Perioperative serum potassium changes in patients undergoing openheart surgery under cardiopulmonary bypass: A comparative study between two group of patients- one group of patients on long term preoperative diuretics and the other group not on diuretics.

A dissertation submitted to the Tamil Nadu Dr. M.G.R. Medical University in partial fulfillment of the requirement for the award of M.D. Branch X (Anaesthesia) degree examination to be held in April

ACKNOWLEDGEMENTS

First and foremost , I thank God, the Almighty for enabling me to do this thesis. I would like to express my sincere gratitude to my guide Dr. Manickam Ponniah for his constant support and encouragement ,with his patience and immense knowledge without whom this study might not been possible. I would like to thank Dr. Mary Korula, the Head of the Department of Anaesthesiology for her continued encouragement. I would also thank Dr. Vinayak Shukla , the Head of the Department of Cardio-Thoracic surgery for giving me permission to use the Cardio-Thoracic Intensive care Unit to conduct this study. I thank Dr. Kirubakaran, my co-guide for his involvement in this study and Mrs. Visali Peravali for all the help in analyzing the data.

I also thank all my colleagues, seniors and juniors, for helping me in filling the proforma and our Anaesthesia technicians who helped a lot in collecting the datas.

Last but not the least , I thank my dear wife Ancy, my loving children Tryphena and Tersanctus for all their sacrifice and support in completing the thesis.

CERTIFICATE

This is to certify that the dissertation entitled **"Perioperative serum potassium changes in patients undergoing open-heart surgery under Cardio-Pulmonary bypass: A comparative study between two group of patients - one group on long term preoperative diuretics and other group not on diuretics"** is a bonafide work of **Dr.ILANGOVAN P** in partial fulfillment of the requirements for the **M.D. Anaesthesiology** (Branch X) degree examination of The Tamil Nadu Dr. M.G.R Medical University, Chennai, to be held in April **2013.**

SIGNATURE OF THE GUIDE

Dr.MANICKAM PONNIAH
Professor
Department of Anaesthesiology
Christian Medical College
Vellore-632004.

Dr. MANICKAM PONNIAH,
Professor
Department of Anaesthesia
C.M.C. Hospital, Vellore-632 004.

SIGNATURE OF THE H.O.D.

Dr.MARY KORULA
Professor and Head
Department of Anaesthesiology
Christian Medical College
Vellore-632004.

Dr. MARY KORULA
Professor & Head
Department of Anaesthesia
Christian Medical College,
VELLORE - 632 004.

CHRISTIAN MEDICAL COLLEGE & HOSPITAL
DEPARTMENT OF ANAESTHETICS
VELLORE - 4

INSTITUTIONAL REVIEW BOARD (IRB)
CHRISTIAN MEDICAL COLLEGE
VELLORE 632 002, INDIA

Dr.B.J.Prashantham, M.A.,M.A.,Dr.Min(Clinical)
Director, Christian Counseling Centre
Editor, Indian Journal of Psychological Counseling
Chairperson, Ethics Committee, IRB

Dr. Alfred Job Daniel, MS Ortho
Chairperson, Research Committee &
Principal

Dr. Nihal Thomas
MD, MNAMS, DNB(Endo), FRACP(Endo), FRCP(Edin)
Secretary, Ethics Committee, IRB
Additional Vice Principal (Research)

Ref: Res/09/2011 November 19, 2012

Dr. Ilangovan P
PG Registrar
Department of Anaesthesiology
Christian Medical College
Vellore 632 002

Sub: **Fluid Research grant project NEW PROPOSAL:**
Perioperative serum potassium changes in patients undergoing open-heart surgery under Cardio-Pulmonary bypass: A comparative study between two group of patients-one group on long term preoperative diuretics and other group not on diuretics.
Dr. Ilangovan P, PG Registrar, Anaesthesiology, Dr. Manickam Ponniah, Cardio-Thoracic Anaesthesiology, Dr. Kirubakaran, Anaesthesiology,

Ref: IRB Min. No. 7906 dated 4.7.2012

Dear Dr. Ilangovan,

Could you please sign the agreement and send it to Dr. Nihal Thomas, Addl. Vice Principal (Research), so that the grant money can be released.

With best wishes,

Dr. Nihal Thomas
Secretary (Ethics Committee)
Institutional Review Board

Dr Nihal Thomas
MBBS MD MNAMS DNB (Endo) FRACP(Endo) FRCP(Edin)
Secretary (Ethics Committee)
Institutional Review Board

CC: Dr. Manickam Ponniah, Professor, Department of Anaesthesiology, CMC ilango van thesis

BY ILANGOVAN P 20114055

10% SIMILAR

-- OUT OF 0

INTRODUCTION:

The patients who undergo cardiac surgery in our hospital can be mainly divided into two groups. The first group of patients are who have coronary artery disease and the second group of patients are those with valvular heart disease. The first group of patients undergo coronary artery bypass grafting and the second group undergo valve repair or replacement. These patients will undergo these surgeries under cardiopulmonary bypass. They are in different class on the New York Heart Association's physical status classification. Based on the severity of the disease and the symptoms, these patients are treated with different group of medications. As the disease advances these patients develop cardiac failure. When systolic heart failure occur, the heart can no more pump adequate amount of blood into the systemic circulation leading to symptoms of low cardic output or of the fluid overload to the heart . When diastolic dysfunction occur, the patients develop heart failure due to atrial hypertension. Congestive cardiac failure leads to the symptoms like easy fatiguability,

Match Overview

1	lifeinthefastlane.com Internet source	3%
2	Submitted to Universit... Student paper	2%
3	C ROSENDORFF. Publication	1%
4	Zamboli, P., L. De Nic... Publication	<1%
5	Kenneth Spalding, H.. ... Publication	<1%
6	Submitted to Universit... Student paper	<1%
7	"Abstracts of the 53rd... Publication	<1%
8	"Abstracts of ESCVS Publication	<1%

TABLE OF CONTENTS

INTRODUCTION

INTRODUCTION:

The patients who undergo cardiac surgery in our hospital can be mainly divided into two groups. The first group of patients are who have coronary artery disease and the second group of patients are those with valvular heart disease. The first group of patients undergo coronary artery bypass grafting and the second group undergo valve repair or replacement. These patients will undergo these surgeries under cardiopulmonary bypass. They are in different class on the New York Heart Association's physical status classification. Based on the severity of the disease and the symptoms, these patients are treated with different group of medications. As the disease advances these patients develop cardiac failure. When systolic heart failure occur, the heart can no more pump adequate amount of blood into the systemic circulation leading to symptoms of low cardic output or of the fluid overload to the heart . When diastolic dysfunction occur, the patients develop heart failure due to atrial hypertension. Congestive cardiac failure leads to the symptoms like easy fatiguability, dyspnea and congestion. The medical management of heart failure includes angiotensin converting enzyme inhibitors, diuretics, vasodilators and digitalis. Diuretics are used to relieve circulatory congestion. Symptoms improve as the pulmonary and peripheral edema are relieved. Diuretics reduce atrial and ventricular diastolic pressures thereby reducing the diastolic stress on the ventricular wall. This will help in preventing persistent cardiac distension and improve subendocardial perfusion. Chronic use of diuretics will lead to hypokalemia. So potassium supplementation is given in patients on chronic diuretics use. Potassium sparing diuretics helps in avoiding hypokalemia but they will not cause adequate natriuresis. Hypokalemia or hyperkalemia in the perioperative period cause cardiac conduction disturbances and they are not desirable. There are various factors in the perioperative period which can alter potassium homeostasis like the prescence of diabetic mellitus, hypertension, chronic renal failure, ischemic and valvular heart diseases, respiratory and metabolic acid-base disturbances, hypothermia, blood transfusion, dose and duration of the use of cardioplegia. The potassium homeostasis is maintained by giving potassium correction in the form of intravenous potassium in hypokalemia and by giving calcium, sodium bicarbonate, glucose-insulin infusion, nebulization with beta 2 agonists when hyperkalemia occurs.

This is an observational study to study the role of preoperative use of diuretics in the incidence of altered serum potassium levels in the perioperative period. We compared two group of patients with one group on long term preoperative diuretic and the other group not on diuretics. This study helped us to understand whether diuretics played a role in the perioperative potassium homeostasis.

AIMS & OBJECTIVES

AIMS AND OBJECTIVES:

1. To study the differences in the perioperative serum potassium changes between one group of patients on long term preoperative diuretics and the second group of patients who were not on preoperative diuretics who underwent openheart surgery under cardiopulmonary bypass.

2.To compare the interventions needed to keep potassium homeostasis between the two groups.

REVIEW OF LITERATURE

REVIEW OF LITERATURE:

POTASSIUM:

Potassium is the fairly abundant positive ion in the intracellular compartment. (1) The total body potassium content is about 135 gms. Out of this 98 percent is present intracellular compartment (2) and about two percent in the extracellular compartment. Potassium plays an important role in (3) cell membrane physiology, especially in maintaining resting membrane potentials and in generating action potentials in the central nervous system and heart.

NORMAL POTASSIUM BALANCE: (4)

Normal serum potassium is between 3.5MEq/L to 5.5 MEq/L. The normal homeostasis of potassium is balanced between dietry intake and excretion through kidneys and gut; and also by its movements between intracellular and extracellular compartments. Increase in the extracellular potassium is sensed by the zona glomerulosa cells of the adrenal medulla which secretes aldosterone. Aldosterone acts on the cortical collecting tubules and increases potassium secretion into the tubular fluid increasing potassium excretion.

EXTRACELLULAR POTASSIUM REGULATION:

The cell membrane Na^+ -K^+ ATPase activity is important in controlling the distribution of potassium between cells and the extracellular fluid. The excretion of potassium through the kidneys is determined by the serum potassium concentration. Generally extracellular serum potassium concentration reflects the balance between potassium intake and excretion.

INTRACOMPARTMENTAL SHIFTS OF POTASSIUM:

Intracompartmental shifts of potassium occur following any changes in the following:

1.Extracellular pH.

2. circulating catecholamine activity.

3. circulating insulin levels.

4. plasma osmolality.

5. hypothermia.

Insulin enhances the activity of membrane-bound Na^+–K^+ ATPase, increasing cellular uptake of potassium in the liver and in skeletal muscle. When the pH is on the acidotic side, extracellular hydrogen ions enter cells, displacing intracellular potassium ions to maintain electrical neutrality. In alkalosis, the reverse will happen and extracellular potassium ions move into cells decreasing serum potassium concentration. Sympathetic stimulation increases intracellular uptake of potassium by enhancing Na^+–K^+ ATPase activity. This effect is mediated through activation of beta 2 adrenergic receptors. Serum potassium concentration decreases following the administration of beta2-adrenergic agonists as a result of uptake of potassium by muscle and the liver. Acute increases in plasma osmolality increase serum potassium concentration. In such instances, the movement of water out of cells, down its osmotic gradient is accompanied by movement of K^+ out of cells. Hypothermia has been reported to lower serum potassium concentration as a result of cellular uptake. Rewarming reverses this shift and may result in transient hyperkalemia if potassium was given during the hypothermia.

ROLE OF POTASSIUM IN GENERATING ACTION POTENTIAL: (5)

The cell membrane of cardiac muscle is more permeable to K^+ but is relatively impermeable to Na^+. The membrane-bound enzyme Na^+–K^+-ATPase concentrates K^+ intracellularly by extruding Na^+ out of the cells. The concentration of Na^+ inside the cell is low but the concentration of K^+ is kept high inside the cells when comparing to its extracellular concentration. The cell membrane is also relatively impermeable to calcium which helps in maintaining a high extracellular to cytoplasmic calcium gradient. When K^+ move out of the cell along its concentration gradient it results in a net loss of positive charges from inside the cell. This will lead to an electrical potential difference across the cell membrane as the anions do not come out along with K^+. This results in the inside of the cell more negative when comparing to the extracellular environment. Thus a resting membrane potential develops which is the balance between two opposing forces – one being the movement of potassium out of the cell along its concentration gradient and the other being the electrical attraction of the negatively charged intracellular space with its attraction for the K^+ ions.

The resting membrane potential of a ventricular cell is –80 to –90 mV. A characteristic action potential develop when the the cell membrane potential reaches a threshold value and becoming less negative.

The membrane potential of the myocardial cell raises to + 20 mV transiently as a

result of the generated action potential causing a spike. This spike is followed by a plateau phase of 0.2 to 0.3 seconds duration. The action potential of the myocardial cell is due to opening of fast sodium channels which cause the spike and a slower calcium channels which cause the plateau phase in contrast with the action potential of the skeletal muscle and nerves which is caused by the sudden opening of the fast sodium channel only. Accompanied by depolarization is a transient decrease in potassium permeability. The membrane potential is eventually restored to normal by the restoration of the normal potassium permeability.

After depolarization, the myocardial cells are refractory to subsequent depolarizing stimuli until phase 4. The minimum interval between two depolarizing impulses that are propagated is called the effective refractory period. In myocardial cells which are fast conducting, the effective refractory period is closely correlated with the action potential duration.

ION CHANNELS IN CARDIAC MUSCLE MEMBRANE: (6)

The sodium channel is voltage gated. It has an outer (m)gate that will open at -60 to -70mV and an inner (h) gate that will close at -30mV. The calcium channel is voltage gated. Transient or T- type calcium channels act during phase 0 of depolariration. The slow L-type or the long-lasting calcium channels allows calcium inflow during the plateau phase. Potassium channels play a role in repolarization. There are three major types of potassium channels. They are I_{To} which results in a transient outward potassium current, I_{Kr} which is responsible for a short rectifying current and I_{Ks} which produces a slowly acting rectifying current that restores the resting membrane potential.

CARDIAC ION CHANNELS: (7)

VOLTAGE-GATED CHANNELS
Na^+
T Ca^{2+}
L Ca^{2+}
K^+
Transient outward
Inward rectifying
Slow (delayed) rectifying
LIGAND-GATED K^+ CHANNELS
Ca^+ activated
Na^+ activated
ATP sensitive
Acetylcholine activated
Arachadonic acid activated

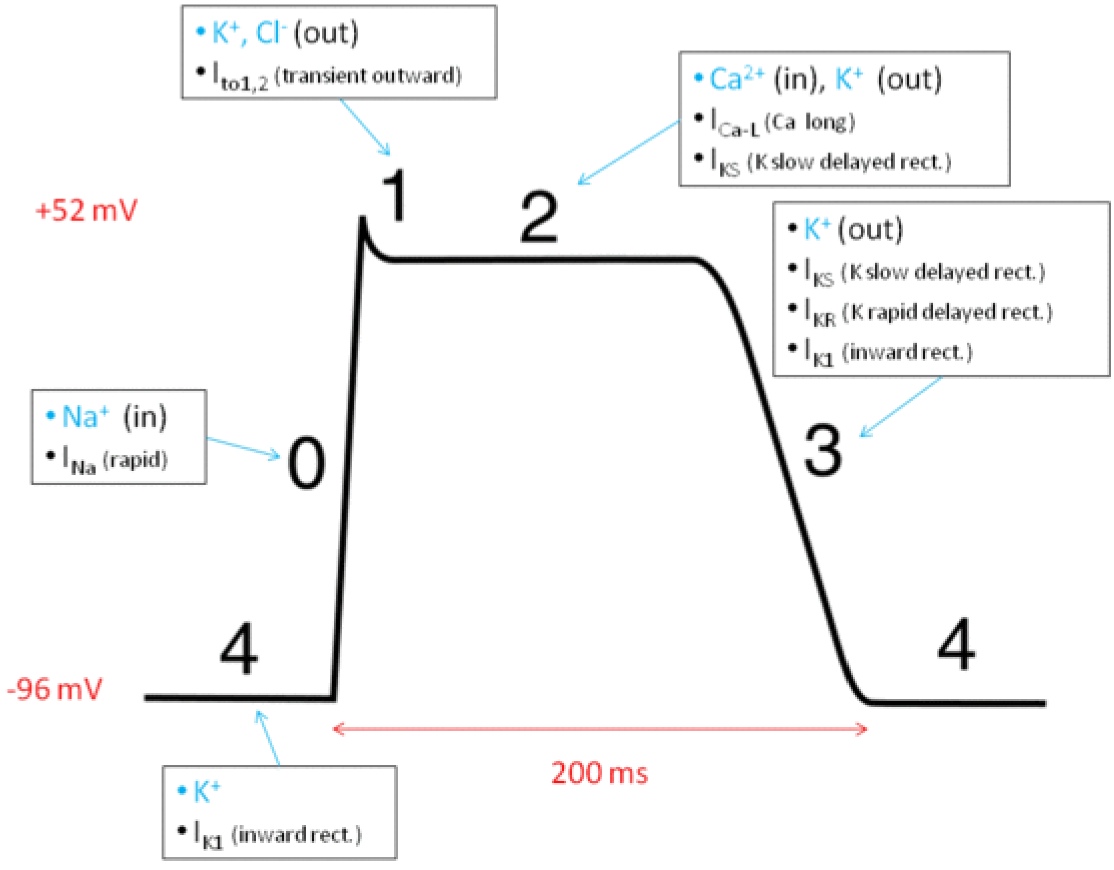
EVENTS IN CARDIAC ACTION POTENTIAL: (8)

PHASE	NAME	EVENT	CELLULAR ION

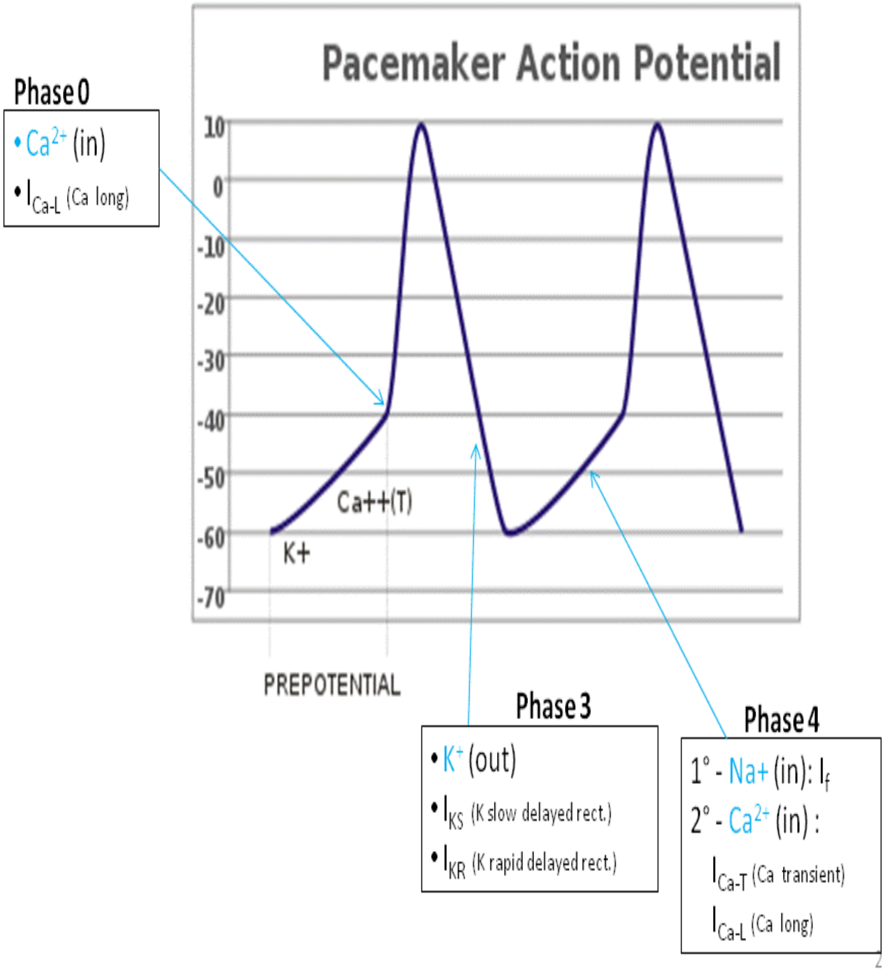
			MOVEMENT
0	Upstroke	Activation (opening) of fast Na^+ channels	Na^+ in and decreased permeability to K^+
1	Early rapid repolarization	Inactivation of Na^+ channel and transient increase in K^+ permeability	K^+ out (I_{To})
2	Plateau	Activation of slow Ca^{2+} channels	Ca^{2+} in
3	Final repolarization	Inactivation of Ca^{2+} channels and increased permeability to K^+	K^+ out
4	Resting potential	Normal permeability restored(atrial and ventricular cells)	K^+ out Na^+ in
	Diastolic repolarization	Intrinsic slow leakage of Ca^{2+} into cells that spontaneously depolarize	Ca^{2+} in

