Gastric Tonometry as a Prognostic Index of Mortality in Sepsis

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Abstract

Background: Splanchnic hypoperfusion in sepsis leads to translocation of bacteria from gut and development of multi-organ dysfunction syndrome (MODS), with increased mortality in critically ill patients. Gastric tonometry can detect this hypoperfusion by measuring carbon dioxide tension ($PgCO_2$) and intramucosal pH (pHi) from gastric mucosa. Therapeutic intervention aimed at improving gut perfusion can improve the outcome and prognosticate the mortality in sepsis patients.
Methods: 100 patients with clinical diagnosis of sepsis were included and divided into two groups of 50 each. Group A patients were managed traditionally without gastric tonometry and in Group B gastric tonometry was used for therapeutic intervention. The intramucosal PCO_2, pHi, end tidal carbon dioxide tension ($EtCO_2$) and ($PgCO_2$-$EtCO_2$) differences were monitored at 0, 12 and 24 hours interval.
Result: Overall mortality in Group A was 64% and 54% in Group B. In Group B 45% patients developed MODS and 54% died with low pHi. As an index of mortality low pHi had a sensitivity of 70% and specificity of 65%.
Conclusion: There is a good correlation between mortality prediction on the basis of pHi and $PgCO_2$-$EtCO_2$ difference and actual mortality in critically ill patients. The gastric tonometer should be used to predict mortality and guide resuscitation in septicemia.

Introduction

Splanchnic ischemia is postulated to be of major importance in the development of multiorgan failure, and death in critically ill patients [1]. The stomach is one of the first organs to suffer from hypoperfusion and the last to be restored to normality by resuscitation [2]. These alterations are reflected by increase in the gastric intramucosal pH (pHi) and carbon dioxide (CO_2). Gastric tonometer measures pHi and carbon dioxide tension ($PgCO_2$) in gastric mucosa (Figs. 1,2). Gastric tonometry is based on the measurement of $PgCO_2$ in gastric mucosa by inserting a multi lumen catheter with a semi permeable silicon balloon at the distal end. The carbon dioxide produced in the mucosal cells being freely diffusible, equilibrates across the semi-permeable membrane of the balloon. Low pHi is associated with poor out come [2,3] and it can serve as a marker of inadequate tissue perfusion/ oxygenation (shock) and an end point of resuscitation [2,4-7].Measurement of gastric intramucosal pH provides a measure of tissue acid base balance in a region of the body that is among the first to develop dysoxia in shock and sepsis [8,9].

Material and Methods

Hundred patients (52 male and 48 female) consisting of both medical and surgical groups having sepsis admitted to intensive care unit (ICU) were included in the study. The diagnosis of sepsis was based on patients having two or more clinical manifestations of systemic inflammatory response syndrome (Table 1). The patients were divided into two groups of 50 patients each. Group A formed the control group and these patients were managed traditionally without gastric tonometry. In Group B (study group) gastric tonometry was used to guide therapeutic intervention in the form of intravenous (IV) crystalloids/ colloids, inotropes (dopamine, dobutamine and noradrenaline) and antibiotics. Exclusion criteria were age less than 18 years, active gastrointestinal bleeding, bleeding diathesis, previous history of peptic ulcer, and more than 45 mm Hg $PaCO_2$.

Patients in both groups were monitored for temperature, heart rate, breath rate, mean blood pressure (BP), SpO_2, total leucocytes count, and arterial blood gas. In Group B patients $PgCO_2$, pHi and $EtCO_2$ was monitored at 0, 12 and 24 hours using gastric tonometer. Once the diagnosis of sepsis was established gastric tonometer catheter was inserted like a standard nasogastric tube into stomach and time taken as zero hour. The position of the catheter was confirmed radiologically. Intramucosal pCO_2 (partial pressure of carbon dioxide in arterial blood), pHi and $EtCO_2$ were monitored using air gastric tonometer (Datex Ohmeda S/5 Compact Critical Care Monitor-Tonocap). The monitor fills the gastric balloon

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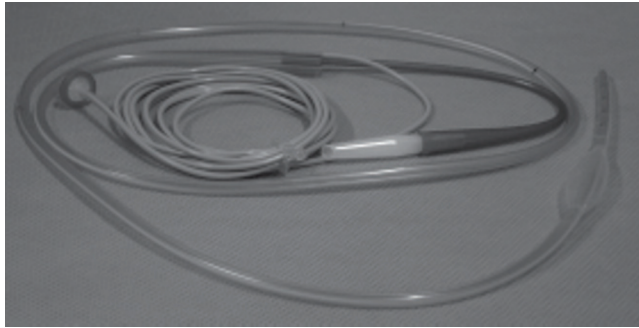
Fig.1:   Gastric tonometer catheter

Table 1

Sepsis Syndrome/ Systemic Inflammatory Response Syndrome (SIRS) Criteria [22]

The systemic inflammatory response to a wide variety of severe clinical insults, manifested by two or more of the following conditions:

