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RESEARCH

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Role of blood urea nitrogen to creatinine ratio in the assessment of hypovolemia who have undergone major surgeries-a cross-sectional study

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Abstract

Background Major surgeries are being carried for certain ailments. Surgeries can be major or minor depending on the extent of intervention. Major surgeries are prone to cause lots of complications such as shock, haemorrhage, wound infection, deep vein thrombosis, pulmonary complications, organ rejection, reactions to anaesthetics etc. Early identification of complications could reduce morbidity and mortality. Laboratory variables used in the assessment of hypovolemia include blood urea nitrogen, sodium, osmolality, hematocrit, and arterial blood gas. This study was undertaken to assess the utility of blood urea nitrogen: creatinine ratio (BCR) in the utility of assessment of hypovolemia in the first post-operative day in individuals who had major surgeries.

Methods and materials The retrospective cross-sectional study included participants from the Departments of Orthopedic Surgery, Obstetrics and Gynecology, General Surgery and Cardiothoracic Surgery. Patients who underwent major surgeries between January 2019 and January 2020 were included**.** Study participants of 30 to 60 years of both genders were recruited into the study. Data were collected from the Medical Records of a tertiary care hospital in Chennai, India. Ethics approval was obtained, the institutional ethics committee (Ref: CSP/21/SEP/99/479 dated 30–12-2021). Waiver of consent was obtained since the patients were treated and discharged from the hospital. The data were analyzed by SPSS version 16. P value ≤ 0.05 was taken to be significant.

Results BCR showed statistically significant difference across the groups with $P = 0.02$. BCR showed statistically significant difference between cardiac patients with total knee replacement and total abdominal hysterectomy surgeries. BCR showed positive correlation with age, fluids intake and negative correlation with pulse rate and respiratory rate.

Conclusion BCR is a simple diagnostic tool for identifying hypovolemia in individuals who undergo major surgeries especially in the first postoperative day. It is significantly altered across the groups with highest value in individuals who have undergone knee replacement surgeries. BCR has high specificity and positive predictive value.

Keywords BCR, BUN: creatinine ratio, Hypovolemia, Major surgeries, Urea: creatinine ratio

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Background

Human beings are subjected to surgical interventions for certain health disorders. Surgeries can be major or minor depending on the extent of intervention. Across globe, approximately 310 million major surgeries are being carried out yearly. Among this, up to 4% of them result in death due to surgery related complications, 15% develop morbidity, less than 15% of them revisit the hospital for management of certain postoperative complications [1]. Number of deaths is approximately eight million which is similar to death from non-communicable diseases and accidents [1]. Approximately 180 lakh surgeries were out in India during the period 2019–20; out of which 48,51,788 were major surgeries [2]. Management of preventable as well as early identification of complications could reduce morbidity and mortality. Guidelines to identify postoperative complications as well as management of them is not uniform across various countries. Thus, there is no consensus in identifying the complications at the earliest so that appropriate management strategies can be implemented faster.

Poor perioperative and postoperative fluid management is one of the causes for poor outcomes in individuals who undergo surgical procedures especially major ones [3]. There is no obvious link between major surgery morbidity and mortality to hypovolemia (pre- or post-operative). The more reliable feature of identifying hypovolemia is decreased urine output as an indicator of hypoperfusion. Laboratory variables used in the assessment of the cause and the magnitude of hypovolemia include blood urea nitrogen (BUN), sodium, hematocrit, osmolality and arterial blood gas. The simplest and fastest means is by measurement of arterial blood pressure. Also, cardiac filling pressures, intrathoracic blood volume index and passive leg raise can be used [4]. This study was conducted to assess the utility of BUN: creatinine ratio in the assessment of hypovolemia in the first post-operative day in individuals who had major surgeries.

