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Original Research Article

PHYSIOLOGICAL ASSESSMENT OF ELECTROLYTE IMBALANCE AND ACID-BASE DISTURBANCES DURING GENERAL ANAESTHESIA IN CASES UNDERGOING ELECTIVE SURGERIES AT A TERTIARY CARE CENTER

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ABSTRACT

Background: Electrolyte and acid-base disturbances are common during general anaesthesia due to the physiological changes induced by anaesthetic agents, surgical stress, and intraoperative fluid management. Early detection and correction are critical to reducing perioperative morbidity. This study was designed to assess intraoperative changes in electrolyte levels and acid-base status among patients undergoing elective surgeries under general anaesthesia and correlate findings with clinical variables.

Materials and Methods: This prospective observational study was conducted at a tertiary care center on 100 adult patients undergoing elective non-cardiac surgery under general anaesthesia. Pre-induction and intraoperative arterial blood gas (ABG) and serum electrolytes were assessed. Changes in pH, $PaCO_2$, HCO_3^-, Na^+, K^+, Cl^-, and Ca^{2+} were analysed. Descriptive statistics and paired t-tests were used to determine significance ($p < 0.05$) by using SPSS v26.0.

Results: Significant changes were observed in acid-base status and electrolytes. Metabolic acidosis was noted in 24% and respiratory acidosis in 18% of cases. Serum potassium showed a statistically significant intraoperative decrease (mean pre operative 4.21±0.36 mmol/L vs post-op 3.91±0.42 mmol/L; $p < 0.001$). Mild hyponatremia occurred in 30% and hypercalcemia in 22%. Use of large volumes of normal saline correlated with hyperchloremia and non-anion gap metabolic acidosis.

Conclusion: General anaesthesia in elective surgeries is associated with notable disturbances in electrolytes and acid-base balance, especially potassium and chloride levels. Intraoperative ABG and electrolyte monitoring are essential to mitigate risk and guide fluid-electrolyte therapy.

Keywords: General anaesthesia, Acid-base imbalance, Electrolyte disturbance, ABG, Hypokalaemia, Hyperchloremia, Elective surgery.

INTRODUCTION

The maintenance of electrolyte balance and acid base homeostasis is critical for optimal physiological function during surgery. General anaesthesia induces complex physiological alterations, affecting cardiovascular, respiratory, renal, and metabolic systems, which can predispose patients to electrolyte imbalances and acid base disturbances.[1,2] These changes arise from a combination of factors, including anaesthetic agents, fluid therapy, surgical stress, mechanical ventilation, and blood loss.[3] Even subtle deviations in electrolyte concentrations or arterial pH can impair cellular metabolism, neuromuscular function, and organ perfusion, leading to adverse perioperative outcomes.[4]

Common perioperative electrolyte derangements include hyponatremia, hypernatremia, hypokalemia, hyperkalemia, and alterations in calcium and magnesium levels.[5] Intraoperative administration of crystalloids or colloids, especially large volumes of 0.9% sodium chloride, may cause hyperchloremic metabolic acidosis by increasing plasma chloride concentration and reducing strong ion difference.[6]

Conversely, the use of balanced salt solutions may mitigate some acid–base changes but can still lead to dilutional electrolyte shifts.[7] Anaesthetic drugs such as propofol, volatile agents, and opioids can also influence electrolyte distribution and acid–base equilibrium by altering ventilation, cardiac output, and renal function.[8]

Acid–base disturbances in the perioperative period are most commonly metabolic acidosis, metabolic alkalosis, and respiratory alkalosis or acidosis.[9] The Stewart approach and Henderson–Hasselbalch equation are widely used to interpret these alterations, with attention to arterial blood gas (ABG) parameters, bicarbonate concentration, base excess, and partial pressures of oxygen and carbon dioxide.[10,11] Rapid detection and correction of these abnormalities are essential to prevent complications such as arrhythmias, impaired myocardial contractility, decreased vascular tone, and delayed recovery from anaesthesia.[12]

Elective surgical patients often receive preoperative fasting, bowel preparation, or diuretics, which may further predispose them to pre-existing imbalances before induction of anaesthesia.[13] Intraoperative monitoring of ABG and serum electrolytes can guide timely intervention, particularly in high-risk groups such as the elderly, those with cardiovascular disease, or those undergoing prolonged procedures.[14]

Despite extensive literature on perioperative fluid management and anaesthesia-related physiological changes, there is limited comprehensive evaluation of simultaneous electrolyte and acid–base shifts during general anaesthesia in routine elective surgeries at tertiary care centres. This study aims to assess these changes systematically, providing insight into their incidence, patterns, and clinical significance, which could contribute to optimizing perioperative care and patient safety.

