Correlation of Pulse Oximetry with SOFA Scores for Evaluation of Tissue Perfusion in Emergency Surgery Patients

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ABSTRACT

Introduction - Worldwide, every year, millions of people require emergency abdominal surgeries, which are urgent and time-critical to treat high-mortality diseases. Post-operatively, patients require continuous monitoring of the vitals and early diagnosis of post-operative complications and management for suitable outcomes of the patient. Pulse oximetry is a noninvasive method of monitoring a person's oxygen saturation.

Physiologic compensatory mechanisms such as peripheral vasoconstriction limit the use of heart rate and blood pressure measurement as indicators for mild central tissue hypoperfusion and hypoxia in early settings. Hypotension is a late marker of hypoperfusion and almost 30% of circulatory volume may be lost before hypotension occurs. Therefore, early recognition of tissue hypoperfusion and hypoxia before the onset of tachycardia or hypotension is of prime importance in the prevention of hypoperfusion and hypoxia-induced organ failure.

AIM - Serial correlation between SpO_2, perfusion index and SOFA score both preoperatively and post-operatively with the ultimate outcome of the patient.

Method - A total of 48 patients requiring emergency abdominal surgery of non-traumatic cause were considered. Vital parameters were assessed and documented. Blood samples were collected under aseptic conditions and deposited in the hospital lab. ABG was done using an ion-selective electrode in an ABG analyzer. SOFA scores of individual patients were calculated.

In our study, patients with uneventful recovery had a mean pre-operative SpO2 value of 95.75% and SOFA score value of 1.5 and post-operative value 97% and 1.13, respectively. On the other hand, patients who died (n = 7) in the post-operative period had mean pre-operative SpO2 values of 87.71% and SOFA scores of 7.29 and post-operative values of 86.57% and 13.71, respectively, at the end of 72 hours.

Result - Preoperatively, compared to uneventful recovery, the mean SOFA score was significantly high in patients who require reservoir bag ($p \leq 0.001$), invasive ventilation ($p = 0.028$), only ionotropic support ($p < 0.001$), ionotropic support plus ventilation ($p < 0.001$), requiring renal replacement therapy ($p < 0.001$) and in patients who died ($p < 0.001$).

Preoperatively, compared to uneventful recovery, mean SpO2 was significantly low in patients who require reservoir bag (p = 0.002), invasive ventilation ($p = 0.003$), only ionotropic support ($p = 0.003$), ionotropic support plus ventilation ($p = 0.003$), required renal replacement therapy ($p < 0.001$) and in patients who died ($p < 0.001$).

Post-operatively, the mean SOFA score, compared to uneventful recovery, was significantly high in patients who require reservoir bag, invasive ventilation, only ionotropic support, ionotropic support plus ventilation, required renal replacement therapy and in patients who died.

Conclusion - Pulse oximetry is widely used for monitoring peripheral oxygen saturation (SaO2). By alerting the surgeon about the onset of hypoxemia or diminished perfusion, pulse oximetry can lead to the rapid institution of supportive treatment even before organ dysfunction begins to happen. Derangements of pulse oximetry parameters will occur several before the SOFA score is raised. Therefore, on the basis of pulse oximetry findings, quick corrective measures can be undertaken to prevent possible serious complications.

Physiologic compensatory mechanisms such as peripheral vasoconstriction limit the use of heart rate and blood pressure measurement as indicators for mild central tissue hypoperfusion and hypoxia in early settings. Hypotension is a late marker of hypoperfusion and almost 30% of circulatory volume may be lost before hypotension occurs. Therefore, early recognition of tissue hypoperfusion and hypoxia before the onset of tachycardia or hypotension is of prime importance in the prevention of hypoperfusion and hypoxia-induced organ failure.

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In the pathophysiology of sepsis-generated organ dysfunction, the basic flaw lies in poor tissue perfusion and cellular oxygenation. This sets off the cascade of metabolic and biochemical events which leads to organ dysfunction after a few hours or days. The key to successful management of such patients lies in controlling the sepsis source and the earliest possible recognition of perfusion and oxygenation deficit before organ dysfunction starts to take place.