Methods and materials

The retrospective cross-sectional study included participants from the Departments of Orthopedic Surgery, Obstetrics and Gynecology, General Surgery and Cardiothoracic Surgery. The study was conducted in the Department of Biochemistry. Patients who underwent major surgeries between January 2019 and January 2020 were included. Study participants of 30 to 60 years of both genders were recruited into the study. These were the patients who had major surgeries such as abdominal, obstetric and gynecologic, lung, heart, orthopedic and brain surgeries between January 2019 and January 2020. Based on the study by Lin et al., 2012, with an odds ratio of 0.443 [5], calculated sample size was 208, and 210 patients were included in the study. Heart failure was diagnosed based on Framingham criteria; liver cirrhosis or severe liver dysfunction (alanine aminotransferase (ALT) or aspartate aminotransferase (AST) above three times the upper reference limit), known case of renal disease or admission serum creatinine more than 2 mg/dL, initial systolic blood pressure of lower than 90 mmHg, fever with core body temperature more than 38 °C, patients on diuretics, aggressive hydration or blood transfusion, anticancer and anti-inflammatory drugs were excluded from the study.

Data collection

Information regarding vital parameters, renal profile, and serum electrolytes were retrieved from the patients' files in the Medical Records Department of a tertiary care hospital in Chennai, South India. Data also included details of surgical procedure, quantity of fluids administered, quantity of blood loss during the surgical procedure, and the duration of the procedure.

Statistical analysis

On compiling the data, further data analysis was using SPSS version 16. Categorical variables were expressed as frequency and percentages. Continuous variables were expressed as mean and standard deviation (SD). Chi-square was used to compare categorical variables. One way Analysis of variance (ANOVA) and Tukey post-hoc tests were done to compare continuous variables between the groups. P value ≤ 0.05 was considered as statistically significant.

Results

The study participants of 210 in number were grouped into four as Group A: total knee replacement (TKR) ($n=56$), group B: cholecystectomy/ hernioplasty ($n=38$), group C: total abdominal hysterectomy (TAH) with or without bilateral salpingo-oophrectomy (BSO) ($n=91$), and group D: coronary artery bypass graft (CABG) ($n=25$). Among knee surgeries, 66% were total knee replacement, 10.7% were knee reconstruction and 16.1% were ACL reconstruction surgeries. Among laparotomies 86.8% has undergone cholecystectomy; among gynecology surgeries 83.6% have undergone total abdominal hysterectomy with bilateral salpingo-oophorectomy. (Table 1).

The demographic and fluid status of the study participants is shown in Table 2. The age group of participants across the four groups was statistically significant ($P<0.001$). Highest in group D (CABG) of 54.56 years followed by group A (Knee surgeries) of 49.88 years. There was significant difference in the distribution of genders across the groups ($P<0.001$). In groups A, B,

Table 1 Shows the type of surgeries under each group of participants

Groups	Type of Surgery	No of cases *n* (%)
A (*n* = 56)	Hip decompression	1 (1.8%)
	Hip Cemented Bipolar hemiarthroplasty	1 (1.8%)
	Distal Fibula Reconstruction	1 (1.8%)
	TKR	37 (66.0%)
	Knee Reconstruction	6 (10.7%)
	ACL Reconstruction	9 (16.1%)
	Proximal Tibia Replacement	1 (1.8%)
B (*n* = 38)	Hernioplasty Cholecystectomy	4 (10.5%)
	Appendicectomy, Cholecystectomy	1 (2.7%)
	Cholecystectomy	33 (86.8%)
C (*n* = 91)	TAH + BSO	76 (83.5%)
	TAH	5 (5.5%)
	VH + PFR	6 (6.6%)
	VH + BSO	1 (1.1%)
	VH	3 (3.3%)
D (*n* = 25)	CABG	25 (100%)

TKR Total knee replacement, *ACL* Anterior cruciate ligament, *TAH* Total abdominal hysterectomy, *BSO* Bilateral salpingo- oophorectomy, *VH* Vaginal hysterectomy, *PFR* Pelvic floor repair, *CABG* Coronary artery bypass graft. Values are expressed as frequency and percentage