ACTION POTENTIAL WAVES AND GRAPHS:

FIVE PHASES OF CARDIAC ACTION POTENTIAL: (9)



PACE MAKER ACTION POTENTIAL: (9)



HYPOKALEMIA:

Hypokalemia is defined as a serum potassium concentration less than 3.5 mEq/L which may occur because of an absolute deficiency or redistribution into the intracellular space. The deficiency may be due to increased potassium loss or an inadequate potassium intake. When the urinary potassium is greater than 20 mEq/L it indicates potassium losses through kidneys.It will be less than 20 mEq/L when the potassium loss is through gastrointestinal tract or due to inadequate intake.(10)

CAUSES OF HYPOKALEMIA: (11)

HYPOKALEMIA DUE TO INCREASED RENAL POTASSIUM LOSS:

Loop diuretics

Thiazide diuretics

High- dose glucocorticoids

Mineralocorticoids

High- dose antibiotics like penicillin, nafcillin, ampicillin

Drugs associated with magnesium depletion like aminoglycosides

Hyperglycemia

Surgical trauma

Hyperaldosteronism

HYPOKALEMIA DUE TO EXCESSIVE GASTROINTESTINAL LOSS OF POTASSIUM:

Vomiting and diarrhea

Zollinger- Ellison syndrome

Malabsorption

Nasogastric suction

Chemotherapy

HYPOKALEMIA DUE TO TRANSCELLULAR POTASSIUM SHIFT:

Insulin

Tocolytic drugs like ritodrine

Beta adrenergic agonists

Respiratory or metabolic alkalosis

Hypercalcemia

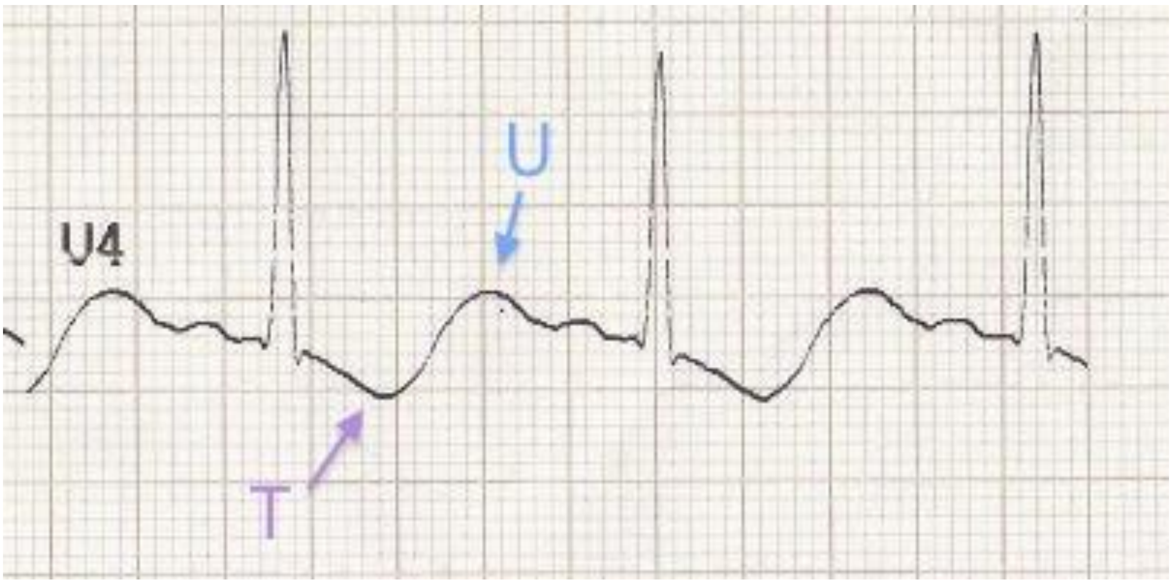
Hypomagnesemia

Familial periodic paralysis

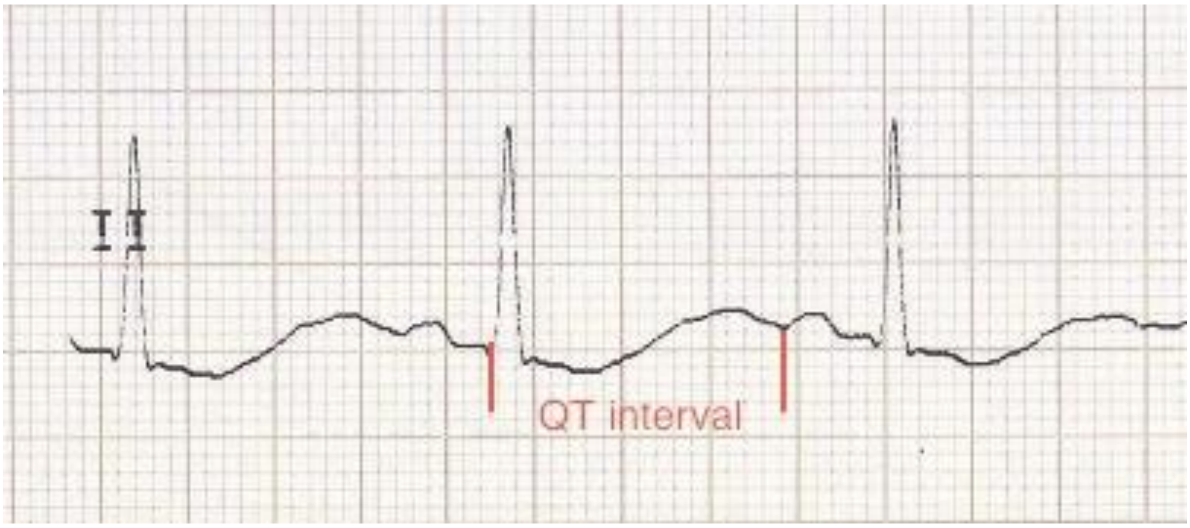
CLINICAL MANIFESTATIONS OF HYPOKALEMIA: (12)

Hypokalemia can lead to widespread organ dysfunction. Symptoms may not occur in most patients till plasma [K^+] is 3 mEq/L. The cardiovascular system is affected most. Hypokalemia can be manifested as an abnormal electrocardiogram , arrhythmias, decreased cardiac contractility, and a labile arterial blood pressure due to autonomic dysfunction. Chronic hypokalemia can also cause myocardial fibrosis. Electrocardiogram changes are primarily due to delayed ventricular repolarization. It includes T-wave flattening and inversion, an increasingly prominent U wave, ST-segment depression, increased P-wave amplitude, and prolongation of the P-R interval. Increased myocardial cell automaticity and delayed repolarization promote both atrial and ventriculararrhythmias.

T wave inversion and prominent U waves in hypokalaemia



Apparent long QT interval with hypokalaemia (actually T-U fusion)



CLINICAL MANIFESTATIONS OF HYPOKALEMIA.

CARDIOVASCULAR: ECG changes

Myocardial dysfunction

NEUROMUSCULAR: Skeletal muscle weakness

Tetany

Rhabdomyolysis

Ileus

RENAL: Polyura

Increased ammonia production

Increased bicarbonate reabsorbtion

HORMONAL: Decreased insulin secretion

Decreased bicarbonate secretion.

METABOLIC: Negative nitrogen balance

Encephalopathy in patients with liver disease

MANAGEMENT OF HYPOKALEMIA: (13)

The treatment of hypokalemia depends on the presence of any associated organ dysfunction. No studies show increased morbidity or mortality for patients undergoing anesthesia with a potassium level of at least 2.6 mEq/L.

The treatment of hypokalemia consists of potassium repletion, correction of alkalemia, and removal of offending drugs. If the hypokalemia is due to depletion of total body potassium, oral supplementation of potassium is generally adequate. Intravenous potassium is indicated when there are cardiac symptoms or muscle weakness. The serum potassium levels and electrocardiography should be monitored continuosly to avoid inadvertent hyperkalemia. The typical replacement rate is 10 to 20 MEq/hr in an average sized adult through a central venous catheter because the rate of administration of potassium must be adjusted for the rate of distribution through the extracellular space before entry into the intracellular space. A peripheral line cannot be used for a correction exceeding more than 8 MEq/hr. Intravenous replacement should generally not exceed 240 mEq/d. In hyperaldosteronemia such as primary aldosteronism and Cushing syndrome, hypokalemia usually responds to reduced sodium intake and increased potassium intake. The effects of hypokalemia is aggravated by the presence of hypomagnesemia, hence it should be treated promptly. In patients with diabetes mellitus or renal disease, potassium supplements or potassium sparing diuretics should be given carefully as an acute hyperkalemia may develop. In diabetic ketoacidosis the patients are hypokalemic as well as acidemic. Hence correction of acidosis should be preceeded by potassium supplementation to avoid acute decrease in serum potassium concentration as pH increases.

HYPERKALEMIA:

Hyperkalemia is defined as a serum potassium concentration of more than 5.5 MEq/L. Hyperkalemia can be caused by increased intake, diminished excretion and due to intercompartmental shifts. It can occur in various disease states.

CAUSES OF HYPERKALEMIA: (14)

INCREASED TOTAL BODY POTASSIUM CONTENT:

Acute oliguric renal failure

Chronic renal disease

Hypoaldosteronism

Drugs that impair potassium excretion like triamterene, spironolactone, NSAIDS.

Drugs that inhibit the rennin- angiotensin- aldosterone system

ALTERED TRANSCELLULAR POTASSIUM SHIFT:

Succinylcholine

Respiratiry and metabolic acidosis

Iatrogenic bolus

Lysis of cells due to chemotherapy

PSEUDOHYPERKALEMIA:

Hemolysis of blood specimen

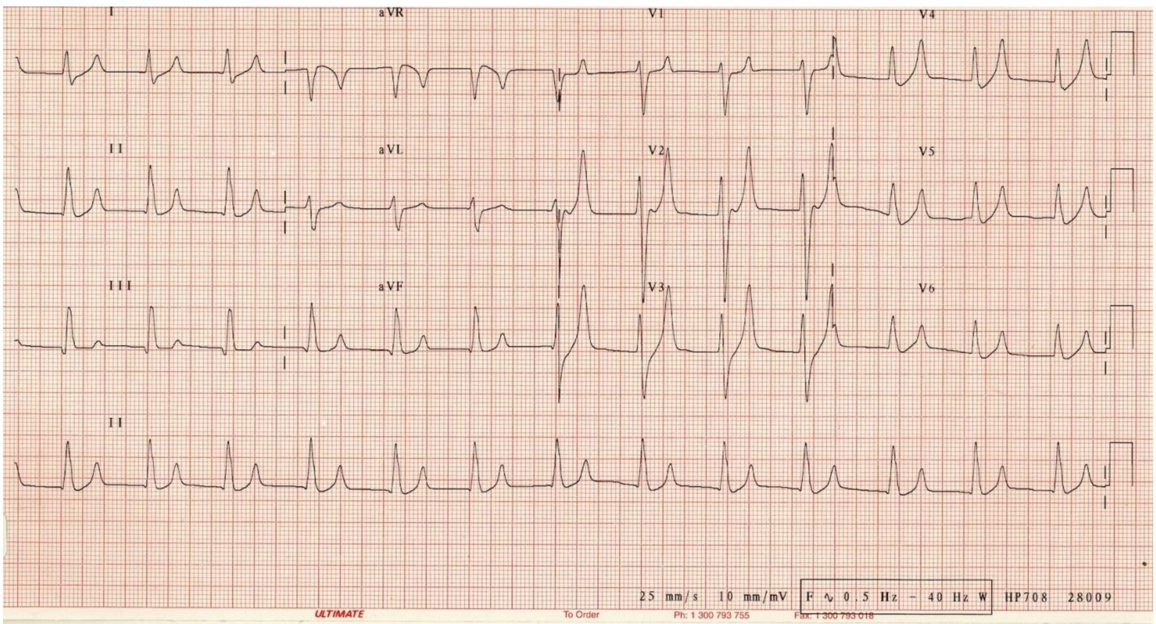
Thrombocytosis/leucocytosis

CLINICAL MANIFESTATIONS OF HYPERKALEMIA:

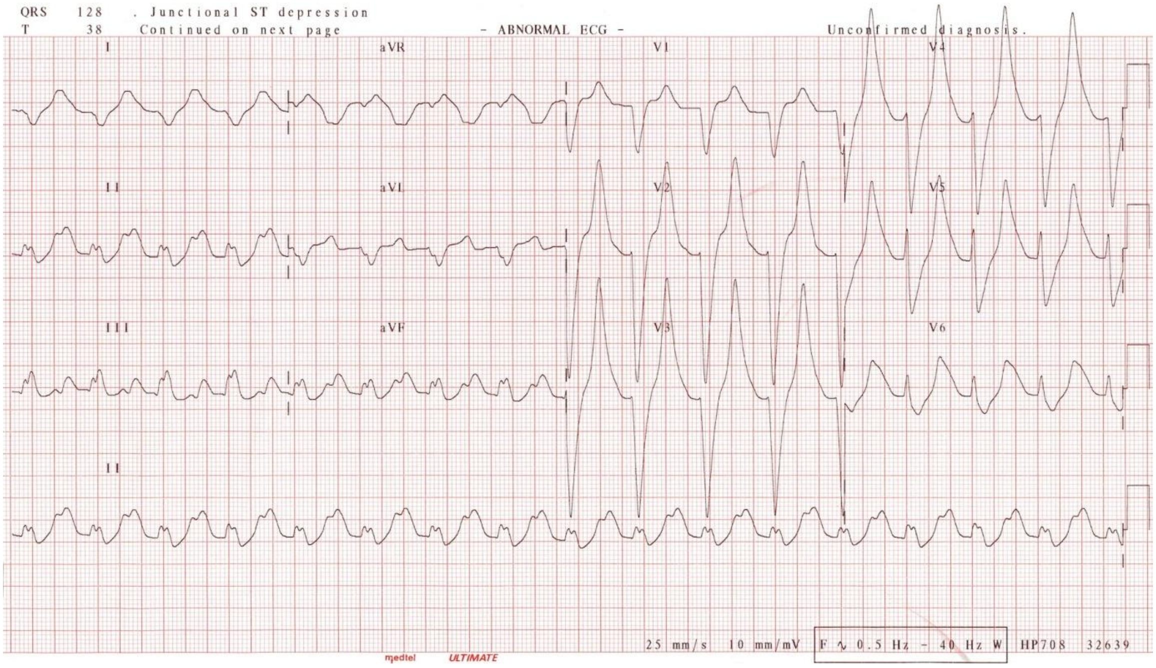
Hyperkalemia can be due to acute or chronic processes in the body. Acute hyperkalemia is poorly tolerated than the chronic one. The common cause for chronic hyperkalemia associated with anaesthesia is renal failure. The most important effects of hyperkalemia are primarily on the skeletal and cardiac muscles. Alterations in cardiac conduction increase and enhance repolarization.

Mild elevations in potassium levels (6 to 7 mEq/L) may manifest with peaked T waves. when the levels approach 10 to 12 mEq/L, a prolonged P–R interval, widening of the QRS complex, ventricular fibrillation, or asystole can occur.(15)Contractility appears to be relatively well preserved. Hypocalcemia, hyponatremia, and acidosis accentuate the cardiac effects of hyperkalemia.

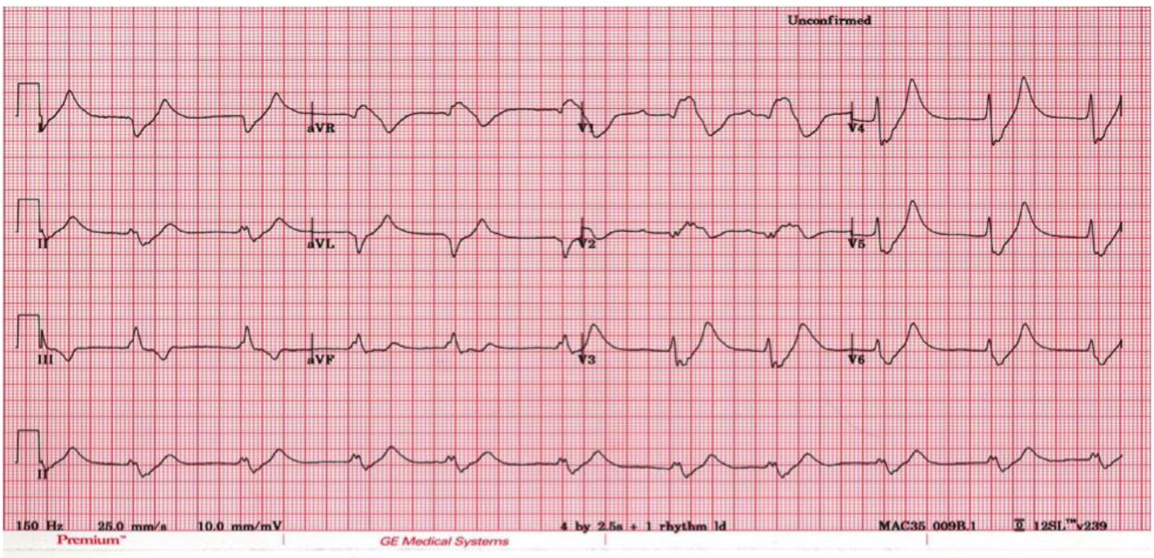
EARLY ECG CHANGES SHOWING PEAKED T WAVES:



EARLY ECG CHANGES SHOWING PEAKED T WAVES:



POTASSIUM OF 9.0 MMOL/L:



TREATMENT OF HYPERKALEMIA: (16)

Treatment of hyperkalaemia includes stabilizing the myocardium to prevent arrhythmias, shifting potassium back into the intracellular space and removing excess potassium from the body.

1.CORRECTION OF SERIOUS CONDUCTION ABNORMALITIES:

Calcium gluconate or calcium chloride is used.Calcium is a very useful agent. It does not lower the serum potassium level, but instead is used to stabilise the myocardium, as a temporising measure.Calcium is indicated if there is widening of QRS, sine wave pattern (when S and T waves merge together), or in hyperkalaemic cardiac arrest. The 'cardiac membrane stabilising effects' take about 15-30min.