Keywords: Pulse oximetry, Perfusion index, SpO2, SOFA score.

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INTRODUCTION

Worldwide, every year, millions of people require emergency abdominal surgeries, which are urgent and time-critical to treat high-mortality diseases. Post-operatively, patients require continuous monitoring of the vitals and early diagnosis of post-operative complications and management, for suitable outcomes of the patient.[1-4]

The sequential organ failure assessment (SOFA) score was developed following a consensus meeting in 1994 in order to describe quantitatively and objectively the degree of organ dysfunction/failure over time in patients of sepsis, but later, the score was found to be accurate in assessing patients of acute morbid illness. SOFA score gives the idea about complications, morbidity and mortality associated in critically ill patients. SOFA Score assesses six organ dysfunction (respiratory, coagulatory, liver, cardiovascular, renal, and neurologic) and the severity of dysfunction.[4-8]

This study includes serial correlation between SpO2, perfusion index and SOFA score both preoperatively and post-operatively with the ultimate outcome of the patient.

Physiologic compensatory mechanisms such as peripheral vasoconstriction limit the use of heart rate and blood pressure measurement as indicators for mild central tissue hypoperfusion and hypoxia in early settings. Hypotension is a late marker of hypoperfusion and almost 30% of circulatory volume may be lost before hypotension occurs. Therefore, early recognition of tissue hypoperfusion and hypoxia before the onset of tachycardia or hypotension is of prime importance in the prevention of hypoperfusion and hypoxia-induced organ failure.

MATERIAL AND METHODS

This was an observational study, which was carried out in the Department of General Surgery, Institute of Medical Sciences, Banaras Hindu University, Varanasi, from October 2020 to October 2022. The Institute Ethical Committee approved the study. All data and sample collection were done following proper consent from the patients included in the study.

In this study, a total 48 patients requiring emergency abdominal surgery of non-traumatic cause were considered in the study (Table 1). General assessment along with vital parameters, were assessed and documented. Blood samples were collected under aseptic conditions and deposited in the hospital lab. ABG was done using an ion-selective electrode in an ABG analyzer. X-rays chest and erected abdomen, USG/CT if indicated, were done. SOFA scores of individual patients were calculated. Post-operative follow-up of each patient was done. Daily progress of each patient and vital was recorded. SOFA scores of individual patients were calculated for three consecutive post-operative days. Patients were grouped according to the diagnosis (etiology and organ involved) and tables were made according to various outcomes. The mean SpO2, perfusion index and SOFA score of each outcome were calculated and correlated at the end of the study.

Physiologic compensatory mechanisms such as peripheral vasoconstriction limit the use of heart rate and blood pressure measurement as indicators for mild central tissue hypoperfusion and hypoxia in early settings. Hypotension is a late marker of hypoperfusion and almost 30% of circulatory volume may be lost before hypotension occurs. Therefore, early recognition of tissue hypoperfusion and hypoxia before the onset of tachycardia or hypotension is of prime importance in the prevention of hypoperfusion and hypoxia-induced organ failure.

RESULTS

Out of a total of 48 patients studied, 29 patients had Intestinal perforation with peritonitis, and 19 patients had Intestinal obstruction with sepsis. Out of total 29 patients of intestinal perforations, seven patients had pre-pyloric gastric perforation, 12 patients had typhoid fever with bowel perforation, six patients had Koch's abdomen with intestinal perforation, one patient had large bowel perforation (due to malignant stricture growth in sigmoid colon), and three patients had iatrogenic perforation (1 colonic-post laparoscopic cholecystectomy and rest 2 had small bowel perforation following prior intervention). Out of 19 patients with intestinal obstruction, eight patients had adhesive bands, two patients had ileal stricture, four patients had obstructed hernia, one patient had volvulus without gangrene, two patients had volvulus with gangrene, and two patients had intussusception. Most patients with obstructive disorders were found to have high SpO2, and low SOFA scores compared to patients with perforation.