C and D were 62%, 45%, 100% and 20% were females respectively. The fluids received was significantly higher in group C which was 1811 mL while in groups A and B were almost the same. There was statistically significant difference across the groups with regard to fluids intake ($P < 0.001$). There was maximum fluid output in group C of 885 mL with statistically significant difference across the groups ($P = 0.03$). Blood loss was maximum in group C (TAH with BSO) of 510 mL while it was almost the same in the other three groups of around 320 mL with statistically significant difference across the groups ($P < 0.001$). The time taken for doing the surgery is maximum in group C of 144.56 min while it was 140.53 min in group B with statistically significant across the groups ($P = 0.01$). Pulse rate was maximum in group C of 84.37 rates/min with statistically significant different across the groups ($P < 0.001$). This is in parallel to time taken for the surgery and the blood loss during the surgery. Systolic blood pressure was maximum of 130 mmHg in group A with statistically significant difference across the groups ($P = 0.04$). There was no statistically significant difference across the groups in diastolic blood pressure, pulse pressure and respiratory rate with $P = 0.09$, $P = 0.31$ and $P = 0.51$ respectively. Mean arterial pressure is maximum in group A of 98.12 mmHg with statistically significant across the groups ($P = 0.04$). (Table 2).

There was statistically significant difference with regard to age among the groups except between the groups B (cholecystectomy) and C (TAH with BSO). With regard to fluid intake, there was statistically significant difference among the groups except between the groups A and B. There was no statistically significant difference among the groups with regard to fluids output. When compared among the groups there were no statistically significant differences in blood loss when group A was compared with groups B as well as group D. The time taken for the surgery showed statistically significant difference between groups A and C ($P = 0.001$). (Table 2).

Table 3 shows the biochemical characteristics of the study participants among the four groups. There was statistically significant alteration in levels of serum blood urea nitrogen (BUN) across the groups ($P = 0.05$). BUN was maximum in group A compared to other groups. Also, serum urea was significantly different across the groups ($P = 0.04$). Serum creatinine showed statistically significant difference across the groups, with highest level in group D (CABG) ($P = 0.001$). BCR and urea: creatinine ratios showed statistically significant difference across the groups with $P = 0.02$ and $P = 0.001$ respectively. eGFR showed statistically significant difference across the groups ($P < 0.001$). Serum sodium showed statistically significant value across the groups ($P = 0.02$). Serum sodium was the highest in group B and with the lowest in group D. Serum chloride was the highest in group C while it was the lowest in group D. There was statistically significant difference across the groups ($P = 0.001$). (Table 3).

There was statistically significant difference between groups A and C in both BUN and urea ($P = 0.04$) and ($P = 0.05$) respectively. When serum creatinine was compared among the groups group C showed statistically significant difference with groups A, B and D. Both BCR and urea: creatinine ratio showed statistically significant differences when group D was compared with either group A or group C. eGFR showed statistically significant difference when group A was compared with groups B and C, as well as when group D was compared with B and C. Serum sodium showed statistically significant difference when group B was compared with groups A and C. Serum chloride showed statistically significant difference when group D was compared with groups A and C. (Table 3).

Discussion

Major surgeries include surgeries involving head, chest and abdomen such as organ transplant, removal of tumor or damaged organ, open heart surgery, laparotomy, caesarean section, cholecystectomy, joint replacement, hysterectomy, bariatric surgeries etc. A minor surgical procedure does not penetrate or expose a body cavity [1, 2]. Complications of major surgeries include shock,

