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# Correlation of Intra Operative Renal Near-Infrared Spectroscopy with the Development of Acute Kidney Injury in Adult Patients Undergoing Cardiac Surgery Using Cardiopulmonary Bypass

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**ABSTRACT**

**Introduction:** The present study aimed to correlate renal oximetry near-infrared spectroscopy (NIRS) values with conventional non-invasive biomarkers for the early detection of acute kidney injury (AKI) in adult patients undergoing cardiac surgery using cardiopulmonary bypass (CPB). Accordingly, renal NIRS can be employed as a trending device for the prevention of AKI development.

**Materials and Methods**: After institutional ethical committee approval, a number of 132 adult patients undergoing cardiac surgery with CPB were selected by consecutive consenting sampling method. Emergency surgery and patients with preexistent renal insufficiency were excluded. NIRS sensor was applied on either the right or the left side of the spine at the lower border of L-1 before starting the induction. A renal regional oxygen saturation (rSO2) score was calculated after recording the renal oximetry values intra- and postoperatively. Urine output and serum creatinine were measured at 24, 48, and 72 hours postoperatively.

**Results**: Out of 132 patients, 22 cases (16.66 %) developed AKI according to Acute Kidney Injury Network (Akin) criteria± Risk, Injury, Failure, Loss, and End-stage kidney disease (RIFLE) classification. Among these AKI patients, three cases required dialysis, and one of these three patients died on the 21st day post surgery. Renal rSO2 scores in the AKI group were measured at 535 and 912 minutes %, in comparison to 162 and 184 minutes % reported in the non-AKI group which was statistically significant ($P< 0.05$).

**Conclusion:** As evidenced by the obtained results, there is a correlation between intraoperatively measured renal NIRS readings and the occurrence of AKI following adult cardiac surgery using CPB.

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## Introduction

Acute kidney injury (AKI) is a complex syndrome occurring in many situations manifested by various symptoms ranging from a small increase in serum creatinine (SCr) to an anuric renal insufficiency (1).

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AKI may develop in up to 41.3% of patients following cardiac surgery, and 9.6% of these patients may require dialysis, particularly those patients with preoperative renal dysfunction (2). Hospital mortality rate is close to 1% when there is no aggravation in renal function. Nonetheless, this rate may rise to around 20% at the presence of moderate alterations, and it may exceed 50% when dialysis is required (3-6). In previous years, there existed discrepancies and disagreement over the diagnosis and definition of acute renal failure (ARF); therefore, more defined classification systems have been developed. Today the two most common models include Risk, Injury, Failure, Loss of kidney function, and End-stage kidney disease (RIFLE) and Acute Kidney Injury Network (AKIN) models (7-9).

Cardiopulmonary bypass (CPB) is accepted to contribute to renal damage, total CPB time >140 min and mean perfusion pressure below 60 mmHg both increase the risk of developing acute renal failure. During CPB, macro and micro embolic insults to the kidney, the release of catecholamine's, and inflammatory mediators increase the renal vascular resistance and decrease the glomerular filtration rates resulting in AKI development. One possible way of manipulating and improving these factors is the use of pulsatile flow by per fusionists (10). Just as with hemolysis, a certain degree of renal injury is inevitable after CPB surgery. The resultant injury even in the mildest form is an independent variable predicting mortality (11).

Renal near-infrared spectroscopy (NIRS) can measure and monitor changes in Real-Time Regional Oxygen Saturation (rSO2). Its technology is based on different absorption of near-infrared wavelengths by oxygenated and deoxygenated haemoglobin. Since kidney performance is strongly linked to cardiac performance, any reduction in cardiac output can lead to AKI. NIRS-based cerebral oximetry has been validated for both pediatric and adult patients as distinguished from somatic monitoring where only pediatric randomized control trials have proven to be successful (12,13,14,15).

The present prospective case-control study aimed to correlate renal NIRS values with conventional non-invasive biomarkers for the early detection of AKI in adult patients undergoing cardiac surgery with CPB.

## Materials and Methods

### Study design

It is a prospective observational study. Before the commencement of the study, institutional ethical committee approval (Ref: IEC 85/18) was obtained and the research was registered in the clinical trial registry Of India (CTRI) (CTRI/2018/12/022843). Thereafter, a number of 132 adult patients undergoing cardiac surgery with CPB were selected by consecutive consenting sampling method. Patients underwent surgery within September 2018-December 2018 in the Department of Cardiovascular and Thoracic Surgery, Lokmanya Tilak Municipal Medical College and General Hospital, Sion, Mumbai. Exclusion criteria were emergency surgery and patient with preexistent renal insufficiency. It is worthy to note that written consent was obtained from all patients.

### Methodology

NIRS sensor was applied on either the right or the left side of the spine at the lower border of L-1 in the transpyloric plane near the crossing of renal hilum before starting the induction (16).A renal rSO2 score was calculated after recording the renal oximetry values intra- and postoperatively. This score has been established in studies on renal NIRS following cardiac surgery in infants; however, it has not been investigated in adults (17). It represents an area under the curve (AUC) measurement that reflects both the depth and duration of desaturations below the set thresholds. We adapted the score for long-term measurements by using minutes instead of seconds in the numerator which yields the following formula:

rSO2 score=(baseline rSO2-threshold rSO2 (%)) × time (minutes).