2. DRIVING OF POTASSIUM INTO THE CELL:

Intravenous fast acting insulin (actrapid) 10-20 units and glucose/dextrose 50g 25-50ml is usually used to drive potassium in to the cell.Insulin drives potassium into cells and administering glucose prevents hypoglycaemia. It will begin to work in 20-30mins. It reduces potassium by 1mmol/L and ECG changes within the first hour.

Sodium Bicarbonate is used in the dosage of 50- 200mmol of 8.4% Sodium bicarbonate. Bicarbonate is only effective at driving Potassium intracellullarly if the patient is acidotic. It will begin working in 30-60 minutes and continues to work for several hours.

Salbutamol is usually given as a nebulisation. The dose is 10-20mg via nebulizer.Beta 2 agonist therapy lower potassium through either IV or nebulizer route. Salbutamol can lower potassium level 1mmol/L in about 30 minutes, and maintain it for up to 2 hours. It is very effective in renal patients who are prone for fluid overload.

3. ELIMINATION OF POTASSIUM FROM THE BODY:

Calcium Resonium is given in the dosage range of 15-45g orally or rectally usually mixed with lactulose or sorbitol. Calcium polystyrene sulfonate is a large insoluble molecule which will bind to potassium in the large intestine and it is excreted in faeces. The onset of action will be in two to three hours.

Furosemide, the loop diuretic is used as a intravenous bolus of 20-80mg depending on hydration status. It excretes potassium in the urine. 0.9% Saline is used to help renally excrete potassium, by increasing renal perfusion and urinary output. It is used with caution in patients with cardiac and kidney failure.Dialysis is considered to be the gold standard method for removing potassium from the body. It can provide immediate and reliable removal. About 1mmol/L of potassium is removed in the first hour and another 1mmol/L over the next 2 hours.

DIURETCS: (17)

Diuretics are defined as the drugs used to increase the rate of flow of urine. The commonly used diuretics in clinical practice also increase the rate of Na^+ excretion which is accompanied by excretion of an anion usually Cl^-. NaCl in the body is the major determinant of extracellular fluid volume. Diuretics are directed toward reducing extracellular fluid volume by decreasing total-body NaCl content.

A sustained imbalance between dietary Na^+ intake and Na^+ loss is incompatible with life. A sustained positive Na^+ balance would result in volume overload with pulmonary edema, and a sustained negative Na^+ balance would result in volume depletion and cardiovascular collapse. Although continued administration of a diuretic causes a sustained net deficit in total-body Na^+, the time course of natriuresis is finite because renal compensatory mechanisms bring Na^+ excretion in line with Na^+ intake, a phenomenon known as diuretic braking . These compensatory, or braking, mechanisms include activation of the sympathetic nervous system, activation of the renin-angiotensin -aldosterone axis, decreased arterial blood pressure (which reduces pressure natriuresis), hypertrophy of renal epithelial cells, increased expression of renal epithelial transporters, and perhaps alterations in natriuretic hormones such as atrial natriuretic peptide. Diuretics not only alter the excretion of Na^+ but also may modify renal handling of other cations *e.g.*, K^+, H^+, Ca^{2+}, and Mg^{2+}, anions *e.g.*, Cl^-, HCO_3^-, and $H_2PO_4^-$, and uric acid. In addition, diuretics may alter renal hemodynamics indirectly.

MAJOR CLASSES OF DIURETICS :

1 Loop diuretics

2 Thiazide and thiazide-like diuretics

3 Potassium sparing diuretics

4 Aldosterone antagonists

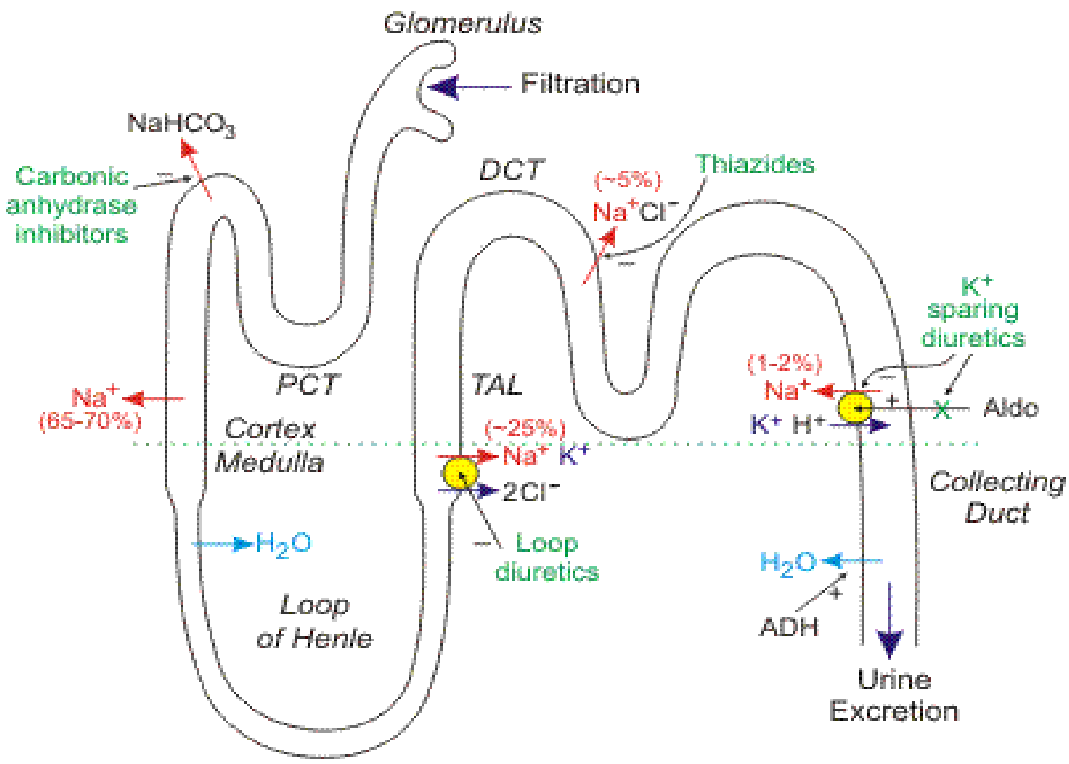
5 Non competitive potassium sparing diuretics

6 Osmotic diuretics

7 Carbonic anhydrase inhibitors.

Of these various classes of diuretics the commonly used ones in cardiac surgical patients are the loop diuretics, the thiazides and the potassium sparing diuretics. (18)

SITES OF ACTION OF THE DIURETICS IN THE NEPHRON: (19)



LOOP DIURETICS:

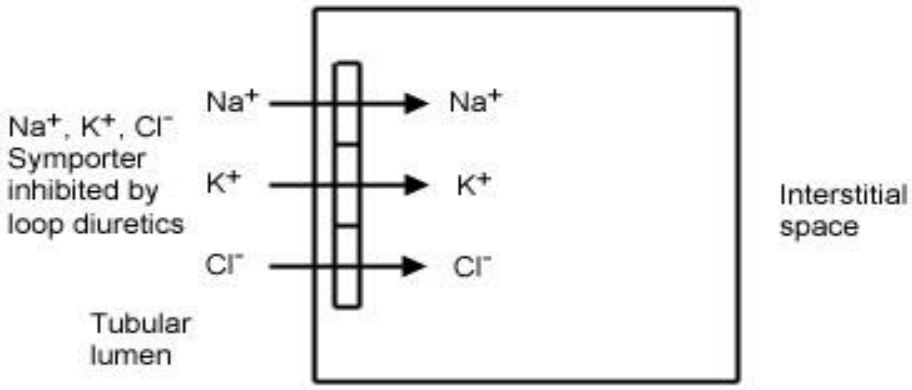
Furosemide, bumetanide, ethacrynic acid, torsemide are the loop diuretics available. Of these furosemide commonly known as lasix is used in patients in valvular heart disease and in ischemic heart disease to avoid fluid overload in a failing heart.

Loop diuretics inhibit Na^+ and Cl^- reabsorption in the thick ascending limb. Sodium reabsorption in the ascending limb requires that all four sites on the Na^+–K^+–$2Cl^-$ luminal carrier protein be occupied. Furosemide competes with Cl^- for its binding site on the carrier protein. It can lead to excretion of upto 15–20% of the filtered sodium load. It impairs both urinary concentrating and urinary diluting capacities. The large amounts of Na^+ and Cl^- presented to the distal nephron overwhelm its limited reabsorptive capability. The resulting urine remains hypotonic.

Loop diuretics are used in the treatment of edematous states like (20) heart failure, cirrhosis, the nephritic syndrome and renal insufficiency. It can reverse the cardiac and pulmonary manifestations rapidly when given in intravenous route. Loop diuretics are also used in the treatment of hypertension as an adjunct with other drugs and also in the treatment of hyponatremia when rapid correction is needed. (21)

The intravenous doses are furosemide, 20–100 mg; bumetanide, 0.5–1 mg; ethacrynic acid, 50–100 mg; and torsemide 10–100 mg

MECHANISM AND SITE OF ACTION OF LOOP DIURETICS:



SIDE EFFECTS OF LOOP DIURETICS:

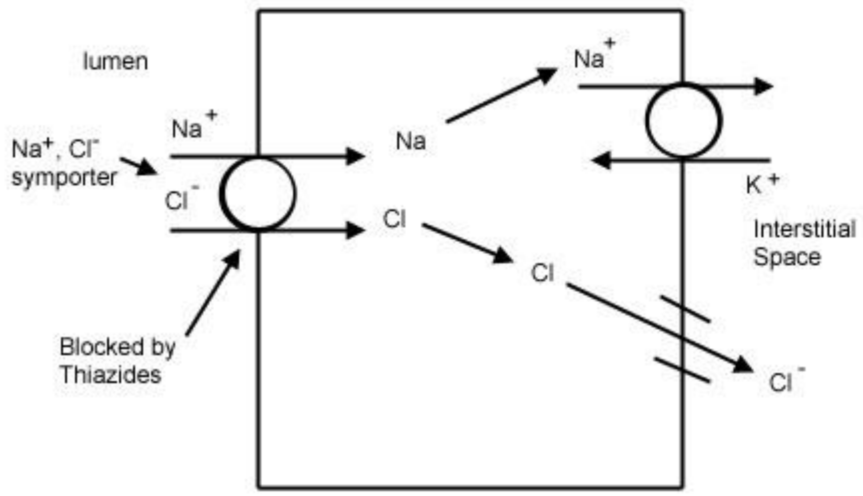
Increased delivery of Na^+ to the distal and collecting tubules increases K^+ and H^+ secretion at those sites and can result in hypokalemia and metabolic alkalosis. Marked Na^+ losses will also lead to hypovolemia and prerenal azotemia. Hypercalciuria can result in stone formation and occasionally hypocalcemia. Hypomagnesemia may be seen in patients receiving long-term therapy.

Hyperuricemia is thought to result from increased urate reabsorption and competitive inhibition of urate secretion in the proximal tubule. Reversible hearing loss has been reported with both furosemide and ethacrynic acid but may be more common with ethacrynic acid.

THIAZIDE- TYPE DIURETICS:

This group includes thiazides, chlorthalidone, quinethazone, metolazone and indapamide. Of these the thiazides are the commonly used one. They act on the distal tubule and the connecting segment and inhibits sodium reabsorption impairing diluting but not the concentrating abiity of urine. The thiazide diuretics compete for the Cl^- site on the luminal Na^+–Cl^- carrier protein. (22) Thiazide diuretics increase Na^+ excretion to only 3–5% of the filtered load because of enhanced compensatory Na^+ reabsorption in the collecting tubules. They also have some carbonic anhydrase inhibiting activity in the proximal tubule. This is normally masked by sodium reabsorption in the loop of Henle but is probably responsible for the often marked ("high ceiling") diuresis seen when thiazides are combined with loop diuretics. Thiazide diuretics augment Ca^{2+} reabsorption in the distal tubule.

MECHANISM AND SITE OF ACTION OF THIAZIDE-LIKE DIURETICS



USES OF THIAZIDES:

Thiazides are often the first-line agents in the treatment of hypertension. (23) Thiazides are used as oral agents for mild to moderate sodium overload. Thiazide diuretics are often used to decrease calcium excretion in patients with hypercalciuria who form renal stones. They are also used in the treatment of nephrogenic diabetic insipidus.

SIDE EFFECTS OF THIAZIDES:

Although thiazide-type diuretics deliver less sodium to the collecting tubules than loop diuretics, the increase in sodium excretion is enough to enhance K^+ secretion and frequently results in hypokalemia. Enhanced H^+ secretion can also occur, enough to result in metabolic alkalosis. Impairment of renal diluting capacity may produce hyponatremia in some patients. Hyperuricemia, hyperglycemia, hypercalcemia, and hyperlipidemia may also be seen.

POTASSIUM-SPARING DIURETICS: (24)

There are two types of potassium sparing diuretics namely

1. Aldosterone antagonists.
2. Non competitive potassium sparing diuretics.

Potassium sparing diuretics prevent potassium excretion but can cause hyperkalemia. Spironolactone is a direct aldosterone receptor antagonist in collecting tubules. It acts to inhibit aldosterone-mediated Na^+ reabsorption and K^+ secretion. As a result, spironolactone is effective only in patients with hyperaldosteronism. Spironolactone is only given orally.

Triamterene and amiloride which are sodium channel inhibitors do not dependent on aldosterone activity. They decrease the number of open sodium channels in the collecting tubules' luminal membrane leading to inhibition of sodium reabsorption and potassium secretion. Amiloride also inhibits Na^+-K^+- ATPase activity in the collecting tubules. They are also given only orally.

SIDE EFFECTS OF POTASSIUM SPARING DIURETICS:

Spironolactone can result in hyperkalemia in patients with high potassium intake or renal insufficiency and in those receiving beta-blockers or ACE inhibitors. Metabolic acidosis may also be seen. Other side effects include diarrhea, lethargy, ataxia, gynecomastia, and sexual dysfunction.

Amiloride and triamterene retain potassium causing significant hyperkalemia and metabolic acidosis. They may lead to nausea, diarrhoea and vomiting. Amiloride cause fewer side effects than triamterene.

CARDIOPULMONARY BYPASS: (25)

Cardiopulmonary bypass or CPB, a form of extracorporeal circulation, is a scientific technique which takes over the cardiac and the pulmonary functions temporarily during surgery on the heart and maintains blood circulation and oxygen supply of the body. It is usually referred to as heart-lung machine or simply the pump.

The perfusionists operate the heart-lung machine with direction from the anaesthesiologists and the cardiac surgeons, who will establish the connection between the patient and the pump. Cardiopulmonary bypass primarily aids in the circulation and oxygenation of blood mechanically bypassing the cardiac and pulmonary circulation. The perfusion of the rest of the body is done by the heart-lung machine while the operating site where the cardiac surgeon operate is managed without much bleeding.

The blood from the venous system is drained by gravity through the venous cannula usually placed in one of the bigger veins like femoral vein, vena cava or directly into the right atrium by the cardiac surgeon. The blood is collected in the reservoir through tubings filled with crystalloid. From the reservoir the blood is sent back to the body through tubing with the help of pumps after oxygenation and after being warmed or cooled to the desired temperature into the ascending aorta or the femoral artery. The blood and the pump fluid is heparinised to prevent clotting and activated clotting time is monitored at regular intervals to maintain adequate heparinization. At the end of the procedure before coming out of the bypass circuit, protamine is given to reverse any residual effects of heparin. Though cardiopulmonary bypass circuits initiate a systemic inflammatory response, it is being used successfully. (25)

While the surgeon is operating on the heart the body temperature is being maintained in the range of 28ºC to 32ºC. The hypothermia during the bypass time helps in reducing the basal metabolic rate and decreasing the oxygen demand of the organ systems. The viscosity of the blood is usually increased with cooling but the dilution of the blood by the fluid in the circuit reduces the hematocrit, thus helping in the circulation.

HISTORY OF CARDIOPULMONARY BYPASS: (26)

Dr. Clarence Dennis and his colleagues did the first ever known surgery by opening the heart on April 5, 1951 with both the cardiac and pulmonary functions being taken over temporarily by machinesl.Unfortunately the patient died because of an unexpected complicating cardiac lesion. Dr.Russell M. Nelson and Er. Eric Charles were the members of the team. Forest Dewey Dodrill did the first successful demonstration of the mechanical support of the left heart function on 3rd July 1952.On May 6, 1953 ,John Gibbon did the first successful open heart procedure under CPB in an 18 year old lady. Robert Hooke was the first one to bring the concept of oxygenator in the seventeenth century. Initially bubble oxygenator and later membrane oxygenator were used. The high-performance microporous hollow-fibre oxygenators are developed and are being used in the modern days.

USES OF CARDIO PULMONARY BYPASS:

Cardiopulmonary bypass helps in operating heart lesions as it is technically difficult to do surgery on a beating heart. Open heart surgeries utilize cardiopulmonary bypass to maintain circulation during the duration of the procedure. The machine will take over the circulating and oxygenating function of the heart and the lungs.CPB is also employed in inducing hypothermia and maintain in that state for upto forty-five minutes without circulation. Hypothermia is very protective for brain.

CARDIOPLEGIA: (27)

Cardioplegia is a technique by which the heart can be paralyzed with the help of chemical compounds or cold. It is usually done during heart surgeries where the heart should be empty and should not be contracting. It will give a bloodless field for the surgeon to operate on a non-beating, flaccid heart. It helps in decreasing the chances of air embolism during surgery on the heart chambers on the left side.It reduces the myocardial oxygen consumption. It can be given warm or cold. It can be antegrade through the coronary ostia or retrograde through the coronary veins.

The cardioplegia can be completely crystalloid based or a mixture of cystallod with blood. The two most important types are Bretschneider's HTK solution or the intracellular cardioplegia and St. Thomas No: 2 solution or the extracellular cardioplegia. The former is similar to that of the intracellular space and is mainly used for heart preservation during transplant. The later is similar to that of body serum and the arrest of the heart is caused from high potassium concentration. This high potassium concentration in the cardioplegia is one of the main reason that hypokalemia is less common in modern days than when cardioplegia was not used. The incidence of hyperkalemia is also attributed to the use of the potassium-rich cardioplegia which was uncommon in the olden days when cardioplegia was not used.

CARDIOPLEGIA COMMONLY USED: (28)

	Sodium	Potassium	Magnesium	Calcium	Bicarbonate	Others
Bretschneider'sHTK solution	15	9	4	0.015	-	Histidin, Tryptophan, Potassium hydrogen-2-ketoglutarate
St.Thomas No:2	110	16	16	1.2	10	Lidocaine

COMMON ADDITIVES TO CARDIOPLEGIA: (29, 30 , 31)

COMPONENT	PURPOSE
KCL	Produce and maintain diastolic arrest
THAM/ histidine	Buffer
Mannitol	Osmolarity, Free radical scavenger
Aspartate/ glutamate	Metabolic substrate
$MgCl_2$	Mitigates against effects of calcium
CPD	Lowers free calcium concentration
Glucose	Metabolic substrate
Blood	Oxygen-carrying capacity

CARDIOPULMONARY BYPASS AND POTASSIUM: (32)

It is very important to maintain a normal seum potassium level in cardio surgical patients. The serum potassium concentration in patients undergoing cardiopulmonary bypass is affected by several factors like

1 Diuretic use in the preoperative period
2 Myocardial protectant solution(cardioplegia) usage. – duration and volume
3 Priming solutions
4 Anaesthetic drugs
5 Peri-operative renal function
6 Ventilation and partial pressure of carbondioxide tension in blood
7 Arterial pH
8 Hypothermia
9 Insulin treatment of Hyperglycemia
10 Mineralocorticoids

Potassium depletion may occur in nearly forty percent of patients undergoing valve surgery. The most commonly and the most frequently observed abnormality of potassium is hypokalemia.