MATERIALS AND METHODS

This prospective observational study was conducted in the Department of Physiology at RVM Institute of Medical Sciences and Research Center from June 2024 to May 2025. A total of 100 cases undergoing elective non-cardiac surgeries under general anaesthesia between 18 to 65 years of age, belonged to ASA grade I and grade II and willing to participate were included. Cases with chronic renal disease, diabetes mellitus, adrenal insufficiency, use of diuretics, use of steroids, cases allotted to emergency surgeries and not willing to participate were excluded. Written informed consent was obtained from each participant and study protocol was approved by the institutional ethics committee.

All participants underwent a comprehensive preoperative assessment including demographic information, ASA grade, and baseline laboratory investigations. A pre-induction arterial blood sample was collected to measure ABG parameters such as pH, $PaCO_2$, PaO_2, HCO_3^-, base excess (BE), and anion gap and serum electrolytes including sodium (Na^+), potassium (K^+), chloride (Cl^-), and calcium (Ca^{2+}). A standardized anesthesia protocol was used for all the cases and intraoperative fluid management was recorded. A second set of arterial blood and serum samples was obtained either 90 minutes post-induction or immediately before tracheal extubation, whichever occurred first. These were analysed for ABG parameters and serum electrolyte levels, identical to the pre-induction assessments.

Data entry and analysis were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD); categorical variables were reported as frequencies and percentages. Paired t-tests assessed changes between pre-induction and intraoperative values. Chi-square test (or Fisher's exact test, as appropriate) examined associations between fluid type/volume and electrolyte or acid–base disturbances. Pearson's correlation coefficient (r) was calculated to assess relationships between fluid volumes and changes in chloride levels or base excess. A p-value < 0.05 was considered statistically significant.

RESULTS

Table 1: Demographic Profile

Demographic variable	Value
Age (In years)	41.2 ± 13.5
Gender	
Male	58 (58%)
Female	42 (42%)
ASA status	
Grade I	61 (61%)
Grade II	39 (39%)
BMI (kg/m²)	24.8 ± 2.9
Mean surgery duration	128 ± 36 minutes
Type of surgery	
Abdominal	42 (42%)
Orthopaedic	18 (18%)
Urology	16 (16%)
ENT	24 (24%)

Table 2: Pre-induction vs Intraoperative electrolyte levels.

Electrolyte	Pre-op Mean ± SD	Post-op Mean ± SD	Mean Diff.	95% CI	p-value
Sodium (Na^+), mmol/L	137.8 ± 3.6	135.9 ± 4.1	-1.9 mmol/L	-3.4 to -0.4	0.012
Potassium (K^+), mmol/L	4.21 ± 0.36	3.91 ± 0.42	-0.30 mmol/L	-0.41 to -0.19	0.001
Calcium (Ca^{2+}), mmol/L	2.16 ± 0.13	2.02 ± 0.14	-0.14 mmol/L	-0.26 to -0.02	0.015
Chloride (Cl^-), mmol/L	102.3 ± 2.9	104.7 ± 3.2	-2.4 mmol/L	-0.8 to -4.0	0.004

Table 3: Details of acid base parameters.

Parameter	Pre-operative (Mean ± SD)	Post-operative (Mean ± SD)	Mean Diff.	95% CI	p-value
pH	7.38 ± 0.03	7.33 ± 0.05	-0.05	-0.07 to -0.03	0.001
$PaCO_2$ (mmHg)	39.6 ± 3.8	44.2 ± 4.2	+4.6 mmHg	+3.0 to +6.2	0.001
HCO_3^- (mmol/L)	24.1 ± 2.3	21.6 ± 2.7	-2.5 mmol/L	-3.9 to -1.1	0.002
Base excess (mEq/L)	0.8 ± 1.1	2.9 ± 1.5	-2.1 mEq/L	-3.0 to -1.2	0.001
Anion gap (mmol/L)	11.2 ± 1.6	10.8 ± 1.9	-	-	NS

Table 4: Pearsons correlation between intraoperative parameters.

Parameters	Pearson r	Interpretation
Cl^- vs HCO_3^-	−0.49*	Moderate negative correlation
Cl^- vs BE	−0.51*	Moderate negative correlation
K^+ vs HCO_3^-	+0.42*	Moderate positive correlation
K^+ vs BE	+0.40*	Moderate positive correlation
Na^+ vs Cl^-	−0.25	Weak negative correlation
Na^+ vs K^+	+0.18	Weak positive correlation
HCO_3^- vs BE	+0.72*	Strong positive correlation

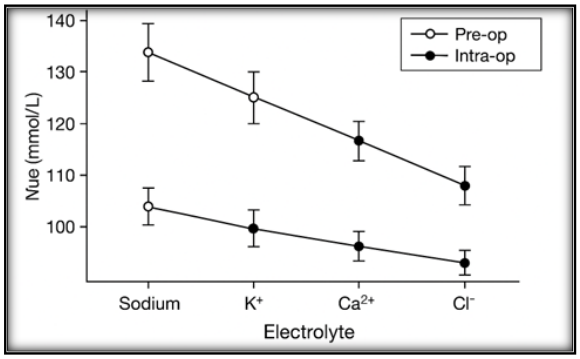

Figure 1: Mean pre and intra operative electrolyte levels.

