utilization of a fluid status monitoring protocol.
- Implement clinical care pathways specific to post-open heart surgery to guide fluid therapy and electrolyte correction.
- Use electronic health record (EHR) systems to help nurses practice managing postoperative complications such as hypokalemia, hyponatremia, and fluid overload, prompt fluid status documentation, and alert for abnormalities.
- Training nurses to focus on evidence-based practices regarding fluid and electrolyte monitoring for cardiac surgery patients.
- Conducting a study with a greater sample size is suggested to achieve generalization of the findings and wider application of the educational package.

Further research: Future studies are recommended to:-

1. Evaluate the long-term impact of educational programs on nurses' performance and retention of skills in monitoring fluids and electrolytes.

2. Investigate the effect of such programs on patient outcomes, particularly among post-cardiac patients, through extended follow-up after ICU discharge.

3.There are some factors that prevent me from measuring the patients' outcomes regarding fluid and electrolyte balance after cardiac surgery are critical condition of the patients, the priority of providing immediate and continuous care and time constraints .

References

Abd Elalem, S., & Fouad, N. (2020):Effect of an instruction intervention about body fluid balance assessment on knowledge and practice among nurses in Intensive Care Unit. *International Journal of Novel Research in Healthcare and Nursing*, *5*(1), 94-105.

Abu Farah, H., & Khleif, M. (2024):Knowledge, attitude, and practice of Palestinian critical care nurses about hemodynamic instability in patients with cardiovascular diseases. *BMC nursing*, *23*(1), 1-8.

Aslam, S., Afzal, M., Kousar, R., Waqas, A., & Gilani, S. (2017):The Assessment of Nurses' Knowledge and Practices about Fluid and Electrolytes Monitoring and Administration among Cardiac Surgery Patients: A Case of Punjab Institute of Cardiology. International Journal of Applied Sciences and Biotechnology, 5(2), 208-215.

Da Silva, T. H. R. (2024). Understanding body fluid balance, dehydration and intravenous fluid therapy. *Emergency Nurse*, *32*(4).

Daniels, A. H., Criddle, S. L., & McDonald, C. L. (2025):Electrolyte Disturbances and Repletion in Orthopaedic and Spine Surgery Patients. *JAAOS-Journal of the American Academy of Orthopaedic Surgeons*, *33*(1), 9-13.

Del Nido, P. J., Kaza, A. K., & Hoganson, D. (2025):Emerging techniques in cardiac surgery. *Nadas' Pediatric Cardiology*, 741-752.

Ellekjaer, K. L., Sivapalan, P., Myatra, S. N., Grønningsæter, L., Hästbacka, J., Young, P. J., ... & Møller, M. H. (2025): Preferences and attitudes on acetate-versus lactate-buffered crystalloid solutions for intravenous fluid therapy—an international survey. *Acta Anaesthesiologica Scandinavica*, *69*(1), e14553.

Eta, V. E. A., Akong, E. R., Bassah, N., & Amahnui, G. (2024):Nurses' Practices of Input and Output Monitoring of Patients on Intravenous Fluid Therapy within Fako Division. *Universal Library of Clinical Nursing*, *1*(1).

Farooq, N. U. A., & John, S. (2022): Evaluation of the Parameters Influencing Nurses' Effectiveness in the Treatment of Patients after Coronary Artery Bypass Graft Surgery in ICU. *Pakistan Journal of Medical & Health Sciences*, *16*(02), 1072-1072.

Gebregzabher, S., Gebretensaye, T., & Alemu, T. (2023):Factors associated with major electrolyte disorders among post cardiac surgery patients at Tikur Anbessa Specialized Hospital and Cardiac Center Ethiopia in Addis Ababa, Ethiopia, 2021. International Journal of Africa Nursing Sciences, 18, 100556.

GOYAL, M. R., BARCELONA, S. S., GALLOCHER, S. L., & VALLEJO, M. (2025): Biofluid Dynamics of the Human Circulatory System. *Biofluid Dynamics of Human Body Systems: Expanded and Revised Edition*, 317.

Gregory, V., & Bett, L. (2025):Medical Nursing and Patient Care. *Textbook of Equine Veterinary Nursing*, 563-624.