Preoperatively, compared to uneventful recovery, the mean SOFA score was significantly higher in patients who required reservoir bag ($p \leq 0.001$), invasive ventilation ($p = 0.028$), only ionotropic support (p <0.001), ionotropic support plus ventilation (p <0.001), requiring renal replacement therapy (p <0.001) and in patients who died (p <0.001).

Preoperatively, compared to uneventful recovery, mean SpO2 was significantly low in patients who require reservoir bag ($p = 0.002$), invasive ventilation ($p = 0.003$), only ionotropic support ($p = 0.003$), ionotropic support plus ventilation ($p = 0.003$), required renal replacement therapy (p <0.001) and in patients who died (p <0.001).

Post-operatively, the mean SOFA score, compared to uneventful recovery, was significantly high in patients who required reservoir bag, invasive ventilation, only ionotropic support, ionotropic support plus ventilation, required renal replacement therapy and in patients who died.

The mean perfusion index, compared to uneventful recovery patients, was significantly low in patients who required face mask, reservoir bag, invasive ventilation, only ionotropic support, ionotropic support plus ventilation, required renal replacement therapy and in patients who died both pre-op and post-op.

In the pathophysiology of sepsis-generated organ dysfunction, the basic flaw lies in poor tissue perfusion and cellular oxygenation. This sets off the cascade of metabolic and biochemical events which leads to organ dysfunction after a few hours or days. The key to successful management of such patients lies in controlling the sepsis source and the earliest possible recognition of perfusion and oxygenation deficit before organ dysfunction starts to take place.

DISCUSSION

Physiologic compensatory mechanisms such as peripheral vasoconstriction limit the use of heart rate and blood pressure measurement as indicators for mild central tissue hypoperfusion and hypoxia in early settings. Hypotension is a late marker of hypoperfusion and almost 30% of circulatory volume may be lost before hypotension occurs. Therefore, early recognition of tissue hypoperfusion and hypoxia before the onset of tachycardia or hypotension is of prime importance in the prevention of hypoperfusion and hypoxia-induced organ failure.

This study was conducted with the aim of evaluating the correlation between pulse oximetry and SOFA score for the evaluation of tissue perfusion in critically ill surgical patients.

Out of the total patients, 29 patients had bowel perforation with peritonitis and 19 patients had bowel obstruction with sepsis. These patients were critically ill, presented with tachycardia, tachypnoea, often hypotension, febrile, requiring oxygen support, with occasional pleural effusion, and abdominal distension and require proper resuscitation, routine monitoring, and urgent surgical intervention with post-op ICU backup. If delayed, the outcome of these patients is severely affected. As the value of SOFA score increases in serial follow-ups, patients' risk for morbidity and mortality along with the duration of hospital stay increases.

In our study, patients with uneventful recovery had a mean pre-operative SpO2 value of 95.75% and SOFA score value of 1.5 and post-operative value 97% and 1.13, respectively. On the other hand, patients who died (n = 7) in the post-operative period had mean pre-operative SpO2 values of 87.71% and SOFA scores of 7.29 and post-operative values of 86.57% and 13.71, respectively, at the end of 72 hours. Similarly, a study done by Flavio Lopes Ferreira *et al.* in 2001 included 352 patients.

This study shows that pre-operative values, when compared with the uneventful recovery group (n = 8), the mean SpO2 is significantly low and the SOFA score is significantly high for patients with different outcomes. Patients on oxygen support with reservoir bag (n = 4) have mean SpO2 and SOFA score 90.75% (*p-value* 0.003) and 6 (*p-value* <0.001), on invasive ventilation (n = 3) had 89.67% (*p-value* 0.003) and 4.67 (*p-value* 0.028), on ionotrope support (n = 4) had 90.25% (*p-value* 0.003) and 5.75 (*p-value* < 0.001), on invasive ventilation with ionotrope support (n = 5) had 87.4% (*p-value* < 0.001) and 7.6 (< 0.001), underwent renal replacement therapy had 88% (*p-value* < 0.001) and 6.67 (*p-value* < 0.001). However, when compared with the uneventful group at the end of 72 hours, the difference of mean SpO2 and SOFA score is significant in patients who required oxygen support with a reservoir bag had 85.25% and 10.75 (n = 4, *p-value* < 0.001 and 0.002), on ionotropic support had 87.75% and 8.25 (n = 4, *p-value* 0.001 and 0.013), on invasive ventilation with ionotrope support had 91% and 10.4 (n = 5, *p-value* 0.03 and <0.001), underwent RRT had 89.67 and 12 (n = 3, *p-value* 0.024 and <0.001, respectively).