Table 2 Shows the demographic and fluid status of study participants

Variables	Overall (*n* = 210)	Group A (*n* = 56)	Group B (*n* = 38)	Group C (*n* = 91)	Group D (*n* = 25)	*p* value
Age (years)	**47.52 ± 7.61**	**49.88 ± 8.40**	**45.32 ± 8.79**	**45.07 ± 5.10**	**54.56 ± 5.59**	**< 0.001****
Significance between groups: p1 = 0.01*, p2 = 0.001**, p3 = 0.03*, p4 = 0.90, p5 = 0.001**, p6 = 0.001*						
Male *n* (%)[a]	62 (30%)	21 (38%)	21 (55%)	0 (0%)	20 (80%)	**< 0.001****
Female *n* (%)[a]	148 (70%)	35 (62%)	17 (45%)	91 (100%)	5 (20%)	
Fluids intake (mL)	1527.91 ± 658.16	1422.77 ± 638.02	1442.89 ± 833.99	1811.81 ± 494.07	859.20 ± 207.34	**< 0.001****
Significance between groups: p1 = 0.99, p2 = 0.01*, p3 < 0.001**, p4 = 0.02*, p5 < 0.001**, p6 < 0.001*						
Fluids output except blood (mL)	779.31 ± 520.97	766.25 ± 713.21	659.47 ± 660.57	885.55 ± 324.76	604.0 ± 177.9	**0.03***
Significance between groups: p1 = 0.77, p2 = 0.71, p3 = 0.47, p4 = 0.18, p5 = 0.96, p6 = 0.06						
Blood loss (mL)	407.36 ± 208.85	321.88 ± 188.43	333.82 ± 185.72	510.93 ± 209.23	333.60 ± 95.82	**< 0.001****
Significance between groups: p1 = 0.99, p2 = 0.04*, p3 = 0.24, p4 = 0.83, p5 = 0.90, p6 = 0.90						
Time taken (min)	138.71 ± 27.98	128.84 ± 27.27	140.53 ± 41.97	144.56 ± 23.02	136.80 ± 6.75	**0.01***
Significance between groups: p1 = 0.81, p2 < 0.001**, p3 = 0.61, p4 = 0/86, p5-0.90, p6 = 0.58						
Pulse rate /min (BPM)	79.50 ± 16.61	79.73 ± 11.85	78.63 ± 17.50	84.37 ± 6.59	62.56 ± 32.49	**< 0.001****
Significance between groups: p1 = 0..90, p2 = 0.28, p3 = 0.001**, p4 = 0.21, p5 = 0.001**, p6 = 0.001*						
SBP (mmHg)	125.55 ± 13.96	130.09 ± 16.75	123.32 ± 12.31	124.18 ± 13.00	123.80 ± 10.92	**0.04***
Significance between groups: p1 = 0.09, p2 = 0.06, p3 = 0.23, p4 = 0.90, p5 = 0.90, p6 = 0.90						
DBP (mmHg)	79.71 ± 8.89	82.14 ± 9.67	77.89 ± 7.32	78.90 ± 9.00	80.00 ± 8.17	0.09
Pulse pressure (mmHg)	45.84 ± 10.39	47.95 ± 13.81	45.42 ± 9.50	45.27 ± 9.23	43.80 ± 5.26	0.31
Mean arterial pressure (mmHg)	94.99 ± 9.68	98.13 ± 10.65	93.04 ± 8.14	93.99 ± 9.56	94.60 ± 8.84	**0.04***
Significance between groups: p1 = 0.06, p2 = 0.06, p3 = 0.42, p4 = 0.90, p5 = 0.90, p6 = 0.90						
Respiratory rate (breaths/min)	14.9 ± 1.34	14.88 ± 1.85	14.89 ± 1.41	14.82 ± 0.89	15.28 ± 1.28	0.51

BPM Beats per minute, *SBP* Systolic blood pressure, *DBP* Diastolic blood pressure

Values are expressed as mean ± SD, [a]: expressed as frequency and percentage; ANOVA was used to compare the groups; P vale: *: significant, **: highly significant

p: *p* value for comparing between the studied groups

p1: *p* value for comparing between Group A and Group B

p2: *p* value for comparing between Group A and Group C

p3: *p* value for comparing between Group A and Group D

p4: *p* value for comparing between Group B and Group C

p5: *p* value for comparing between Group B and Group D

p6: *p* value for comparing between Group C and Group D

haemorrhage, wound infection, deep vein thrombosis, pulmonary complications, organ rejection, reactions to anaesthetics etc. All these complications can prolong hospital stay, change in treatment regimen, increased expenditure leading to morbidity and mortality [3].

In the present study, among knee surgeries, most of them had total knee replacement, among laparotomies, cholecystectomy was the most common surgery, among gynecology surgeries more than 80% had undergone total abdominal hysterectomy with bilateral salpingo-oophorectomy (Table 1). The age group of participants across the four groups is statistically significant ($P < 0.001$). Highest in CABG of 54.56 years followed by patients who underwent knee surgeries. There was statistically significant difference among the groups except between the groups B (cholecystectomy) and C (TAH with BSO) (Table 2). There was significant difference in the distribution of genders across the groups ($P < 0.001$) (Table 1).