Before the introduction of cardioplegia hyperkalemia was rarely seen in cardiac surgery patients except in patients who have diadetes mellitus or kidney disease. In modern days, hyperkalemia is more common for a brief period immediately after the release of the cross-clamp of aorta. (33) (34)

Temperature also plays a role in serum potassium levels. Normothermic cardiopulmonary bypass requires more cardiplegia than the hypotermic bypass. This is the reason that hyperkalemia is more common in normothermic bypass.

Potassium is also lost through kidneys and this loss depends on the urine flow implying that the concentration of potassium in the urine must remain nearly constant. (35) Increased potassium loss in urine is usually seen in the postbypass period.

Moffitt et al. (36) found out and reported that a greater decrease in serum potassium concentration occur when whole blood priming is used than when blood-free priming solution is used. The role of calcium is also important in maintaining potassium concentration while on cardiopulmonary bypass emphasizing to maintain normocalcemia.

In hypothermic cardiopulmonary bypass the drop in potassium concentration is proportional to the decrease in body temperature. (37) On the other hand, during the rewarming phase potassium concentration raises and hyperkalemia is the common finding.(38)

In hypothermic cardiopulmonary bypass an increase in blood glucose level (39) and a fall in insulin level occurs. Insulin causes an intracellular shift of potassium along with glucose. The levels of stress hormones like cortisol, aldosterone, and catecholamines (40)are increased during CPB and this may contribute to hypokalemia. An increase in urinary excretion of potassium is caused by aldosterone and cortisol where as catecholamines contribute by increasing the uptake of potassium by skeletal muscle.

Beta adrenergic antagonists (41) inhibit skeletal muscle uptake of potassium but the hepatic release of potassium caused by beta adrenergic stimulation is not inhibited thus causing hyperkalemia. Adding albumin (42) to the priming solution helps in bringing down the incidence of hypokalemia as albumin molecules are negatively charged which may help to maintain adequate potassium concentration which is positively charged.

Potassium concentration is monitored very frequently during CPB. A strict normokalemia should be present for normal cardiac electrical activity (43, 44). Increases in Peripheral vascular resistance is found to increases with bolus intravenous potassium of 8 mEq or more during CPB. With less than 8 MEq/ L doses, an initial fall may be there, which will be followed by a mild increase in systemic vascular resistance. (45).

METHODOLOGY

METHODOLOGY:

STUDY SETTING:

The study was conducted in the Cardiothoracic operating suites and in the cardiothoracic intensive care units in Christian Medical College Hospital, Vellore.

STUDY POPULATION:

100 consecutive patients between 14 – 75 years who underwent cardiac surgeries during the 6 months study period in Christian Medical College Hospital, Vellore.

Inclusion criteria:

- Age < 14 years
- Chronic renal failure with serum creatinine > 1.6 mgms%

STUDY PERIOD:

The study was conducted over a period of 6 months between July to December 2012. A pilot study was conducted prior to the commencement of the study.

SAMPLE SIZE: (46)

Sample size was calculated using the formula for single proportion – Absolute precision

$$\eta = \frac{Z^2 P (1- P)}{d^2}$$

where η = sample size

Z = Z statistic for a level of confidence i.e. for 95% is 1.96

P = expected prevalence or proportion

d = precision

Expected proportion is 60%. So P = 0.6

For 10% precision, d = 0.1

Desired confidence interval is 95%.

Substituting the values for Z, P and D,

$$\eta = \frac{1.96^{2}\ (0.6)\ (1 - 0.6)}{0.1^{2}}$$

$$\eta = 92$$

A total sample size of 92 patients would be needed for the study.

This study had a total number of 100 patients with with 50 patients in each arm.

SELECTION OF STUDY PATIENT:

Prior permission was obtained from the institutional review board and the ethics committee to conduct the study. Patients who were scheduled for cardiac surgery were evaluated by the anaesthetist in the preanaesthesia clinic and were explained in detail about the study design. Patients who had given consent and fulfilled the inclusion criteria were allocated into either of the group depending on their diuretic intake.

INFORMED CONSENT:

The informed consent was printed in the language familiar to the patient and in case the patient being illiterate,it was read out loud and explained by the attender. In case of minor patients the consent was taken from one of the parents or a legal guardian.

DEFINITIONS:

Duration of diuretic intake: Any patient who is on diuretic for more than a month are considered as being on chronic diuretic use.

Hypokalemia is defined as a serum potassium of less than 3.5 MEq/L and Hyperkalemia in defined as a serum potassium of more than 5.5 MEq/L.

Chronic renal failure: Patients whose serum creatinine value is more than 1.6 are considered to be in chronic renal failure and they were excluded from the study

STUDY METHOD:

The patients who fulfilled the inclusion criteria and gave consent were enrolled in the study. All medications that the patient was taking preoperatively were continued as per the routine schedule except ACE inhibitors. Tablet lorazepam and tablet omeprazole were given as premedication the night before and on the day of surgery.The preoperative comorbid conditions like diabetic mellitus, chronic renal failure, the medication taken like diuretics, ACE inhibitors, digoxin, Potassium supplements are all noted in the proforma. A baseline arterial blood gas (ABG) is done and the values entered in the proforma. The ABG is repeated once the patient is on the cardiopulmonary bypass circuit, before coming out of bypass circuit and after coming out of the bypass circuit. Any incidence of hypokalemia or hyperkalemia in noted along with the interventions made to keep the potassium levels normal. In hypokalemia, potassium chloride (kcl) is given and in hyperkalemia the treatment includes calcium, sodium bicarbonate, glucose insulin infusion. Any need for blood transfusion is noted as it may have an influence on serum potassium levels. The potassium rich cardioplegia is used to arrest the heart during cardiac surgery. The dose and the duration of cardioplegia is also noted. These patients are not extubated in the operation suite. They are shifted to the cardiothoracic intensive care unit (I C U)with endotracheal tube and electively ventilated for a day. The patient is followed in the for first two postoperative days in the ICU.

In the ICU, arterial blood gas (ABG) is repeated every four to six hourly. Any event of hypokalemia or hyperkalemia along with the interventions needed to keep the the potassium level normal in noted. All patients received nebulizations with salbutamol and ipratropium bromide after extubation .We could enroll 100 patients in this study with 50 patients in the diuretic group and fifty I n the non-diuretic group. Once the adequate sample size has been achieved, all these datas were entered in the Epidata soft ware and exported into the Excel spreadsheet.

STATISTICAL METHODS: (47)

All the datas collected were analyzed using Generalized Estimating Equations.

RESULTS

RESULTS:

Total number of 100 subjects who underwent cardiac surgery under cardiopulmonary bypass, were enrolled in this study . None of them were excluded.

The outcome variables between the two groups were analyzed using Generalized Estimating Equations. There were 50 subjects in the diuretics group and 50 subjects in the non-diuretics group.

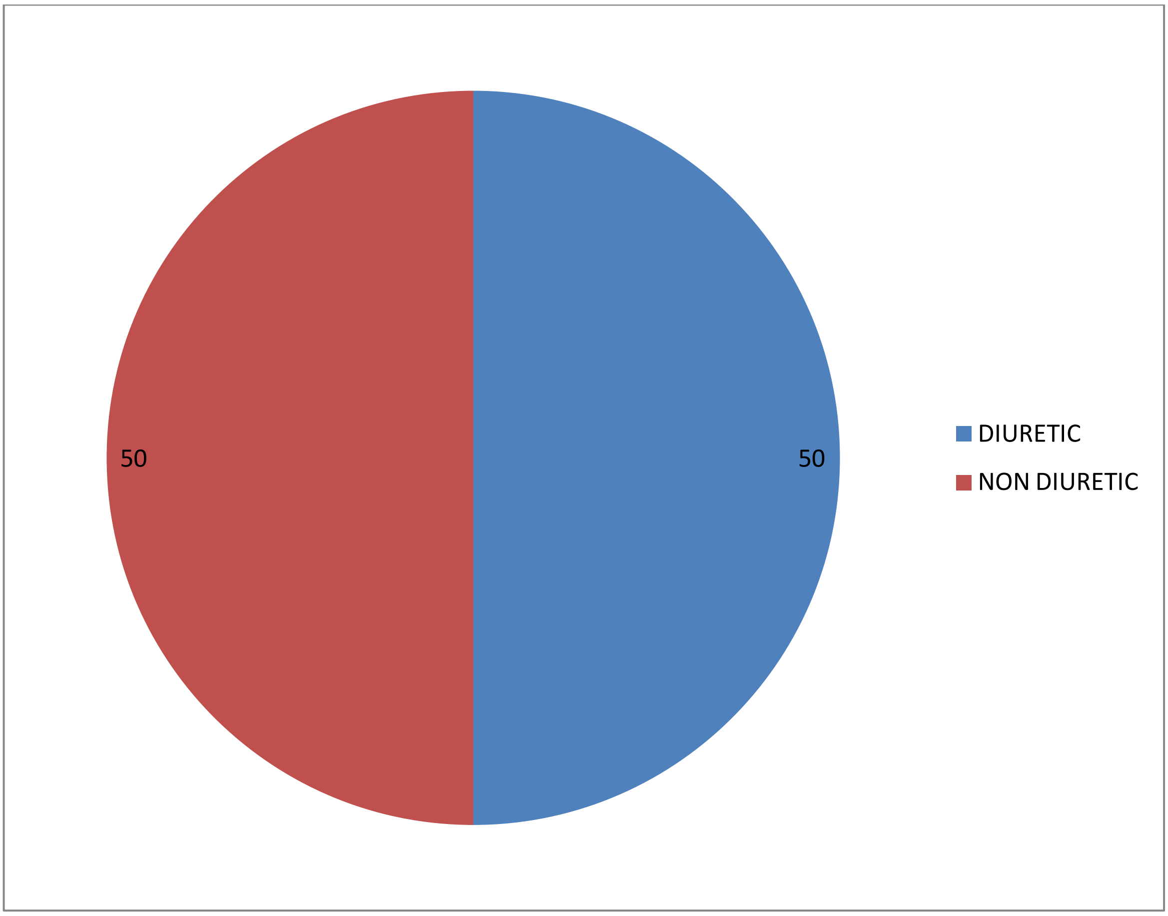


Figure 1: shows number of patients in the diuretic group and non-diuretic group.

Among the 50 patients who were on long term diuretics, 43 of the patients were taking the loop diuretic furosemide and 7 patients were taking the potassium sparing diuretic spironolactone.

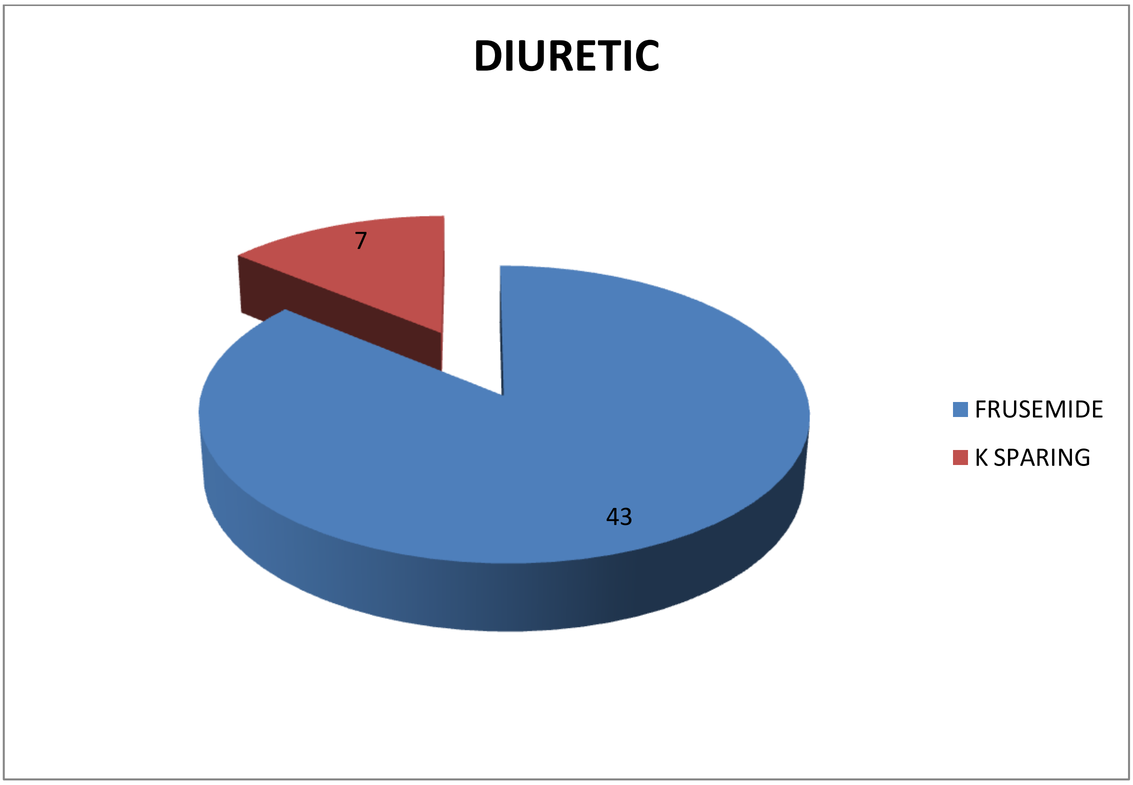


Figure 2: shows the number of patients on different types of diuretics.

CLINICAL CHARACTERISTICS OF THE PATIENTS IN EACH GROUP:

AGE DISTRIBUTION:

The median age of the patients in the diuretic group was 43 years. And the median age in the non-diuretic group was 56 years. The patients with age less than 30 years were more in the diuretic group and with the age more than 60years were more in the non-diuretic group.Between the age 30 to 60 years the patients were equally distributed in both the groups.

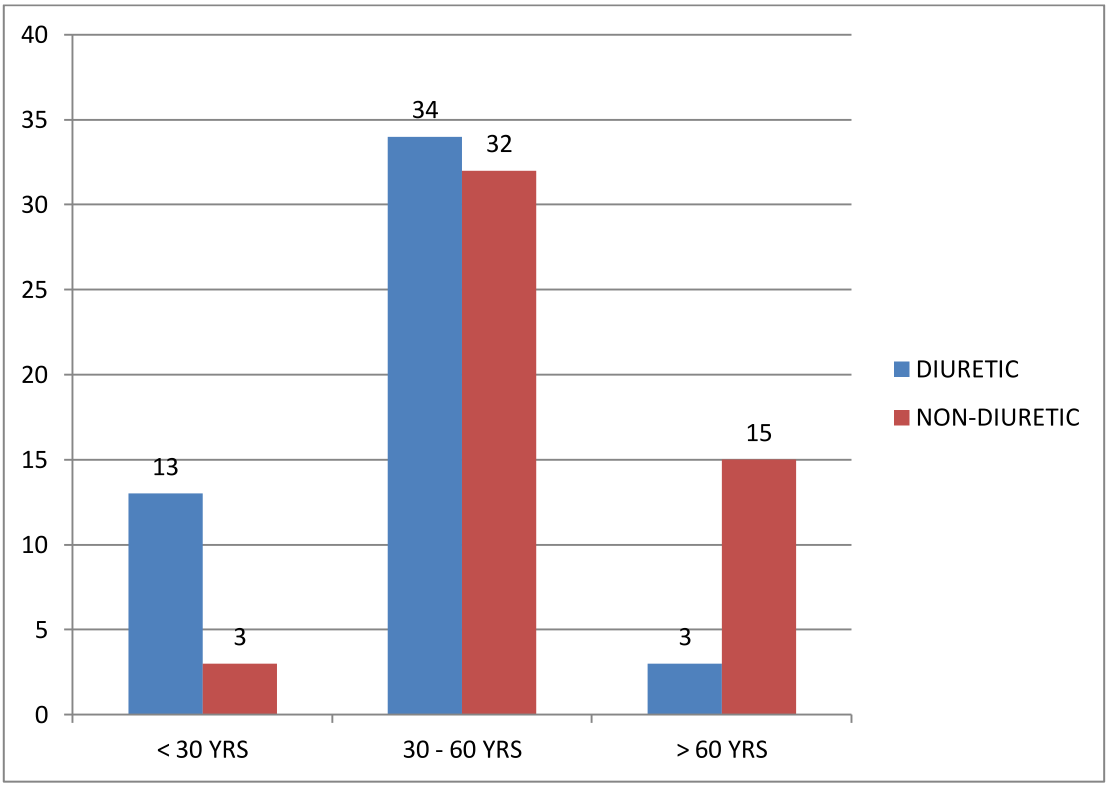


Figure 3: shows the age distribution between the two groups.

SEX DISTRIBUTION:

There sex was equally distributed in the diuretic group with 25 male patients and 25 female patients. In the non-diuretic group there were 37 male patients and 13 female patients.

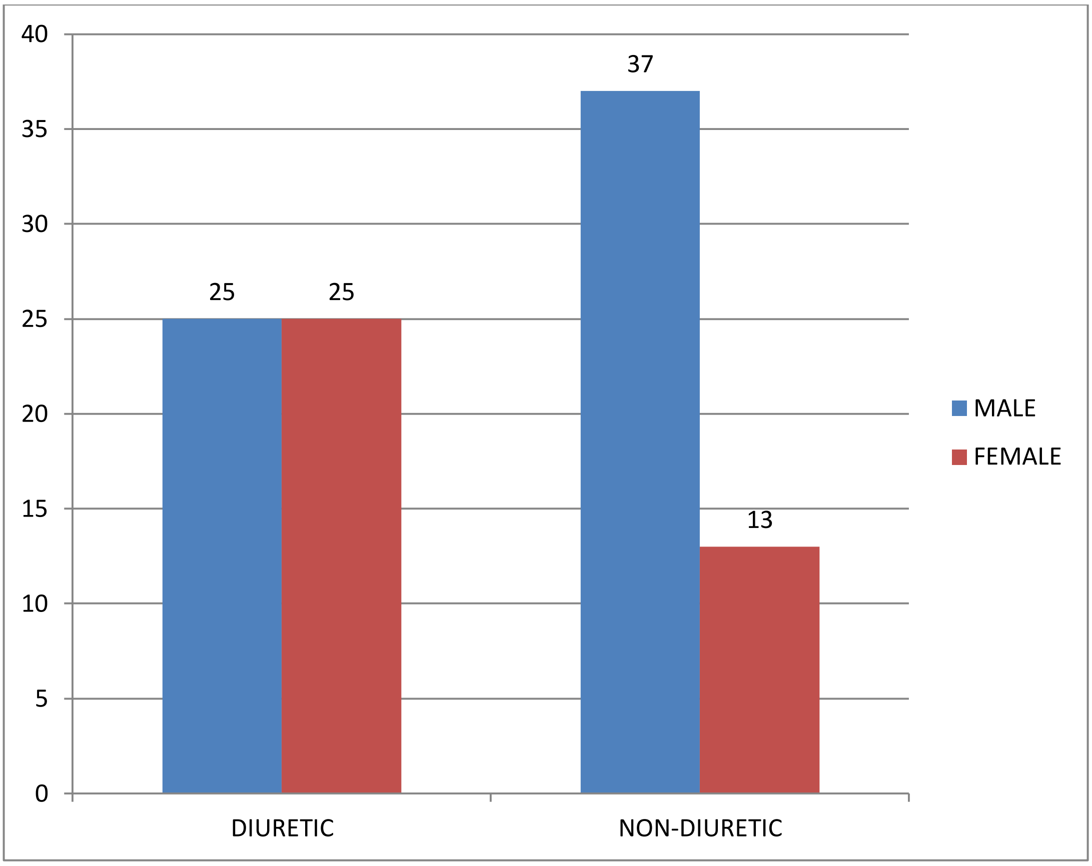


Figure 4: shows the sex distribution between both the groups.

