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Elemental Profile of Postoperative Infected Wound Exudates in Hospitalized Surgical Patients: A Cross-Sectional Study at People's Medical College Hospital, Nawabshah

Altaf Hussain Ghumro[1], Inayat Ali Zarzadari[1], Agha Asad Noor[1], Aftab Ahmed Kandhro[2], Shabana Khaskheli[3]

[1]*Institute of Microbiology, University of Sindh, Jamshoro, Pakistan*
[2]*Dr. M. A. Kazi Institute of Chemistry University of Sindh, Jamshoro, Pakistan*
[3]*Suleman Roshan College of Nursing and Midwifery, Tandoadam, Pakistan*

ABSTRACT

Background: Pyogenic infections following surgery are important contributors to post-surgical morbidity and may be related to surgical site and biochemical properties of wound exudates. Pus elemental profiling can give information on the wound microenvironment which can direct individual clinical interventions.

Methods: The study design was analytical cross-sectional with 370 consecutive patients (aged 15-80 years) who had infected postoperative wounds in Peoples Medical College Hospital, Nawabshah, Pakistan, between June 2023 and July 2025. Six gastrointestinal surgical sites were aseptically collected pus/wound-exudates. In the wet digestion, sodium, potassium, magnesium, calcium, zinc, copper and chromium were measured in triplicate by inductively coupled plasma optical emission spectrometry. One-way analysis of variance and independent student's *t*-test were used to test the differences by surgical site and age, respectively, and by sex.

Results: The sample comprised 181 males (48.92%) and 189 females (51.08%); 115 patients (31.08%) were aged 61–80 years. Concentrations differed among surgical sites for sodium (p=0.002), magnesium (p=0.001), zinc (p=0.002), copper (p=0.003), and chromium (p=0.004), but not potassium (p=0.104) or calcium (p=0.103). Gut-cancer exudates showed the highest sodium (140.00±7.30 mmol/L), copper (24.00±1.65 µmol/L), and chromium (14.50±1.30 µmol/L). All seven elements were found to be different among the age groups (p=0.001–0.003), all elements except potassium were different by sex.

Conclusion: The work highlights the increased level of sodium, calcium, copper and chromium in the samples of the gut cancer and increased magnesium and zinc in the exudates from the colon and stomach. Significant higher contents of sodium, calcium, copper and chromium are in exudates of females while in males, magnesium and zinc are higher. Sodium, potassium, copper and zinc levels are higher in 61-80 years age group than in other age groups.

Keywords: *Elemental; Exudative; Infection; Metal; Surgical; Wound.*

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INTRODUCTION

Postoperative pyogenic infections, otherwise known as surgical site infections (surgical site infections are still one of the most common complications after surgery and continue to be a worldwide problem in healthcare. They play a significant role in extended hospital stay, increased use of antimicrobial, and in morbidity and mortality. Recent studies indicate that most surgical site infections are primarily due to endogenous flora of the skin and not contamination from the environment, thus demonstrating the interplay between the host biology and surgical trauma in the mechanism of infection[1,2]. Despite the use of improved aseptic techniques and perioperative care, surgical site infections continue to occur at clinically significant rates, especially in resource poor healthcare environments.

In low and middle income countries, the impact of surgical site infections is greater and is associated with a higher proportion of patients presenting late, poor perioperative infection control practices and poor monitoring infrastructure for the postoperative period[3]. In addition, several risk factors have been demonstrated to affect the incidence of surgical site infection and clinical outcomes, such as surgical site, patient comorbidities, and demographic factors like age and gender[4]. Emergency and abdominal surgery also have been reported to have increased rates of infection, likely because of increased exposure to microbes and contamination of the tissues during surgery, especially gastrointestinal surgery[5]. Existing studies however have been mainly microbiological in nature, and limited exploration of the biochemical environment of infected wounds.

Recent studies have shown a key role for the biochemical composition of wound exudates in addition to microbial load in wound healing and progression of infection. Electrolytes and trace elements such as sodium, potassium, magnesium, calcium, zinc, copper, and chromium are integral to the inflammatory regulation, modulation of oxidant stress, promotion of enzymatic activity, and tissue repair processes[6]. Elemental imbalance of these elements can modify immune reactions and slow wound healing and therefore elemental analysis of pus may be a more powerful tool for understanding wound pathophysiology than is conventional microbiological analysis[7].