Baseline rSO2= renal rSO2 recorded prior to premedication was labeled as baseline renal oximetry (rSO2).

Threshold rSO2= the lowest rSO2 recorded, as compared to the baseline value

The following abbreviation for the three renal NIRS readings: rSO2-1-on CPB, rSO2-2-off CPB.

Other parameters to be measured included mean Arterial Pressure (MAP), UO (Urine Output), Lactate, Systemic venous saturation, Ionotropes, CPB time, and cross-clamp time. Moreover, postoperative parameters to be measured were UO, Serum Creatinine at 24, 48, and 72 h.

**Statistical analysis**

After data collection, data entry was performed in Microsoft Excel 2007. The data were analyzed in SPSS software (version16). Descriptive analysis for numerical data consisted of mean with standard deviation (SD), whereas analysis of categorical data included frequencies and percentages for various parameters. The following statistical tests of significance were used. Student's t-test for the comparison of the mean of the categorical variable with two categories. Mann- Whitney U test -if the variables do not have a normal distribution. A p-value less than 0.05 was considered statistically significant.

**Results**

Among 132 patients, 22 cases (16.66 %) developed AKI according to Acute Kidney Injury Network (Akin) criteria +/- Risk, Injury, Failure, Loss, and End-stage kidney disease (RIFLE) classification. Out of these 22 patients, three cases required dialysis, and one of these three patients died on the 21st day post surgery. There was a statistically significant difference between the two comparing groups regarding mean age: AKI group (64±10) and non-AKI group (45±12) and also the number of diabetic patients in each group (Table 1). Nevertheless, the incidence of AKI in different surgeries was not statistically significant (Table 2).

**Table-1** Demographic features and comorbidities in study population

| Clinical data | AKI* group | Non AKI group | P value |
|---|---|---|---|
| Age ( years ) | 64 ± 10 | 45 ± 12 | 0.04 |
| Male | 13 (59.09%) | 72 (65.45%) | 0.8 |
| Female | 9 (40.90%) | 38 (34.54%) | |
| Hypertension | 5 (22.72%) | 25 (22.72%) | 0.1 |
| Diabetes mellitus | 9 (40.90%) | 35 (31.81%) | 0.04 |

* Acute Kidney Injury (AKI)

**Table- 2** Different type of surgery in AKI and non AKI group

| Type of surgery | AKI group* | Non AKI group | P value |
|---|---|---|---|
| Valve replacement | 9 (40.90%) | 63 (57.27%) | 0.2 |
| CABG | 3 (13.63%) | 17 (15.45%) | 0.1 |
| Valve replacement+ CABG | 4 (18.18%) | 22 (20%) | 0.3 |
| Adult congenital | 1 (4.54%) | 5 (4.54%) | 0.09 |
| Other surgery | 1 (4.54%) | 3 (2.72%) | 0.07 |

* Acute Kidney Injury (AKI)

Out of 22 patients who developed AKI, stage I was reported in 12 patients, stage II in 6 patients, and stage III in 4 patients at, according to AKIN +/- RIFLE criteria. Mean urine output on days 1 in AKI group is 15.6 ml/kg and in non AKI group it is 53.4 ml/kg, the difference is statistically significant ( P = 0.0045). On day 2 urine output in AKI group 15.2 ml/kg and non AKI 51.2 ml/kg (P =0.0172), and on day3, it is 19.7 and 51.3 ml/kg respectively in AKI and non AKI group (P=0.0396). (Figure1).

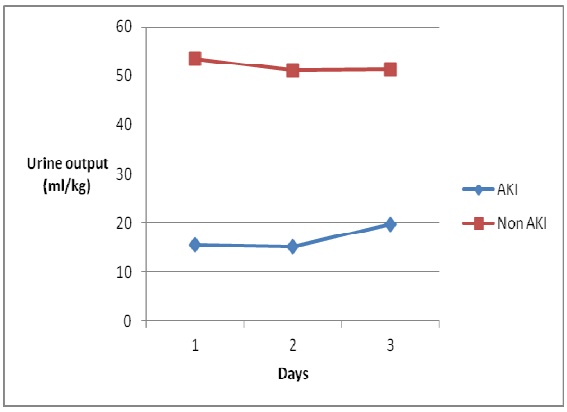


**Figure 1**: Urine output in postoperative period in AKI and non AKI group.

The course of mean serum creatinine in both groups and P value is displayed in Figure 2. The renal rSO2 during the intraoperative course showed significantly higher rSO2 scores (and therefore worse oxygenation values) in AKI patients, as compared to non-AKI patients. Renal rSO2-1 score was obtained at 535 (69 to 4564) min% in AKI group vs.162 (0 to1735) min% in the non-AKI group (P = 0.02). Moreover, the rSO2-2 score was measured at 912(70 to11273) min% in AKI group vs 184(0 to 2430) min% in the non-AKI group (P=0.009) (Figure 3)