PREOPERATIVE CHARACTERISTICS BETWEEN BOTH THE GROUPS:

ASSOCIATED SYSTEMIC DISEASES:

Diabetes mellitus, hypertension and renal dysfunction were the major systemic diseases which affects the perioperative serum potassium levels. Their incidences varied between both the groups.

DIABETIC MELLITUS:

Patients with diabetes mellitus were more in number in the non-diuretics group than in the diuretic group. Only 6% of the patients were diabetic in the diuretic group where as 40% of the patients were diabetic in the non-diuretic group.

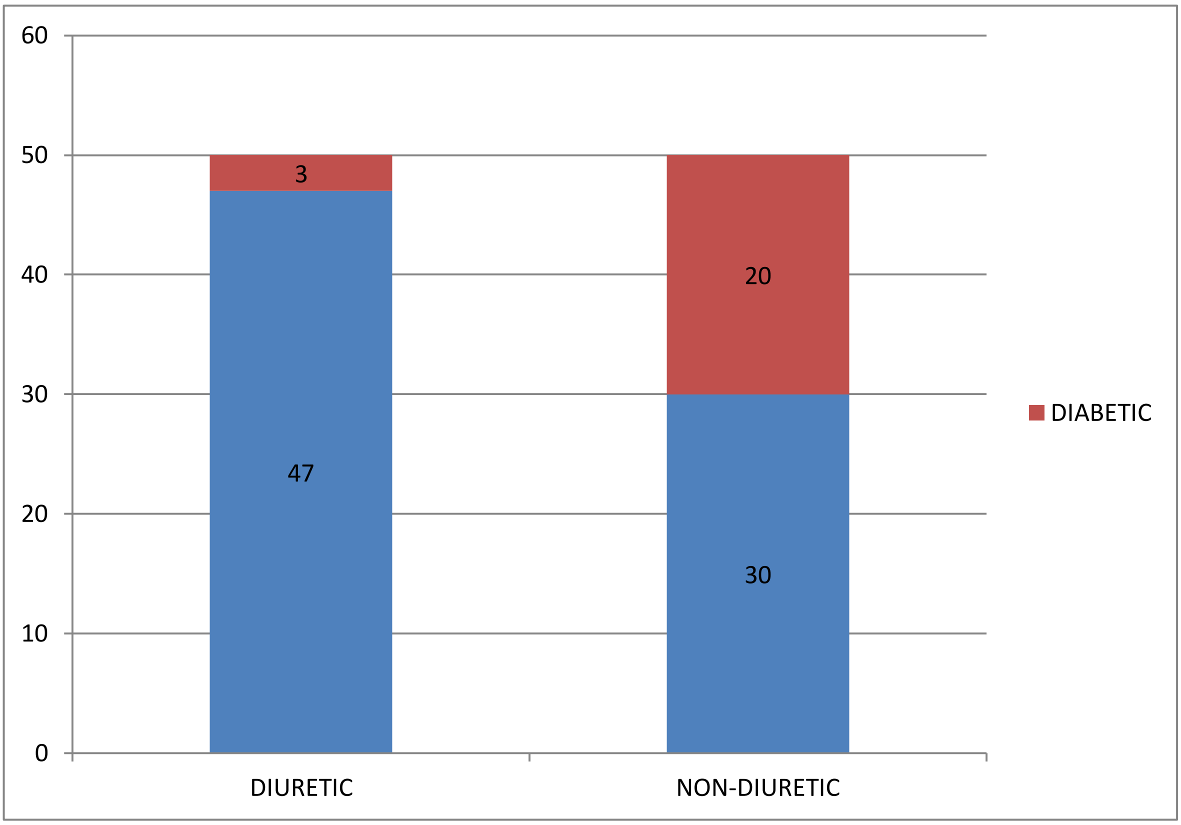


Figure 5: shows the number of patients with diabetic mellitus in each group.

RENAL DYSFUNCTION:

Preoperative renal dysfunction was uncommon in both the groups. The serum creatinine of all the patients in the diuretic group was less than 1.5 mgms whereas in only 4 patients in the non-diuretic group the serum creatinine was more than 1.5 mgms. The serum creatinine on the second postoperative day showed that 4 patients in the diuretic group newly had their serum creatinine raised above 1.5mgms whereas only one patient had his serum creatinine raised above 1.5mgms newly when compared to the preoperative value.

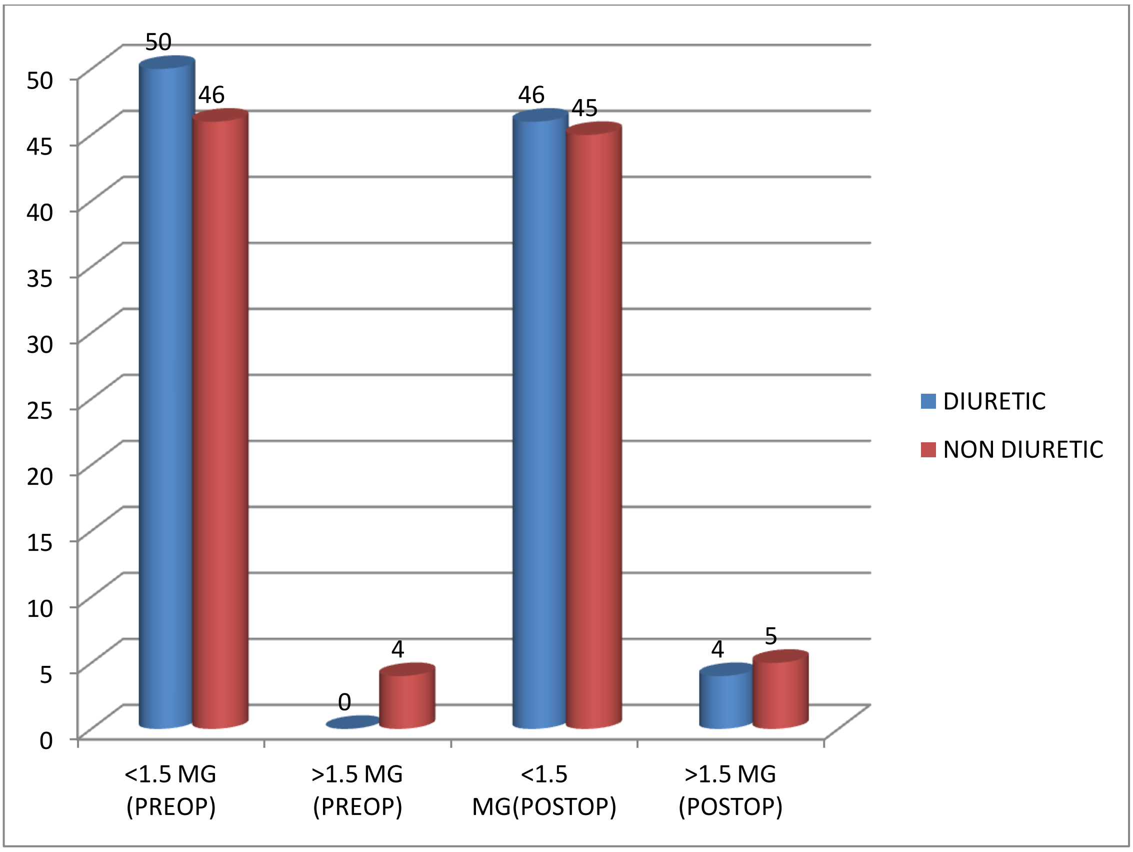


Figure 6: Preoperative and postoperative serum creatinine in both groups.

PATIENTS ON ACE INHIBITORS:

Angiotensin converting enzyme inhibitors are known to cause hyperkalemia in patients with renal insufficiency and in patients who are on potassium sparing diuretics and potassium supplements. In our study only three patients were found to be on this drug of which twowere in the diuretics group and one patient in the non-diuretics group.

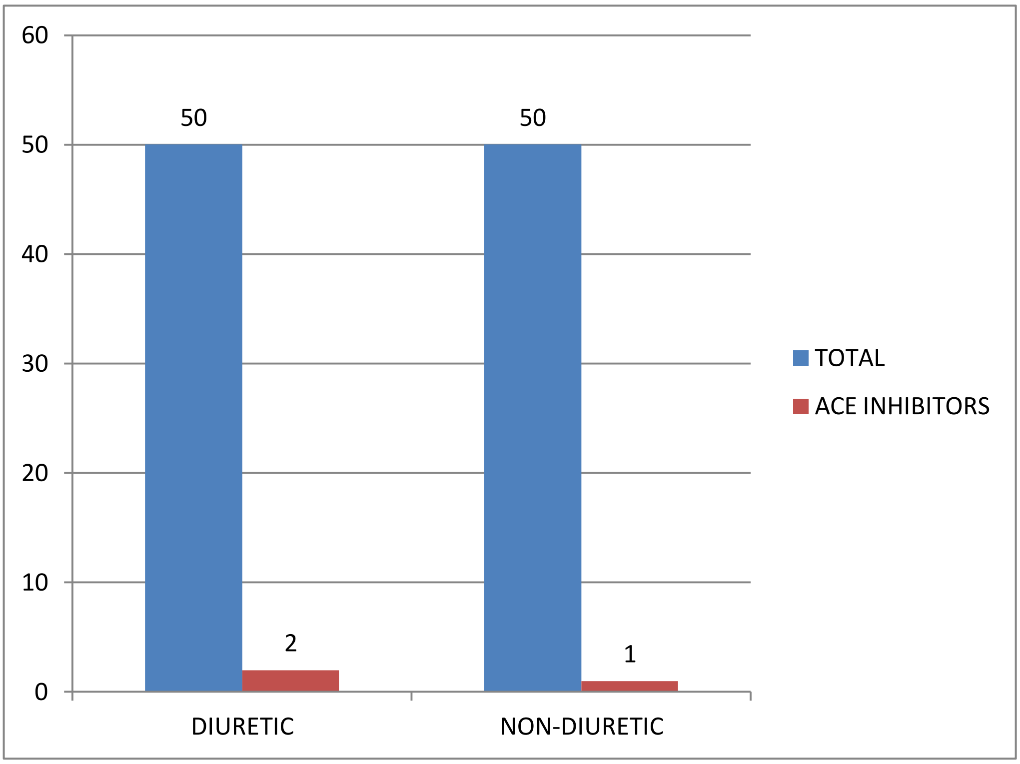


Figure 7: shows number of patients on ACE inhibitors in each group.

PATIENTS ON DIGOXIN AND POTASSIUM SUPPLEMENTS:

The number of patients who received digoxin and potassium supplements were more in thediuretic group. As diuretics are known to cause hypokalemia and hpokalemia in patients on digoxin will lead to digoxin toxicity, almost all these patients were on potassium supplements. In the diuretic group 33 patients were on digoxin and 32 patients were on potassium supplements in the preoperative period whereas only 3 patients were on digoxin in the non-diuretics group and none of these patients were on potassium supplements in the preoperative period.

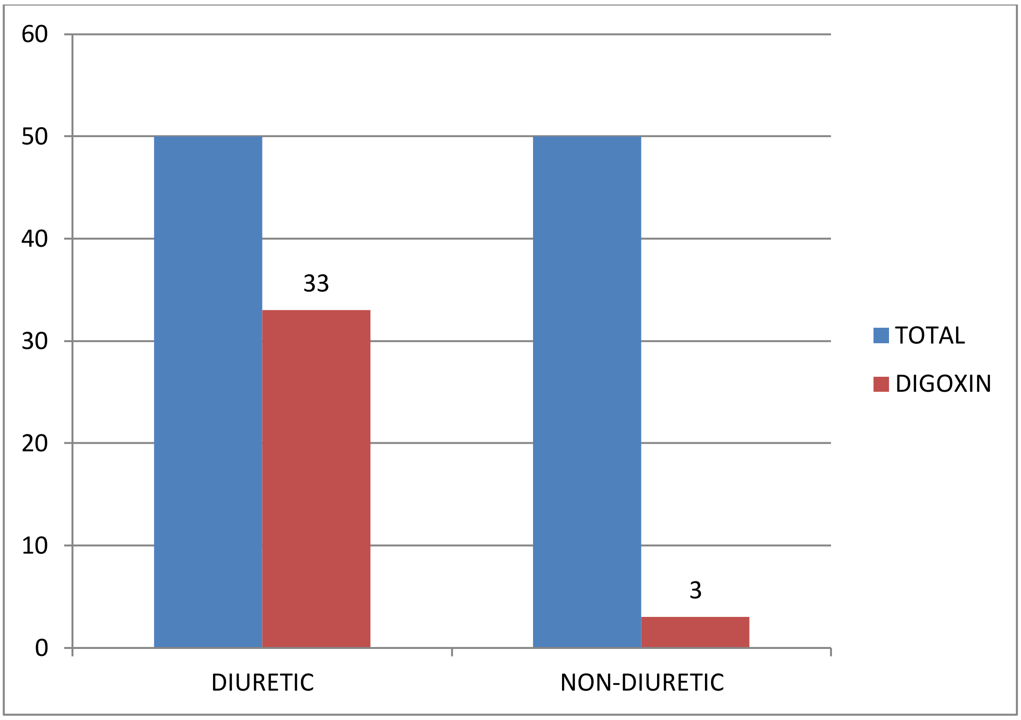


Figure 8: shows the number of patients on digoxin in each group.

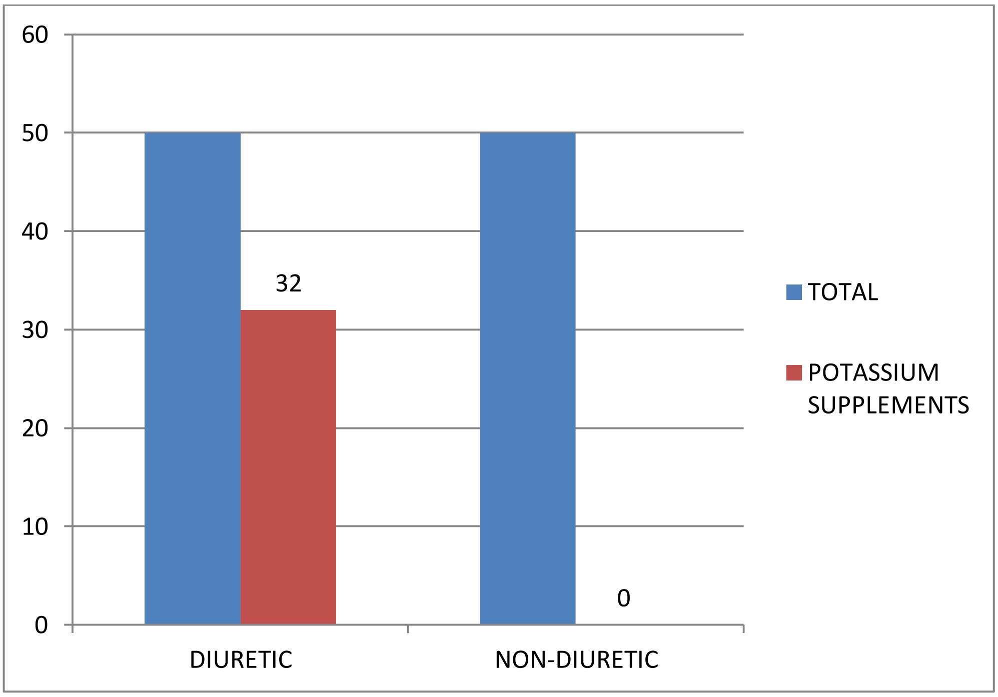


Figure 9 : shows the number of patients on potassium supplements.

PREOPERATIVE DIAGNOSIS AND SURGERY:

The nature of cardiac lesion for which the patient underwent surgery differ in both the groups. The patients with coronary artery disease underwent coronary artery bypass grafting(CABG) and the patients with valvular heart disease underwent valve replacement surgeries. The valve replacement surgery included mitral valve replacement, aortic valve replacement and double valve replacement. Few patients underwent a combination of a valve replacement and coronary artery bypass grafting.

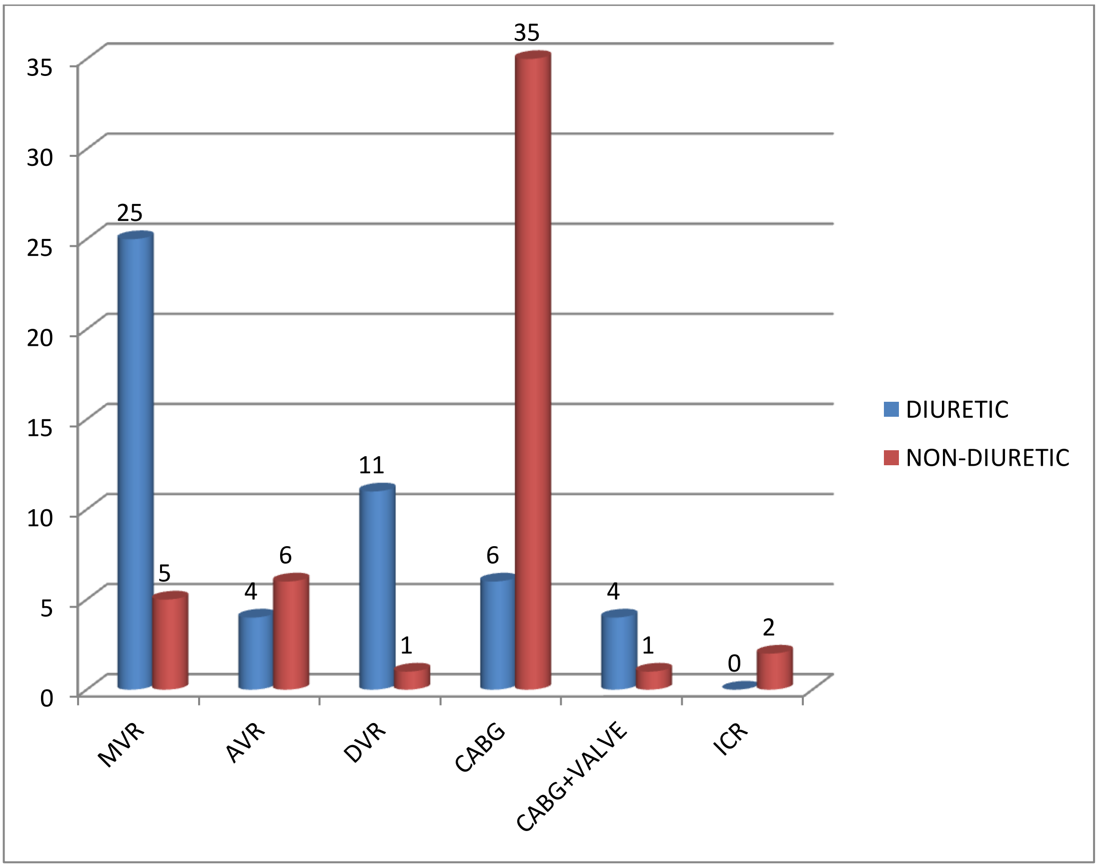


Figure 10: shows the type of surgery in each group.