Although there is increasing awareness of the role of trace elements in tissue repair, there is still a significant lack of literature that provides a comprehensive elemental profile of the pyogenic wound exudate of postoperative patients. Furthermore, few studies have considered demographic, anatomical and biochemical data together in an analytical model for infection heterogeneity. Thus, in the present study, elemental composition of pus samples from the various surgical sites were evaluated and the association between elemental composition of pus samples with patient's demographic was investigated, which will help to understand the biochemical profile of postoperative wound infections and inform future targeted therapeutic interventions[8,9].

Infection of the postoperative wound continues to be a leading cause of excess morbidity, unnecessary clinical interventions, prolonged hospital stays, delay in recovery, and unnecessary use of antimicrobials, especially in resource limited hospitals. While the identification of the causative organism and the choice of antimicrobial drug is important, microbiological culture alone does not account for all the potential biochemical milieu that is present locally when infection, inflammation, tissue injury, and repair occurs. The composition of postoperative wound exudates may have some elements of the wound microenvironment and can thus offer complementary information. Postoperative wound exudates include inflammatory cells, cellular debris, extracellular fluid, microbial products, electrolytes, and trace elements. Sodium, potassium, magnesium, calcium, zinc, copper, and chromium are involved in fluid and electrolyte balance, cell signaling, enzymatic function, immune function, oxidative stress management, coagulation, collagen formation, angiogenesis and tissue regeneration. The purpose of present study was to compare the elemental composition of pus samples from pyogenic infection following surgery in cases.

MATERIALS AND METHODS

Study Design and Reporting Guideline

This study is an analytical cross-sectional study which was conducted at Peoples Medical College Hospital, Nawabshah, Pakistan during the period of June 2023 to July 2025. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies were used for reporting[10]. Study Population Patients between the ages of 15 and 80 years with clinically infected postoperative wounds after clean or clean-contaminated elective/emergency surgery were the study population. Those that had been treated with a systemic antibiotic prior to the sample collection, who needed reoperation or had not given written informed consent were excluded. Surgical sites included small intestine, colon, duodenum, stomach, spleen and gut-cancer resection sites. Participants were approached sequentially until 370 participants were recruited, with 181 males and 189 females. The sample size and participant recruitment.

Sample Collection and the Recruitment of Participants

A minimum sample size for the estimation of a single population proportion was computed using

$$n = Z^2 p\,(1-p)/d^2,$$

Where Z = 1.96 for the 95% confidence level, p = 0.50 (no good estimate of p was available), and d = 0.0523. A size of 352 was initially estimated and to account for the possibility of non-response, 5% was added to this, providing a 370 sample size[11] with 415 patients being assessed during recruitment. Forty-five patients were excluded: 15 had been treated with systemic antibiotics prior to sampling, 11 required reoperation, and 19 refused to participate.

There were 370 participants in the final analysis (Figure 1). A non-probability sampling method, consecutive sampling was employed.