DISCUSSION

Intraoperative electrolyte and acid base disturbances remain a critical consideration in anaesthesia practice, with implications for perioperative morbidity and mortality. This prospective observational study of 100 adult patients undergoing elective non-cardiac surgery under general anaesthesia provides important insights into perioperative electrolyte and acid base dynamics. We observed significant intraoperative changes characterized by a reduction in serum potassium (mean -0.30 mmol/L), as well as decreases in sodium and calcium levels. In contrast, chloride levels rose (+2.4 mmol/L). Acid base disturbances were frequent: mixed metabolic and respiratory acidosis--predominantly of the non-anion gap (hyperchloraemic) variety--was apparent, with a significant post-operative fall in pH (-0.05), rise in $PaCO_2$ (+4.6 mmHg), and drop in HCO_3^- (-2.5 mmol/L). Correlation analyses revealed that chloride increases were negatively associated with both HCO_3^- and base excess, while potassium correlated positively with these parameters, underscoring linked physiological mechanisms rather than isolated fluctuations. This highlights significant perioperative shifts in sodium, potassium, calcium, chloride, and key acid base parameters, corroborating findings from earlier anaesthesia physiology research.[6,7]

We observed a mean sodium decrease of 1.9 mmol/L ($p = 0.012$), aligning with previous reports of mild dilutional hyponatremia from perioperative fluid administration.[13] Potassium reduction (−0.30 mmol/L, $p = 0.001$) likely reflects intracellular shift due to alkalinising effects of ventilation and β-adrenergic responses, consistent with findings by Morgan et al.[1] Calcium decline (−0.14 mmol/L, $p = 0.015$) supports the concept of citrate-binding from transfusion products and hypoalbuminemia effects.[14]

Chloride showed a statistically significant rise (+2.4 mmol/L, $p = 0.004$), correlating inversely with bicarbonate and base excess. This hyperchloremic trend is well documented with normal saline infusions and is associated with metabolic acidosis risk.[15] Our moderate-to-strong correlations between Cl^- and HCO_3^-/BE reinforce the Stewart approach to acid–base balance.[16] Acid base analysis demonstrated a mean pH fall of −0.05 ($p = 0.001$) and an increase in $PaCO_2$ (+4.6 mmHg, $p = 0.001$), reflecting mild respiratory acidosis during anaesthesia. This is in line with reports by Dubin et al., who emphasised the impact of controlled ventilation strategies.[9] The bicarbonate drop (-2.5 mmol/L, p=0.002) and base excess reduction point to combined respiratory and metabolic contributions.

Cihoric M et al. conducted a study on 354 patients undergoing emergency high-risk abdominal surgery to evaluate the prevalence and clinical impact of perioperative electrolyte disturbances. They reported

that preoperative hypochloremia and hypokalemia were more common in patients with intestinal obstruction (34% vs. 20% and 37% vs. 25%, respectively), while hyponatremia was highly prevalent in both intestinal obstruction and peritonitis/vascular groups. Both pre- and postoperative hypochloremia were independently associated with increased 30-day postoperative morbidity and mortality in intestinal obstruction cases (OR = 2.87, 95% CI 1.35–6.23, p = 0.006 and OR = 6.86, 95% CI 1.71–32.2, p = 0.009, respectively). Furthermore, hypochloremic patients had significantly reduced long-term survival compared with those who were normochloremic or hyperchloremic ($p < 0.05$). In contrast, no significant association between plasma sodium or potassium levels and patient outcomes was observed.[17]

While the changes were generally within physiological tolerance, the patterns observed underscore the importance of vigilant intraoperative monitoring and judicious fluid/ventilation management. The findings reinforce earlier calls for balanced crystalloid use, tailored ventilation, and perioperative biochemical surveillance.[8,12] This study has limitations in terms of total calcium measurements rather than ionized calcium measurement and magnesium and phosphate were not assessed. In addition, postoperative clinical outcome was not correlated with intraoperative biochemical shifts, though these physiologic changes may be clinically meaningful.

CONCLUSION

This study reinforces the physiologic vulnerability of surgical patients to electrolyte and acid-base disturbances under general anaesthesia, particularly highlighting hypokalaemia and hyperchloraemic metabolic acidosis as common and interrelated phenomena. Vigilant intraoperative monitoring and judicious anaesthetic fluid choices can help mitigate these disturbances and potentially improve perioperative safety and outcomes.

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