In the diuretic group Mitral valve replacement was the commonest surgery and in the non diuretic group coconary artery bypass grafting was the commonest surgery.Overall in the diuretic group 25 patients had mitral valve replacement, 4 patients had aortic valve replacement, 11 patients had double valve replacement, 6 patients had CABG and a valve replacement. In the non-diuretics group 35 patients had CABG, 6 patients had aortic valve replacement, 5 patients had mitral valve replacement, one patient had double valve replacement, one patient had CABG with a valve replacement and two patients had intracardiac repair.

PERIOPERATIVE CHARACTERISTICS BETWEEN THE TWO GROUPS:

CARDIOPLEGIA REQUIREMENT:

All patients underwent cardiac surgical procedure under cardiopulmonary bypass and with cardioplegia. Cardioplegia, a potassium rich fluid given to arrest the heart which helps the surgeon to operate on a non-beating heart and a bloodless surgical field. Simple cardic procedures requires cardioplegia once which lasts for almost 20 minutes. More complicated procedures and double valve replacement may take a longer time that cardioplegia should be given more than once which may affect the serum potassium levels in the perioperative period. The figure 11, shows the details of cardioplegia requirements in both the groups.

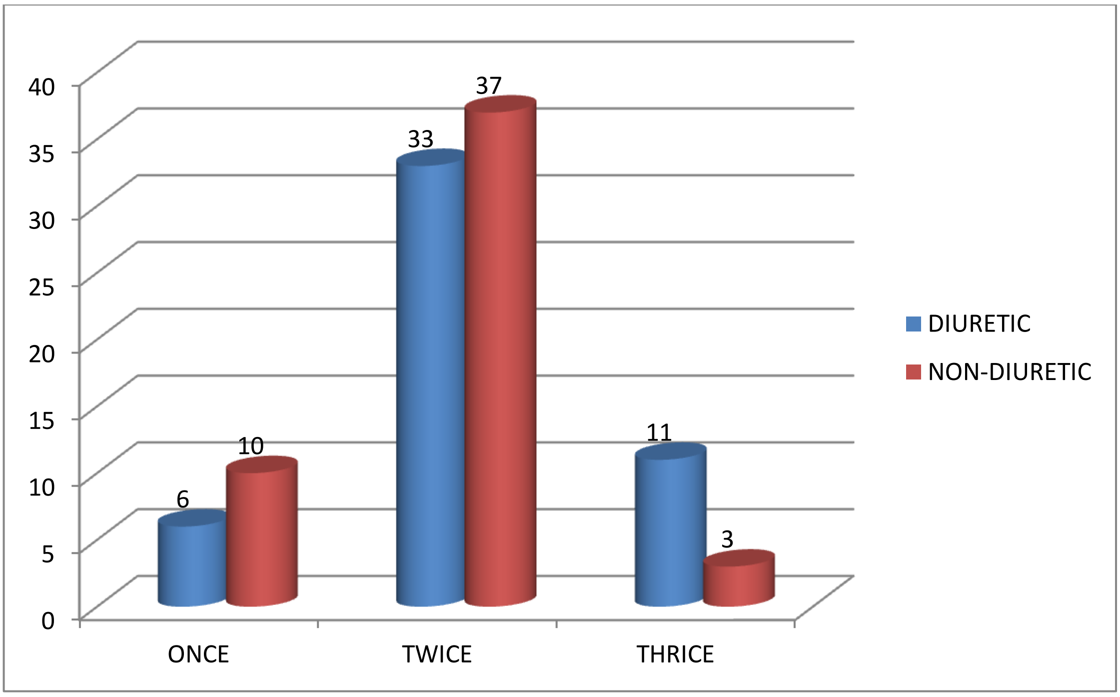


Figure 11: shows the cardioplegia requirements in each group.

The requirements of cardioplegia in the diuretic group was, once in 6 patients, twice in 33patients and three times in 11 patients. In the non-diuretic group 10 patients required cardioplegia once, 37 patients required twice and 3 patients required cardioplegia three times.

BLOOD AND BLOOD PRODUCTS REQUIREMENT:

Cardiac surgeries require back-up of adequate numbers of blood and blood products in the perioperative period. Blood loss is common intraoperatively. The dilution of blood by the heart-lung machine will cause the haemoglobin to drop. Also post operative blood loss through the wound drain is also anticipated. The Figure 12, shows the intraoperative and the postoperative blood transfusion requirements.

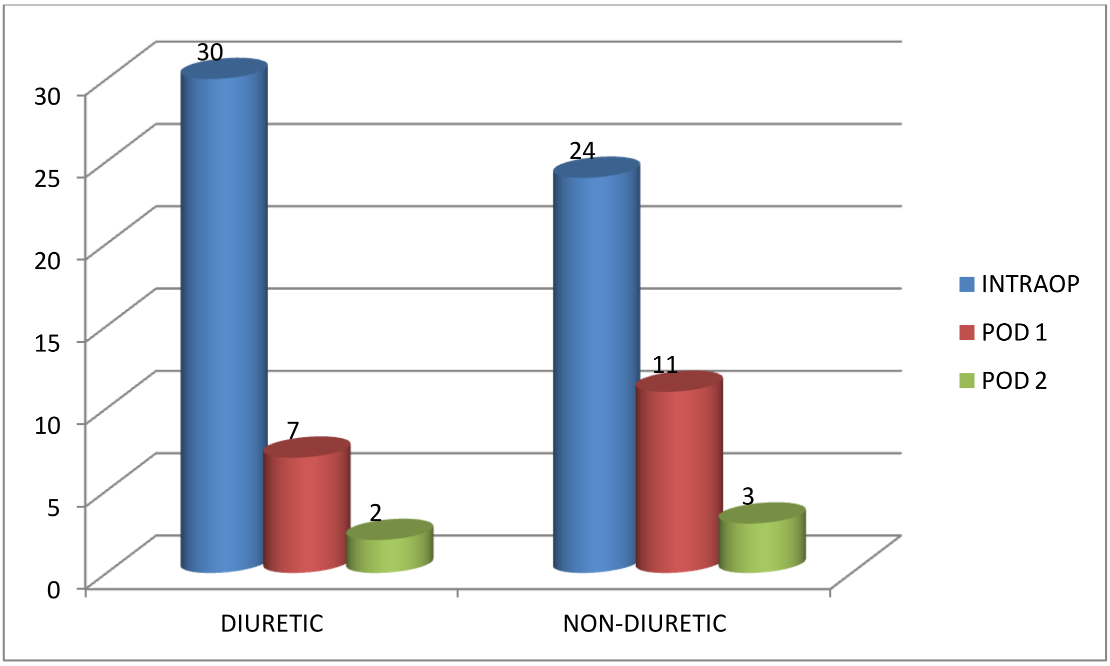


Figure 12: shows the transfusion requirements in each group till second postoperative day.

In the diuretic group 30 patients required packed cell transfusion intraoperatively, 7 patients on the first postoperative day and 2 patients on the second postoperative day. In the non-diuretics group 24 patients required packed cell transfusion in the intraoperative period, 11 patients in the first postoperative day and 3 patients in the second postoperative day.

HYPOKALEMIA AND POTASSIUM CORRECTION:

The combination of factors like diuretics, hypothermia, cardiopulmonary bypass are expected to cause hypokalemia. Injection Potassium Chloride (kcl) is given as intravenous infusion to correct hypokalemia. Figure 13 and 14 shows the number of patients who required potassium correction and the amount of potassium needed to correct hypokalemia. In cardiac surgical patients a serum potassium level of more than 4

MEq/L is desired.As a result patients whose serum potassium is between 3.5 to 4 MEq/L also received potassium correction. Hence the amount of potassium chloride required to keep the serum potassium above 4 MEq/L is also recorded.

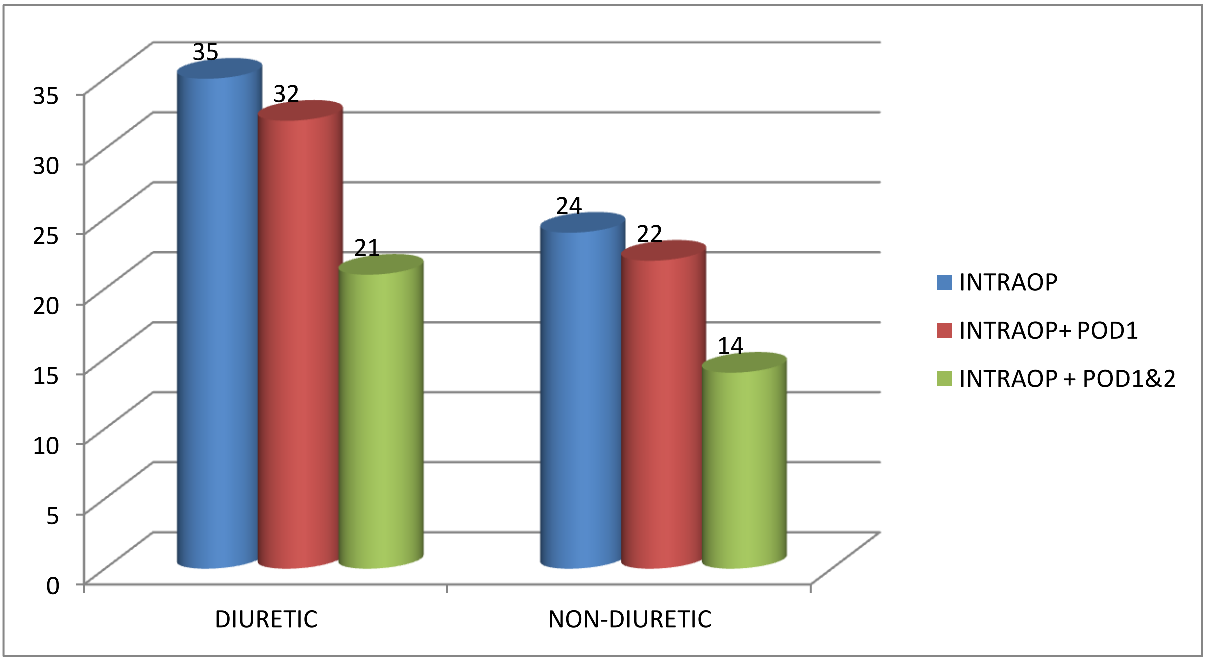


Figure 13: shows the number of patients who needed kcl correction in the perioperative period.

In the diuretic group 35 patients required potassium correction in the intraoperative period, 32 patients required correction in the intraoperative and the first postoperative day and 21 patients needed potassium correction all the three days. In the non-diuretics group 24 patients required kcl correction in the intraoperative period, 22 patients required correction in the intraoperative and the first postoperative day and 14 patients needed potassium correction all the three days.

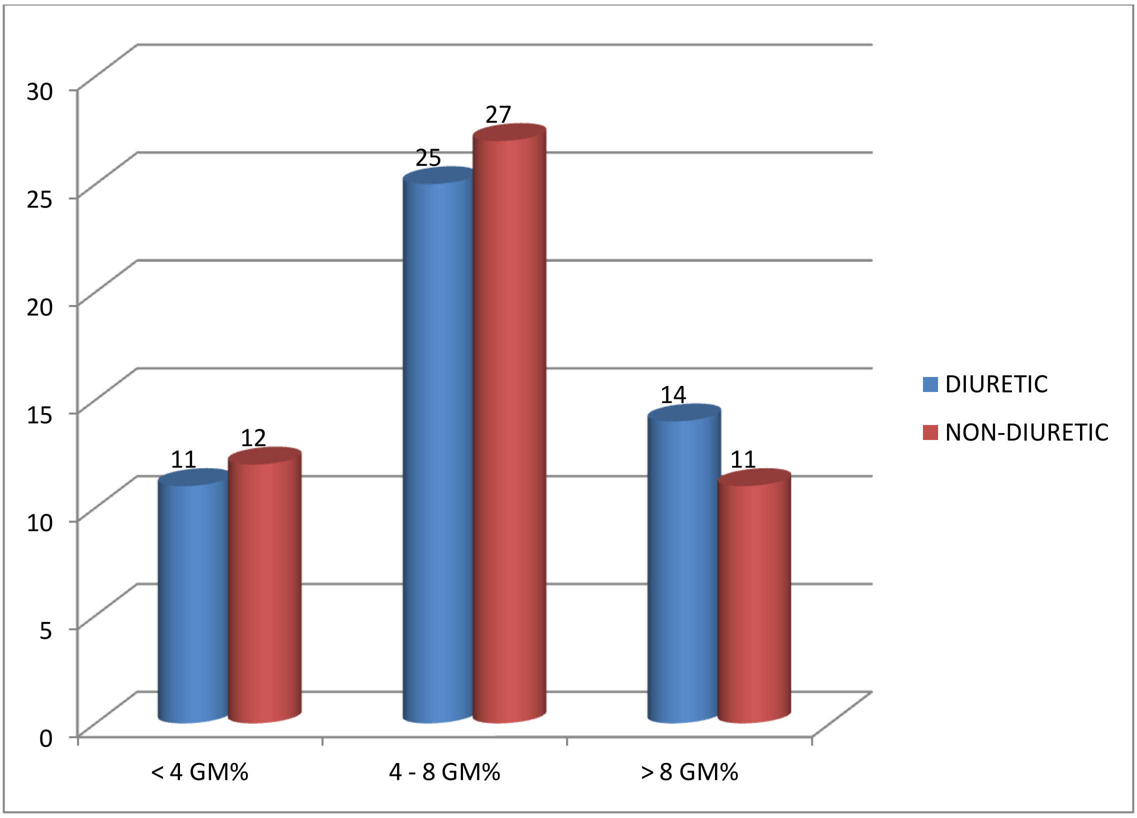


Figure 14: shows the amount of kcl needed to keep serum potassium > 4MEq/L

In the diuretic group 11 patients required less than 4 gms kcl, 25 patients required 4-8 gms kcl and 14 patients required more than 8 gms kcl in all the 3 days to keep the serum potassium level more than 4MEq/L.In the non-diuretic group 12 patients required less than 4 gms kcl, 27 patients required 4-8 gms kcl and 11 patients required more than 8 gms kcl in all the 3 days to keep the serum potassium level more than 4 MEq/L.

INSULIN REQUIREMENT:

Good glycemic control is important in cardiac surgical patients. Insulin is usually given as an infusion if blood sugars are high. Glucose-insulin infusion is started as a treatment of hyperkalemia. The requirement of insulin in the perioperative period between both groups is given in the figure 15.

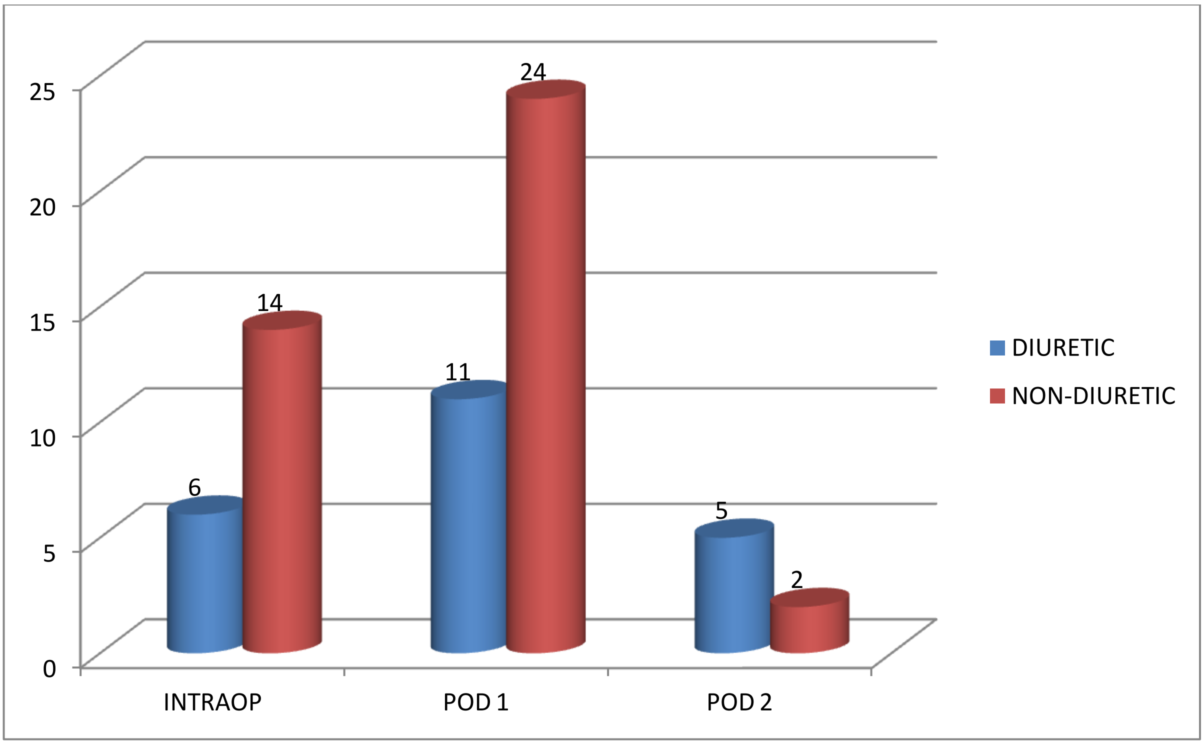


Figure 15: shows the insulin requirement in the perioperative period in both the groups.

In the diuretic group 6 patients require insulin in the intraoperative period, 11 patients needed insulin in the first postoperative day and 5 patients required insulin in the second postoperative day.In the non-diuretics group 14 patients required insulin in the intraoperative period, 24 patients required insulin in the first postoperative day and 2 patients needed insulin in the second postoperative day. Incidently the non-diuretics group had more patients who are diabetic than in the diuretic group.

TREATMENT WITH SODIUM BICARBONATE:

7.5% sodium bicarbonate is given as intravenous bolus dose or as an infusion to correct acidosis. It is also used in the treatment of hyperkalemia. Maintaining the acid base balance is important to keep the serum potassium level with in the normal range.

Acidosis leads to hyperkalemia and alkalosis leads to hypokalemia due to intercompartmental shift of potassium ions. Figure 16, shows the details of sodium bicarbonate requirements in the perioperative period.