The human body consists around 70% water; water have a major role in maintenance of temperature and electrolyte levels [6]. Normally the intake of water in the body is balanced by the output from the body. When more fluids are taken into the body it can lead to over hydration which could manifest as headache, nausea, and even convulsions. On the contrary, when the intake of fluids is lesser than the required quantity it leads to dehydration; manifesting as headache, renal stones, impaired function of kidney, gastrointestinal tract and cardiovascular system. Insufficient water in the brain can lead to impaired cognition [6]. In hypovolemia, extracellular fluid (ECF) level decreases due to loss of sodium and water. ECF volume should be restored back to normal to maintain homeostasis in the individual. ECF is readily measured by arterial blood pressure. Symptoms of decreased ECF volume or hypovolemia include easy fatiguability, malaise, muscle

Table 3 Shows biochemical characteristics of study participants

Variables	Overall (*n* = 210)	Group A (*n* = 56)	Group B (*n* = 38)	Group C (*n* = 91)	Group D (*n* = 25)	*p* value
BUN (mg/dL)	**10.19 ± 3.71**	**11.30 ± 3.88**	**10.21 ± 4.11**	**9.64 ± 3.35**	**9.64 ± 3.58**	**0.049***
Significance between groups: p1 = 0.49, p2 = 0.04, p3 = 0.24, p4 = 0.83, p5 = 0.90, p6 = 0.90*						
Urea (mg/dL)	**21.75 ± 7.98**	**24.19 ± 8.30**	**21.85 ± 8.79**	**20.73 ± 6.95**	**19.80 ± 8.63**	**0.04***
Significance between groups: p1 = 0.49, p2 = 0.05, p3 = 0.10, p4 = 0.87, p5 = 0.72, p6 = 0.90*						
Creatinine (mg/dL)	**0.71 ± 0.19**	**0.76 ± 0.23**	**0.74 ± 0.2**	**0.64 ± 0.11**	**0.82 ± 0.18**	**0.001****
*Significance between groups' p1 = 0.90, p2 = 0.001**, p3 = 0.52, p4 = 0.02*, p5 = 0.34, p6 = 0.001***						
BUN: creatinine ratio	**14.62 ± 4.95**	**15.35 ± 5.0**	**14.01 ± 4.93**	**15.16 ± 4.95**	**11.97 ± 4.0**	**0.02***
Significance between groups: p1 = 0.55, p2 = 0.90, p3 = 0.02, p4 = 0.60, p5 = 0.36, p6 = 0.02**						
Urea: creatinine ratio	**31.23 ± 10.64**	**32.85 ± 10.70**	**29.97 ± 10.55**	**32.63 ± 10.23**	**24.42 ± 9.80**	**0.001****
Significance between groups: *p1 = 0.54, p2 = 0.90, p3 = 0.001**, p4 = 0.54, p5 = 0.16, p6 = 0.001***						
eGFR (mL/mt)	**105.21 ± 15.18**	**100.33 ± 19.49**	**109.07 ± 14.24**	**108.72 ± 10.35**	**97.52 ± 15.30**	**< 0.001****
Significance between groups: p1 = 0.02, p2 = 0.005**, p3 = 0.83, p4 = 0.90, p5 = 0.012*, p6 = 0.004***						
Serum Sodium (mmol/L	**137.33 ± 8.46**	**138.57 ± 3.86**	**133.45 ± 17.02**	**137.93 ± 2.84**	**138.24 ± 9.10**	**0.02***
Significance between groups: *p1 = 0.02*, p2 = 0.090, p3 = 0.90, p4 = 0.03*, p5 = 0.12, p6 = 0.90*						
Serum Chloride (mmol/L)	**10.77 ± 7.73**	**104.52 ± 5.35**	**102.24 ± 4.04**	**105.18 ± 3.34**	**99.32 ± 18.85**	**0.001****
Significance between groups: p1 = 0.48, p2 = 0.90, p3 = 0.02*, p4 = 0.18, p5 = 0.44, p6 = 0.001**						

BUN Blood urea nitrogen, *eGFR* Estimated glomerular filtration rate

Data are expressed as mean ± SD; ANOVA was used to compare the groups; *P* vale: *: significant, **: highly significant

p: *p* value for comparing between the studied groups

p1: *p* value for comparing between Group A and Group B

p2: *p* value for comparing between Group A and Group C

p3: *p* value for comparing between Group A and Group D

p4: *p* value for comparing between Group B and Group C

p5: *p* value for comparing between Group B and Group D

p6: *p* value for comparing between Group C and Group D

cramps, thirst and dizziness. On examination, the individuals are found to have dry skin and mucous membranes, loss of skin turgor, and orthostatic hypotension. If untreated can lead to shock, decreasing alertness and intrinsic renal disease [7].