1.   Temperature > 38°C or < 36°C
2.   Heart rate > 90 beats/minute
3.   Respiratory rate > 20/ minute or $PaCO_2$ < 32 mm Hg
4.   White cell count > 12000/cumm or < 4000/cumm or presence of 10% immature (band) neutrophils

attached to the standard catheter with 5 ml of room air, which is kept there for 10 minutes for equilibration with gastric mucosal CO_2. The sample is then withdrawn and analyzed for CO_2 content.Tonocap calculates the pHi when $PaCO_2$ and pH values are entered from arterial blood gas analysis. Normal pHi value is taken as >7.32. The monitor also calculates $PgCO_2$ and $EtCO_2$ difference. All patients received ranitidine 50 mg intravenously 8 hourly and were fasted for one hour before taking reading of $PgCO_2$ and pHi. The catheter was removed after 48 hours. Patients on ventilator were kept well sedated with midazolam and opioid.

Results

The findings of Group A patients (Table 2) show a mortality rate of 64 %. It was noticed that tachycardia and tachypnea persisted in nonsurvivors despite adequate resuscitation. The findings of Group B (Table 3) show an overall mortality of 54%. It was seen that patients with low pHi developed multi-organ failure and had higher mortality. Table 4 shows changes in parameters in survivors and non survivors. The

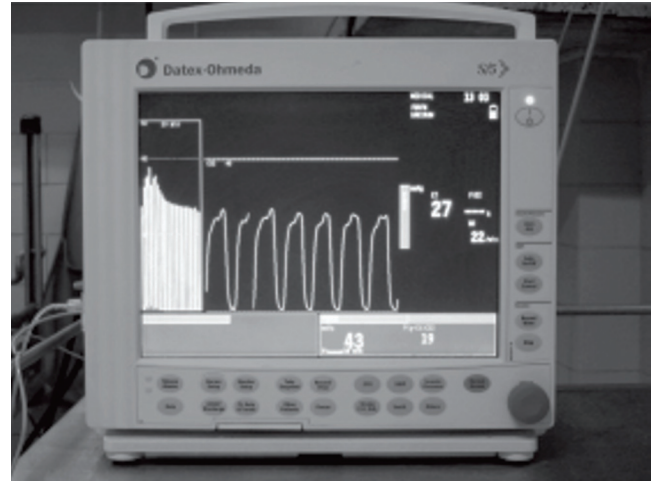Fig. 2:   Datex Ohmeda S/5 monitor–gastric tonometer

survival was better in the patients whose pHi returned back to normal value after treatment. In 67 % patients pHi remained low and in 35 % patients increased to normal value after treatment. The decrease in pHi in nonsurvivors was 7.2 and above 7.34 in survivors. The prediction of mortality with mean value of pHi and $PgCO_2$-$EtCO_2$ gap at 0, 12 and 24 hours is shown in Table 4. As an index of predicted mortality, low pHi had a sensitivity of 70 % and specificity of 65 %.

We did not find the CVP, temperature and SpO_2 as the major determinant of outcome in critically ill patients.

Discussion

Measurements of gastric mucosal pH (pHi) at 0, 12 and 24 hours has predictive value in critically ill patients.

pHi and $PgCO_2$-$EtCO_2$ ($PaCO_2$) are better indicators of splanchnic ischemia than pHi because the effect of systemic acid-base balance on gastric intramucosal acid-base balance is eliminated [7,10]. Our results confirm findings of other workers that pHi can distinguish survivors from nonsurvivors in critically ill patients during early period [11,12].

Patients with low pHi at zero hours have a higher mortality particularly if pHi does not improve with intervention within 24 hours [2,11,13,14]. A large

Table 2

Group 'A' (Conventional treatment without gastric tonometer monitoring) (S= survivors, NS= non survivors, all mean values)

Measured parameters	Mean value (zero hours)	Response to therapy (12 hours)		Response to therapy (24 hours)	
		S	NS	S	NS
Heart rate (per minute)	107.0 ± 4	104	110 ± 9	96	110 ± 10
MAP (mm Hg)	81.4 ± 5.0	88.5	58.9 ± 6.5	86.6	61.5 ± 6.0
Temperature	102.0 ± 0.75	100.5	102.5 ± 0.55	99.5	102.8 ± 0.55
White cell count	14,000 ± 1500	14,000	14,500	15,000	11,000
$PgCO_2$	44.6	43.5	59.0	40.5	56.4
pHi	7.29	7.34	7.22	7.36	7.25
$EtCO_2$	35.0	33.5	39.0	36.5	38.0
$PgCO_2$-$EtCO_2$	9.6	9.5	20.0	8.5	18.4

(Temp=°F, white cell count = per cumm, $PgCO_2$ and $EtCO_2$ = mm Hg, MAP = mean arterial pressure)

Table 3

Group 'B' (Therapy guided with gastric tonometer findings) (S= survivors, NS= non survivors, all mean values)