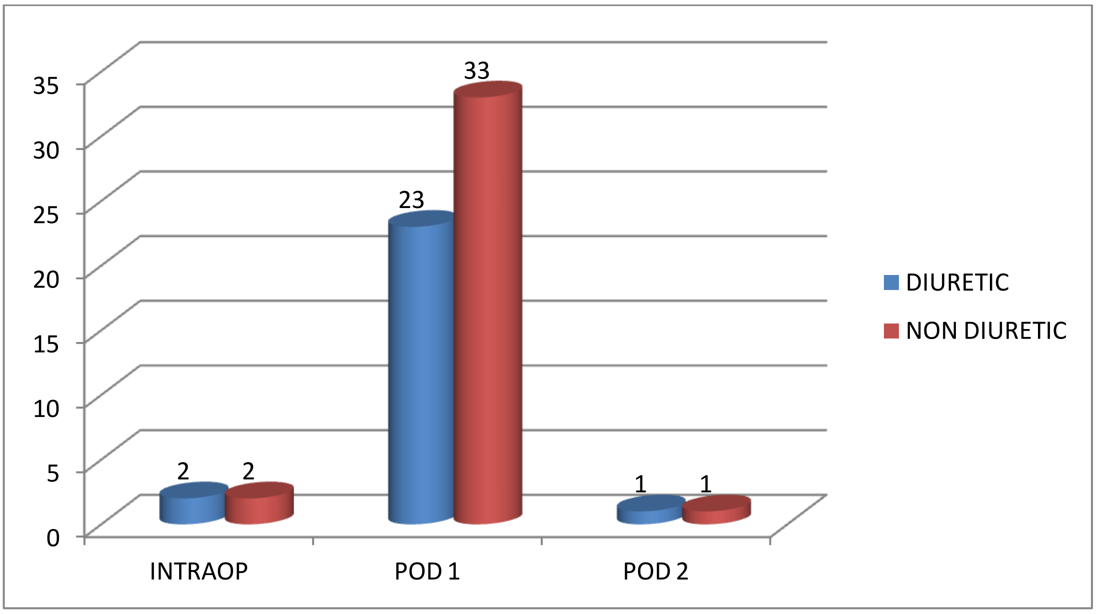


Figure 16: shows sodium bicarbonate requirement in the perioperative period in both the group.

The requirement of sodium bicarbonate peaked in the first postoperative day with 23 patients in the diuretic group and 33 patients in the nondiuretic group needing it. In both the diuretic and the non-diuretic group only 2 patients intraoperatively and 1 patient on the second postoperative day required treatment with sodium bicarbonate

CALCIUM REQUIREMENT:

Maintaining serum calcium level is important for the optimal contractility of the myocardium. Calcium is given intravenously when the ionic calcium is low. It is also given as the first line of drug in the treatment of hyperkalemia. Calcium protects the heart from the deleterious effects of hyperkalemia though it will not lower serum potassium level.

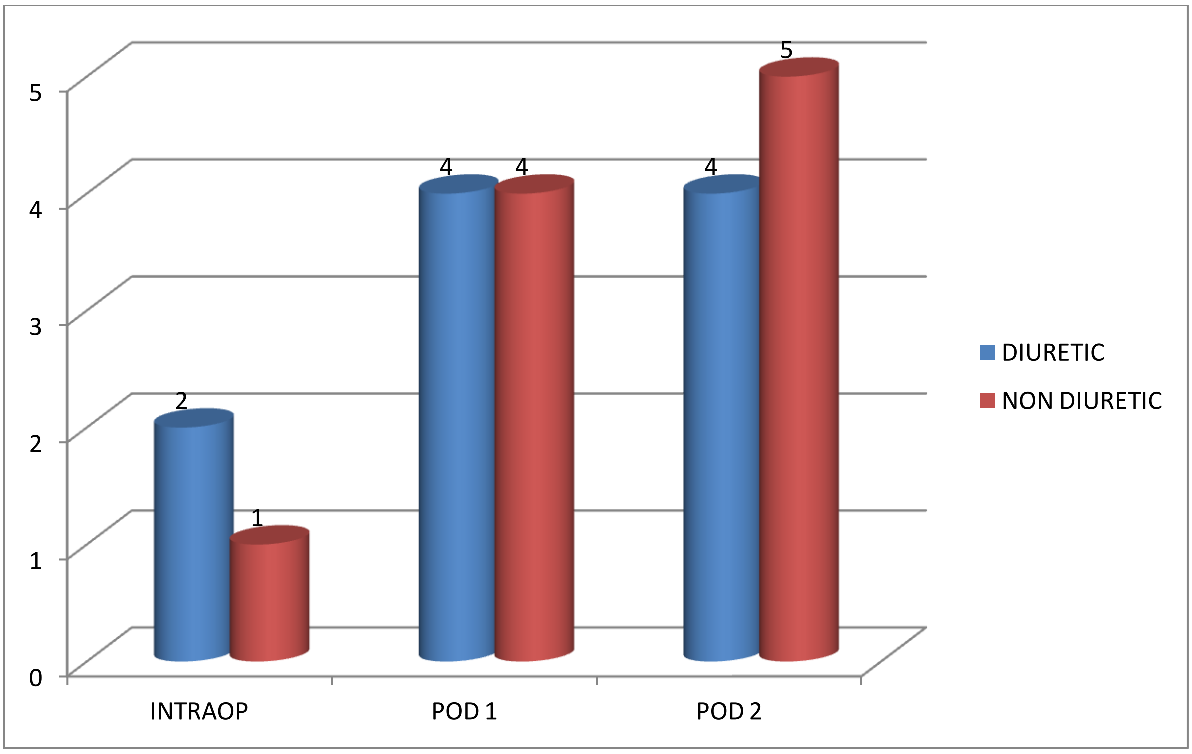


Figure 17: shows the number of patients treated with calcium in both groups.

The total number of patients who required calcium is very less indicating hyperkalemia was uncommon in both the diuretic and non-diuretic groups. In the diuretic group only 2 patients required calcium in the intraoperative period, 4 patients required calcium in the first post operative day and 4 patients needed calcium in the second postoperative day. In the non-diuretic group only 1 patient received calcium intraoperatively, 4 patients required calcium in the first postoperative day and 5 patients required calcium in the second postoperative day.

MAGNESIUM REQUIREMENT:

Hypomagnesemia is one of the cause for perioperative arrhythmias. Hypokalemia associated hypomagnesemia will not respond to treatment with potassium correction alone. Magnesium should be given as an intravenous bolus in case of arrhythmias not responding to potassium correction. Most of the time magnesium is given empirically to treat arrhythmias which is not getting corrected even after potassium correction for hypokalemia. Figure 18 shows the details of magnesium requirement in the perioperative period.

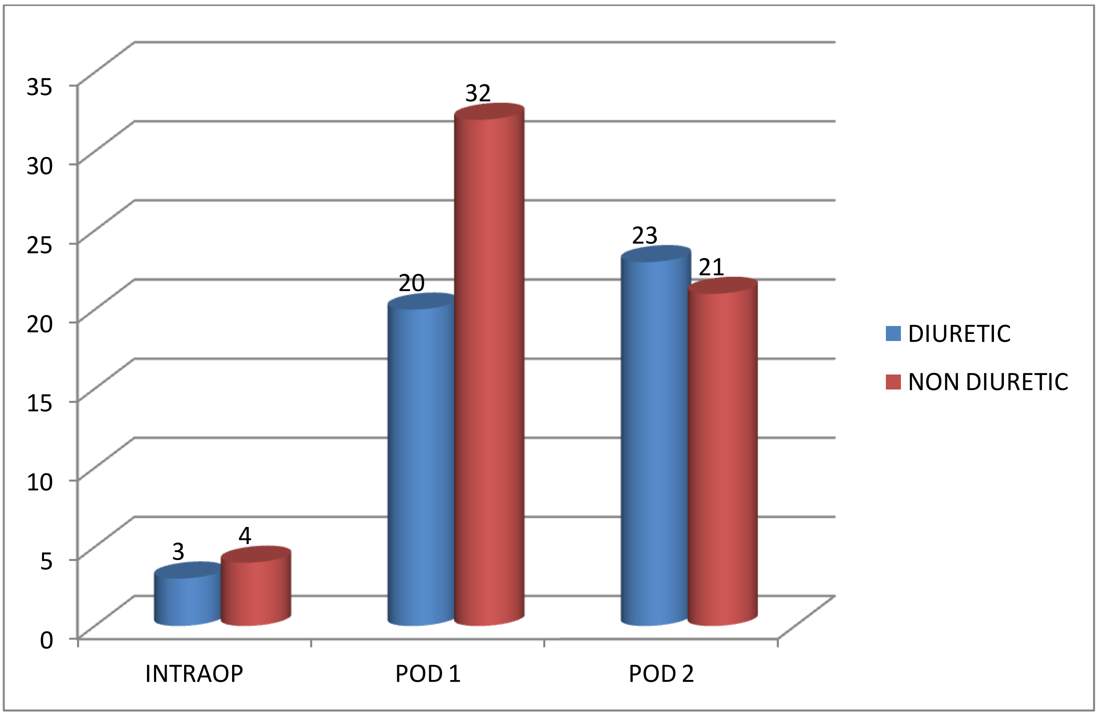


Figure 18: shows the number of patients treated with magnesium in both groups.

In the diuretic group, 3 patients required magnesium intraoperatively, 4 patients required magnesium on the first postoperative day and eight patients received magnesium in the second post operative day.In the non-diuretics groups, 3 patients required potassium in the intraoperative period, 2 patients in the first and the second postoperative day.

PERIOPERATIVE FUROSEMIDE REQUIREMENTS:

Furosemide commonly known as lasix is a loop diuretic used in the cardiac surgical patients. As fluid overload cannot be tolerated well in these patients in the postoperative period, furosemide administration is common in the post operative period.

Also furosemide is given in the treatment of hyperkalemia so that potassium is excreted out. The following picture shows the details of furosemide requirements in the perioperative period.

The following figure shows the details of furosemide requirement in both the diuretic and non diuretic group.

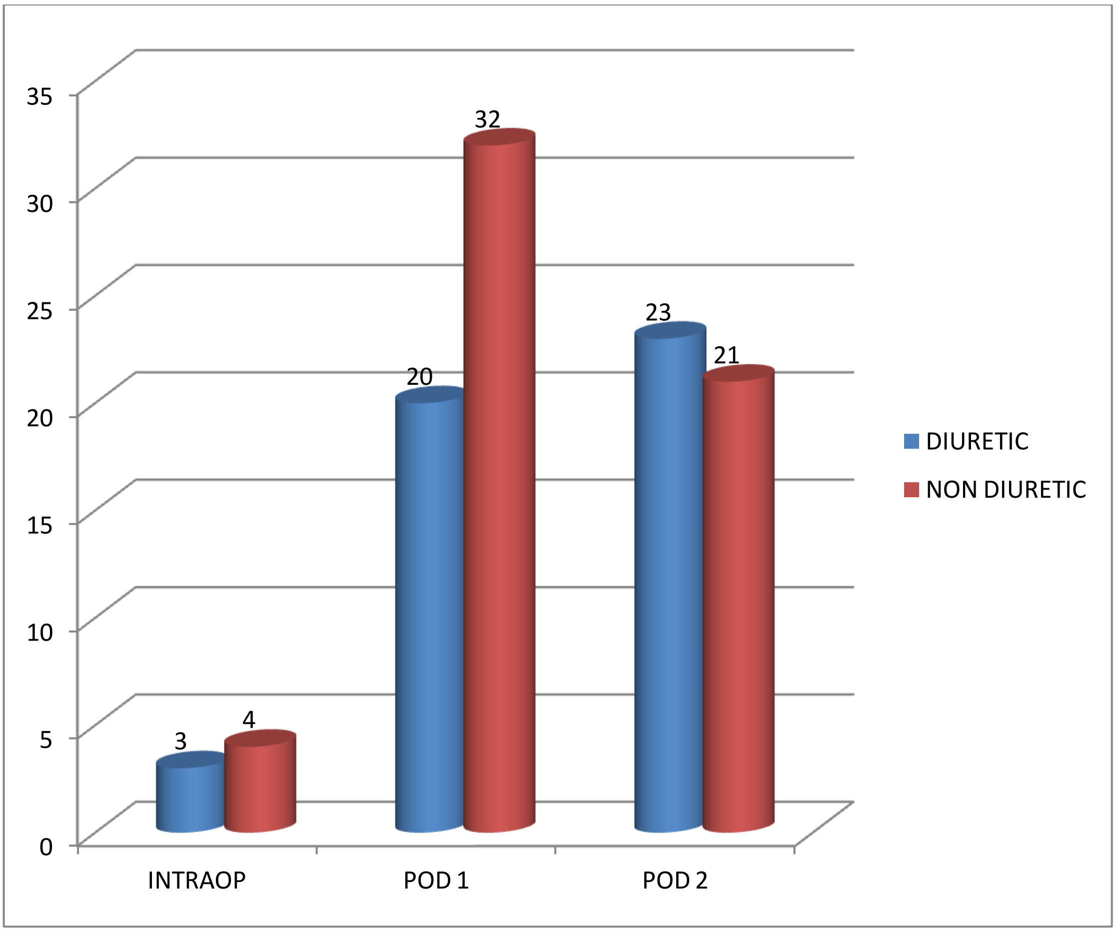


Figure: 19 shows the number of patients received lasix in the perioperative period in both the groups.

The number of patients who received furosemide intraoperatively are 3 in the diuretic group and 4 in the non-diuretics group. In the first postoperative day, 20 patients in the diuretic group and 32 patients in the non diuretic group required furosemide. The requirements of furosemide on the second postoperative day are 23 patients in the diuretic group and 21 patients in the non-diuretics group.

DISCUSSION

DISCUSSION:

Chronic use of diuretics like frusemide and thiazide is known to cause hypokalemia. In the cardiac patients who undergo open heart surgery, hypokalemia significantly increases the risk for perioperative arrhythmias.

Most of these patients are on oral potassium supplements to prevent hypokalemia. Also patients who are on digoxin are known to develop toxicity if serum potassium is low.

On the other hand patients who are taking potassium sparing diuretics and angiotensin converting enzyme inhibitors are known to develop hyperkalemia because of potassium retension by kidneys due to the inhibited effect of aldosterone. Patients with chronic renal failure poorly excrete potassium and are known for elevated serum potassium levels.

Diabetic mellitus with insulin treatment cause intra cellular shift of potassium causing hypokalemia in the extracellular compartment. In contrast, patients with diabetic nephropathy may develop hyperkalemia.

This is an observational study which evaluated the role of long term preoperative diuretics on the perioperative serum potassium changes namely hypokalemia and hyperkalemia.

All the datas were analyzed using Generalized Estimating Equations.

In our study there was a clinically significant hypokalemia in the patients who were on long term diuretics preoperatively.

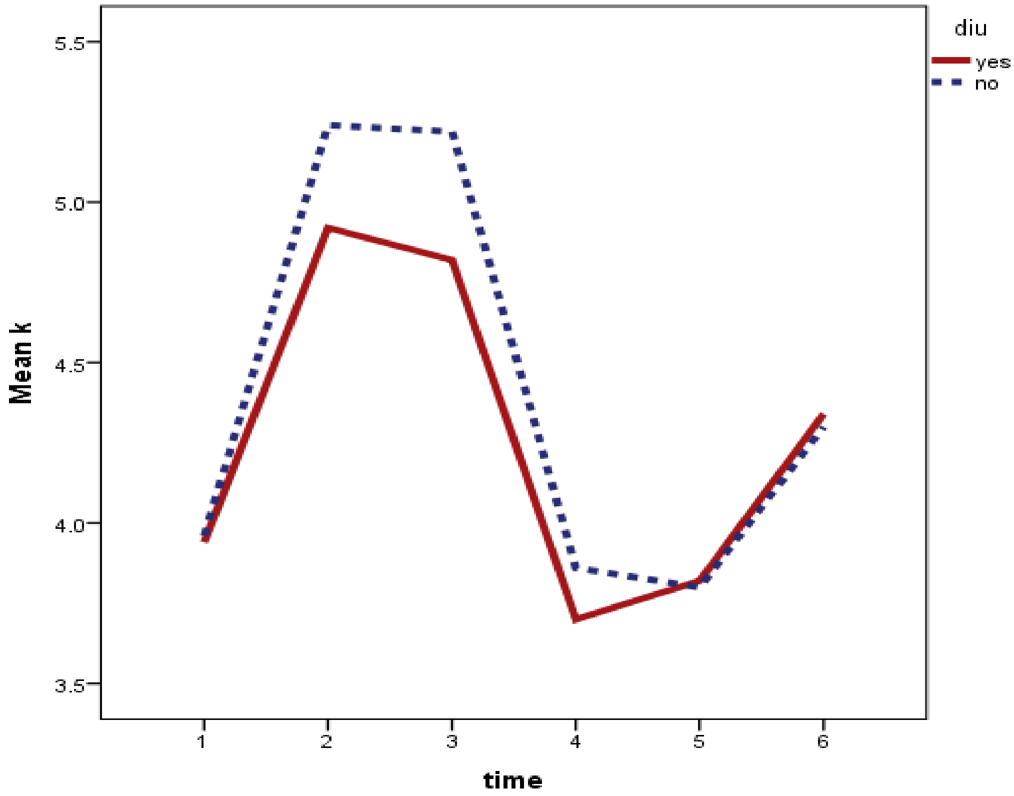
In both diuretic and non diuretic groups serum potassium was higher in the sample immediately after cardioplegia comperd to baseline. This may be attributed to the high potassium in the cardioplegia solution.

The serum potassium levels tend to drop slightly after the cross clamp release and a further decrease after coming of bypass. This trend seen in both the groups may be due to the diuretic effect of mannitol.

Most of the patients had serum potassium supplementation in the 1^{st} post operative day to keep the serum potassium levels between 4-4.5 mEq/L. even though the serum potassium trends in both the groups are similar, patients in the diuretic group had lower potassium levels compared to non diuretic group.

However these changes are not statistically significant. Also there is no statistically significant difference in the potassium requirements. This may be partly due to the fact that potassium is a predominantly intracellular cation.

These changes are similar to the results of Babka R, Pifarre R titled ‘potassium replacement during cardiopulmonary bypass’. (48)



Graph 1 : shows the trend of serum potassium levels in the preoperative period(1), on pump(2), before coming out of bypass (3), after coming out of bypass(4), first post operative day (5) and the the second postoperative day(6).

In a similar study published in 1990, Bhatt SB etal (49) reported a similar results where there was no significant difference in the incidence of hypokalemia and the potassium requirement between two group.

In an older study by , Saidi M etal (50) done in children between two group of patients with one group on diuretics and digitalis and other group not on these drug, it was found that the chidren taking digitalis and diuretics had increased incidence of hypokalemia when comparing to the other group. Our study also reflects the same pattern with the incidence of hypokalemia was more in the diuretic group which was clinically significant but not statistically.

The incidence of hypokalemia during the intraoperative period was more in the diuretic group than the non-diuretic group. Only three patiets in the diuretic group and two patients in the non-diuretic group in whom hypokalemia settled with intraoperative correction of potassium.

All the hundred patients included in this study in either group needed potassium correction at least once in either intraoperative or in the first or second postoperative day. As many as 35 patients in the diuretic group had hypokalemia where as the number in the non-diuretic group was 24 in the intraoperative period.

In the diuretic group 21 patients required potassium correction all the three days where as only 14 patients required potassium correction all the three days in the non-diuretic group. The amount of kcl required to keep the potassium in the normal range also varied between the two groups. The number of subjects who required less than four grams of kcl correction were 11 in the diuretic group and 12 in the non-diuretic group. Similarly 25 and 27 subjects in the diuretic and the non-diuretic group required a potassium correction of between 4 to 8 gms kcl, respectively. The subjects who required more than 8 gms kcl correction are also comparable between both the groups. It was 14 in the diuretic group and 11 in the non-diuretic group.