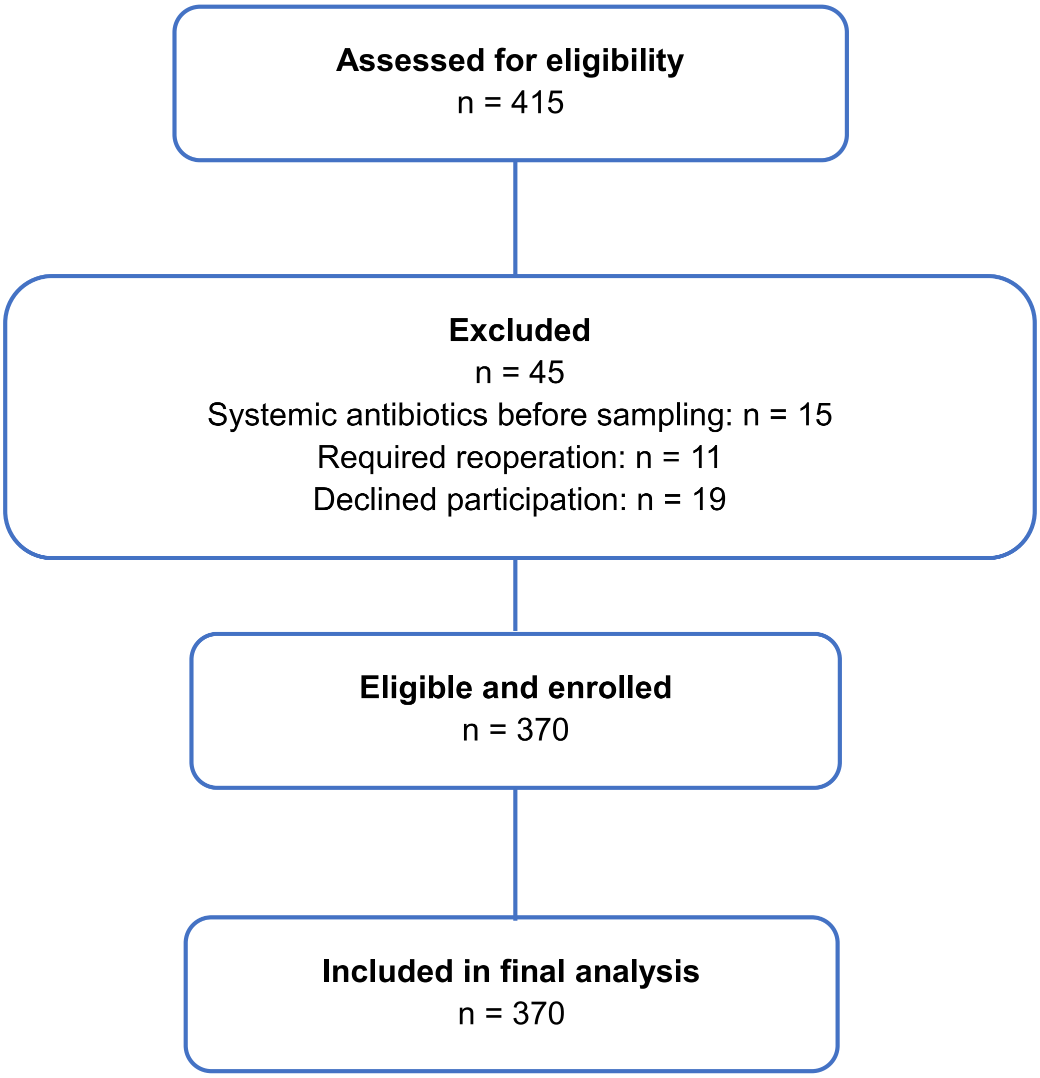

Figure 1. STROBE Flow diagram for selection of participants

Sample Collection

Specimens comprised pus/wound exudate collected directly from infected postoperative wounds, there was no blood or plasma collected for elemental analysis. Pus was aseptically taken with a sterile syringe or sterile swab suitable for the quantity and accessibility of the exudate and processed in accordance with standard biosafety precautions, using trace-element-free materials. Samples were transferred to the laboratory under 8ºC in vaccination ice box with 15 minutes. The procedures were standardized in order to limit contamination and measurement bias and were followed by all participants. The methods used in this lab were Wet Digestion and ICP-OES Elemental Analysis.

Elemental Analysis

All pus samples were homogenized. Sample preparation was done with some modifications of the method reported by Santos et al. in 2019[12]. About 0.25 g of homogenized pus sample was accurately weighed in a PTFE microwave digestion vessel, and 5 mL concentrated nitric acid (HNO_3, 65%) and 2 mL hydrogen peroxide (H_2O_2, 30%) were added to the vessel. The pre-digestion time was 15-20 minutes at room temperature and the microwave digestion took place for complete oxidation of organic matter, following a controlled temperature program (maximum temperature 180-200°C). The digested solutions were then quantitatively transferred to acid washed polypropylene tubes and diluted to 25 mL using ultrapure deionized water. Reagent blanks and quality control samples were run concurrently and the resulting solutions were analyzed in triplicate by inductively coupled plasma optical emission spectrometry (ICP-OES). Sodium, potassium, magnesium and calcium concentrations were reported in mmol/L; zinc, copper and chromium concentrations were reported in µmol/L.