During major surgeries, fluid loss can occur during surgery as well as in the postoperative period to such an extent that hypovolemia can occur. This leads to inadequate tissue perfusion and impairment of effective cellular function. To handle hypovolemia, it is better to infuse fluids alone or with extracellular fluid volume expanders [8]. Fluid can be lost via bleeding, fluid loss through drainage tubes, vomiting, urination, loss through insensible water and third spaces. This is exacerbated by already dehydrated state of the patient due to avoidance of oral intake, and the vasodilatory effect of various drugs administered during surgery or immediate postoperative period. Due to hypovolemia, the oxygen supply to the organ decreases which delays wound healing. Excessive hydration is not acceptable since it causes edema, delayed collagen regeneration and wound healing. Studies are being done to find the association between the volume of fluids administered and the mortality of the patient during surgery. It has been found that mortality is higher when fluid administration is inappropriate [9].

During major surgeries, maintaining adequate hydration is mandatory to get good outcomes of the surgery. This ensures that tissue perfusion is maintained which facilitates adequate and prompt wound healing. Due attention should be given to fluid balance in the individual and based on the extracellular fluid status, quantity and type of fluid to be given is to decided. During and immediately after major surgical procedures, adequate fluid maintenance leads to better recovery of the patient. Effective administration of fluids reduces the morbidity and shortens hospital care and fastens recovery [10]. Maintaining adequate hydration is a real challenge in the peri- and post-operative period. Fluid status maintenance is not generalized and it is not the same for all the individuals; it varies with age, gender, muscle mass and various other factors. Withholding of fluids for few hours prior to the surgery, causes preoperative hypovolemia and this may predispose to hypotension during induction of anesthesia [11]. According to Jacob et al., overnight fasting of ten to 12 h do not alter the blood pressure as measured prior to the surgery [12, 13]. As per Miller et al., it is better to have limited fasting period to avoid preoperative hypovolemia [14]. Patients may be allowed to continue to take oral liquids especially water even up to few hours before major surgeries. Gastrointestinal tract surgeries involve huge preoperative preparation which causes major fluid loss from the system. Other factors which favor fluid loss include inflammatory conditions like bowel obstruction or pancreatitis, ongoing bleeding, coagulopathy, abdominal insufflation during laparoscopy, ventilatory support, long hours of surgery with exposed open operative sites [15]. It is found that fluid losses are lesser from surgeries which are lesser invasive than major ones [16]. Also, patients can be encouraged to drink clear fluids early in the post-operative period [14].

In the present study, fluids intake received was significantly higher in hysterectomy patients compared to other groups. There was statistically significant difference across the groups with regard to fluids intake ($P<0.001$). And there was statistically significant difference among the groups except between the groups A and B. There was maximum fluid output in hysterectomy patients with statistically significant difference across the groups. However, there was no statistically significant difference among the groups with regard to fluids output. Blood loss was maximum in group C (TAH with BSO) of 510 mL while it was almost the same in the other three groups with statistically significant difference across the groups ($P<0.001$). When compared among the groups there were no statistically significant differences when group A was compared with groups B as well as group D. The time taken for the surgery was maximum for hysterectomy surgeries of 144.56 min while it was 140.53 min in group B with statistically significant across the groups ($P=0.01$). This was proportionate to the amount of blood loss in group C individuals. There was statistically significant difference between groups A and C ($P=0.001$). Pulse rate was maximum in group C of 84.37 rates/min with statistically significant different across the groups ($P<0.001$). This is in parallel to time taken for the surgery and the blood loss during the surgery. Systolic blood pressure was maximum of 130 mmHg in group A with statistically significant difference across the groups ($P=0.04$). There was no statistically significant difference across the groups in diastolic blood pressure, pulse pressure and respiratory rate with $P=0.09$, $P=0.31$ and $P=0.51$ respectively. Mean arterial pressure is maximum in group A of 98.12 mmHg which was statistically significant across the groups ($P=0.04$) (Table 2). There is statistically significant increase in systolic and diastolic blood pressures when individuals are supplied with only 75% of normal water intake for three days [6].