Hafez Ramadan El-Shaboury, R., Hessin Yousef Heggy, E., Faried Abdelwanees Ali, A., & Mohamed Abdelfatah Sliman, A. (2022): Effect of Implementing Fluid and Electrolyte Resuscitation Educational Package on Nurses' Performance and Outcomes of Patients with Burn. *Egyptian Journal of Health Care*, *13*(3), 868-886.

Hassan, A. (2021):EFFECT OF APPLYING GUIDELINES ON NURSESPERFORMANCE REGARDING FLUID AND ELECTROLYTE IMBALANCE IN. Port Said Scientific Journal of Nursing, 8(2), 14-36.

Horikawa, C., Takahara, M., Katakami, N., Takeda, Y., Takeuchi, M., Fujihara, K., ... & Sone, H. (2025): Dietary potassium intake and its interaction with sodium intake on risk of developing cardiovascular disease in persons with type 2 diabetes: The Japan Diabetes

Complication and its Prevention Prospective study (JDCP study 12). *Diabetes, Obesity and Metabolism*, *27*(1), 394-406.

Hosny, A., Sherief, W., & Mohamed, M. (2022): Assessment of Nurses' knowledge and Performance Regarding Fluid and Electrolyte Management for Cardiac Surgery Patients. *Mansoura Nursing Journal*, *9*(1), 31-40.

Mahmoud, F. H., Ammar, S. A., & Mohamed, A. S. M. (2023): Nurse's Knowledge and Practice Regarding Care of Fluids and Electrolytes Imbalance among Critically Ill Patients. *Journal of Survey in Fisheries Sciences*, *10*(3S), 4257-4266.

Mahmoud, F. H., Ammar, S. A., & Mohamed, A. S. M. (2023): Nurse's Knowledge and Practice Regarding Care of Fluids and Electrolytes Imbalance among Critically Ill Patients. *Journal of Survey in Fisheries Sciences*, *10*(3S), 4257-4266.

Mahmoud, F., Ammar, S., & Mohamed, A. (2023): Nurse's Knowledge and Practice Regarding Care of Fluids and Electrolytes Imbalance among Critically Ill Patients. Journal of Survey in Fisheries Sciences, 10(3S), 4257-4266.

Mansour, H. E. (2020): Developing Nursing Standards for Maintaining Fluid and Electrolyte Balance for Critically Ill Patients in Intensive Care Units. *Journal of intensive and critical care*, *5*(1), 4.

Michelsen, C. F., Svendsen, M. B. S., Bagger, M. L., & Konradsen, H. (2022): A study on accuracy and precision of fluid volume measurements by nurses, patients and healthy persons in a clinical setting. *Nursing open*, *9*(2), 1303-1310.

Mohamed, M. A., Mohammed, I. R., & Taha, S. H. (2020): Effect of educational protocol regarding accurate monitoring fluid balance on critical care nurses' knowledge and practice. *Minia Scientific Nursing Journal*, *4*(1), 76-82.

Mohammed Weheda, S., Roshdy Mohammed, I., & Mokhtar Elsayed, I. (2020):Effect of Safe Hydration Management Educationa Program on Nurses' Performance and Patients' Outcomes. *Assiut Scientific Nursing Journal*, *8*(22), 11-21.

Ouda, M., Said, S., & Mohamed, S. (2020): Effect of an Educational Program on Nurse's Performance Regard Monitoring Fluid and Electrolyte Replacement for Burned Patients. Egyptian Journal of Health Care, 11(4), 460-481.

Rahimi, S., Abdi, A., Salari, N., Shohaimi, S., & Naghibeiranvand, M. (2023):Factors Associated with Long-Term Mechanical Ventilation in Patients Undergoing Cardiovascular Surgery. BMC cardiovascular disorders, 23(1), 276.

Rasmussen, A. V., Nissen, K. J., Konradsen, H., & Deininger, M. (2024):A concept for improving fluid balance monitoring during hospitalisation. *Nordisk sygeplejeforskning*, *14*(1), 1-8.

Vervoort, D., Meuris, B., Meyns, B., & Verbrugghe, P. (2020): Global Cardiac Surgery: Access to Cardiac Surgical Care Around the World. The Journal of Thoracic and Cardiovascular Surgery, 159(3), 987-996.