Data Analysis

Categorical variables were summarized as frequencies and percentages, and elemental concentrations as mean ± standard deviation. Concentrations were compared among surgical sites and age groups using one-way analysis of variance, and among sexes using independent-samples Student t test. The level of significance was determined as $p<0.05$ for 95% confidence interval. All statistical analyses and graphical presentations were done in Microsoft Excel 2013.

RESULTS

In Figure 1 among 370 participants, 181 (48.92%) were male and 189 (51.08%) were female. The 61–80-year group was the largest (n=115, 31.08%), followed by 46–60 years (n=95, 25.68%), 31–45 years (n=90, 24.32%), and 15–30 years (n=70, 18.92%). The distribution of income was split into three groups, lower income (61.62%), middle income (35.68%) and upper income (2.70%) and 57.30% of the population were in the rural part of the country, while 42.70% were in the urban (Figure 2). These percentages reflect the study sample which was infected and are not to be interpreted as incidence or independent risk values as denominators for all operated patients were not available.

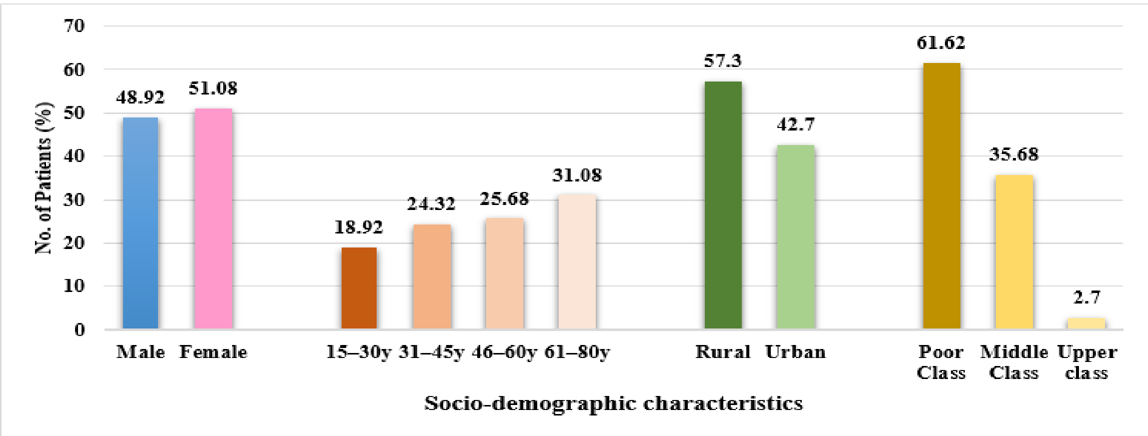

Figure 2. Socio-demographic characteristics of hospitalized patients with postoperative pyogenic infection

There were differences in elemental concentrations between the six surgical sites (Table 1). Significant between-site differences were observed for sodium (p=0.002), magnesium (p=0.001), zinc (p=0.002), copper (p=0.003), and chromium (p=0.004). No significant difference was found between Potassium (p=0.104) and calcium (p=0.103). Gut-cancer exudates had the highest mean sodium (140.00±7.30 mmol/L), magnesium (2.70±0.25 mmol/L), zinc (22.50±1.60 µmol/L), copper (24.00±1.65 µmol/L), and chromium (14.50±1.30 µmol/L).

Table 1. Elemental Profiling of pus samples recovered from Postoperative Pyogenic Infection from different Surgical Sites