The potassium requirement to keep the serum potassium above 4meq/l was higher in the non-diuretic group. This can be explained by the fact that the diabetic patients were more in the non-diuretic group. Most of these patients required insulin infusion in the perioperative period. As insulin causes intracellular shift of potassium, these patients required more amount of potassium to keep the serum potassium level above 4- 4.5 meq/L. This explains the reason for the increased potassium requirement in the non-diuretic group. Diabetic mellitus and glucose intolerance were associated with statistically significant hyperkalemia in a study conducted by Donald O. Weber and Michael D. Yarnoz.(40)

In a subgroup of patients in the diuretic group who are also on oral syp. potassium in the preoperative period, the amount of potassium correction needed to keep the serum potassium value above 4meq/l, is significantly lesser when compared to the patients who were not on potassium supplements preoperatively. This can be explained by the fact that even when the patients were taking diuretics, the potassium lost in the urine is constantly replenished by the potassium supplements. This was found to be a statistically significant finding with the p value of 0.000.

The effects of parameters like haemoglobin, serum creatinine, serum bicarbonate, base excess, pH, Pco2 were all found to be clinically insignificant in affecting the perioperative potassium requirements in both the groups with the p values more than 0.7.

In our study 15 patients in the diuretic group and 7 patients in the non diuretic group required magnesium treatment. However this was not statistically significant. Magnesium supplementation is usually done on an empirical basis as a personal preference. We do not routinely measure serum magnesium in our patients. But assume that hypomagnesemia is associated with hypokalemia.

In the diuretic group, there were only 7 patients who were taking spironolactone, an aldosterone antagonist and a potassium sparing diuretic. The analysis shows that the patients who were taking potassium sparing diuretic had required 0.07 gms kcl lower than who were not on that drug. This is statistically insignificant with the p value of 0.8.

The subjects who were taking angiotensin converting enzyme inhibitors (ACE inhibitors)were two patients in the diuretic group and only one patient in the non diuretic group. Though ACE inhibitors are expected to cause hyperkalemia , this is statistically insignificant (p = 0.7) in this study as overall only 3 patients were on this drug.

Patients in both the groups received sodium bicarbonate either as a treatment for acidosis or in some instances as a treatment for hyperkalemia.26 patients in the diuretic group and 36 patients in the non diuretic group required sodium bicarbonate treatment in the intraoperative and the post operative period. The incidence of alteration in the serum potassium levels in these patients is statistically insignificant with the p value of 0.2.

Calcium is given in the perioperative period to correct hypocalcemia and also as a first line of treatment of hyperkalemia.10 patients in each of the groups receive calcium correction in the perioperative period. The effect of diuretic intake and calcium correction was not found to play any statistical significance (p = 0.3) in the incidence of hypokalemia or hyperkalemia.

The diuretic furosemide commonly known as frusemide is given to cardiac patients in the perioperative period to avoid or treat fluid overload. As frusemide is expected to excrete potassium along with urine the effect of usage of intraoperative and postoperative frusemide was also studied. Only 3 patients in the diuretic group and 4 patients in the non diuretic group required frusemide intraoperatively. In the first post operative period 20 patients in the diuretic group and 32 patients in the non diuretic group received lasix. In the second postoperative day, 23 patients in the diuretic group and 21 patients in the non diuretic group required frusemide. Among the patients who received perioperative frusemide treatment, those in the diuretic group required 0.17 gms less kcl than in the non diuretic group which is statistically insignificant.

The role of cardioplegia, the high potassium rich fluid , in altering the serum potassium levels is also studied. In the diuretic group 6 patients received cardioplegia once, 33 patients twice and 11 patients thrice. In the non diuretic group 10 patients received once, 37 patients received twice and 3 patients received thrice. Adjusting for the cardioplegia, the analysis shows that the diuretic group required 0.05 gms less potassium than the nondiuretic group. However this is found to be statistically insignificant ($p = 0.9$).

The role of blood transfusion in altering the serum potassium levels also studied between the two groups. The intraoperative need for blood transfusion was more in this study, with 30 patients in the diuretic group and 24 patients in the nondiuretic group received blood intraoperatively where as 11 patients in the diuretic group and 14 patients in the nondiuretic group received blood postoperatively. Adjusting for blood transfusion, the study shows that the diuretic group received 0.45 gms more kcl than the nondiuretic group which though clinically significant is not statistically significant ($p =0.5$).

TABLE SHOWING RISK VARIABLES, THE MAGNITUTE OF CHANGE(B), THE CONFIDENCE INTERVAL AND THE P VALUE

RISK VARIABLES	B	95% CONFIDENCE INTERVAL	P VALUE
Diuretic	-0.107	-0.692 TO 0.478	0.720
K sparing	-0.073	-0.675 TO 0.530	0.813
Diabetic			
YES	-1.331	-2.343 TO -0.319	0.010
NO	0.183	-0.440 TO 0.807	0.564
ACE Inhibitor			
YES	-0.500	-3.272 TO 2.272	0.724
NO	-0.093	-0.681 TO 0.496	0.757
K supplements			
YES	-2.043	-2.574 TO -1.511	0.000
NO	-0.448	-1.180 TO 0.284	0.230
Digoxin			
YES	-0.334	-0.914 TO 0.245	0.258

NO	0.231	-0.726 TO 1.184	0.636
Creatinine	-0.240	-0.861 TO 0.382	0.450
Haemoglobin	-0.040	-0.670 TO 0.590	0.901
HCO3	-0.082	-0.663 TO 0.498	0.781
Base Excess	-0.081	-0.666 TO 0.504	0.787
PCO2	-0.108	-0.692 TO 0.477	0.718
Urea	-0.072	-0.834 TO 0.689	0.852
Cardioplegia	-0.054	-0.852 TO 0.744	0.895
Blood			
YES	0.466	-0.908 TO 1.839	0.506
NO	0.200	-0.884 TO 1.284	0.718
Insulin			
YES	-0.684	-2.654 TO 1.285	0.496
NO	0.456	-0.205 TO 1.117	0.177
Sodabicarb			
YES	0.775	-0.670 TO 2.219	0.293
NO	0.327	-0.228 TO 0.882	0.248

Calcium			
YES	1.714	-1.589 TO 5.017	0.309
NO	-0.253	-0.844 TO 0.338	0.402
MgSo4			
YES	-0.750	-5.194 TO 3.694	0.741
NO	-0.137	-0.705 TO 0.432	0.638
Lasix			
YES	-0.173	-1.248 TO 0.903	0.753
NO	0.650	-0.132 TO 1.431	0.103

CONCLUSION

CONCLUSIONS:

The observations of the study on ‘perioperative serum potassium changes in patients undergoing open heart surgery under cardiopulmonary bypass: A comparative study between two group of patients – one group of patients on long term preoperative diuretics and the other group not on diuretics’ are

1. There is no significant statistical difference in the incidence of hypokalemia or hyperkalemia between the two group of patients.

2. A subgroup of patients who received preoperative oral potassium supplementation were found to be requiring 2 gms lesser potassium correction than in those who never received oral potassium in the preoperative period which is statistically significant with the p value of 0.000.

3. The patients who were diabetic and also on long term diuretic therapy required 1.3 gms lesser kcl to keep their potassium above 4 mEq/L than those who were not diabetic. This was found to be statistically significant with a p value of 0.010.

4. The role of other preoperative medications like ACE inhibitors, digoxin, did not have any statistical significance in causing a difference in serum potassium levels in both the groups.

5. The effects of parameters like haemoglobin, serum creatinine, serum bicarbonate, base excess, pH, Pco2 were all found to be clinically insignificant in affecting the perioperative potassium requirements in both the groups with the p values more than 0.7.

6. This study did not show any significant statistical difference in the perioperative requirement of sodium bicarbonate, calcium, magnesium ,glucose-insulin infusion and frusemide.

7. The role of cardioplegia and blood transfusion were also found to be statistically not significant in causing a change in serum potassium levels between both the groups.

LIMITATIONS

LIMITATIONS:

1. Though the patients in the diuretics group required more interventions to keep the serum potassium in the normal range this study did not show any statistical difference. Had the study been done with a bigger sample size, it would have shown statistical significance in the incidence of hypokalemia in the diuretic group.

2. The distribution of type of surgery between the two groups were not uniform. The valve replacement surgeries were common in the diuretic group whereas coronay artery bypass grafting was common in the non-diuretic group.

3. In the same way there were more number of diabetic patients in the non-diuretic group comparing to the diuretic group. This might be a confounding factor.

RECOMMENDATION

RECOMMENDATIONS:

1. We recommend that the study to be repeated with a bigger sample size.

2. Confounding factors like the distribution of patients with diabetic mellitus mainly to the non-diuretic group should be addressed.

3. The distribution of the type of surgery was also not uniform: such as the valve replacement surgery in the diuretic group in contrast to the coronary artery bypass grafting in the non-diuretic group. This has to be addressed.

BIBLIOGRAPHY:

1. The importance of potassium by Hans R.Larsen MSc ChE.

2. Potassium and anaesthesia. Review article by John E Tetzlaff, Jerome F.O'Hara Jr, Michael T. Walsh.

3. Potassium ion and anaesthetic implications by S. Parthasarathy, M. Ravishankar . J Anesth Clin Pharmacology 2007;23 (2): 129 -144.

4. Morgan's Clinical Anaesthesiology, 4th Edition. Chapter 28 . Page 676 – 682.

5. Principles of cardiac electrophysiology. Massachusetts institute of technology. Pages 115-126

6. A model of the ventricular cardiac action potential. Depolarization, Repolarization, and their interaction by Ching-hsing and Yoram Rudy. Circulation Research 1991;68:1501-1526

7. Ganong WF; Review of Medical Physiology, 21st ed. McGraw-Hill, 2003

8. Morgan's Clinical Anaesthesiology, 4 ed. Table 19-1, page 417.

9. Wikipedia, the free encyclopedia.

10. Hines & Marschall:Stoelting's Anesthesia and CO-Existing Disease, 5TH ed.

11. Adapted from Gennari JF: Hypokalemia . N Engl J Med 1998; 339: 451 -458.

12. Clinical Anesthesia, Barash, 6th ed. 2009. Chapter 14, page 313

13. Miller's Anaesthesia, 7th ed. Chapter 54.

14. Adapted from Solomon RJ, Katz JD : Disorders of potassium homeostasis. In Stoelting RK (ed): Advances in Anesthesia. Chicago, Year Book MedicalPublishers 1986.

15 Sood MM, Sood AR, Richardson R: Emergency management and commonly encountered outpatient scenarios in patients with hyperkalemia. Mayo Clin Proc 2007; 82: 1553–1561.

16. Critical Care Medicine 2008 Vol. 36, No. 12 Lawrence S. Weisberg.

17. Googman and Gilman's The Pharmacological basis of Therapeutics 11th ed. Chapter 28.

18. Chobanian AV, Bakris GL, Black HR, et al: Seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: The JNC-7 Report. JAMA 289:2560, 2003.

19. Cardiovascular pharmacology concepts by Richard E. Klabunde.

20. Loop Diuretics in Acute Decompensated Heart FailureNecessary? Evil? A Necessary Evil? G. Michael Felker, MD, MHS; Christopher M. O'Connor, MD; Eugene Braunwald, MD; for the Heart Failure Clinical Research Network Investigators.

21. Ann Pharmacother. 2009 Nov;43(11):1836-47. doi: 10.1345/aph.1M177. Epub 2009 Oct 20.A comprehensive review of the loop diuretics: should furosemide be first line? Wargo KA, Banta WM.

22. A review of critical differences among loop, thiazide, and thiazide like diuretics.Bokyung Min and C. Michael White.Hospital Pharmacy vol 44, no 2, pp129 – 149, 2009.

23. Thiazide and Thiazide-Like Diuretics: Perspectives on Individualization of Drug and Dose Based on Therapeutic Index. Hypertension. 2012;59:1089-1090, published online before print April 30 2012, AHA journals.

24. HorisbergerJ-D, GiebischG: Potassium-SparingDiuretics. Renal Physiol 1987;10:198-220 (DOI: 10.1159/0001 73130)

25. Modulation of systemic inflammatory response after cardiac surgery. Review paper by Shahzad G Raja, Gilles D Dreyfus.

26. Historical perspective in cardiology by William S. Stoney. Circulation Journal of AHA, 2009;119:2844-2853

27. . Fundamentals of the past: cardioplegia: the first period revisited by Sigurd Gunnes and Per Jynge.

28. What is the Role of Different Cardioplegic Solutions in thePerioperative Immune Response During Cardiac Surgery?Wolfgang Lante, MD; Axel Franke, MD; ChristianWeinhold, MD; AndreasMarkewitz, MD; The Journal of The International Perfusion Association 2008.

29. Geissler, HansJ., Mehlhorn, Uwe. Cold crystalloid cardioplegia MMCTS 2006:1040.

30. HensleyFA, MartinDE, GravleeGP. APractical Approach to Cardiac Anesthesia, 4th.Ed Philadelpia: Lippincott Williams & Wilkins ,2008:

31.Kaplan,JA.EssentialsofCardiacAnesthesia,1sted.Philadelphia:SaundersElsevier,2008:

32. Cardiopulmonary Bypass : principles and practice by JOHN F. BUTTERWORTH and RICHARD C. PRIELIPP

33. Severe electrolyte disorders following cardiac surgery: a prospective controlled observational study by Kees H Polderman and Armand RJ Girbes

34. The challenges of hyperkalemia on cardiopulmonary bypass by Derman Ozdemir and Richard Chan. NSUH-Long Island University School of Cardiovascular Perfusion.

35 Patrick JSivpragasam S. The prediction of postoperative potassium excretion after cardiopulmonary bypass. J Thorac Cardiovasc Surg 1977;73:559–562.

36. Moffitt EA, White RD, Molnar GD, et al. Comparative effects of whole blood, hemodiluted, and clear priming solutions on myocardial and body metabolism in man. Can J Surg 1971;14:382–391.

37. Munday KA, Blane GF, Chin EF, et al. Plasma electrolyte changes in hypothermia. Thorax 1958;13:334–342.

38. Lim M, Linton RABand DM. Rise in plasma potassium during rewarming in open-heart surgery [letter]. Lancet 1983;1:241–242.

39. Glycemic control during coronary artery bypass graft surgery . Review article by Harold L.Lazar in International Scholarly Research Network. Vol 2012.

40. Weber DOYarnoz MD. Hyperkalemia complicating cardiopulmonary bypass: analysis of risk factors. Ann Thorac Surg 1982;34:439–445.

41. Bethune DWMcKay R. Paradoxical changes in serum-potassium during cardiopulmonary bypass in association with non-cardioselective beta blockade [letter]. Lancet 1978;2:380.

42. Henney RP, Riemenschneider TA, DeLand EC, et al. Prevention of hypokalemic cardiac arrhythmias associated with cardiopulmonary bypass and hemodilution. Surg Forum 1970;21:145–147.

43. Manning SH, Angaran DM, Arom KV, et al. Intermittent intravenous potassium therapy in cardiopulmonary bypass patients. Clin Pharmacol 1982;1:234–238.

44. Role of potassium currents in cardiac arrhythmias by Ursula Ravens and Elisabetta Cerbai. Europace(2008) 10,1133-1137

45. Schwartz AJ, Conahan TJ III, Jobes DR, et al. . Peripheral vascular response to potassium administration during cardiopulmonary bypass. J Thorac Cardiovasc Surg 1980;79:237–240.

46. Practical issues in calculating sample size for prevalence studies. L.Naing, T.Winn, B.N Rusli. Archives of Orofacial sciences 2006; 1: 9-14

47. Statistical analysis of correlated data using generalized estimating equations: an orientation. By James A. Hanley etal. American journal of epidemiology vol. 157,No.4.

48. J Thorac Cardiovasc Surg. 1977 Feb;73(2):212-5. Potassium replacement during cardiopulmonary bypass. Babka R, Pifarré R.

49. Indian J Med Res. 1990 Dec;92:433-9 Potassium homeostasis during & after cardiopulmonary bypass.Bhatt SB, Jayalakshmi TS, Dash HH, Raghavan SV, Bithal PK, Kale SC.

50. Anaesthesist. 1977 Apr;26(4):184-6.The serum potassium level during and after cardio-pulmonary bypass in children: a comparative study of the effects of the preoperative administration of digitalis and diuretics .Saidi M, Nadjmabadi M, Tarbiat S

ANNEXURES

PROFORMA FOR STUDY ON POTASSIUM CHANGES:

NAME:

AGE: SEX: HOSPITAL NO: WT:

SURGERY:

PREOPERATIVE:

MEDICATIONS: 1. DURATION: 1.

2. 2.

3. 3.

INVESTIGATIONS: HB:

Na: K: Ca:

S.CREATININE:

INTRAOPERATIVE:

INV	BASELINE	ON BYPASS	BEFORE COMING OUT	OFF BYPASS	POST OP
HB					
PH					
HCO3					
BE					
Na/K					

CARDIOPLEGIA DOSAGE AND TIMINGS:

1. @

2. @

3. @

BLOOD AND PRODUCTS GIVEN IF ANY:

GLUCOSE-INSULIN INFUSION IF ANY: INTRAOP:

POST OP:

POTASSIUM CORRECTION IF ANY: INTRA OP:

POST OP:

INV POST OP: DAY 1 DAY 2

S.CREATININE:

UREA:

CONSENT FORM

PERIOPERATIVE SERUM POTASSIUM CHANGES IN PATIENTS UNDERGOING OPENHEART SURGERY UNDER CARDIOPULMONARY BYPASS:A COMPARATIVE STUDY BETWEEN TWO GROUP OF PATIENTS - ONE GROUP ON LONG TERM DIURETIS AND THE OTHER GROUP NOT ON DIURETICS.

I, ____Hospital No:________________

do hereby give my consent/ I give consent for my __________________ (relation), Name______________________ Hospital No ______________________to be enrolled in the study titled "Perioperative serum potassium changes in patients undergoing openheart surgery under cardiopulmonary bypass:A comparative study between two group of patents- one group on long term diuretics and the other group not on diuretics'.

I have been given a copy of the Patient Information Sheet in a language that I understand. The study protocol has been explained to me and I have been given adequate time to ask questions and they have been answered to my satisfaction. [ ]

I make this decision to be enrolled in this study freely, of my own volition, and without any external influence, coercion, or incentive. [ ]

I understand that refusal to enroll in this study will not affect the standard of care provided to me, and that I can withdraw myself from the study anytime. [ ]

By agreeing to be enrolled in this study, I give my consent for the following:

I understand that no extra blood other than that for the routine test will be drawn for the purpose of the study. [ ]

I understand that all usual standards of care will be followed during the study. [ ]

I will not receive any financial returns for taking part in this study, whether in terms of actual cash, or as a reduction in the hospital bill. [ ]

Signature ___________________ ___________________

(Study Participant) (Witness) (Relation to Participant)

Investigator: _____________________________ **Date:**

PATIENT INFORMATION SHEET

Perioperative serum potassium changes in patients undergoing openheart surgery under cardiopulmonary bypass:A comparative study between two group of patients.-One group on long term diuretics and the other group not on diuretics.

Normal potassium level in the blood is important for the optimal functioning of the heart.Potassium level in the blood in patients undergoing openheart surgery is affected by different parameters like inadequate dietry intake,preoperative use of diuretics and the use of potassium rich fluid during the surgery.Diuretics excrete potassium also along with water in the urine.This will cause low serum potassium levels affecting normal cardiac function.

This study helps in the following way

By doing this study we will come to know whether the potassium levels reduce significantly in patients who are taking long term diuretics in the preoperative period and to know whether this will affect the function of heart in patients on diuretics.

How are you involved in this study?

If you consent to participate in this study,the results of the blood tests done on you will be used to analyze the effects of diuretics.No extra tests or extra blood will be used other than that which is used routinely.

There is no additional cost to you from this study.