Hypovolemia leads to decreased stroke volume of the heart resulting in impaired circulation to the various organs; if timely interference is not implemented leads to multiorgan failure [17]. Monitoring of hydration status in patients who have undergone major surgeries: frequent vital signs- pulse and respiratory rates, blood pressure, daily weight, strict input and output charts, including drain and nasogastric losses. Changes in haematological and urine parameters, and bioelectrical impedance. Measurement of central venous pressure (CVP) is an indicator of preload to the heart. CVP is a measure of circulatory volume particularly in intensive care settings. The extracellular fluid (ECF) volume status of an individual is considered to be normal if CVP is 8 -12 mmHg. CVP decreases only when ECF volume decreases by more than 10%. [18]. Assessing hydration status always by clinical examination may not always be appropriate, especially in doubtful borderline cases laboratory examination test results are required [19].

In the present study, there was statistically significant alteration in levels of serum blood urea nitrogen (BUN) across the groups ($P=0.05$). BUN was maximum in group A compared to other groups. Also, serum urea was significantly different across the groups. There was statistically significant difference between groups A and C in both BUN and urea. Serum creatinine showed statistically significant difference across the groups, with highest level in group D (CABG). This could probably that CABG patients would have had associated comorbidities which could result in high serum creatinine levels compared to others. Also, these people were at the highest age group compared to other groups, which indicated that age related changes could have occurred in the kidneys. When serum creatinine was compared among the groups group C showed statistically significant difference with groups A, B and D (Table 3).

Since 1940, utility of blood urea nitrogen (BUN) to creatinine ratio (BCR) has been in practice to assess the cause of acute kidney injury (AKI) whether it is of prerenal or renal origin [20]. This is sensitive marker of prerenal AKI indicating hypoperfusion of kidneys. In these conditions, hypovolemia causes avid reabsorption of urea from proximal convoluted tubule, but there is no alteration of creatinine in the kidneys, net result being increased BCR [21]. In 1939 Fishberg observed that there is an earlier disproportionate increase in urea compared to creatinine; this is highly evident even before the increase in serum creatine values. [22]. In normal individuals, taking the normal biological reference interval of blood urea nitrogen and serum creatinine into consideration, blood urea nitrogen to creatinine ratio (BCR) can be 15:1. In conditions with prerenal failure, BUN increases disproportionately to that of serum creatinine resulting in much higher ratios [23]. BCR has high specificity and positive predictive value. In individuals with gastrointestinal bleeding, BCR is much higher than that in other organs. Bleeding in the upper gastro-intestinal tract (GIT) causes a much higher BCR (>35) compared to bleeding in lower GIT [24]. Since most of the patients with heart failure (HF) have decreased renal perfusion, BCR will be higher in these individuals. Further increase in BCR indicates that these individuals are at high risk of progression of kidney disease with poor outcomes [25].

In the present study, BCR and urea: creatinine ratios showed statistically significant difference across the groups. eGFR showed statistically significant difference across the groups ($P<0.001$). Both BCR and urea: creatinine ratio showed statistically significant difference when group D was compared with groups A and C. But, the statistically significant P value was much higher for urea: creatinine ratio than with BCR that is $P=0.02$ versus $P=0.001$. eGFR showed statistically significant difference when group A was compared with groups B and C, as well as when group D was compared with B and C (Table 3). BCR was compared with other variables. BCR showed positive correlation with age ($r=0.14$), fluids intake ($r=0.157$) and eGFR ($r=0.175$) and negative correlation with pulse rate ($r=-0.119$) and respiratory rate ($r=-0.167$). There was no statistically significance. (Table not shown).