Element	Small Intestine n=83 Mean±SD	Colon n = 51 Mean±SD	Duodenum n = 61 Mean±SD	Stomach n = 56 Mean±SD	Spleen n = 59 Mean±SD	Gut Cancer n = 60 Mean±SD	ANOVA p-value (<0.05)
Sodium (mmol/L)	128.50±5.20	135.30±6.80	122.00 ± 7.00	138.50±6.90	125.70 ± 7.10	140.00 ± 7.30	0.002
Potassium (mmol/L)	4.10 ± 0.20	4.55 ± 0.28	3.95 ± 0.27	4.65±0.26	4.00 ± 0.25	4.70 ± 0.28	0.104
Magnesium (mmol/L)	2.10 ± 0.15	2.50 ± 0.22	2.00 ± 0.21	2.60±0.23	2.05 ± 0.20	2.70 ± 0.25	0.001
Calcium (mmol/L)	2.05 ± 0.15	2.40 ± 0.25	2.00 ± 0.22	2.50±0.23	2.10 ± 0.20	2.55 ± 0.25	0.103
Zinc (µmol/L)	19.50 ±1.50	21.50 ± 1.55	18.50±1.50	22.00±1.55	19.00 ± 1.50	22.50 ± 1.60	0.002
Copper (µmol/L)	20.50 ±1.40	23.00 ± 1.60	19.50±1.55	23.50±1.55	21.00 ± 1.50	24.00 ± 1.65	0.003
Chromium (µmol/L)	12.50 ±1.20	14.00 ± 1.25	11. ±1.22	14.20±1.25	12.20 ± 1.20	14.50 ± 1.30	0.004

There was a significant difference (p<0.05) in sodium, magnesium, calcium, zinc, copper and chromium; however, there was no significant difference (p=0.41) between sexes for potassium (Table 2). Females had higher mean sodium (135.50±7.10 mmol/L), calcium (2.40±0.23 mmol/L), copper (23.50±1.65 µmol/L), and chromium (14.50±1.30 µmol/L). Males had higher magnesium (2.95±0.28 mmol/L) and zinc (22.00±1.55 µmol/L).

Table 2. Gender-wise Comparison of Elemental Concentrations in pus samples recovered from Postoperative Pyogenic Infection

Element	Male n =181 Mean ± SD	Female n = 189 Mean ± SD	p-value (<0.05)
Sodium (mmol/L)	130.50 ± 7.20	135.50 ± 7.10	0.028
Potassium (mmol/L)	4.25 ± 0.25	4.30 ± 0.28	0.41
Magnesium (mmol/L)	2.95 ± 0.28	2.70 ± 0.25	0.032
Calcium (mmol/L)	2.25 ± 0.22	2.40 ± 0.23	0.035
Zinc (µmol/L)	22.00 ± 1.55	21.00 ± 1.50	0.030
Copper (µmol/L)	22.00 ± 1.50	23.50 ± 1.65	0.029
Chromium (µmol/L)	13.80 ± 1.25	14.50 ± 1.30	0.031

The differences among the elemental concentrations were significant for all the age groups (p=0.001-0.003) (Table 3). The 61–80-year group had the highest sodium (140.00±7.30 mmol/L), potassium (5.20±0.30 mmol/L), zinc (24.00±1.70 µmol/L), copper (25.00±1.65 µmol/L), and chromium (14.80±1.30 µmol/L), while magnesium and calcium were highest in the 15–30-year group (3.60±0.25 and 2.60±0.25 mmol/L, respectively). These comparisons are unadjusted and attempt to control for the effect of age as an independent variable.

Table 3. Age-wise Comparison of Elemental Concentrations in Pus samples recovered from Postoperative Pyogenic Infection

Element	15–30 years (n=70) Mean ± SD	31–45 years (n=90) Mean ± SD	46–60 years (n=95) Mean ± SD	61–80 years (n=115) Mean ± SD	p-Value (<0.05)
Sodium (mmol/L)	128.50 ± 7.00	135.00 ± 7.50	130.50 ± 7.20	140.00 ± 7.30	0.001
Potassium (mmol/L)	4.15 ± 0.20	4.55 ± 0.25	4.80 ± 0.25	5.20 ± 0.30	0.002
Magnesium (mmol/L)	3.60 ± 0.25	2.50 ± 0.20	3.00 ± 0.22	2.10 ± 0.15	0.001
Calcium (mmol/L)	2.60 ± 0.25	2.40 ± 0.20	2.25 ± 0.20	2.05 ± 0.15	0.003
Zinc (µmol/L)	19.50 ± 1.50	21.00 ± 1.55	22.00 ± 1.55	24.00 ± 1.70	0.001
Copper (µmol/L)	20.50 ± 1.40	22.50 ± 1.50	23.00 ± 1.55	25.00 ± 1.65	0.002
Chromium (µmol/L)	12.50 ± 1.20	13.50 ± 1.25	14.00 ± 1.25	14.80 ± 1.30	0.003