In this study, patients who recovered without any difficulty had pre-operative mean SOFA scores of 1.5 (uneventful recovery, n = 8) and 2.57 (face mask, n = 228) and corresponding perfusion index 6.36 and 4.3, respectively. Whereas patients who were critically had mean pre-operative SOFA scores of 7.6 (patients requiring invasive ventilation with ionotrope support, n = 5) and 7.29 (patients who died, n = 7) and corresponding perfusion index 1.14 (*p-value* <0.001) and 1.05 (*p-value* < 0.001), respectively.

Similarly, the post-operative mean SOFA score on day 3 was 1.13 (uneventful recovery, n = 8) and 1.71 (requiring face mask post-op, n = 28), with mean perfusion index values 6.7 and 4.65, respectively. Whereas critically ill patients had a mean SOFA score at the end of 72 hours is 10.4 (On ionotrope with invasive ventilation, n = 5) and 13.71 (died, n = 7) with mean perfusion index 1.38 (*p-value* < 0.001) and 0.95 (*p-value* <0.001), respectively (Table 2).

Similarly in a study done by Huai-Wu He *et al.*, 2013,[9] used and showed that non-surviving. The peripheral circulation in septic shock was altered due to the heterogeneous distribution of blood flow in sepsis and was a hallmark of early septic shock.

Ehrenfeld *et al.*[10] concluded by using pulse oximetry in non-cardiac surgery patients.

In a study done by Pratik P. Pandharipande *et al.*,[11] they calculated total SOFA scores using pulse oximetry in OT and ICU and results were significantly respiratory component of the SOFA scores correlated as well (Table 3 and Figure 1). The study also concluded SF based respiratory SOFA score predicted similar outcomes whenever ABG is not possible in trauma and surgical patients.

In the pathophysiology of sepsis-generated organ dysfunction, the basic flaw lies in poor tissue perfusion and cellular oxygenation. This sets off the cascade of metabolic and biochemical events which leads to organ dysfunction after a few hours or days. The key to successful management of such patients lies in controlling the sepsis source and the earliest possible recognition of perfusion and oxygenation deficit before organ dysfunction starts to take place.

The SOFA score was developed to assess the risk of acute morbidity and mortality in patients with critical illness, e.g., for patients with sepsis. Evidence from many observational studies like Garcia-Gigorro R *et al.*,[12] concluded that minor change in SOFA score is associated with high mortality.

Grooth *et al.*[13] conducted randomized trials and identified.

Tekade *et al.* (2017) studied the non survivors had high initial, mean, and highest SOFA scores as compared to survivors. High SOFA scores and increasing SOFA scores in serial follow-ups were found to be significantly associated with mortality and length of ICU stay.[14]

CONCLUSION

The management of patients with abdominal sepsis and deteriorating organ functions is an ongoing challenge for surgeons. While source control is paramount, early identification of poor perfusion and tissue oxygenation, which can lead to organ dysfunction and eventual failure, is equally important. This is used for predicting overall prognosis with regard to mortality. Considering the parameters such as PaO2/FiO2 ratio, serum bilirubin, serum creatinine, platelet count, glasgow coma scale, and mean arterial pressure, it is evident that the SOFA score is going to be deranged only after organ dysfunction or hemodynamic instability has already set in.

In the pathophysiology of sepsis-generated organ dysfunction, the basic flaw lies in poor tissue perfusion and cellular oxygenation. This sets off the cascade of metabolic and biochemical events which leads to organ dysfunction after a few hours or days. The key to successful management of such patients lies in controlling the sepsis source and the earliest possible recognition of perfusion and oxygenation deficit before organ dysfunction starts to take place.