Measured parameters	Mean value (zero hours)	Response to therapy (12 hours)		Response to therapy (24 hours)	
		S	NS	S	NS
Heart rate (per minute)	107.2 ± 4	102.4	108.5 ± 9	104	110 ± 10
MAP (mm Hg)	75.7 ± 5.5	87.5	62.3 ± 3.5	88.6	61.8 ± 3
Temperature	100.6 ± 0.75	100.2	102.8 ± 0.55	99.5	102.2 ± 0.55
White cell count	12600 ± 1500	1300	13500	10500	14000
$PgCO_2$	45.8	43.5	59.2	40.5	62.4
pHi	7.28	7.34	7.19	7.35	7.20
$EtCO_2$	35.6	33.5	39.0	34.5	40.0
$PgCO_2$-$EtCO_2$	10.2	9.5	20.2	8.5	22.4

(Temp=°F, white cell count =per cu mm, $PgCO_2$ and $EtCO_2$=mm Hg)

Table 4

Mean values in survivors and nonsurvivors

Parameters	Time (hours)	Survivors	Nonsurvivors
pHi	0	$7.3 \pm 0 .05$	7.19 ± 0.055
	12	7.32 ± 0.05	7.22 ± 0.05
	24	7.33 ± 0.05	7.24 ± 0.05
$PgCO_2$-$EtCO_2$ ($PgCO_2$ Gap)	0	10 ± 2.5	15 ± 3.5
	12	12 ± 2.75	18 ± 2.5
	24	14 ± 3.5	15 ± 4.25

difference in the partial pressure of carbon dioxide between gastric mucosa and arterial blood ($PgCO_2$-$PaCO_2$) has been shown to be more specific indicator of splanchnic ischemia and predictors of outcome [15,16]. Our study is in agreement with these findings. Santoso et al [17], documented the potential usefulness of pHi as a variable that might trigger therapeutic interventions during resuscitation in critically ill patients. A measure of the adequacy of gastric perfusion as determined by gastric tonometry is particularly attractive because of the importance of gut in the pathophysiology of critical illness [18]. Various studies have demonstrated neurohormonal responses to critical illness shunt blood away from the gut, which can leave the gut inadequately perfused and the pHi low at the time when other indices of perfusion show that the resuscitation is adequate [17,19,20].

Patients in whom therapeutic interventions failed to correct a low gastric intramucosal pH at zero and at 12 hours had the highest mortality rate (88.6%). Survival improved in those patients where pHi increased within this period (34%). These observations are similar to Doglio et al [2],who observed 86.7% and 36.45% mortality in similar groups. Our study shows that the initial low pHi value carried a high mortality and has a positive out come if it is corrected within 24 hours. The overall mortality as predicted, on the basis of low pHi value did not improve significantly with resuscitative measures. Gastrointestinal mucosal acidosis has been documented in both clinical and experimental studies of septic shock. In septic patients, development of gastric mucosal acidosis correlates with early death and the development of the multiple organ dysfunctions [6,7,21].

The higher survival rate of patients with normal gastric intramucosal pH during first 12 hours in ICU makes a strong argument for using gastric intramucosal pH as a monitor of local tissue hypoxia [2]. Doglio et al [2], supported the hypothesis that a substantial proportion of ICU patients benefit from pHi monitoring. However, Gomersall et al [12] did not recommend routine use of titrated treatment against pHi in the management of critically ill patients.

We monitored $PgCO_2$ and pHi after stopping feed for one hour as in the study by Marik [23].The measurement of intramucosal pH following a sudden change in arterial bicarbonate such as that induced by an IV injection of bicarbonate should be delayed [15]. Thorburn et al [24], found that gastric feeding decreased the gastric intramucosal PCO_2 and $PgCO_2$-$PaCO_2$ difference with increase in pHi as compared with the unfed state, contrary to those found in adult studies.

Sepsis is known to induce ischemia at a higher level of oxygen delivery than that induced in the absence of sepsis [18]. Similarly, endotoxins induce a decrease in intramucosal pH while flow to the gut is maintained at control levels. Fiddian-Green RG [4], concluded that indirect measurement of actual pHi provides a sensitive and specific index of tissue oxygenation. Temperature correction is not required in air-gas tonometer [25]. Silva et al [26], have shown that the effects of fluid challenge on gastric mucosal PCO_2 are variable and related to baseline PCO_2 gap rather than to systemic variables. Oud et al [27] studied the effects of resuscitation of patients with severe sepsis to conventional hemodynamic end points and normal blood lactate levels on post resuscitation sequential assessments of gastric intramucosal pH (pHi) and concluded that gastric intramucosal acidosis develops and persists for at least 48 hours in patients resuscitated from septic shock to

conventional resuscitative end points, including the normalization of lactate levels. These regional changes were not reflected in corresponding changes in systemic acid-base and oxygen utilization variables. Direct determinations of pHi and therapy directed toward the resolution of splanchnic ischemia may be required to improve the outcome in these patients.

Our findings suggest correlation between the mortality prediction on the basis of pHi and $PgCO_2$-$EtCO_2$ gap and actual mortality in critically ill patients. Resuscitation done on the basis of pHi and $PgCO_2$-$EtCO_2$ definitely affects the outcome. Identification of different sub groups of patients will make the study more accurate. Inspite of shortcomings the study provides a basis for use of gastric tonometer in critically ill patients to predict the outcome and guide the therapy in sepsis.

Conflicts of Interest

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