DISCUSSION

Present study aimed to compare the elemental composition of pus samples obtained from pyogenic infections after surgical procedures in cases. The results indicated that the infected subjects were almost equally distributed between females (51.08%) and males (48.92%) as shown in Figure 1. Previous studies showed gender to have little effect on the incidence of surgical site infection.[13] A large German surveillance study found that the adjusted surgical site infection rates were greater for males in general, and for abdominal surgery, and greater for females after some cardiac and vascular surgery. These conflicting findings suggest that sex differences are procedure based and could be greatly influenced by clinical and perioperative rather than sex alone[11].

Older aged groups may be associated with a higher level of surgical activity and exposure, unlike to what was previously reported in regional hospital studies which showed younger and middle aged groups were reported to have postoperative infections.[14] The higher proportion of patients from rural areas may indicate well-known reasons between inadequate access to health care and inadequate postoperative care in rural areas, which has been linked to higher risk of infection in surgical patients[15]. However, in an observational study of elective laparotomy patients, there was no statistically significant relationship between age or sex with the risk of surgical site infectopn, whereas nutritional and perioperative factors were more significant. Thus the present age distribution should not be viewed as suggesting that the older patients were at greater risk of infection as the number of operated patients in each age group was not given, only the number of patients with infection[16].

The lower prevalence among urban residents on the other hand, may suggest better perioperative care and hygiene practice[17]. There was a socioeconomic difference, with higher infection rates in lower income patients. This trend may be due to poor nutrition status, lack of knowledge about postoperative care and inability to seek timely medical attention, all of which are recognized risk factors for surgical site infections[18,19]. Minimal involvement of the upper class highlights the importance of socioeconomic status for health outcomes after surgery, consistent with what other epidemiological studies have found[20]. Thus, the rural population and low income should be considered as population characteristics of the infected group and not as separate risk factors. Delayed presentation, transportation problems, nutrition, postoperative follow-up, and access to wound care are potential factors which are still plausible and should be investigated analytically[21].

The large differences in elemental concentrations in various surgical locations (in Table 1) indicate that the biochemistry of the wounds may be affected by both the tissue type and the surgical site. The significant high amounts of sodium, copper and chromium in the cancer of the gut and stomach wounds may be related to the high level of inflammation and metabolism in these tissues and the literature suggests that these elements have a crucial role in tissue repair, enzymatic activity and immune response[22,23]. These sites had relatively low concentrations of magnesium and zinc, and relatively high concentrations in colon and stomach wounds, which is consistent with previous studies indicating that these minerals play an important role in collagen synthesis and oxidative stress control during wound healing[24,25]. The uniformity observed in the site of calcium and potassium has suggested a regulation of potassium during the healing and infection process, which is consistent with the reported regulation of electrolyte in postoperative exudates[26].

The concept of a local biological environment varies between surgical sites, with recent genomic data demonstrating that endogenous microbes from the patient play a role in postoperative infections observed at each site. The present study does not provide direct support, however, the study investigated the origin of microorganisms rather than concentrations[27]. Cancer, malnutrition, contamination level and complexity of the operation have been identified as independent factors associated with surgical site infection following abdominal surgery, suggesting that the gut-cancer group may have differences in clinical characteristics from those undergoing non-cancer surgery. Therefore, it is important that the higher concentrations of the elements were not associated with the malignant tissue or anatomical site alone, but should be considered in the context of these factors[28]. In patients with burn, a significant amount of Zn and Cu have been found to be excreted in the wound exudate and there is also a reduction in the systemic Zn and Cu status. This is significant because, a high level of an element in wound fluid does not necessarily mean that the systemic nutritional status is adequate or that there is any redistribution or loss due to wound leakage. Therefore, the present findings are generalizable to the evidence that the exudate from a wound can contain clinically relevant amounts of trace elements but serum levels and nutritional status would be needed to ascertain whether the patients were deficient[29].