The objective of early detection of tissue perfusion and oxygenation deficit can be achieved by continuous monitoring of the peripheral oxygen saturation (SpO2) and the perfusion index (PI). Derangement of these parameters can precede derangement of the SOFA score by several hours or even a day or two.

Pulse oximetry is widely used for monitoring peripheral oxygen saturation (SaO2) and the perfusion index (PI). By alerting the surgeon about the onset of hypoxemia or diminished perfusion, pulse oximetry can lead to the rapid institution of supportive treatment even before organ dysfunction begins to happen. Derangements of pulse oximetry parameters will occur several before the SOFA score is raised. Therefore, on the basis of pulse oximetry findings, quick corrective measures can be undertaken to prevent possible serious complications.

In our study, patients with uneventful recovery had a mean pre-operative SpO2 value of 95.75% and SOFA score value of 1.5 and post-operative value 97% and 1.13, respectively. On the other hand, patients who died (n = 7) in the post-operative period had mean pre-operative SpO2 values of 87.71% and SOFA scores of 7.29 and post-operative values of 86.57% and 13.71, respectively, at the end of 72 hours.

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Appendix

Table 1: Distribution of Emergency Surgery patients included in the study (n = 48)

Diagnosis	*Number of patients*
Bowel Perforation	29
Peptic Ulcer Perforation	07
Small bowel Perforation (Enteric, Tubercular, Iatrogenic)	18
Large Bowel Perforation	04
Intestinal Obstruction	19
IO without Bowel Ischemia or Gangrene	17
IO with Bowel Ischemia or Gangrene	02

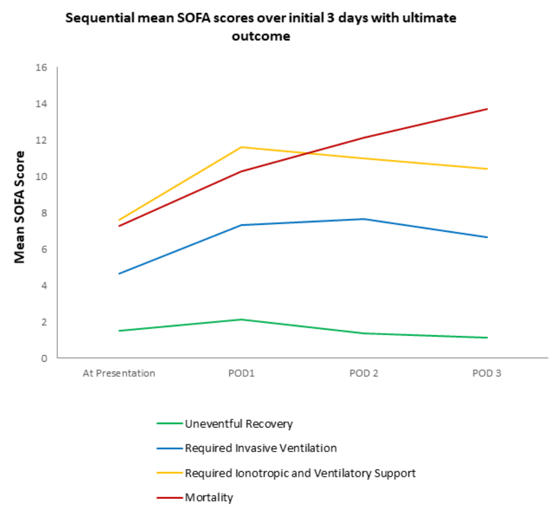

Figure 1: Sequential mean SOFA scores over initial 3 days with ultimate outcome

Table 2: Division of patients according to diagnosis with mean SOFA score and SpO2 at presentation, POD 1, 2, and 3

Diagnosis	*At Presentation*		*POD - 1*		*POD - 2*		*POD – 3*	
	Mean SOFA Score	*Mean SpO2*	*Mean SOFA score*	*Mean SpO2*	*Mean SOFA Score*	*Mean SpO2*	*Mean SOFA score*	*Mean SpO2*
Peptic Ulcer Perforation (n=7)	3.29	89.7	5.43	93	4.29	94.3	3.57	93.6
Small Bowel Perforation (n = 18)	4.2	91.1	5.6	94.1	4.4	94.7	4	93.2
Large Bowel Perforation (n = 4)	5.5	91	6.75	93.8	5.5	91.7	5	92
Intestinal obstruction without Ischemia or Gangrene (n=17)	2	93.9	3.4	93.3	2.4	94.4	2.2	95.1
Intestinal Obstruction with Ischemia or Gangrene (n=2)	5.5	91	8.5	90	8.5	88.5	9	87.5

Table 3: Sequential mean SOFA scores over initial 3 days with ultimate outcome

Outcomes	*At Presentation*	*POD1*	*POD 2*	*POD 3*
Uneventful Recovery	1.5	2.13	1.38	1.13
Required Invasive Ventilation	4.67	7.33	7.67	6.67
Required Ionotropic and Ventilatory Support	7.6	11.6	11	10.4
Mortality	7.29	10.29	12.14	13.71