In the present study, serum sodium showed statistically significant value across the groups ($P=0.02$). Serum sodium was the highest in group B and with the lowest in group D. Serum chloride was the highest in group C while it was the lowest in group D. There was statistically significant difference across the groups ($P=0.001$). Serum sodium showed statistically significant difference when group B was compared with groups A and C. Serum chloride showed statistically significant difference when group D was compared with groups A and C (Table 3). There is no statistically significant change in serum sodium and chloride when individuals are on 75% of normal water intake for three days. (25) Sodium and its anions constitute the major contributing to measurement of extracellular fluid volume (ECFV). Fractional excretion of sodium is useful when plasma sodium concentration is abnormal [26]. When there is considerable decrease in fluid intake, urine osmolality is found to be more than 900 mOsm/kg [27]. Also, specific gravity of urine increases and deepened urine color, which can be semi quantitatively measured by urine dipsticks [28].

When there is dehydration with loss of water from any route, the blood constituents get concentrated resulting in raised blood cell counts especially red blood cells, hemoglobin, sodium and osmolality. During this process, there is a shift of fluids between intracellular and extracellular compartments according to the level of serum osmolality. This redistribution of water takes with and without external sources of fluids. The sources of fluids can be through parenteral or oral administration. When there is unattended long-standing dehydration, during initial administration of fluids there may be persistent shift of fluids between the various compartments with resultant inadequate management of dehydration [29].

Bioelectrical impedance analysis (BIA) is being tried in assessing the constituents of various body compartments. It is reliable, reproducible, non-invasive and cost-effective. Various radiological methods which include computerized tomography (CT), magnetic resonance imaging (MRI) and dual-energy X-ray absorptiometry (DEXA) can be used. BIA estimates impedance, which is calculated from the sum of resistance and reactance. It includes body with and without excess fat, so that individuals with under- and over-nutrition states will be taken into consideration. The fat composition could influence the hydration status as well as the outcome of the major surgeries [10]. Also, BIA is influenced by various factors requiring standardization of these techniques. Hence, its applicability into routine diagnosis is not possible [30].

Limitations

All the major surgeries were not included in the study. Comparison of biomarkers on the first postoperative day with the complications and duration of hospital stay was not done. It is better to measure the markers during surgery and continue till the variables reach the preoperative levels. Implementing markers which can identify at the earliest stage of hypovolemia could not done.

Conclusion

The BUN: creatinine ratio (BCR) is a simple and diagnostic tool for identifying hypovolemia in individuals who undergo major surgeries especially in the first postoperative day. It is significantly altered across the groups with highest value in individuals who have undergone knee replacement surgeries. In conditions of decreased perfusion to kidneys with normal functioning of tubules, the rate of increase in BUN levels is much higher and faster compared to that of serum creatinine concentration, with resultant increase in BCR. Increase in urea content of the blood is much earlier than the creatinine values. BCR has high specificity and positive predictive value. Serum sodium and chloride were significantly altered across the groups. Systolic blood pressure was significantly altered across the groups whereas diastolic blood pressure did not show any significant change.

Abbreviations

ACL	Anterior cruciate ligament
AKI	Acute kidney injury
ANOVA	Analysis of variance

BCR	Blood urea nitrogen: creatinine ratio
BIA	Bioelectrical impedance analysis
BPM	Beats per minute
BSO	Bilateral salpingo- oophorectomy
BUN	Blood urea nitrogen
CABG	Coronary artery bypass graft
CT	Computerized tomography
CVP	Central Venous Pressure
DBP	Diastolic blood pressure
DEXA	Dual-energy X-ray absorptiometry
ECF	Extracellular fluid
ECFV	Extracellular fluid volume
eGFR	Estimated glomerular filtration rate
GIT	Gastrointestinal tract
HF	Heart failure
MRI	Magnetic resonance imaging
PFR	Pelvic floor repair
SBP	Systolic blood pressure
SD	Standard deviation
TAH	Total abdominal hysterectomy
TKR	Total knee replacement
VH	Vaginal hysterectomy

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Availability of data and materials
Data is available with the corresponding author and the same will be shared with the readers on a reasonable request through email.

Declarations

Ethics approval and consent to participate
The institutional ethics committee (Ref: CSP/21/SEP/99/479 dated 30–12-2021) had given approval to conduct the study. Waiver of consent was obtained since the patients were treated and discharged from the hospital.

Consent for publication
Not applicable.

Competing interests
The authors declare that there were no competing interests.

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