The higher concentrations of sodium, calcium, copper and chromium in females (Table 2) may be due to a gender difference in metabolism and/or inflammatory responses to the wounds. Whether the role of these elements in enzymatic function, modulation of oxidative stress and tissue repair is different between the sexes has been reported, and if so, it is one that may be specific to these functions[30,31]. On the other hand, magnesium and zinc were raised in males, which aligns with their known functions in collagen formation, immune regulation, and antioxidant protection in wound healing process[32,33]. There was no significant difference in potassium, which agrees with the results of other studies in which potassium was closely regulated in both sexes[34].

There are also conflicting results with regard to sex in the broader surgical site infection literature; some large surveillance studies have observed higher rates of surgical site infection in males following abdominal surgeries, while more comprehensive and detailed studies have controlled for obesity, malnutrition, cancer, operative time, contamination, and transfusion and reported no independent association with sex. This may therefore be due to the different distributions of age, type of surgery, malignancy, lactation status, nutritional status, renal function, intravenous fluid and comorbidities between male and female. They should be interpreted as a difference, rather than as evidence that biological sex directly affected the composition of wound-exudates[28].

The great age-dependent variation in elemental concentrations indicates that there may be physiological age changes affecting the biochemistry of wounds (Table 3). Increased levels of sodium and potassium could represent changes in fluid balance and cell homeostasis that occur during tissue repair as previously seen in recovery after surgery[35]. Higher levels of Cu and Zn in older groups might suggest greater demand for enzymes and/or oxidative stress in the course of chronic or complicated healing[34]. The levels of magnesium and calcium vary with age in middle aged patients, and is related to their function in enzymatic activity, collagen formation and inflammatory regulation, which varies with metabolic rates and nutrition status[36,37]. The age-related differences seen in the observed responses emphasize the need to take patient's age into consideration when assessing the potential for wound healing and when planning postoperative care, such as the use of trace elements as supplements[35,36]. Older age has been previously linked to this more directly, including obesity, malnutrition, malignancy, contamination, operative time, laparotomy, and blood transfusion. Data on the elemental findings related to age should, therefore, be treated as exploratory and should be confirmed by multivariable regression analysis if possible using age as a continuous variable[26]. Wound exudate elemental concentrations may be influenced by cellular breakdown, inflammatory cells, blood contamination, bacterial metabolism, local tissue composition, wound irrigation, dressings, and fluid movement.

Because of its cross-sectional design and its monocentric nature, it is not possible to determine the cause of the changes and the findings may not be generalizable. There are no non-infected postoperative-wound controls available, therefore a normal exudate elemental profile cannot be defined. However, serum or tissue elemental levels, nutritional status, renal function, and exposure to intravenous fluids, comorbidities, wound contamination class, and microbiological findings were not measured and therefore local exudate concentrations cannot be interpreted as systemic deficiency or associated to specific pathogens. The analyses were unadjusted; differences by surgical site, sex or age might be due to confounding. Control groups, as well as standardization of laboratory protocols, microbiological characterization and multivariable modelling should be incorporated in future multicenter studies.

CONCLUSION

Significant differences across surgical site were seen for Na, Mg, Zn, Cu and Cr, but not for K and Ca. Additionally, the differences between the sexes were determined, with the females having more sodium, calcium, copper, and chromium and the males having more magnesium and zinc. These results reflect biochemical variability of exudates from infected postoperative wounds, but do not prove causality or clinical value. Patient management should be guided by elemental profiling which needs to be validated in controlled, multicenter studies.

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Author Contributions

AHG: Conceived and designed the study, supervised the research, and contributed to manuscript drafting.
IAZ: Assisted in study design, data collection, and data analysis.
AAN: Contributed to the literature review, data interpretation, and manuscript preparation.
AAK: Assisted in data collection, data entry, and manuscript editing.
SK: Critically revised the manuscript, provided overall guidance, and approved the final version.

Funding Source

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Conflict of Interest

The authors declared no conflict of interest.

Data Availability

Data will be available on request.

Ethical Approval

The protocol was approved by the Institute of Microbiology University of Sindh, Jamshoro (Ref No. IMB/ 217 /2023).

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