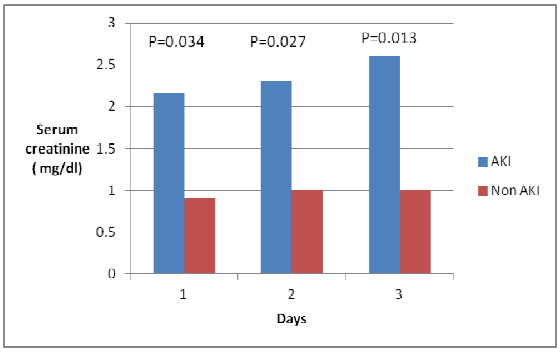


**Figure 2:** Course of serum creatinine levels in postoperative period in AKI and non AKI group

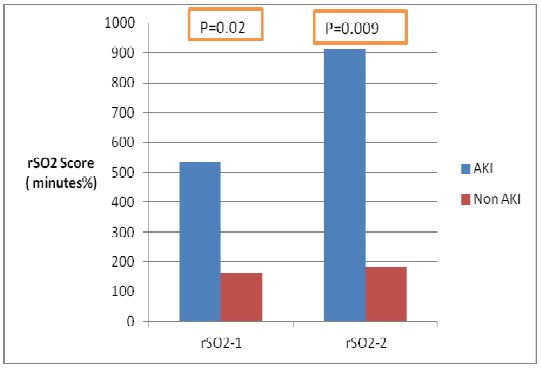


**Figure 3:** rSO2 score at different stages of surgery in AKI and non AKI group

Intra operative variables are illustrated in Table 3. There was no significant difference between CPB, cross-clamp time, and systemic venous saturation in two groups. Mean serum lactate was measured at 6.4mmol/L in the AKI group, as compared to 2.5 obtained in the non-AKI group (P=0.02). Mean arterial pressure was significantly lower in the AKI group (i.e., 52 mm of hg), in comparison to 63 in the non-AKI group (P=0.04). The need for in otropes (nor adrenaline>0.1mcg/kg/min) was detected more frequently in AKI patients (n=7), as compared to non-AKI cases (n=2) which was statistically significant (P= 0.01)

## Discussion

The main finding of the present study was the significant relationship between an intraoperatively-measured renal NIRS score and the postoperative occurrence of AKI in adult cardiac surgery with CPB. This finding is of great help in the prevention of AKI by the implantation of early intraoperatively measures. High rSO2 score during the transition on and off CPB in the AKI group was indicative of the decreased oxygenation of the kidney during that period which has been correlated with a rise in serum creatinine and a decrease in urine output in the postoperative period (Figures 1 & 2).Demographic features and comorbidity distribution between AKI and non-AKI groups has demonstrated that aging and diabetes mellitus are two risk factors for the development of AKI (Table 1).

| Intraop Variables | *AKI group | Non AKI group | P value |
|---|---|---|---|
| CPB time ( minutes) | 115 ± 2 | 80 ± 10 | 0.07 |
| Cross clamp time ( minutes ) | 70 ± 9 | 50 ± 6 | 0.05 |
| Lactate( mmol/L) | 6.4 ± 1.7 | 2.5 ± 0.7 | 0.02 |
| Systemic venous saturation | 59 ± 7 | 62 ± 6 | 0.2 |
| Ionotropes NA > 0.1 mics/kg/min | 7 (31.81%) | 2 (1.81%) | 0.01 |
| Mean arterial pressure ( mm of hg ) | 52 ± 8 | 63 ± 7 | 0.04 |

* Acute Kidney Injury (AKI)

CPB time and cross-clamp time were comparable in both groups suggesting that AKI and non-AKI groups were similar in terms of the surgery duration. In addition, the difference in serum lactate, the need for inotropes (noradrenaline>0.1 mics/kg/min) after coming off CPB, and mean arterial pressure were statistically significant in AKI and non-AKI groups. It indicates ongoing hypoxia which also correlates with our NIRS readings and the development of AKI in the postoperative period; nonetheless, mixed venous saturation was comparable in both groups.Bettina R et al. (12) investigated the correlation between renal NIRS readings and the development of AKI and found a statistically significant difference in rSO2 score in two groups. Neutrophil gelatinase-associated lipocalin (NGAL) in urine or plasma did not demonstrate a significant difference between AKI and non-AKI patients 2-4 and 24 h postoperatively. To the best of our knowledge, no study has been carried out on the effectiveness of renal oximetry in the detection of AKI in adults following cardiac surgery. In this regard, the current study demonstrated that renal NIRS can be reliably used for the early detection of AKI and the prevention of AKI- associated morbidity in postoperative period.

**Limitations**

Every study has some limitations which should be addressed in the paper. The major limitation of the present study was the non-use of other renal biomarkers, such as cystatin C and NGAL, to correlate with serum creatinine and renal NIRS value.

**Conclusion**

As evidenced by the obtained results, renal NIRS is a very effective tool for the early Detection of AKI in adult cardiac surgery with CPB. Moreover, it is recommended that further research be conducted to find new therapeutic measures to prevent the development of AKI following CPB.

**Conflicts of interest**

The authors declare that they have no conflict of interest regarding the publication of the current article.

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